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Industry Study

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AIRCRAFT INDUSTRY STUDY 2012

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PLACES VISITED

Domestic Visits

23 February	Boeing Rotorcraft	Philadelphia, PA
24 February	Aerospace Industries Association	Arlington, VA
9 March	Lockheed Martin Fighter Demonstration Center	Crystal City, VA
22 March	Pratt & Whitney	Middleton, CT
23 March	Sikorsky	Stratford, CT
3 April	Boeing Commercial Aircraft	Everett, WA
4 April	Boeing Defense, Space and Security	Renton, WA
30 April	Lockheed Martin Aeronautics	Fort Worth, Texas
1 May	Bell Helicopters	Fort Worth, Texas

International Visits

3 May	EADS Corporate Headquarters	Paris, France
4 May	SAFRAN	Paris, France
5 May	Institut des Hautes Etudes de Défense Nationale	Paris, France
6 May	SIBAT – Israel Ministry of Defense	Tel Aviv, Israel
7 May	Technion University	Haifa, Israel
7 May	ELBIT Systems	Haifa, Israel
7 May	Rafael Advanced Defense Systems	Haifa, Israel
8 May	Top I Vision	Moshav R., Israel
8 May	Israel Aircraft Industries	Lod, Israel

EXECUTIVE SUMMARY

The U.S. defense industry has for decades delivered innovative technology that has guaranteed the U.S. military advantage's advantage on the global stage. But the changing nature of an increasingly multinational and technically complex defense industry coupled with looming defense spending cuts threaten the defense industry's welfare. The primary question of concern for the health of today's defense industry is: In an era of defense budget downturn and increasingly multilateral defense relationships, what strategy should the U.S. implement to ensure the enduring technological advantage of its defense industrial base?

Understanding the future aerospace market requires a global perspective on emerging markets, international competition, and the impact of multi-role platforms such as the F-35 Lighting II on the industry. To gain the critical insight needed to fully understand how the defense budget downturn and increasingly multilateral defense relationships affect industry, it is necessary to discuss the two most critical aerospace markets in the defense industry today: the fighter and unmanned aerial vehicle markets.

In the fighter market, there has been an inexorable downward trend in U.S. military aircraft development programs. 2010 was the first year in which the U.S. aircraft industry was not designing a military aircraft of any type. This reflects the U.S. military's recent preference for fewer complex, multi-purpose aircraft such as the F-35 in lieu of greater numbers of less sophisticated platforms.

If continued, such structural developments could have significant negative long-term ramifications for the U.S. government, as a lack of competition will inevitably lead to higher costs—and perhaps the loss of fighter design and manufacturing expertise at previously reliable firms. Additionally, while global demand for fighters may continue rising, the companies competing to fill 5th generation fighter orders in 2020-2025 could possibly have dwindled to just Lockheed Martin and Russia's Unified Aircraft Corporation (and maybe China's J-20 producer).

The burgeoning unmanned aerial vehicle (UAV) industry offers proven and versatile alternatives to the increasingly costly, complex and consolidated fighter market. With low barriers to entry, UAVs potentially represent an entirely new direction for the aircraft industry. U.S. firms are well positioned, but to compete internationally must market world-class systems while accommodating customers' desire for work share, offsets or technology transfer concessions.

Beyond understanding international markets and the effect major aerospace platforms will have on them in the coming years, the U.S. must also address issues *fundamental* to preserving its current industrial capacity and mitigating the risks to its military superiority that lurk in today's markets. These foundational areas include government-industry relations, supply chain management and industry talent pool retention.

The U.S. defense industry consistently generates the most capable weapons in the world, but without an agile acquisition system that adapts to fast-paced changes in the global defense landscape, the U.S. will be unable to field the technology today's war fighter requires. The need to balance technological risk with more integrated relationships with industry call for a stronger government engineering cadre. Likewise, ambitious acquisition projects must incorporate risk-mitigation measures to help nurture disruptive technologies.

Today's increasingly multinational defense industry has benefitted the defense industry, particularly in terms of innovation—but globalized supply chains also create vulnerabilities

that, if left unchecked, pose technology transfer and sustainment risks to U.S. sovereignty. In an environment of increased interaction between international communities, the U.S. government must discern the long-term impacts of competition and international trade to ensure its policies adequately address those risks. It must also determine if the trade restrictions that protect critical U.S. technologies still align with its aims and industrial strategy.

Political considerations are also key. Successful International Trafficking in Arms Regulations (ITAR) reforms and expedited Arms Export Control Act (AECA) processes coupled with expanded bilateral defense trade agreements would augment U.S. fighter aircraft and Unmanned Airborne Systems' (UAS) overseas sales, helping offset sinking U.S. defense budgets and soaring fighter aircraft procurement costs.

The growing trend to develop multi-role platforms has greatly decreased both the number of firms and people that can do the critical research, development, test and evaluation that has long given the U.S. its unexcelled defense capabilities. To forestall this worrying trend, science, technology, engineering and math (STEM) education must be a strategic national priority. To ensure a sufficient pool of engineering professionals, the U.S. should reallocate education subsidies toward degrees that support national interests and promote post-graduate employment in critical industries.

The prosperity and security of the U.S. is inextricably tied to the health of its national defense industrial base. The aircraft industry—like its cousins across the defense spectrum—is in turn tied to international technology, material and labor markets through an expanding web of multinational corporations and international partnerships. Today's realities clearly illustrate the need to retool the U.S. government's relationship with the defense industry. To realize change, U.S. leaders must understand that the U.S. defense industry cannot remain healthy and viable without a visionary and comprehensive U.S. policy that seeks to preserve an industry sector that is fundamental to U.S. national security.

"We must continue to maintain our margin of technical superiority and ensure our Nation's industrial base is able to field the capabilities and capacity necessary for our forces to succeed in any contingency"
The National Military Strategy of the United States of America, 2011

The assertion that the U.S. will remain the preeminent military and economic power in the foreseeable future can no longer be a foregone conclusion. The importance of a strong military establishment to influence the international security environment in pursuit of our national security interests is as crucial now as any time in history.

Today, force strength is secondary to technological superiority. A healthy defense industry that fosters excellence through innovation and production capacity has long delivered that technology, guaranteeing the U.S. military advantage. But the changing nature of an increasingly multinational and highly technical defense industry coupled with increased austerity in defense spending threatens the defense industry's well-being. The primary question of concern for the health of today's defense industry is: In an era of defense budget downturn and increasingly multilateral defense relationships, what strategy should the U.S. implement to ensure the enduring technological advantage in the U.S. defense industrial base?

In no industry is this concern more pressing than in the aerospace sector. The Defense Department's (DoD) 2013 budget request represents a $259 billion reduction over the next five years[1] - and is only the first half of a planned $487 billion cut over the next decade.[2] Such a reduction could atrophy the military aircraft industry if other challenges are not addressed.

This fiscal decline mirrors a steady downward trend in U.S. military aircraft development programs. 2010 was the first year in which there were no military aircraft being designed in the U.S., reflecting the U.S. military's recent tendency to purchase fewer platforms in exchange for complex, multi-purpose aircraft such as the F-35 Lightning II. Such acquisitions lead to unfavorable compromises by forcing industry into "must win" cost competitions and creating programs that are "too big to fail."[3] Infrequent development programs have also had a direct deleterious impact on the pool of industry talent able to design, test, evaluate and build modern aircraft.

There are still more problems with defense acquisition today: incomplete up-front alternatives analysis, poor systems engineering support, inadequate product development strategies, debatable performance/cost/value trade-offs, requirements creep and questionable contract incentives are among the principal concerns. From a manpower standpoint, rapidly evolving aircraft innovations challenge program managers to remain abreast of cutting-edge technologies to properly assess the programs they manage.

External factors also affect the industry. The ever more multilateral nature of the aircraft industry clashes with the historical U.S. insistence on self-sufficiency and protectionism, a contrast that threatens industrial competitiveness. Compounding this trend is the increased use of international supply chains, which not only makes the U.S. more reliant on partner nations for its national security but also poses a greater risk of compromising sensitive technologies.

These factors combine to place the U.S. at a strategic crossroads. The U.S. must address fundamental issues to preserve its current industrial capacity and mitigate risks to its military superiority, but the traditional shot in the arm for the aircraft industry—increased defense industrial spending—is threatened by the competing need to slash the defense budget during a historic economic downturn.

To better encapsulate the effect of the defense budget downturn and increasingly multilateral defense relationships on aerospace companies, insight is necessary into the industry's two most critical defense platforms today—fighters and unmanned aerial vehicles (UAVs). Understanding how these market segments affect the industry and what the U.S. must do to remain the world's preeminent military power, one must consider how acquisition, supply chain and the available talent pool of industry professionals affects the health of the industry.

Fighters: The most critical platform in today's fighter market and the costliest DoD acquisition today is the F-35—a multi-role and multinational fighter projected to dominate the world fighter market for decades. With so much riding on its success, it is critical to understand the profound effect the F-35 has already had on foreign and domestic competition and aircraft production.

Unmanned Aerial Vehicles: The fighter market's increasing cost, complexity and consolidation leave space for low-cost, capable alternatives. With low barriers to entry and proven worth in defense and civilian applications, UAVs comprise the fastest growing market in the aerospace industry today. The U.S. aircraft industry's ability to exploit the growing UAV market opportunities may have lasting implications on its health and future employment.

Government-Industry Relations: The U.S. defense industry produces the world's most capable platforms, but without an acquisition system that adapts to the changing complexities of a high-tech, global industry, the U.S. will face repeated cost overruns, delays to its major acquisition programs and threats to its national sovereignty. Acquisition reform has long been a common theme amongst those seeking reform, but the current defense budget downturn could create the necessary window of opportunity for meaningful change.

Supply Chain: Today's increasingly multinational aircraft industry provides significant benefits for defense industry health, particularly in the area of innovation. Yet there are risks to globalized supply chains that, if left unmitigated, menace U.S. industrial sovereignty and capacity. These risks include not only considerations about technology transfer, but also sustainment: multi-nationalism has important implications for maintaining the critical capabilities demanded of today's military.

Talent Pool: People run the defense business. Acquisition begins with designers and engineers. The infrequent development of new airframes in recent years has decreased the number of firms and people with the requisite skills to research, develop, test and evaluate the disruptive technologies that have made the U.S. the world's premiere military power. How will an increasing dearth of engineers able to produce cutting-edge aircraft affect the future health of the defense aerospace industry?

A decade after 9/11, the U.S. faces both familiar and unfamiliar challenges: increased global interdependence, an economic crisis and significant uncertainty about the future threat landscape are realities that dictate the pressing need for a new approach to ensuring the health of the U.S. defense industry. While strategic documents such as the *National Military Strategy of the United States of America (2011*) eloquently articulate the need for a healthy defense industry, neither it nor its predecessor documents have provided a strategic roadmap outlining a path to that desirable outcome.

FIGHTER AIRCRAFT MARKET

Increased utilization rates among aging tactical jets over the past ten years, coupled with nations' desires to retain strategic and operational advantages signify that demand within the fighter aircraft market will remain strong for the foreseeable future. The current United States fighter industry essentially comprises prime defense contractors Boeing and Lockheed Martin. While competition is intense among fourth-generation fighter suppliers, Lockheed Martin's fifth-generation Joint Strike Fighter (JSF) F-35 Lightning II appears leveraged to dominate the future market. In fact, unless a sixth-generation fighter emerges to rival the F-35, forecasters expect Lockheed Martin to eclipse Boeing to become the only U.S. domestic fighter aircraft prime, vying possibly with Russia's Sukhoi to dominate the global fighter market (2025-2030 timeframe).[4]

U.S. Market Analysis

The U.S. fighter market structure is a *duopoly* in which Boeing and Lockheed Martin compete with a high degree of negotiation between the government and each firm. Although not a perfectly competitive market, both firms have established winning fighter programs. Boeing's F/A-18E/F Super Hornet has successfully acted as the U.S. Navy's principle strike fighter, while their F-15 Strike Eagle has brought significant Foreign Military Sales (FMS) capital to the firm. Lockheed Martin has recently established even firmer ties with DoD via its success with F-16 and F-22 sales to the Air Force and, most importantly, its triumph in the JSF competition.

The domestic fighter market *structure* operates under significant government policy limitations and restrictions regarding competition, price, and export controls. There is a lack of international competition in the U.S. market, which typically features fixed-price production contracts. Firms create value in the domestic fighter market by providing a substantiated return on invested capital, but their value also includes the ability of the defense industrial base to satisfy the U.S. military's requirements. Fortunately for the U.S. government and its primary fighter aircraft providers, up to now they have created value from both a utility and profit-making viewpoint. Future value in the market depends on Lockheed Martin's ability to successfully deliver on cost, schedule and performance with its "all eggs in one basket" F-35 Lightning II.

Although the top aircraft firms are creating value on par with the long-term S&P 500 average return, long-term debt could surface as a concern for both Boeing and Lockheed Martin. Still, both primes have enough orders to solidify their position in the near term. The Teal Group forecasts that the two companies will control approximately 53% of the world fighter market (by value) over the next decade.[5] With increasingly austere defense budgets on the horizon, global sales will be imperative to maintain the value and overall health of the U.S. fighter industrial base.

Five Forces Analysis

Porter's *Five Forces* model provides an opportunity to further analyze the U.S. fighter market competition beyond simply considering the established rivals themselves.

The market's *competitive rivalry* is intense. Although there was little product differentiation among fourth-generation fighters, Lockheed Martin's fifth-generation Joint

Strike Fighter should provide the firm with a significant and enduring product edge that builds upon the advantage Lockheed Martin's popular fourth-generation F-16 had already provided.

Still, Boeing has found enough success to stay in the race, particularly with recent F-15 foreign military sales such as the substantial multi-billion dollar Saudi order that carries through 2018.[6] Boeing should also see additional U.S. Navy orders for its F/A-18 since recent F-35 cost increases will inevitably reduce the number of Lightning II purchases. While this rivalry will likely intensify in the medium term, the F-35's presumed eventual success should position Lockheed Martin to become the sole domestic fighter prime beyond 2020.

The aircraft market has unparalleled barriers to entry, challenging government policy limitations significant front-end research and development (R&D) costs and large economies of scale at every production phase. This combination of factors renders the *threat of new entrants* into this market quite low.

The *bargaining power of buyers*, in this case the U.S. government, is currently moderate for fourth-generation fighters. Cost overruns and delays with the F-35 program have limited government options. The military services' have a pressing need to recapitalize aging fleets and fulfill their established joint requirement for a fifth-generation stealth fighter. The F-35 is the only choice.

Fourthly, *suppliers' bargaining power* is variable. Single-source suppliers of complex items such as engines and critical electronics have considerable bargaining leverage. However, the global supply chain and co-production agreements for other components tend to decrease their bargaining power. Additionally, a recent surge in counterfeit parts in the aircraft market has increased the need for reliable partners in the global supply chain.

Porter's final competitive force addresses the *threat of substitute products*, which has increased slightly in the last few years. One reason for this is the emergence of next-generation unmanned aerial systems. Both Unmanned Aerial Vehicles (UAVs) and Unmanned Combat Air Vehicles (UCAVs) are improving at a rapid pace, but most industry experts concur that manned fighters will be necessary for the foreseeable future.

While UAVs are a factor, it is the F-35's rising cost that creates a vulnerability to substitute products. Since the unrivaled fifth-generation domestic fighter belongs to Lockheed Martin, any threat of a substitute could only emerge if the U.S. were to assume the staggering investment of developing a sixth-generation contender. Unless something dramatic changes the economic and strategic landscape, that prospect appears doubtful.

What is certain is that most OECD countries face decreasing defense budgets, which may force them to perform mid-life upgrades to their current fighter inventories or buy late-model fourth-generation fighters rather than the F-35. Furthermore, even if ongoing Chinese or Russian efforts to build fifth-generation fighters only result in aircraft with 80% the F-35's capabilities, they would represent significant upgrades to the fourth-generation fighters they are designed to replace. That quality edge, coupled with their undoubtedly more attractive price tags than the F-35, would make them formidable competitors to Lockheed Martin's product.

Strategic Game Board Analysis

Utilizing the *strategic game board* as an analytic tool also helps to understand these two firms' strategies. Regarding *where to compete*, Boeing has chosen to continue straddling the commercial and defense sectors. In the defense sector, Boeing plans to remain viable as a defense prime by leveraging P-8, V-22, F-15, AH-64 and F/A-18 sales and near-term investments in UAVs to counter Lockheed Martin's large JSF contracts. Considering *when to*

compete, Boeing has, concluded now is the time to "bet the farm" on its smaller, game-changing 787 commercial aircraft as a more agile and efficient option that will ultimately produce a significant return on investment for "Team Boeing." The firm is also pursuing its chance to market its fourth-generation fighters as the F-35 remains behind schedule.

As previously noted, Lockheed Martin has responded to the *where to compete* question by electing to concentrate exclusively on government markets. The firm has achieved a significant advantage through high-end fifth generation fighter aircraft and appears leveraged for success with its F-35 even as the last planned F-22 Raptors roll off the line and global F-16 sales continue. Under the same heading, Lockheed Martin has opted to compete internationally by marketing to allied nations and any other countries the U.S. government deems eligible for foreign sales. Although the U.S. government will plainly remain the primary customer, foreign buyers clearly represent a significant base for future sales. Regarding *when to compete*, Lockheed Martin is determined to emphasize a number of promising high-tech proposals in which it enjoys significant economies of scale and can leverage its technology-based advantage to remain viable. In the fighter market, building the high-profile F-35 program's momentum is the priority. Lastly, to answer the question of *how to compete*, Lockheed Martin has focused on changing the rules of the game with a fifth-generation fighter program that incorporates widespread industrial participation to strengthen regional and national strategic relationships. This joint acquisition program appears to have forever changed the nature of high-profile defense programs. Lockheed Martin will continue to compete in this market by leveraging its vast experience, innovation opportunities, integration abilities and full-spectrum support services.

The Broader Global Fighter Market

Global demand for fighters has recently skyrocketed, and is expected to remain strong past 2020. Specifically, while the fighter market experienced a demand for 2,473 fighters worth $150 billion between 2002 and 2011, Teal Group forecasts the market will experience a 15% growth in value (~40% when RDT&E costs are included) between 2012 and 2021.[7] 2012 is expected to be a strong year for the fighter market, with 246 deliveries worth nearly $16 billion.[8]

The greater fighter aircraft global market is best described as an *oligopoly* with various externalities, including nation-state regulations, export controls and countless political concerns such as subsidies and enduring/strategic partnerships. The market currently contains a number of competitors beyond Boeing and Lockheed Martin's entries, including France's Rafale, into which its recent win in the Indian Medium Multi-Role Combat Aircraft competition has breathed life; the Eurofighter Typhoon backed by Germany, Britain, Spain, and Italy, which could exit the market by 2020-2025; Russian MiG fighters, which remain competitive; Sukhoi's fifth-generation PAK-FA that will come into its own toward the end of the decade; as well as emerging Chinese fighters which could overcome their near-term lack of appeal to contend beyond 2020. Many currently forecast that the global fighter market will condense to just two prime competitors by decade's end: Lockheed Martin from the U.S., and Russia's Unified Aircraft Corporation (OAK). Some additional highlights in the global aircraft market:

Europe: Recent "draconian UK and German defense cuts" will greatly impact the European fighter aircraft market and, may, in particular, hasten the Eurofighter's death.[9] Although the UK, the Netherlands, and Italy have continued in their (limited) support of the F-35 program, Norway's government coalition has recently hesitated about funding more than $7

billion worth of F-35 acquisitions.[10] Despite its 2011 win in Switzerland and long-term Swedish government support, Saab will have to cope with a difficult international competitive position if it does not win the ongoing Brazil competition.

Russia: Russia continues to receive orders for its improved MiG line. The Indian Navy requested MiG-29K's and Russia has expressed interest in additional purchases. [11] Russia's Su-37/30 also continues to sell. Recently, Russia expressed concern over potentially selling 48 Su-35 Flankers to China. [12] The Russians want a guarantee that China won't produce "reverse-engineered copies" of the fighter that China will likely balk at providing. The Russian Sukhoi T-50, regarded as similar to the F-22 but with current-generation systems, isn't likely to be fielded until close to the end of the decade.[13] The Russian Air Force is set to receive the first 48 of the newly built Sukhoi Su-35s, for which Putin signed following the 2009 Moscow Air Show. [14]

Turkey: Turkey had considered a partnership with South Korea for the KF-X project, but decided against that option due to a perceived unequal partnership. Turkey still plans to purchase 116 F-35s, even as it continues to assist Lockheed Martin by purchasing additional F-16s. [15]

Middle East: Saudi Arabia's recent order for 84 F-15s extends the Boeing line through 2018. Additional competitions in Qatar, Kuwait, Malaysia, Oman, and UAE offer additional opportunities for fighter aircraft firms, since the F-35 will not play a role there. [16] Additionally, as Russian defense sales to the Asia-Pacific area have recently decreased, Moscow has increased its business with Syria, which has ordered MiG-29 fighters. [17]

South America/Brazil: Embraer maintains a leading role in global *regional aircraft* sales and Brazil offers solid military *trainers* for interested nations. The U.S. decision to cancel its order for training aircraft may impede Boeing's ability to compete with France and Sweden for a potential $30 billion fighter jet contract for the Brazilian military. [18]

Asian Market: South Korea is pursuing the purchase of approximately 150 long-term next-generation fighters (KF-X) to replace its current F-16C/D. In January of 2012, the government announced the third phase of its F-X program with Boeing's F-15SE Silent Eagle competing against Lockheed Martin's F-35 Lightning II and the Eurofighter Typhoon. [19] A Lockheed Martin win in South Korea would further accelerate its dominance in the fighter market.

Japan: Japan recently signed on for its Air Self-Defense Force to purchase 42 F-35As to replace its last two squadrons of Vietnam-era F-4EJ Phantom fighters, despite an earlier preference for Lockheed Martin's F-22 Raptor.[20] The greater debate within Japan reportedly concerns choosing whether to produce F-35s locally or purchase them off the shelf to save money.[21]

Singapore: Singapore began receiving post-2009 its 12 F-15SG orders and is expected to require about 20 more fighters to replace its F-5S Tigers sometime in the next decade (possibly with JSF/F-35).[22]

Australia: Australia has joined the F-35 program, but concerns over the F-35s availability date coupled with the age of its F-111 force recently led it to make an interim buy of 24 F/A-18F Super Hornet Block II aircraft at a cost of $4.6 billion. Further, Australia is funding an F/A-18 Hornet upgrade at a cost of about A$107M.[23]

China: China is continuing to develop a fourth-generation fighter program while leaning into a fifth-generation capability that may surface post-2020. Like Russia's T-50 program, China's J-20 program should be closely monitored.

Conclusion

Lockheed Martin will likely be the single major U.S. fighter prime in the medium term, leaving Boeing to rely on other markets as its ability to compete in the fighter niche erodes. This scenario could have significant negative long-term ramifications for the U.S. government, as a lack of competition will inevitably lead to higher costs—and perhaps the loss of fighter design and manufacturing expertise at previously reliable firms. Additionally, while the global demand for fighters may continue to rise, by 2020 competition in the world fighter market will have dwindled to just two challengers as Lockheed Martin and Russia's Unified Aircraft Corporation square off in what will remain an intense fighter aircraft market; Europe having been co-opted by the F-35, and China still emerging in the high end of the fighter market.

UNMANNED AERIAL VEHICLES

The consolidation of fighter aircraft expertise within a single U.S. vendor has advantages, but it also leaves the market without competition. This trend, however, creates an environment where there is no market for low-cost manned combat aircraft. The Unmanned Aerial Vehicle (UAV) market provides a counter toward these trends because it provides opportunities for new entrants to the market and as well as a viable low-cost alternative to traditional manned platforms.

The UAV market is among the aerospace industry's most dynamic sectors. The market has expanded by an order of magnitude since operations in Bosnia.[24] Despite multiple challengers, U.S. firms are sufficiently well positioned, financed and innovative to maintain dominance in the most valued segments of the domestic and international UAV markets.

U.S. Market Analysis

Structurally, the domestic market is largely a monopsony, with numerous providers serving one customer, the U.S. government (primarily DoD). Internationally, the market is an oligopoly. Although there are numerous suppliers and buyers, the buyers are principally sovereign governments, predictably leading to imperfect competition. Thus, structurally, power, wealth, influence, alliances, coalitions, adversarial relationships and politics all play greater roles in the market than product differentiation. Governments nearly always simultaneously play the part of buyer, seller and regulator, and are typically willing the pay a sovereignty price to purchase domestically, or at least collect *juste retour*.

Five Forces Analysis

Threat of New Entrants: The UAV market is one developing nations can enter on the low end and move up market. The wide variety of UAV types means the barriers to entry at the mini UAV end of the market are substantially lower than for any other type of aircraft. Additionally, the affordability of UAVs enables them to attract a wide assortment of new customers. In this market ripe for innovation, many firms could enter, engage in internal research and development and bring speculative products to market in hopes of generating sales.

The U.S. currently accounts for 77% of all UAV research, development, testing and evaluation (RDT&E) and 69% of procurement spending.[25] Israel long led the UAV market,

but expanding U.S. demand for wars in Afghanistan and Iraq, and the global War on Terror made the U.S. the dominant player in terms of programs, sensors and broad operational experience in all segments of the UAV market. Indeed, $3.2 billion in U.S. UAV contracts, or 15% of the entire market, is currently out for bids.[26] DoD's long-range plan calls for a 45% increase to its Medium-Altitude Long-Endurance (MALE) and High-Altitude Long-Endurance (HALE) fleets by 2042.[27]

Europe has multiple companies seeking to compete across the range of UAV/UCAV categories, but thus far they represent only 4% of the world market and will need to collaborate to achieve reasonable economies of scale.[28] However, they will likely be willing to pay the sovereignty price to stay in a market that may prove lucrative and have spin-off command-and-control, autonomous-vehicle and airspace-control technologies. Italy and Germany have both flown UCAV technology demonstrators, [29, 30, 31] but only the joint effort between France (Dassualt) and Sweden (Saab) on the Neuron UCAV demonstrator with stealth features has production potential. [32, 33,34, 35,36] In Asia, with the exception of China[37,38,39] and possibly Japan,[40] countries appear content to buy rather than produce UAVs in the near term. China seems willing to compete on a cost basis, but is currently unable to generate technologically competent designs.[41]

In the longer term, all countries will continue to confront the rising costs of defense procurement, training and manpower. Firms with increasingly automated UAVs will enjoy a competitive market advantage by virtue of reducing training and manpower burdens. Northrup Grumman is keen to guard the arguable advantage its Global Hawk has in this respect. However, using their significant robotics expertise, South Korea, Japan or and Singapore could bring highly differentiated automated UAVs to the market. Long-time UAV leader Israel seeks to do much the same.

The non-defense portion of the UAV market remains small and specialized, and suffers more than do defense efforts from airspace control and regulation issues. Law enforcement is the area of greatest potential, but most UAVs are geared for defense customers and are far more robust than required by law enforcement agencies. Cost is also a factor for all but the largest police forces. Probable infrequent use and the contaminant training issues, in an operating environment constrained by privacy and civil rights considerations are but a few of the burdens that will constrain the non-defense UAV market.

Bargaining Power of Suppliers: Customers can demand to become suppliers via technology transfer and offsets, giving them the power of buyer and supplier in a single stroke. Small UAVs do not have overly complex supply chains, typically enabling the companies that make them to vertically integrate. The situation is more complicated at the HALE and UCAV levels, but overall, excepting instances of offsets and work share to secure sales, suppliers do not have a great deal of power in this market.

The heart of the market is at the MALE level and below. In that arena there are multiple offerings from the US, Israel and the plethora of new entrants mentioned above. Buyers have significant and growing power, and will be able to make demands in terms of price, sustainment, training, offsets, production and technology transfer.

Threat of Substitute Products: Threats to UAVs include conventional alternatives like those the USAF turned to when Predator production could not meet wartime demand. These include the RC-26 Liberty, the OC-130 and a variety of other conventional platforms.[42] Assets in the HALE category face competition from the P-8, RC-135 and similar aircraft.

Rivalry among Existing Competitors: General Atomics, with its breakthrough Predator

platform, has captured 81% of the MALE market and 33% of the entire UAV market.[43] Northrop Grumman is competing in the Vertical Take-off Unmanned Aerial Vehicle (VTUAV) and HALE markets with its Fire Scout and Global Hawk, respectively, and should demonstrate carrier landings next year with the X-47B, the only official U.S. UCAV program.[44] The combined strength of General Atomics and Northrup Grumman accounts for 73% of the global UAV market value.[45] Boeing has undertaken extensive UAV efforts, but its only active sales are of the Scan Eagle Small Tactical Unmanned Aerial Vehicle (STUAV). Long-term innovative efforts include the hydrogen-powered Phantom Eye MALE, the Solar Eagle HALE, and multi-role Phantom Ray technology demonstrator.[46,47]

Thus, domestically, the prime competitors are avoiding each other's strengths: Boeing is taking the STUAV segment; General Atomics the MALE; and Northrop Grumman VTUAV, HALE and UCAV. The remaining players thus assume supplier roles. Boeing may challenge in the future with its VTUAV, but its MALE and HALE offerings are distant propositions with such distinct capabilities that they may not directly compete with General Atomics or Northrop Grumman.

Internationally, Israel is an active and direct competitor, has widely sold UAVs and competes in the Tactical Unmanned Aerial Vehicle (TUAV) and MALE markets. With their small domestic market, Israel's UAV firms depend on exports. As a result, they have been more than willing to partner with European and South American nations on UAV projects.[48, 49, 50, 51]

Strategic Game Board

When to Compete: While U.S. firms certainly have a golden customer in the U.S. government, current conflicts are winding down and the defense budget is shrinking. U.S. firms should compete whenever a potential customer expresses interest, and they should embolden that interest through IRD technology demonstrations and outreach.

Where to Compete: After 2013, Asia will become the second-largest UAV market after the U.S.[52] China, and possibly Japan,[53] will become producers, but the remaining countries are content as buyers.[54] Europe, while declining to third place,[55] will still actively procure new systems.[56, 57, 58] Orders from Africa, the Middle East and Latin America could reach $500 million during the coming decade,[59] although Africa and South America will remain minor markets,[60, 61] India hopes to produce UAVs, but will remain a buyer for some time, during which time their needs will likely span all UAV categories.[62]

How to Compete: With the number of market entrants, many in start-up firms in developing countries, cost pressure is inevitable. U.S. firms must compete on differentiation, most notably in the areas of technology and innovation. As civilian use of UAVs will remain limited in the near term, and the UCAV business case is suspect as a $35 million UCAV is only estimated to survive 15 missions in a contested environment,. Cruise missiles could perform the same missions for $15 million.[63]

The future for ISR UAVs is bright. Every category of UAV is finding utility in the ISR role. It currently accounts for more than 80% of the global market is expected to rise to 90% by the end of the decade at which point it will become the most profitable segment.[64, 65, 66,67]

Conclusion

All of these market opportunities are viable for U.S. firms, all represent diplomatic opportunities for the United States, and all, in some respect, are open to highly reputable, highly regarded, and combat-proven U.S. weapons systems. Foreign governments are,

however, well aware of their many alternatives, and will expect concessions, offsets and technology transfer as a cost of doing business.

The global UAV market is dynamic and growing, and likely represents a new direction for the entire aircraft industry. U.S. firms are well positioned, but must continue to lead in the UAV market to maintain their advantage in the aircraft industry. Given the open nature of the market in terms of receptivity to innovation and new entrants, companies must be on their game to successfully compete. While many of these new entrants will attempt to compete on price, U.S. firms must stay true to their strengths of high technology, innovation and integration in order to create differentiated products. Those strengths are more likely to pay dividends at the high end of the market than they are with smaller airframes, where new entrants will compete strongly. Lastly, globalization and international sales are critical to success. While U.S. firms must bring world class systems to market to compete, they must also acknowledge that customers have choices, and they are unlikely to go with even the best systems on the market without concessions of work share, offsets, or technology transfer. One method to circumvent this problem is for U.S. firms to co-opt or acquire foreign companies that participate in production and development in order to become insiders in overseas markets.

For the U.S. government, promoting and marketing UAVs internationally provides an opportunity to forge and influence relationships as a means to achieve foreign policy ends. The U.S. should expect a sort of *juste retour* in return for security guarantees and political support. Collectively, these efforts can keep America on top in the UAV market and the broader aircraft industry.

GOVERNMENT-INDUSTRY RELATIONS

Independent of whether the DoD purchases manned fighter aircraft or UAVs, the methods used by the DoD to purchase those systems have substantial impact on the industry. In addition to understanding the market dynamics, the DoD acquisition power, federal acquisition process, and US Government technology trade arrangements must be understood and reformed in order to ensure the U.S. stays competitive at home and abroad.

The DoD's FY13 defense budget request represents a $259 billion reduction over the next five years relative to last year's request.[68] This is the first half of a planned $487 billion reduction over the next decade,[69]which is, in turn, about half the "draconian" reduction that would occur under sequestration. Many analysts cite historically larger post-conflict downturns in defense spending as evidencee that sequestration-size cuts are inevitable. The US aerospace industry is justifiably concerned that such reductions could lead to the atrophy or "hollowing-out" of the military aircraft industrial base.[70] This decline continues a daunting trend in the number of new military aircraft development programs in the US. The following figure (adapted from Gunzinger and further adapted from a RAND study) illustrates the alarming decline in new aircraft designs since the 1950s.[71]

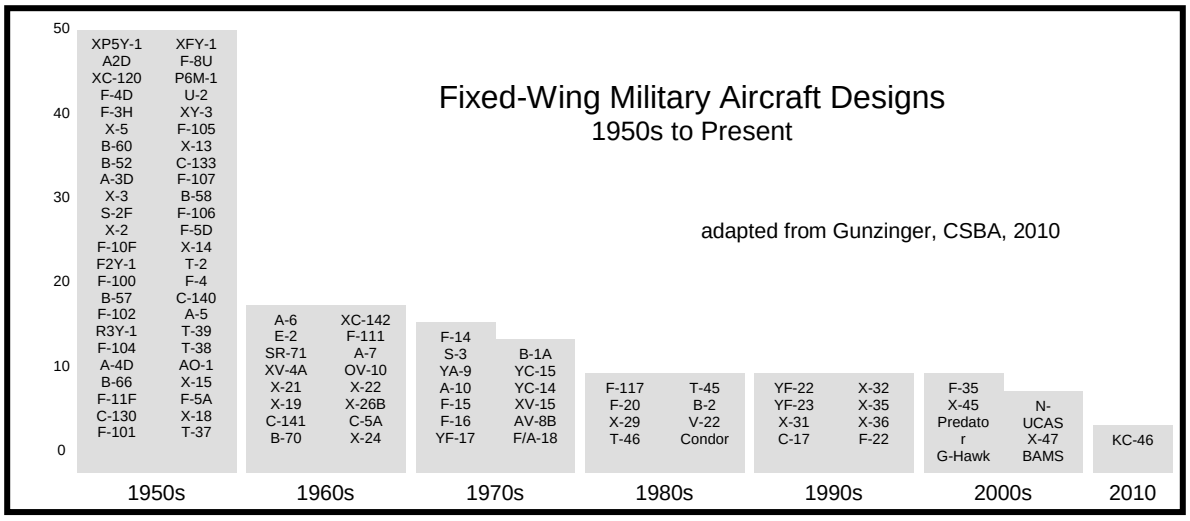


Figure 1 – New Aircraft Designs 1950s to Present

While the above figure illustrates the lack of new programs, a more telling trend is the greater paucity ofer Major Defense Acquisition Programs (MDAPs) of aircraft intended to become operational. The F-22 and the F-35 are the only entirely new USAF fighter MDAPs in production since the Advanced Tactical Fighter program began in 1981.

Although this paper focuses primarily on fighter programs, it is worth noting that this phenomenon is far broader: prior to the nascent KC-46 program, the last new tanker MDAP was the KC-10, first flown in 1980. In the 60 years since the B-52's first flight, only two new bombers have been produced for USAF, the B-1 and the B-2. Likewise, the C-17 is the only large transport MDAP since the 1960's-era C-5.

Winner-Take-All Programs

These trends, coupled with the significant consolidation of the defense industry since 1993, have resulted in "winner-take-all" defense industry contracts. According to the Defense Acquisition Performance Assessment Project's panel report, consolidation of the defense industrial base and attrition of the supplier base at the second- and lower tiers has reduced competition and increased acquisition instability.[72]

The current acquisition model, in which programs like the F-35 consolidate multiple capability needs into a single acquisition, force industry into "must win" cost competitions and create programs that are "too big to fail."[73] The panel found that in these competitions, industry's confidence in its ability to deliver the capabilities specified with the dedicated financial and temporal resources is only 20 percent specifi.[74] Contracts are then awarded at the proposed cost and schedule.[75] This "Conspiracy of Hope" almost ensures that programs will experience significant cost growth and schedule extensions during development.[76] The culture surrounding defense acquisition feeds off the Conspiracy of Hope and puts Program Managers (PMs) in an impossible situation. According to the GAO, this pressures PMs to produce overly optimistic cost and schedule estimates.[77]

Growth of EMD Phase Cost and Schedule

An alarming trend of increasing costs and schedules of MDAPs, particularly during the Engineering and Manufacturing Development (EMD) phase, also threatens the industry's health. In its March 2012 annual assessment, GAO reported that development costs for DoD

weapons programs grew by $13.7 billion in 2011.[78] The F-35 represents nearly $4 billion of the increase; the F-22 $780 million, and the Global Hawk $722 million.[79]

These are *developmental* cost increases, despite the fact that the programs have been in *production* for an average of eight years.[80] The GAO also reported that additional 2011 schedule delays signify that the average weapon system is now delivered 23 months behind schedule. Two factors driving these cost and schedule increases are the development of new technologies as part of EMD (closely associated with overly ambitious requirements) and the initiation of production prior to completing flight tests, a process known as concurrency.

Effects of Uncertainty in Predicting the Future Defense Environment

Predicting the strategic, political and technological environment 2-4 years into the future is difficult enough, but DoD typically undertakes acquisition programs of considerably longer duration—increasing the degree of uncertainty about the environment in which systems will operate. Time is linear. Defense environment uncertainty and development costs are not. As developmental timelines extend, the effects of uncertainty become ever more dominant...and costs increase ever more rapidly.

As the following figure illustrates, a ten-year development program faces greater uncertainty and cost than three nearly consecutive five-year developments.

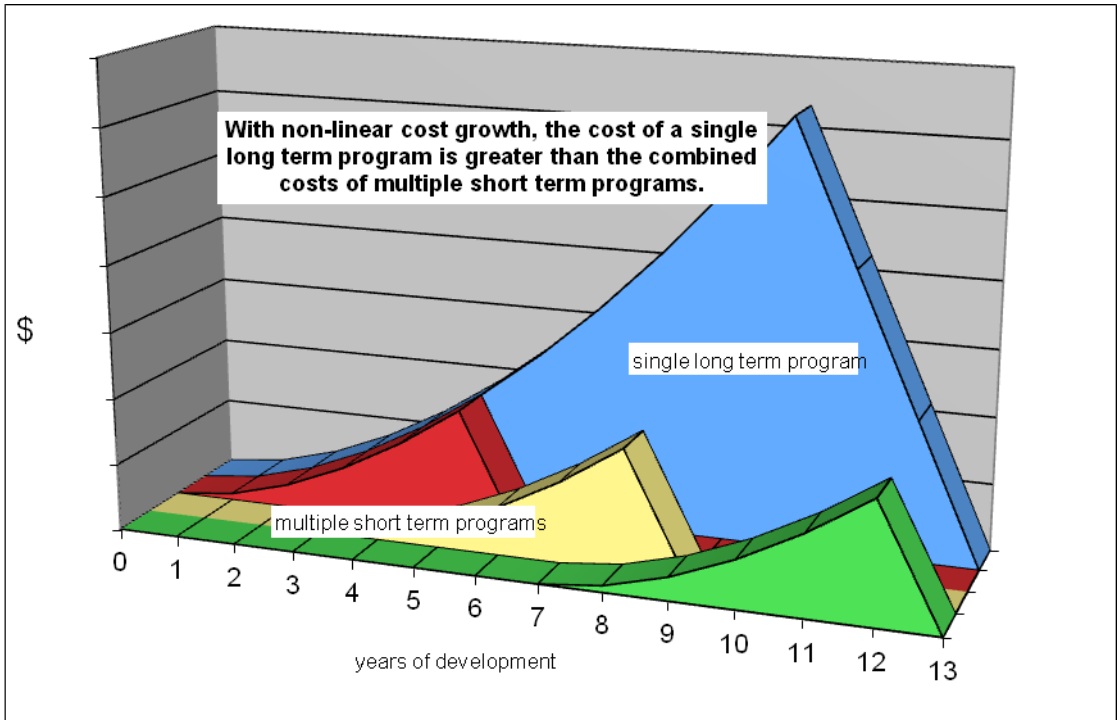


Figure 2 – Effects of Increasing Uncertainty

The cost of multiple programs' additional contracts and program offices is more than offset by exponentially rising price tag of a single long-term development in which early decisions and mistakes--as well as the commitment to a single contractor--are borne through production and sustainment. The DoD must find ways to check the trends of rising costs and lengthening schedules in the major aircraft programs which then become "too big to fail".

Programs are also becoming more complex, which casts further doubt on the future of long-term projects. But complexity cannot be reduced because it is precisely what gives new systems their advantage over legacy systems.[81] If a combat system were removed from the F-35, or if systems were made to operate in an independent rather than an interconnected manner, much of their combat capability would be lost. In complex systems, it is impossible to get it right on the first try: flexibility and resilience are the cornerstones for dealing with complex situations.[82] Future U.S. acquisition programs must take that fact into account.

The F-35 program brings complexity to an entirely new level. There are three versions of the aircraft: a conventional takeoff and landing (CTOL), a short takeoff and vertical landing (STOVL) and a carrier version. These versions are associated with the Air Force, Marine Corps, and Navy, respectively—each of which has a different set of management and oversight rules.

Added to the mix of entities the F-35 must ultimately satisfy are the eight countries (Britain, Australia, Canada, Turkey, Italy, Denmark, Norway and the Netherlands) that partnered with the United States to fund the aircraft. Japan and Israel have also announced plans to purchase the F-35.[83] The amount of offsets to manufacture parts in their countries and input into the F-35's development to which partner countries are entitled depends on how much they invested in the program.

This management complexity would be a challenge by itself, but the aircraft is also one of the most complex weapons systems ever built: its 24 million lines of software code triple those of the F-22 and are six times more than the F-18E/F's.[84] Every system is integrated and fuses data to provide the pilot with a single display of the tactical environment. Therefore, a shortfall in one system can affect everything else.

The F-35 features an innovative built-in sustainment system that Lockheed calls the Autonomic Logistics Information System (ALIS). It consists of sensors on the aircraft that determine when a part is failing and automatically alert maintainers to order a replacement through an F-35-specific Lockheed Martin supply chain. Perhaps 'weapons system' is not an insufficient title for the F-35, which has taken the term 'complexity' to an unprecedented level.

Unfortunately, the DoD still relies on its legacy program management structure to oversee the F-35's development. So far, it is not working.

Vice-Admiral David Venlet, who oversees the F-35's Joint Program Office (JPO), faces numerous complex challenges. First, the program relies on partners to help fund and keep overall unit costs down. As concurrency concerns prompt DoD to cut the F-35's production run, foreign aircraft continue to roll off the assembly line. With the DoD buying fewer F-35s, their unit price is rising and foreign partners are beginning to question their decision to buy F-35s. This could create a unit cost-related death spiral if countries decide to bail on the F-35. In March, U.S. officials attempted to assuage partner nations' concerns by pledging there would be no further program delays.[85] It is hard to imagine the U.S. can fulfill that promise given the complex nature of the F-35 and the lack of testing on mission systems to date.

The need for the JPO to coordinate across services with competing demands has created its own challenges. The JPO decided to issue only electronic flight manuals for each F-35 variant, but the Navy Department's regulations stated it required paper copies. The problem was the JPO never consulted the Navy about its preference about the manuals until the contract to produce them was already in place with Lockheed Martin.

The flight test requirements fell into the same trap. Initially the JPO decided to start unmonitored flight training concurrently with developmental testing. Unfortunately for the

JPO, that was not its decision to make: each service has its own flight clearance authority, and each demanded more developmental flight-testing prior to training. This resulted in moving the F-35s' delivery from Eglin AFB to Edwards AFB and restructuring the test program only two months from the time unmonitored flying was scheduled to begin at Eglin. These were not unknown 'black swans.' Better program management would have anticipated and prevented these issues.

These examples point to the F-35 program's interconnectedness and the seemingly insurmountable challenge to corral all the entities involved. Perhaps the problem is not the F-35's complexity, but rather the program management structure. The DoD should review and redesign its acquisition management construct to better deal with complex systems like the F-35.

Technology Development and Overly Ambitious Requirements

Too often, PMs use the EMD phase to develop and demonstrate technology rather than to integrate proven technology. DODI 5000.02 defines the purpose of the EMD phase is to integrate technologies, develop manufacturing processes, etc.[86] It specifically states that technology risk reduction should occur prior to EMD.

The desire to use an MDAP for technology development stems in part from the overly ambitious requirements often levied on new programs. Because the timelines for new aircraft developments have grown so significantly, USAF requirements officers must acknowledge that any potential technology *not fielded* as part of a particular aircraft development will not come to fruition for another 20-30 years. As a result, technologies which are today only dreams become "must-have" requirements despite their immaturity. This caused great difficulties during the development of the F-22.

The Concurrency Mistake

The Block 30 Global Hawk program provides a recent example of a failed attempt at concurrency. The GAO's latest acquisition assessment describes the concurrency built into the program: "The program procured all of its Block 20 and more than half of its Block 30 aircraft before completing operational testing…and plans to procure all of its Block 40 aircraft before it begins operational testing in 2013. In May 2011, the Director, Operational Test and Evaluation, found that the Block 30 system was not operationally effective or suitable…"[87] The DoD cancelled the Block 30 Global Hawk in January 2012 after excessive cost growth.

F-35 Program Makes Both Mistakes

The F-35 is the largest acquisition program the DoD has ever undertaken. The DoD's faith in the F-35's design maturity and the advanced design tools used to develop it led DoD to lay out a program in which low-rate initial production would start while development and testing were ongoing.[88] This decision involved accepting the risk the design would mature in a predictable fashion, problems discovered during testing would be minor and fixes could be easily incorporated into existing aircraft. Simply put, program decision makers deemed acceptable the risk of refitting production aircraft vs. the cost and schedule of a serial program.

However, the risks associated with the decision to establish a highly concurrent development, test, and production program for the F-35 aircraft have now been realized. Design changes continue at a relatively high rate, software scope and complexity persist and structural changes have been identified during testing. According to the GAO, the F-35 now

has more than 9 million lines of software code, three times the F-22's number.[89] As of 2011, it has cost the government an estimated $373 million to fix deficiencies on delivered aircraft due to problems discovered during development testing.[90] The GAO predicts the number of design changes will remain at a high level through 2019.[91]

Acting Undersecretary of Defense for Acquisition, Technology, and Logistics Frank Kendall called the decision to begin F-35 production years before its first flight test "acquisition malpractice." [92] An executive DoD team's recent review concluded the F-35 continues to suffer technical issues at a rate typical of previous fighter development programs,[93] contributing to the F-35 program's staggering cost growth and delays.

KC-46 Program is Making Both Mistakes

The KC-46 entered directly into EMD with a Milestone B declaration in February 2011. A recent GAO report identified three technologies on the KC-46 that "have not yet been demonstrated in a realistic environment".[94] The USAF could readily have tested each of these technologies prior to EMD on platforms other than the $51.7-billion KC-46. In a response to the GAO report, the KC-46 Program Office (PO) stated that Boeing is contractually bound to demonstrate the technologies in an operational environment by Milestone C.[95] Unfortunately, as this is precisely what should have happened prior to Milestone B, it effectively states that the program will be no more than *one milestone behind schedule* by the end of EMD.

The GAO report further states, "The program has an accelerated schedule with significant overlap, or concurrency, among the development, testing, and production of initial aircraft."[96] The PO response only says that its concurrency compares favorably with that of "other major aircraft acquisition programs". Given those programs' well-documented recent difficulties, the PO response does not qualify as a convincing defense.

Despite the supposed maturity of technologies required for the KC-46, five years are allotted for EMD. Even with this generous period, both the GAO and PO identify schedule risk as their primary concern. The GAO estimated that KC-46 program costs already exceed the contract amount by $900 million, only one year after contract award. Immediately after the GAO published its report, the Pentagon raised its development and procurement estimate by $276 million and added that the annual operating cost for a single KC-46 will be 60% greater than the KC-135 it replaces.[97]

Hollow DoD Acquisition Engineering Workforce

One of the recent reports on the DoD acquisition, the Defense Science Board (DSB) report *Creating a DoD Strategic Acquisition Platform* (April 2009), identified a long list of execution issues within DoD acquisition: lack of sufficient up-front analysis of alternatives; poor systems engineering support; inadequate performance, cost, and value trade-offs; poorly designed product development strategies; poor management of technical risk; growing requirements; selection of inexperienced contractors; poor contract incentives; and budget instability.[98] The role of the weapon system program office involves understanding the technical performance, cost, and schedule trade space and managing the associated risk. It is clear from the above list of execution issues that acquisition is a technical business and takes technically astute people to execute. Further, most risks on an acquisition program have a technical root cause. Meaning, it takes significant technical understanding of the complex systems the Air Force is acquiring in order to deliver the needed capability affordably and on schedule.

The DoD needs a cadre of engineering talent to work with industry to provide a 21st-century military capability. However, mid-1990s acquisition reform initiatives to halve program offices' size added to an already stunning drop in the number of Air Force and DoD acquisition personnel.[99] The workforce has fallen by more than 60 percent since 1990 while the procurement budget has grown significantly.[100] In addition, the number of major programs continues to rise: from 74 to 98 between 2002 and 2010.[101]

As Figure 2 illustrates, the Air Force's aircraft acquisition engineering workforce was hit equally hard.

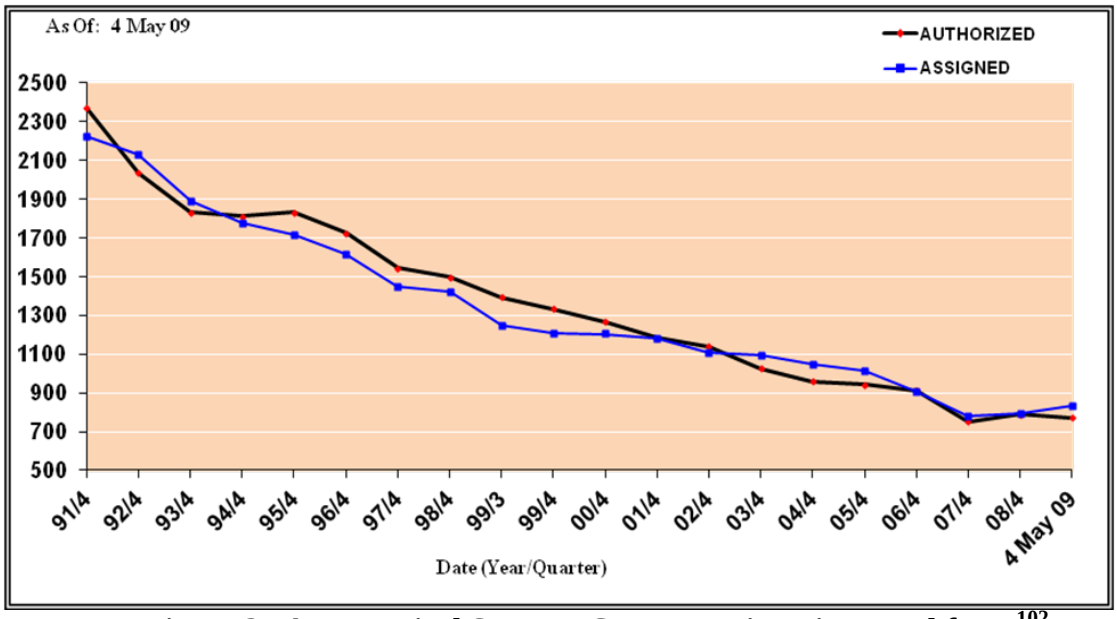


Figure 2. Aeronautical Systems Center Engineering Workforce[102]

These dramatic personnel reductions prompted the Air Force to change the way it executed acquisition programs. Locations such as the Electronics Systems Center at Hanscom Air Force Base, Massachusetts, outsourced their government engineering work to contractors or Federally Funded Research and Development Centers (FFRDCs). Others, such as the Aeronautical Systems Center (ASC, to which Figure 2 refers) at Wright-Patterson Air Force Base, the home of fighter acquisition, did not supplement Air Force programs with major increases in contractor engineering support. In neither case did the government maintain across-the-board in-house technical expertise. Instead, the Air Force managed aircraft acquisition programs from a much higher level it termed "insight" vs. "oversight." Gone were subject-matter experts supported by a functional home office of technical experts who offered independent assessments of program technical maturity and cost, schedule, and performance risks; ensured operational safety, suitability, and effectiveness; and attested to airworthiness. In their place was a much smaller engineering staff covering a much broader technical expanse and devoting more time and less detail to far more complex systems.

Both the time and expert resources that were once available for Air Force acquisition programs have evaporated in the past 20 years, leaving the engineering workforce unable accomplish its former job. Air Force acquisition engineering is a hollow force.

However, the future does not have to be gloomy. In the early 1990s, the French faced the same problems and applied a unique three-point solution: they consolidated all acquisition

management into a single government agency, they brought the acquisition workforce's technical knowledge to par with industry and they overhauled the way contracts were written to ensure fairness when determining whether the government or the contractor was liable for cost overruns.[103] Politically, implementing these reforms in the Air Force or DoD is nearly impossible but there are critical takeaways for the U.S.

Seeing that too many public and service-specific agencies had undue influence on the acquisitions process, the French consolidated all the defense acquisition institutions into one executive agency in the Ministry of Defense: the Délégation Générale pour l'Armement (DGA). The DGA handles all elements of acquisition from cradle to the grave, and is even responsible for foreign military sales.[104] The head of the DGA reports directly to the minister of defense. This is a worthy U.S. reform objective, but may be a bridge too far due to the congressional action necessary to implement it and the service parochialism surrounding acquisition.

Regarding the U.S. Air Force, several in-house measures are in fact akin to the French reform's first lesson. The Air Force almost had this type of organization with Air Force Systems Command (AFSC). Terry Mahon stated that,

Systems Command cultivated and evolved the professional management of technology and programs, employing and institutionalizing the same best practices found in private industry. It also provided high-level career paths for the technical professionals upon which the future of the service depends. Historically, many of AFSC's technocrats reached the highest levels of service leadership and achieved enviable records.[105]

Mahon recommends that the Air Force at least "re-establish a professional acquisition organization lead by senior technical professionals with full membership in 'the club'."[106] This could pay dividends merely by providing a single focal point for USAF acquisition issues.

Closely related to the first French reform is the second one—creating technically competent acquisition professionals. The French experienced the same issues with complexity management in the 1990s as the US faces today—they relied on industry to provide their technical expertise. When French officials grappled with daunting technical details—much like the F-35 JPO finds itself forced to take industry at its word with respect to the state of the F-35 program today—they established the DGA and recruited engineers from the best schools in France to staff it. Their approach would be comparable to the Air Force only hiring engineers from MIT or CalTech. To give the engineers experience on par with industry, the DGA placed them with industry or the French arsenals. Finally, the DGA assigned the engineers to a particular program for a sufficient time that they thoroughly understood it.[107]

The Air Force can do this today. An expert intimately familiar with the F-35 program might not have overlooked the Navy's need for a different flight manual format or the Air Force's desire for more pre-training developmental flight testing. However, a program manager's average length of assignment in the DoD is only two years.[108] There is no wonder the U.S. cannot effectively manage its programs. Additionally, USAF program managers receive little training and are often not acquisition professionals.

Terry Mahon offers three ways to increase the technical competency of Air Force acquisition professionals: enhance the program-management career path, promote subject-matter experts to support program managers and hire experienced industry technologists in areas in which the USAF is weak.[109]

These simple steps would offer huge benefits for the Air Force's acquisition process. The first two require no human or capital resources—only a shift in mindset. The program

managers that cycle through the F-35 JPO today are mostly test pilots fulfilling an obligatory staff job. They are not acquisition professionals and move on to other jobs just as they learn the ropes.

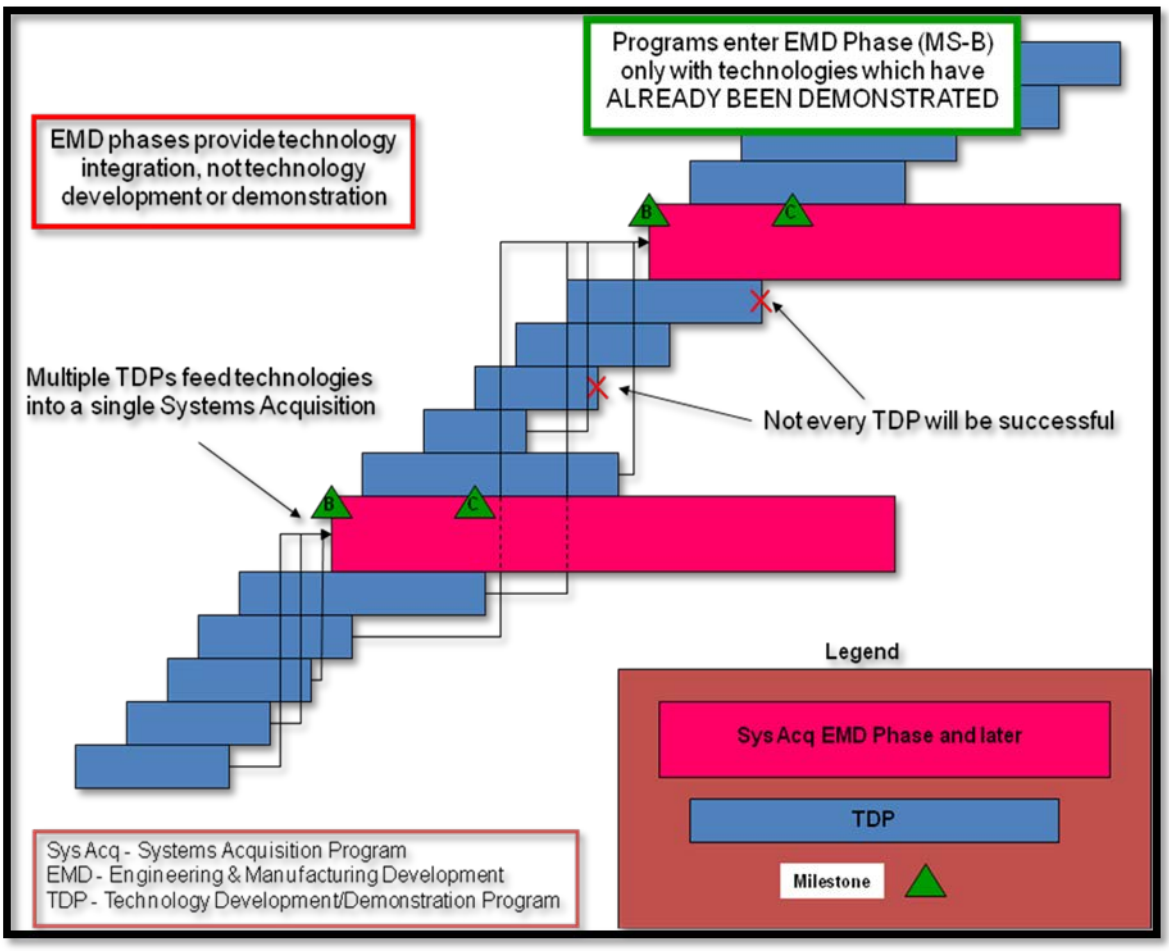
The third lesson from the French is creating fairness in contract performance. With the advent of new highly trained and technologically savvy professionals, the French found it much easier to have an open dialogue with contractors because the government could better ascertain whether the contractor was telling the truth. If contractors underbid, DGA officials could quickly discern it.[110] The U.S. DoD has lost its ability to judge a project's degree of difficulty and feasibility.[111]

By contrast, the French became so good at it they were able to use firm-fixed price contracts from the beginning (with breathing room for growth in advanced and new technologies) because there was enough expertise among both contract parties to actually predict costs. The French also hold each side accountable for cost overruns: if the government changes a requirement, it is liable; if industry underbids, it is responsible.[112] Contract types do not change the complexity of weapons systems but it is enlightening to see what is possible with experts on both sides of the aisle vice the U.S. model in which the majority of the expertise resides within industry.

By developing institutions replete with longstanding expertise the French provide illustrate how to better manage complex systems. The DoD has devolved from this technical approach toward a more managerial approach. Perhaps the lessons from the successful French model are ones DoD can use to better manage its future complex systems. Combining this with historical lessons on concurrency, the DoD can posture itself to more effectively manage these systems.

Recommendations

Changes to Acquisition Policy: This paper advocates changes to acquisition policy that attempt to eliminate overly ambitious requirements, forestall technology development during EMD and reduce concurrency. First, modest and more frequent MDAPs supported by multiple technology development programs (TDPs) should supplant single and massive, "Winner-Take-All" MDAPs. These TDPs will nurture technologies to the point of demonstration—Technology Readiness Level-6 (TRL-6)[113]—in a relevant environment. Only at that stage should such technologies become the bases of an acquisition program's requirements. These TDPs will provide decision-makers a menu of mature technologies. Figure 3 below provides a notional depiction of this framework.



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fFigure 3 – Proposed Acquisition Framework

The next proposal is a means of managing when defining requirements. Milestone Decision Authorities (MDAs) should not grant Milestone B (MS B) approval until all relevant technologies have achieved TRL 6. U.S. Code Title 10—Armed Forces, already includes this as law. "A [MDAP] may not receive [MS B] approval…until the [MDA]…certifies that…the technology in the program has been demonstrated in a relevant environment…".[114]

The USAF frequently fails to abide by this law. Indeed, DoD policy also dictates that "Technology developed in S&T or procured from industry or other sources shall have been demonstrated in a relevant environment or, preferably, in an operational environment to be considered mature enough to use for product development".[115] The Joint Requirements Oversight Council (JROC) should help "save PMs from themselves" by only validating requirements associated with TRL-6 or higher technologies for MDAPs.

The next proposal is a mandated limitation on the contractual length of EMD phases to no more than three years unless waived by USD AT&L.[116] Limiting the length of EMD will further force PMs to develop acquisition strategies which do not rely on technological development during EMD. A final proposal is to reduce the use of "concurrency" in weapons development. Concurrency typically occurs when programs begin production prior to the completion of the EMD phase, and often prior to the completion of flight test. Each phase of acquisition is intended to serve a distinct purpose. Starting a phase before prior phases are complete may be an attractive way to save money on paper, but all too often it costs more in the

long run when it becomes necessary to take apart and retrofit deficient aircraft in the field. These retrofits are often far more expensive than the savings gained by early production starts on unproven systems.

Fix Hollowed-Out Workforce: In 2009, the president and secretary of defense directed that the acquisition workforce be revitalized.[117] The 2010 Quadrennial Defense Review identified a plan to increase the number of acquisition personnel by 20,000 by 2015.[118] The DoD's Defense Acquisition Workforce Improvement Strategy explained that 10,000 new hires and 10,000 converted contractors would comprise the 20,000 additions to the federal workforce. Now, the DoD and the Air Force must identify the critical areas for in-house technical knowledge and develop the acquisition workforce. Fighters are technology-driven systems and fighter acquisition is a technically challenging business and requires people with strong technical skills and abilities to execute programs. Program management is fundamentally about identifying, managing, and mitigating risk. Virtually all risks in fighter acquisition programs have technical root causes and require technically astute people to understand and manage them.

There are many lessons the United States can learn from the French. The DoD cannot copy the system, but it can place trained acquisition professionals in positions to better manage complex systems. Having the right people with the proper knowledge in positions where they are granted flexibility and resiliency to deal with complex systems is the key to ensuring the viability of the DoD acquisition corps. The DoD must use the looming fiscal restraints as a springboard to overhaul the current acquisition system. In order to continue to develop new complex technologies while minimizing fiscal scrutiny, it is imperative DoD makes the necessary overhauls in program management today to secure its future.

ITAR Reforms: Defense industry companies in general and fighter aircraft manufacturers in specific complain that U.S. export licensing delays have given market share to their international competitors. All seek a less restrictive export approval process that would allow for easier completion of international projects, reduced barriers to international cooperation and an opportunity to increase market share in a less restrictive ITAR (International Trafficking in Arms Regulations) environment.

U.S. aircraft manufacturers and international defense industry partners alike view the current ITAR regime as a burdensome bureaucratic labyrinth that delays the processing of exports and demands extensive industry resources to comply with an overprotective and outdated technology-protection mechanism[119]. In response to industry complaints about ITAR, former Defense Secretary Robert Gates, in collaboration with several U.S. government agencies, proposed in April 2010 the "four singles" recommendations to improve and streamline the ITAR system.

These reforms consist of a single-tiered export control list versus the current United States Munitions List (USML) and Commerce Control List (CCL), a single export-control agency, a single enforcement agency and a new integrated information technology system to manage the export license application process.[120] The reforms' main objective is to reduce the number of controlled export items through a tiered listing regime that protects only those technologies deemed critical to national security.

Implementation of the "four singles" is an ongoing process and will at some point require consolidating several government agencies' resources to form a single agency responsible for administering the export of defense items. By allowing the fighter aircraft industry to export via bilateral defense trade agreements items expressly excluded from blanket

ITAR trade agreements, the "four singles" approach is a fundamental component to expediting U.S. fighter exports. The defense trade agreements the U.S. signs with allied countries include an approved system to vet industry-trading partners and monitor the use and transfer of critical technology. That element must serve as a key factor favoring more rapid approval of export licenses.

Successful ITAR reforms and expedited Arms Export Control Act (AECA) processes coupled with expanded bilateral defense trade agreements would augment U.S. fighter aircraft and Unmanned Airborne Systems' (UAS) overseas sales, helping offset sinking U.S. defense budgets and soaring fighter aircraft procurement costs. To satisfy the defense industrial base's needs, an increase in bilateral trade agreements and a selectively more liberal UAS export policy should complement ITAR reforms.

Defense Trade Agreements: With more than 2700 airframes on order over the next 25 years, the F-35 program is one to which the U.S. government remains strongly committed. The F-35 will replace aging fighter aircraft and provide new capabilities to the U.S. military and international partners.[121] Although the U.S. commitment is steadfast, prime contractor Lockheed Martin and the U.S. government are experiencing escalating program costs and schedule delays. Continuing problems of this nature in a fiscally squeezed acquisition environment portend a persistent rise in program costs that will likely result in fewer options for additional program funding from congressional overseers. Faced with limited funding prospects to cover F-35 cost overruns and U.S. government hesitance to place excessive financial risk on Lockheed Martin, the DoD must consider other policy approaches to ensure the U.S. maintains the innovative edge in the global fighter aircraft industry that enables it to sustain its global market share.

How can the U.S. foster a fiscally sound and innovative domestic fighter industry that retains—or expands upon—its dominant global market share? The U.S. government and U.S. fighter manufacturers must continue spreading fighter development costs and production risk by promoting and expanding the use of government-to-government bilateral defense trade agreements that clearly articulate technology transfer terms across a wide spectrum of military capabilities. Some advantages of defense trade agreements:

- Cost sharing during capital-intensive development and production phases
- ITAR waiver authorities that enhance exports by reducing trade barriers
- Compliance monitoring systems that protect U.S. intellectual property rights and "crown jewel" technologies[122]
- Cooperative production agreements between governments and industry
- Collaboration across core industry disciplines that fosters development of innovative strategies and technology
- Increase in international partners' reliance on U.S. technology
- Promotion of joint projects that further U.S. expansion into untapped markets
- Spin-off technologies that enhance U.S. defense sector capabilities

Currently there are three bilateral U.S. defense trade agreements that affect the fighter aircraft sector: two active and one in the implementation process. The U.S. also operates defense cooperation agreements with North Atlantic Trade Organization (NATO) members and accords expedited export of defense-related equipment and services to countries outside NATO such as Japan and Israel.

Implemented via the 1963 Defense Development Sharing Agreement, Canada's was the first defense trade agreement. Under it, Canada is the world's sole beneficiary of a nearly

complete ITAR exemption. This unique partnership came under the aegis of a North American defense treaty designed to enhance the bilateral defense posture and expedite the transfer of military technology that supports the Canadian and U.S armed services.[123] The result is that Canadian and U.S. defense industries need not seek specific export control licenses under the AECA for certain defense-related equipment or services. This much sought-after ITAR exemption allows for the expeditious sale and transfer of export- and import-controlled USML items between U.S. industry, international partners—and, in some cases, third-party international allies on a jointly approved list. In addition to Canada's exemption, a United Kingdom (U.K.) exemption came into effect in April 2012 and Australia will soon acquire similar status upon approval of the Australian government's 2012 Defense Trade Control Regulations.

Establishing a formal defense trade treaty can be a lengthy process. In 2007 both Australia and the U.K. signed defense cooperation trade treaties with the U.S. Executive Branch, but Congress did not fully ratify these signed commitments or the associated implementing legislation until 2012. A pitfall of bilateral trade agreements is that signatory countries must engage with their respective political and government institutions to amend existing laws and regulations—or create new ones—to permit the execution and implementation of new agreements. In the Australian and British cases, that process has taken more than five years. Amendments to ITAR rules by the U.S. State Department's Directorate of Defense Trade Controls further delayed Congress's final ratification of the two defense trade treaties. Approved congressional changes to the AECA also contributed to the delay.

When finally implemented, the new defense trade agreements will provide Australia and the U.K. with ITAR exemptions very similar to Canada's.[124] A U.S. State Department fact sheet outlines the new treaties' core benefits:

- With the exception of certain exempt USML items, signatories will be able to export U.S. defense products into and amongst the approved community without normally ITAR-mandated prior export licenses;
- Exported items must support military or counter-terrorism operations; cooperative security and defense research; development, production and support activities; and mutually agreed security and defense projects for which the end user is the U.K. or Australian government; or certain U.S. government end uses
- Establishment of approved defense, government and private sector communities within the respective treaty countries;
- Approval and vetting of these communities by the U.S., U.K. and Australian governments;
- Congressional notification requirements under the Arms Export Control Act procurement thresholds must be followed for exports of defense articles and services exceeding $25 million for major defense equipment and $100 million for other defense articles and services. [125]

The conditions listed above will provide a more expeditious export control process for U.K., Australian and U.S. fighter aircraft components and services in certain aircraft subsystems such as landing gear, avionics, flight control surfaces and generic airframe components. However, there are still restrictions in the treaties that will require export ITAR licensing compliance, although these restricted areas will now receive expedited ITAR processing when requested by trusted partners. To protect certain key defense knowledge, the State Department has introduced export exemptions in Part 126 of the AECA that may limit the fighter aircraft industry's ability to operate export license free in a global market:[126]

- Classified defense articles and services, unless exported pursuant to U.S. Department of Defense request, contract or directive;
- Items on the Missile Technology Control Regime Annex;
- Reduced observables or counter low observables;
- Sensor fusion except that required for display or identification;
- Method or existence of compliance with anti-tampering measures made at U.S. government direction;
- Gas turbine engine hot section components and digital engine controls;
- Various types of software source code.

Many of the restricted items above are inherent to large DoD fighter aircraft acquisition programs, specifically stealth low observable, sensor fusion and turbine gas engine technology and will thus still require separate export license approval that could hamper the industry's ability to achieve a completely open and competitive global defense trade. These limitations are designed to ensure that certain technologies considered essential to U.S. national security interests are protected. These measures must be regarded as a necessary risk-mitigation measure by the fighter aircraft industry.

Overall, the two defense trade treaties currently being implemented will allow for expedited defense trade between international partners; generate greater access to foreign defense aircraft markets for the U.S., U.K. and Australia; improve collaboration through the exchange of military capability and technologies; reduce private industry overhead necessary to manage export licensing requirements; increase opportunity to negotiate offsets early in a fighter aircraft procurement process with a reasonable expectation that new technology can be transferred rapidly and provide improved opportunity for U.S. fighter aircraft industry to compete for defense services in international markets.

UAS Exports and the Missile Technology Control Regime: Despite growing worldwide interest in UAS for military, civilian and commercial purposes, U.S. application of its overly restrictive Missile Technology Control Regime (MTCR) obligations hampers consistent UAS exports. To promote the U.S. defense industrial base health in this fledgling technological area, gain or keep access to strategic areas of the world and increase interoperability with partner nations, the U.S. should adopt an export decision-making construct that enforces its MTCR obligations and protects pivotal U.S. technology while giving U.S. companies more space to export their products.

Established in April 1987, the MTCR aims to limit the proliferation of weapons of mass destruction (WMD) by controlling the transfers of delivery systems and associated technology.[127] The regime's 34 members, who include most of the world's missile manufacturers, agree to restrict their exports of missiles and related technologies capable of carrying a 500 kg payload at least 300 km.[128] Originally intended only for missiles, the MTCR in 1992 incorporating rockets, drones, cruise missiles and UAS as part of the most restrictive "Category I".[129] While exports of Category I items are not completely banned, members agreed to a case-by-case export-control policy using a "strong presumption to deny" philosophy.

That is not to say that all exports are banned. MTCR members weigh five factors when evaluating a possible export: the proposed recipient's ambitions for acquiring WMD; the purpose and capabilities of the recipient's missile and space programs; the potential contribution the export would have on the recipient's development of WMD delivery systems; the credibility of the recipient's stated purpose; and whether the sale adheres to multilateral treaties.[130] Besides relying upon government assurances and US intelligence sources,

confidence in the buyer's answers is strengthened when the government in question is a signatory to the MTCR, the Treaty on Non-Proliferation of Nuclear Weapons, and the United Nations Chemical and Biological Weapons Conventions. If the answers are not satisfactory, then the "strong presumption of denial" is used to deny the export request. If the answers are satisfactory and the export otherwise meets U.S. export and national security requirements, the export request should be approved with the full confidence that MTCR obligations are fulfilled. The ultimate decision to export MTCR-controlled technology remains the sole and sovereign judgment of the member government.[131]

Translating the MTCR's payload and range restrictions to current UAS aircraft illustrates that the MTCR does not address Group 1-3 small tactical UAS, thus should be included in bilateral trade negotiations and aggressively promoted for export in accordance with the AECA and the U.S. export policy process.[132] The larger Group 4 and 5 UAS—among them the Predator, Global Hawk and Hummingbird—do fall within the MTCR's parameters. While many Group 4 and 5 UAS such as the MQ-9 and the future UCAV can deliver limited conventional weapons, most are designed purely for ISR use and are not realistic WMD delivery vehicles.[133]

Recognizing this dilemma, the Bush Administration and the U.K. proposed removing certain ISR UAS from the MTCR's Category I list—thus obviating the "strong presumption of denial" policy. Most member nations agreed with the approach, but the U.S. and U.K. failed to obtain consensus of all 34 members: the language change was not implemented.[134]

Although the U.S. can export UAS technology within the current MTCR agreement, the Departments of Commerce and State—which execute the policy—seem to view its "strong presumption of denial" as a "requirement to deny." They have approved since 2003 only 25 UAS export licenses (mostly of small tactical UAS) valued at a total of $4 million.

U.S. export policy often appears to focus more on inhibiting the export of UAS than it does on achieving the MTCR's stated goal of preventing WMD proliferation.[135] This has led UAV companies and interested countries to lobby the U.S. government to resume the Bush Administration's quest to relax parts of the MTCR. The same groups also desire an updated U.S. policy with a path for overcoming the "strong presumption of denial" restriction. [136]

DoD responded in February 2011 with a Defense Security Cooperation Agency policy memorandum that guides Security Cooperation Organization actions in support of purchase requests for MTCR Category I ISR UAS and UCAV. This policy essentially provides a more-detailed blueprint for assessing the implications of exporting MTCR technologies to foreign governments. It asks 20 comprehensive questions that provide the information needed to effectively assess the regional security implications, interoperability issues and risk for inadvertent technology transfer involved with potential sales.[137]

While adjusting the language of the MTCR may seem the best long-term solution to the UAS export issue, obtaining consensus among 34 member states with individual agendas is difficult, time consuming and risky. Several of the existing MTCR's characteristics also make internal US export policy adjustments the preferred course of action.

First, the MTCR is voluntary: export decisions rest solely on sovereign member governments. Additionally, although U.S. law mandates sanctions for individuals, companies and governments that transfer technology to states identified as WMD proliferators or threats to U.S. security, there are no penalties for exporting MTCR-controlled items.[138] Finally, numerous UAS producers such as Israel and China are not signatories of the MTCR and export UAS technology without regard for the WMD proliferation implications. A reformed U.S.

export policy that encourages UAS sales while ensuring the technology is not used for WMD delivery is clearly a preferable option.

The MTCR strives to deny the export of UAS with range and payload capabilities that could be used or adapted to deliver WMDs. If the UAS range is less than 300 km or the payload capability is less than 500 kg, then the UAS meets MTCR guidelines and should qualify for export provided it complies with other U.S. export controls and national security objectives. This will include the vast majority of Group 1-3 small tactical UAS. However, as customers covet the extended flight duration of most Group 4 and 5 UAS, they will likely exceed the MTCR's 300-km range limit. Since range is calculated by the one-way distance using the most fuel-efficient flight profile independent of external limitations such as line-of-sight data links or operational constraints, there is little that can be done to artificially curtail the range of export UAS.[139]

The payload restriction, however, may provide an avenue for MTCR relief and additional WMD proliferation protection. According to the MTCR, the term "payload" includes munitions of any type; mechanisms and devices for safing, arming, fuzing or firing and any other mission equipment that can be removed without violating the integrity of the vehicle.[140] Safeguards that preclude removing mission payloads or compromise the airworthiness of UAVs upon their removal would satisfy the payload criterion and permit authorization of export requests with the caveats previously discussed. If these safeguards are impossible or unacceptable to the customer, the MTCR still provides an avenue to complete the export provided the U.S. government receives assurances that the proposed recipient of the UAS will use it only for the purpose stated on the export license without modification and the system will not transferred without U.S. consent.[141] This caveat could also be used for MQ-9 or UCAV exports although clearly they would carry higher risk than ISR UAS.

The benefits of returning the U.S. interpretation of its MTCR obligations to the regime's core goal of preventing WMD proliferation are clear. First, the U.S. is freed to export UAS in a manner that serves its overarching national security strategy. Given the second-largest UAS market is in the Asia-Pacific region and that the new U.S. military strategy calls for a pivot to that same vital region, UAS exports may increase the U.S. ability to build regional partnerships and improve interoperability with respective militaries. Additionally, increased U.S. ability to export UAS will better promote the health of the defense industrial base. Despite the planned increase in domestic sales, the numbers and types of UAS are still somewhat limited and insufficient to support a highly competitive UAS industry and fully fund research and development. Export sales should encourage more firms to stay in the market, strive to improve capability and above all in an era of fiscal austerity, minimize costs.

SUPPLY CHAIN MANAGEMENT

The quickening globalization trend juxtaposed with the historical U.S. insistence on self-sufficiency creates a dynamic with enduring implications for the industrial competitiveness and national security of the United States. Likewise, the reduction in the number of domestic suppliers and need for increased innovation drive industry toward the global supply base for aircraft components. The U.S. Government must understand how the increased use of the global aviation supply chain affects important issues such as sovereignty, capability, and life-cycle costs.

A multinational, risk-sharing supply chain compromises sovereignty, and as such places the U.S. at a strategic crossroads. As prime contractors anticipate and adapt to reduced and/or more focused defense spending, they are becoming more international and diversified. These market-driven choices have long-term consequences and fundamental strategic ramifications beyond current contract performance. The need (or not) to preserve current industrial capacity and pursue expanded or new capabilities requires strategic decisions to mitigate potential risks, long-term U.S. vulnerabilities, and unintended loss of underlying resources or competencies.

In the sections below, we will identify – from a supply chain perspective – the challenges and potential strategies to implement in an era of a defense budget downturn to ensure an enduring U.S. competitive and high-technology advantage in the fighter aircraft and unmanned aerial vehicle (UAV) defense industrial base.

Departmental Focus

To devise a strategic approach that protects the supply chain, the Department of Defense (DoD) must accurately assess its current state by conducting a "radar sweep" to ensure its suitability for the future. Historically, the Department summarizes such information in its *Annual Industrial Capabilities Report to Congress*. A review of the most recent report (September 2011) indicates that it may be insufficient to provide the necessary insights from which to derive strategic policy decisions. However, DoD is actively upgrading its analysis. The OSD Office of Manufacturing and Industrial Base Policy has instituted a Sector-by-Sector, Tier-by-Tier (S2T2) Industrial Base Review process, with an objective of supplying the Department with an analysis of the:

- Extent of globalization in the defense industry;
- Use of commercial suppliers and subcontractors in the defense industry;
- Changing participation of subcontractors in military innovation;
- Emergence of single points of failure in the defense supply chain.[142]

Eight sectors are examined in the S2T2 process. Those most relevant to this paper are Aircraft and C4ISR. The S2T2's use of the Joint Defense Manufacturing Technology Panel "to seek a factory-floor perspective from defense programs and suppliers in four focus areas: metals, composites, electronics, and the advanced manufacturing enterprise" implies OSD is merging its analysis of manufacturing capability with evolving supply chain processes to provide a truly holistic approach.[143] However, given the strategic international linkages in programs like the F-35, it is unclear that this approach can produce an accurate picture below Tier 1 or 2. Also, concurrent technical development is inherently unpredictable when the supply-chain characteristics ultimately needed must ensure both production and lifecycle sustainment. The potential for undetected linkages in the supporting industrial bases between *separately analyzed* sectors such as missiles, C4ISR, and aircraft only further complicates analysis.

Logistical Challenges

Performance Based Logistics: DoD's current logistical/procurement processes exacerbate the challenges of strategically widening the aperture on future critical capabilities the supply chain must deliver. For example, Performance Based Logistics (PBL) contracts are a huge cultural shift in managing life-cycle sustainment of major weapons systems that was dictated by DoD's desire to manage costs from cradle to grave as well as to improve systems' readiness for the warfighter. The government now uses such contracts to buy performance in lieu of the old-

fashioned way of buying parts.[144] "Within the aerospace community, relationships between the manufacturers and the customers extend well-beyond the initial time of sale … [and] two-thirds of the funds that a military customer spends on its aircraft occur after the original purchase date."[145] The aftermarket support of military aircraft is a large source of profit for the aerospace industry.[146] This strategy allows DoD to tap into the industry's best business practices, new technologies, supplier networks and new ideas that reduce costs, cycle time, and logistical footprints while improving availability, reliability, and business practices.[147] PBLs allow contractors to determine requirements, quantities, and schedules as well as align the supply chain to deliver the required performance.[148] These contracts can be organic, private, or a mix of public-private partnerships.

Over time, policy, guidance, and statutory requirements document the specifics for the implementation of PBL contracts and product support. Often they are at odds. For example, reliance on contracted logistics support (and therefore the contractor's procurement/subcontract management systems) often means that 1) DoD's cognizance of the third-, fourth-, or lower subcontractor tiers is obstructed; and 2) DoD is reliant on contractor-controlled logistical support data and supply-chain expertise. This presents a significant obstacle to a systematic approach to managing the supply chain/industrial base given that a comprehensive supply-chain strategy requires knowledge of *evolving* technologies (i.e. composite materials), processes (i.e. flight control computer integration); and inventory, transportation and commercial business practices (i.e. increasing globalization).

Globalization: Global supply-chain management is the most critical challenge for meeting both current production expectations and long-term sustainment, as the recent GAO report illustrated:

Overseas suppliers are playing a major and increasing role in JSF manufacturing and logistics… In addition to ongoing supplier challenges–parts shortages, failed parts, and late deliveries--incorporating international suppliers presents additional challenges. In addition, the program must deal with exchange-rate fluctuations, disagreements over work shares, technology transfer concerns, different accounting methods, and transportation requirements that have already caused some delays. Also, suppliers have sometimes struggled to develop critical and complex parts while others have had problems with limited production capacity. Lockheed Martin has implemented a stricter supplier assessment program to help manage supplier performance.[149]

To highlight the F-35 complexity, Lockheed Martin identified that this platform has approximately 1300 Tier 1 suppliers.[150] Adding to this difficulty, the program has eight international partners that have apportioned shares of the supply chain, and it also claims a growing number of foreign military sales (FMS) customers (to include Japan and Israel). The inclusion of a growing number of FMS customers is a further complication in that they will likely expect offset-type arrangements as a spur to their respective industrial bases. This can be both a benefit–serving as a forcing-function for second-source development–or a detriment, by creating the need to incorporate additional supplier relationships. The takeaway is that the structure and management of the supply chain is no longer strictly a manufacturer's prerogative driven by economics; rather it is tied to *national* strategy.

A compounding challenge associated with an increasingly diverse global supply chain is the data rights needed to ensure continuity. Commercial, non-commercial and software technologies all have their own data rights requirements and limitations in the Federal Acquisition Regulations. Including them in the latest fighter and UAV systems creates a

patchwork data-rights quilt with many seams that can easily fray. So it is not surprising that the increasing complexity of the supply chain and policies that limit government reach pose a real threat to supply-chain management. To highlight, a May 2011 GAO report found that:

DOD has not clarified ambiguities in the required technical-data policies to ensure their full implementation. Specifically, DOD has not clarified how program offices should address the requirement for documenting technical-data assessments, and has not clarified a recent requirement to conduct a business-case analysis on technical-data needs. Without internal controls such as clear instructions on how to respond to these policies, DOD and the military departments risk incomplete and inconsistent actions and documentation in response to the technical-data requirements.[151]

The increasing criticality of data rights to the aircraft supply chain is demonstrated in this C-17 example: "Air Force officers realized they needed more core maintenance facilities at other government depots for its C-17 airplane in case of national-defense emergencies. However, they had to alter plans to expand because of limited rights to technical data. The Air Force had to form partnerships with vendors, even as some contractors would not release pieces of technical data, according to a 2006 GAO report that analyzed technical data rights."[152]

An additional challenge exists regarding UAVs: primes must forge evolving high-end technology and mission requirements with concurrent production into a viable business model. This need has led some primes to partner with or integrate firms that possess critical specialized capabilities. However, low sales volumes coupled with high development costs dictate a business model unlike the fighter market with its large production runs and significant associated sustainment requirements.

When linked to customer demands for a "modular" platform that allows quick integration (i.e. "plug and play") of new sensor suites, weapons capabilities, etc., this fact will require key subcontractors to extract maximum revenue from primes during initial sales to hedge against lost future work determined by evolutionary mission requirements and leaps in supporting technologies. It has also been noted that, "The UAV sector does not have a powerful lobbying vehicle…to jealousy guard the interests of domestic firms versus international manufacturers and provide information and analysis about the impact of UAV procurement decisions on the industry as a whole."[153]

Core Capabilities: Hand-in-glove with DoD logistics strategy is the core capability of the various government-owned and operated depots that serve "as the ready and controlled source of technical competence and resources necessary to ensure effective and timely response to a mobilization, national defense contingency situations, and other emergency requirements."[154] The DoD has a specific process to ensure its weapons platforms obtain the necessary support (delineated in DoDI 4151.20). These depots are both links in the supply chain and major users of it. So how is the existing process for depot assignment and support postured as related to future fighter and UAV platforms – is it sufficient to meet future demands? It appears not. According to an independent study done for DoD in response to the *Duncan Hunter National Defense Authorization Act for Fiscal Year 2009:*

"Several challenges complicate the organic depots' ability to respond to an uncertain future: an ambiguous statutory framework, acquisition decisions that are not connected to considerations of the organic depot system, an inconsistent application of the core determination process and oversight reporting that does not provide timely warning of eroding capability or workload. The multiple semiautonomous management structures also make it difficult to address the depots' challenges uniformly and efficiently."[155]

Adding further complexity is the sheer magnitude of fragmented systems and processes that must be analyzed to determine true requirements. It has been noted there were more than 200 inventory systems and 550 logistics systems in DoD, which as GAO noted "…are not integrated and thus have multiple points of data entry, which can result in data integrity problems."[156] DoD has not been idle in seeking improvement. The GAO noted "the July 2010 Logistics Strategic Plan…is DoD's most recent effort to provide high-level strategic direction for future logistics improvement efforts, including those in the area of supply-chain management." However, this plan does not appear to be a true panacea for DoD to meet its future fighter and UAV supply-chain challenges. The GAO underscored that "the plan lacks specific and clear performance measurement information…definition of key concepts, identification of problems and capability gaps, and discussion of resources needed to achieve goals."[157] It was also noted, "Despite the positive steps it has taken, DoD continues to face a number of challenges in addressing systemic weaknesses that remain in the three focus areas for improvement."

The weaknesses to which GAO referred are requirements forecasting, asset visibility and material distribution.[158] The F-35's Autonomic Logistics Information System (ALIS)—an information infrastructure that captures, analyzes, identifies, and communicates F-35 characteristics and data—shows how contractors are mitigating sustainment strategy challenges. It ties together F-35 operational planning, prognostics and health management to enhance the worldwide fleet. This secure global information system will serve as the foundation of streamlined fleet sustainment, resulting in F-35 parts, systems, and expertise reaching any location when they are needed. Also, the associated Global Logistics System brings information fusion to the many individual logistics components to enable system optimization.[159]

Procurement: The globalization of the supply chain–driven in part by "partnering" such as with the F-35–must be a top consideration in DoD procurement practices. Domestic source restrictions such as the Buy American Act (BAA), the "Berry Amendment" or targeted industries' protection (such as specialty metals or ball bearings) must not impede supply chain responsiveness. To ensure this, the U.S. government must consider strategic "exceptions" to protectionist measures akin to those trade agreements such as the North American Free Trade Agreement (NAFTA) provide to the application of the BAA to acquisitions. Such exceptions have an impact on the U.S. domestic industrial base, either positive (by allowing additional sources of supply) or negative (by increasing competitive pressure on domestic firms), so their application must be predicated upon desired strategic outcomes. How would the U.S. respond if countries increasingly critical to U.S. supply chains, but with whom the U.S. has no trade agreements, pressure for considerations similar to those specified under NAFTA?

A related challenge is the DoD budget process, which complicates contract execution due to multiple funding streams from various appropriations with different constraints and distinct "colors" of money. Working capital funds can be a solution to funding supply support, but not all aspects of PBLs. The string of continuing resolutions stemming from Congress' recent challenges to pass a budget highlights the challenge, as contractors have had to "float" cash for their suppliers until government funds were approved.[160]

Conclusion/Recommendations

Actions by the U.S. government today will clearly have long-term strategic consequences. The U.S. must use its resources wisely to support its strategic objectives and

maintain a competitive industrial advantage: logistical practices must adapt, become more efficient and support U.S. aspirations by leveraging U.S. strengths across the global industrial base. DoD's need, under budgetary pressure, to support the warfighter's evolving operational requirements drive the logistical changes. Globalization is not going away. The U.S. must adjust to supply-chain interdependency to achieve a balance between economic prosperity and national-security strategy. There are specific actions that can holistically preserve supply-chain capability while mitigating associated risks:

First, ensure DoD conducts an inclusive and robust annual industrial-base analysis. To maintain a robust DoD fighter/UAV supply chain, such analyses should go beyond data gathering and mapping to become an impetus for change, forming the core of both a formal regulatory and statutory development process that produces an industry-engagement strategy for senior DoD leaders. The S2T2 process, integrated with the Joint Defense Manufacturing Technology Panel, is a key first step. Because specific sectors will likely "share" subcontractors at multiple tiers, analyses must address such sectoral cross-pollination. Additionally, in concert with the Departments of Commerce and State, analyses should consider the geopolitical and economic stability of international contractors to ascertain inherent risk to U.S. interests while ensuring alignment with national strategy and policy.

Second, empower an Office of Primary Responsibility to develop a holistic solution. The preceding recommendations require the integration of three distinct AT&L communities. The strategic management of a robust supply chain for future fighters and UAVs dictates that development be coordinated among the industrial, procurement and logistics communities. This approach enables coordinated and concurrent — rather than sequential — execution of the development, review, and modification process.

Finally, enforce and resource a pre-Milestone A sustainment strategy as part of the acquisition process: Sustainment strategies that utilize PBL contracts must be transparent and include hedging options. DoD must establish overarching goals and measures to collectively assess PBLs by implementing DoD Product Support Business Case Analyses to identify the sustainment strategy's seams, gaps and vulnerabilities.

TALENT POOL

While the supply chain has substantial impacts on the overall aircraft industry, the supply of talent to make those parts is arguably the foundation of the overall aviation industry. Without appropriate talent, new aircraft cannot be designed, manufactured, remanufactured, overhauled, and repaired. As such, the health of the domestic engineering talent pool is important and must be considered in the greater context of the overall health of the aviation industry.

According to the Aerospace Industries Association (AIA), 2010 was the first year in which there were no military or civilian jets being designed in the U.S.[1], reflecting the U.S. military's recent tendency to purchase fewer complex, multi-purpose aircraft that are expensive and time-consuming to develop. The gaps between programs has had a direct impact on the talent pool in the aircraft industry: whereas aircraft companies could formerly reassign development, systems and software engineers to new projects when their current ones concluded, there often now are no other projects to which to transfer them. In the ever-longer lull between programs, how do aircraft manufacturers retain their talent pools and maintain fresh their skills until the next research and development (R&D) project arrives?

One industry executive said, "We use contract labor to handle variable levels of work thereby keeping our core employees always engaged, be it on a military or commercial project... However, if the requirements are far in the future, difficult to determine, undefined, or have little to no commercial application, then the absence of government funds can present a significant obstacle to continued development."

Linked with the staffing challenges posed by the paucity of recent development projects, industry experts point to the aging aerospace workforce as a source of potential concern going forward. Essentially, at the pace at which new R&D projects are currently inaugurated the skilled workers who executed previous programs have departed before the next similar program's initiation, taking the institutional memory with them. In remarks before the U.S. Chamber of Commerce last year, Boeing Commercial's president and chief executive officer, Jim Albaugh, cited Boeing's experience with what he called "intellectual disarmament":

"To be a viable contractor and an integrator of very complex systems, you have to understand how to do R&D. You have to take R&D into detailed design. You have to transition detailed design into production…What we're seeing right now with no new start in the Department of Defense is we are losing our ability to do detailed design. We are losing our capability to transition design into manufacturing. Once that's gone, it will take a long time to reconstitute…That was one of the problems we had on the 787 program. We had not done a new development program since the 777, and we paid the price as a result."[1]2

AIA points to a litany of demographic statistics in the industry workforce to underscore Albaugh's point about the gap in critical skill sets created by lengthy hiatuses between R&D projects:

- Almost 60 percent of the U.S. aerospace workforce was age 45 or older in 2007. Many of them are already eligible to retire.
- A 2007 Aviation Week survey concluded that 13 percent of the aerospace workforce was eligible for retirement, representing more than 82,000 people.
- Retirements from the STEM labor force are likely to become more significant over the next decade. 26 percent of all science, technology, engineering and math (STEM) degree holders in the labor force are age 50 or older.
- Among STEM doctorate holders in the labor force, 40 percent are age 50 or older.[3]

In his 2011 Chamber of Commerce appearance, Boeing's Albaugh also flogged two measures the aerospace industry has long sought: a dialogue with the Defense Department about the defense community's long-term goals and the industry workforce requirements necessary to address them; and a relaxation of U.S. export controls, which would pave the way for greater U.S. industry sales to favored foreign governments. Both would provide aircraft industry leadership greater predictability and consistency--and enable them to better identify and retain people with desired skill sets in the future.

One positive aspect of the present austere R&D environment may be that it breaks down longstanding stovepipes between divisions--both within corporations and their families of companies. In an effort to shelter one company's specialized talent from the vagaries of the R&D cycle, an executive noted that they had "started to double down on understanding our talent as a competitive advantage" and begun offering training opportunities that allowed employees to acquire new skills to maximize their future performance. One corporate affiliate recently established a training program devoted to cybernetics, one of the newest disciplines within the aerospace and defense field. Interested professionals with congruent skills from

throughout the corporate structure had been offered access to the new training program, with an eye on increasing the fluidity of movement between the company's various entities in order to protect critical staff.

Another aerospace industry population has begun to benefit from the greater ease of movement between specializations. Airframes now feature composite components, unusual alloys, revolutionary fibers and sensors arrays throughout their skins, signifying that their assembly is no longer merely a question of bending metal or driving rivets. "Touch laborers" must understand the behavior of each structural element and recognize the performance parameters of an array of complex electronic equipment. The growing convergence between white-collar occupations that traditionally demanded four-year university degrees and blue-collar jobs typically requiring two-year degrees or periodic certifications has prompted the aircraft industry to explore new linkages between universities and vocational schools. Indeed, the changing role of the touch labor force has prompted many industry observers to expand the traditional STEM label to STEM+M, signifying the augmented importance of manufacturing education in the aerospace field.

The other facet of maintaining an adequate talent pipeline in the aircraft industry is a longer-term concern: proportionally fewer U.S. students are opting for careers in the science, technology, engineering and math (STEM) disciplines. Said Boeing Defense Industry CEO Dennis Muilenburg: "More than 4 million students will begin kindergarten this year. Of those, only 60,000 will become engineers--of any type. Boeing will need more than four times that many aerospace engineers alone. If you ask what keeps me up at night, that's it."[4]

The fact that aircraft companies are limited almost exclusively to a "clearable talent" pool comprising only U.S. citizens further narrows their hiring options. Six years ago, AIA (which represents more than 150 member companies) established two committees to promote the expansion of STEM education in U.S. schools. Working with federal, state and local governments--and lobbying aggressively with Congress and the Executive Branch for more robust STEM funding--AIA attempts to pique the interest in STEM-related disciplines among students from the pre-kindergarten to the 12th-grade level, whom they strive to engage through national activities such as the Team America Rocketry Challenge. AIA also seeks to bolster linkages between secondary and tertiary educational institutions and the aircraft industry.

One aircraft industry insider captured the challenge AIA initially faced in its drive for STEM education: "With technology moving so fast and future development projects so unclear it's difficult to say where that shortage will ultimately fall. I tend to think of STEM as a gathering storm. You don't know whether it's going to be a Category One or a Category Five, but you can feel it forming offshore. It may not become a major storm, and even if it does, it may not hit you. So, how much are you willing to pay for insurance you may not need during a down business environment?"

That's a battle that's clearly in the past: AIA's are now among many initiatives in the field--often driven by second- and third-tier suppliers who sensed, particularly at the local level, the existential urgency of the STEM educational crusade well before their larger brethren found religion. Promising initiatives--many directed at the '+M' element of STEM+M--include:

- The Business-Higher Education Forum's (BHEF) collaboration with Raytheon and Ohio State University to craft the U.S. STEM Education Model, which assesses the impact of different policy prescriptions on secondary student interest in STEM fields--and on the eventual number of resulting STEM college graduates. Through its "American Imperative" initiative, BHEF also tries to develop quality science and math teachers at the middle

school level, where a 2008 U.S. Department of Education survey concluded that math educators who had no major or certification in mathematics were teaching 68.5% of U.S. middle school students. For science, the proportion was 57.2%.[5]

- Edmonds Community College; 180 Skills, a Purdue University on-line educational program; and Boeing worked together to create a training center tailor made for the aircraft manufacturing industry. Boeing donated USD 2.5 million in equipment and materials, and guarantees job interviews to all program graduates. As of November of last year, 494 students had completed the program...and more than 75% now work with Boeing.[6]
- Pratt & Whitney and its parent company UTC teamed with Penn State University to recruit and retain more diverse STEM students through Penn State's Engineering Ambassadors program. The expanding program now includes the University of Connecticut, Rensselaer Polytechnic Institute and Worcester Polytechnic Institute.[7]

Finding hundreds of isolated projects of a similar nature that would benefit from coordination, AIA and more than 40 like-minded organizations combined to form the Business and Industry STEM Education Coalition (BISEC) in March 2010. BISEC hopes its greater membership translates to more influence with the U.S. government. On a societal level, it purports to portray professionals in STEM-related occupations in a positive light. In this vein, perhaps the most intriguing BISEC partner is the Entertainment Industries Council, which seeks to suffuse popular television shows and movies with positive STEM role models.

BISEC's nascent programs haven't yet yielded quantifiable results but BISEC has begun sponsoring seminars around the country to create links among industry, education and state government stakeholders. One of the STEM organizations that exemplifies the direction in which BISEC hopes other states will go is North Carolina's.

In 2008, the NC STEM Community Collaborative was created to help coordinate STEM education efforts, a necessary step if the state wished to retain--and expand upon--its healthy high-tech base. The jewel in North Carolina's high-tech crown is Research Triangle Park, which hosts more than 170 corporations and works with research facilities at the area's array of fine universities: North Carolina, Wake Forest, Duke and North Carolina State. With numerous military bases also forming an important economic component for the state, educators and local officials discussed leveraging those assets to underwrite STEM education and groom students to fill the high-paying engineering and scientific jobs that support the research and military establishments...and ultimately pad the local tax rolls. There were jobs to be had in North Carolina's high-tech industries, but if the graduation trends in STEM-related fields continued there wouldn't be sufficient qualified people to fill them.

A Gates Foundation gift in 2008, part of a multi-state effort to create similar STEM education resources nationwide, provided a structure on which to erect what became the NC STEM program, and North Carolina Lt. Gov. Walter Dalton's ability to convene stakeholders from academia, industry and government provided the necessary organizational impetus and mission focus. Among the first steps NC STEM's advocates identified was finding all the individual programs in the state and identifying and cataloging best practices.

Wherever possible, NC STEM incorporated its members' existing initiatives: numerous high-tech industries had adopted specific school programs and the junior high school and high school levels and provided opportunities for hands-on learning for students of all ages. NC STEM sought to organize those efforts into a coherent whole, creating geographical and organizational linkages between schools, corporations and local governments.

NC STEM is only four years old, but its groundbreaking efforts have already begun

paying dividends. Working with local leaders, NC STEM developed a Community Visioning and Design Process that has produced innovations that serve thousands of North Carolina students. NC STEM helped adopt and implement a statewide strategic plan for STEM education. To move forward in a concerted fashion, NC STEM is now working to implement the details of that plan by designing tools and programs, including comprehensive evaluation measures and a catalogue capturing more than 600 STEM programs.[8]

NC STEM Policy and Communications Director Mark Ezzell noted that government leadership was the pivotal element in getting the group off the ground: "While individual educators and non-profit organizations had shown considerable interest and initiative, the involvement of the state government was ultimately the key element to put everyone together around a table and begin to tackle how to coordinate all the isolated programs--and there were a lot of them--in a way that would best serve the students, the industries and the state."[9]

Aircraft industry executives echo Ezzell's sentiment about the essential nature of government leadership, while flagging the need to devise a structure to overcome dependency on individuals: "The leaders of STEM initiatives at the state level often move on very quickly, meaning we suffer from a transient thought leadership," offered one. "We miss the clarity of an *überleader*."

The aerospace industry's challenge in attracting a sufficient number of qualified personnel for its cutting-edge technical positions will only sharpen in the future, making government leadership to ever more important. Tech and Internet behemoths such as Apple and Google have largely displaced the aircraft industry as the companies at which students perceive they can take an active part in pushing the fast-moving technological envelope. This is particularly true for systems and software engineers, two of the professions for which aerospace industry demand is already most acute.

The graying of technical workers in the aerospace field makes the industry's need for new blood all the more keen. It is in this arena that the long gaps between DoD projects is most telling: if the flow of programs were more predictable and more frequent industry primes could adjust their staffing levels to ensure their professional staffs at all levels acquired and retained requisite skill sets. Without an influx of young skilled workers and a steady diet of DoD development programs--even during budgetary crunches--what is currently a talent gap could become an abyss.

Although aerospace may no longer offer the sexiest occupations in the STEM realm, they are still attractive professions. Under the "rising tide raises all boats" heading, AIA's nascent alliance with other like-minded groups in BISEC is an acknowledgement that it's in the best interests of all tech-heavy companies to increase the overall applicant pool...as is the more than USD 200 million annually that AIA companies spend to promote STEM education.[10]

One key element to luring young talent to study STEM is to ensure their teachers possess knowledge to pass along. A 2008 U.S. Department of Education survey concluded that math educators who had no major or certification in mathematics were teaching 68.5% of U.S. middle school students. For science, the proportion was 57.2 percent.[11] That statistic must change. Industry-driven programs such as summer externships to improve the quality of STEM teachers are relatively new concepts, but are critical to inculcating the love of STEM in the next generation.

Retaining top talent already in the industry is a separate challenge. The advent of greater mobility for talented workers with targeted skills between companies under the same corporate umbrella is a new phenomenon, and a shrewd and necessary measure. Secondary and

tertiary suppliers are more buffeted by budgetary winds than the prime contractors with which they are affiliated. They are often also a rich source of both innovation and talent that parent companies are loath to lose. There is a direct correlation between the small size and vulnerability of suppliers and the inexperience and mobility of their skilled workforces. Cross-training with their colleagues from throughout the corporate structure offers corporate families' most promising young talents the chance for exposure and upward mobility--or at least enhanced job security--during lean times. This helps cultivate and preserve the skill sets that are intrinsic to the long-term success of the aircraft industry.

The blurring of the lines between the salaried white-collar and the clock-in blue-collar staff is the most intriguing and potentially revolutionizing phenomenon in the industry today. Recognizing the convergence dictated by evolving technologies, aircraft executives and educators have only recently begun linking schools and blending scholarship that had previously been decidedly separate. Herein lies the chance to produce a new breed of aircraft professional, offering career opportunities for talented blue-collar workers that their predecessors didn't enjoy. This has potential to pay dividends across generations, as children of formerly "working-class families" could see greater upward mobility, opening doors to people with traditional allegiances to the aircraft industry to pursue professional degrees--hopefully in STEM-related fields.

Conclusion / Recommendations

The staffing-related alarms going off across the aircraft industry should be a call to action for educators and government officials at the national, state and local levels. Some possible measures to ensure an adequate supply of engineers and technicians in an industry long regarded as a national security priority include:

- Foster greater transparency between DoD and aircraft industry leadership about the future direction of military interests and the skill sets inherent in realizing those aims
- Make a conscious DoD effort to preserve a continuous flow of R&D projects, even during budgetary downturns
- Reexamine US government export restrictions on sensitive US technology to balance national security considerations with aircraft industry employment concerns
- Review US government security restrictions on talented foreign-born US-educated students to determine whether they best serve US national interests
- Sponsor federal-, state- and local-government initiatives to promote and standardize STEM education at all levels
- Create and fund linkages between aerospace corporations, secondary and tertiary educational institutions and local governments that foster STEM education and apprenticeships

FINAL REMARKS

The changing nature of an increasingly globalized, multi-national, and highly technical defense industry coupled with increased austerity in defense spending challenges the well being of the American defense industry. The U.S. remains somewhat stuck in a “Cold War culture” of thinking where current approaches toward the defense industry do not reflect the policies required in a 21st century high-technology economy and innovation system. The stakes are high. If the technological edge is lost it cannot be easily regained.

Lockheed Martin will likely be the single major U.S. fighter prime in the medium term, leaving Boeing to rely on other markets as its ability to compete in the fighter niche erodes. This scenario could have significant negative long-term ramifications for the U.S. government, as a lack of competition will inevitably lead to higher costs—and perhaps the loss of fighter design and manufacturing expertise at previously reliable firms. Additionally, while the global demand for fighters may continue to rise, by 2020-25 competition in the world 5th generation fighter market might well dwindle to just two challengers as Lockheed Martin and Russia's Unified Aircraft Corporation to square off in what will remain an intense fighter aircraft market; Europe having been co-opted by the F-35, and China still emerging and making substantial efforts for a more relevant position in the high end of the fighter market.

The global UAV market is dynamic and growing, and likely represents a new direction for the entire aircraft industry. U.S. firms are well positioned, but must continue to lead in the UAV market to maintain their advantage in the aircraft industry. Given the open nature of the market in terms of receptivity to innovation and new entrants, companies must be on their game to successfully compete. While many of these new entrants will attempt to compete on price, U.S. firms must stay true to their strengths of high technology, innovation and integration in order to create differentiated products.

Those strengths are more likely to pay dividends at the high end of the market than they are with smaller airframes, where new entrants will compete strongly. Lastly, globalization and international sales are critical to success. While U.S. firms must bring world class systems to market to compete, they must also acknowledge that customers have choices, and they are unlikely to go with even the best systems on the market without concessions of work share, offsets, or technology transfer. One method to circumvent this problem is for U.S. firms to co-opt or acquire foreign companies that participate in production and development in order to become insiders in overseas markets.

For the U.S. government, promoting and marketing UAVs internationally provides an opportunity to forge and influence relationships as a means to achieve foreign policy ends. The U.S. should expect a sort of juste retour in return for security guarantees and political support. Collectively, these efforts can keep America on top in the UAV market and the broader aircraft industry.

While published national strategies demonstrate understanding of industry's importance and the need for change, they fall short in identifying specific objectives or setting a clear strategy for change. In order for the United States to secure a lasting position as the preeminent world power, a fundamental shift must occur that transforms U.S. government interaction with the defense industry. Nowhere is this more critical than the aerospace industry.

The critical nature of government's relationship with the defense industry should be the primary consideration, not a secondary concern. The U.S. needs to analyze the total acquisition environment and foster the necessary policies, regulations, and planning tools that promote the health of the defense industry as part of national security. The choice today is not a marginal one, it is a distinct trade off: compete globally or forgo the next generation of technologies.[161] Therefore the focus of the U.S. should be to link the right acquisition strategy to the right defense strategy.[162]

The lack of a synergistic relationship between government and industry means an inherent disconnect to how resources are applied. While uncertainty in the international security landscape will certainly exist, it does not have to exist between government and its own industry. An aligned and adhered to industrial strategy, which clearly delineates desired

vision, objectives for change, and how the government will shape its policy approach is needed to provide the stability required for industry to develop viable firm strategies that will meet U.S. military needs *and* promote industry health. In other words, we must align corporate strategy and U.S. policy. At a minimum, any long-term industrial strategy should include:

- ***Technology:*** Treat science as a strategic national asset and seek to improve government, industry, education and national laboratory dialog for common national security objectives. Reallocate education subsidies towards technical degrees that support national interests (e.g. STEM) and promote post-graduate employment within industry and government.
- ***Politics:*** In addition to completing the ongoing ITAR reform, create a standing construct that rapidly updates and approves export license requests. Department of State should leverage FMS as a policy tool to preserve the U.S. defense industrial base. This will include easing restrictions on foreign trade, increasing tolerance for multinational mergers and alliances, and increasing receptivity to acquiring foreign defense products. The U.S. Government must allow our industries to thrive in the global marketplace while balancing risk to national security and technology transfer.
- ***Finance:*** Expand funding for the export-import bank. U.S. government must leverage DoS and DoD to actively promote FMS in cooperation with industry to improve stable cash flow, allowing for future R&D and continued design and manufacturing expertise
- ***Acquisition:*** The proposed framework for technology development reduces the scope of EMD phase, minimizes cost and schedule growth, and increases opportunities for industry development of new technologies and systems. Additionally, the complexity of today's technology drove an increased reliance on industry expertise (as opposed to government technical experts) to manage defense contracts. The need to understand technological risk coupled with the need for more integrated relationships with industry mean that a stronger engineering cadre within government is needed. Likewise, the increased pace of technology development and joint acquisition projects encompassing multiple customers leads to greater likelihood of requirements creep. To compensate, significant acquisition projects need to build in risk mitigating conditions as much as possible and increase technological expertise within government.
- ***Supply Chain:*** Ensure DoD bases its strategy on an annual industry analysis
- ***Understanding of Industry:*** With increased interaction between international communities, the U.S. Government needs to investigate with more detail the long-term impacts of competition and international trade to ensure the right policies are in place.[163] It must also determine if current trade restrictions that protect critical U.S. technologies reflect today's industrial realities and align with its Industrial Strategy. Coupled with this is the need to understand critical supply choke points in major acquisitions in order to avoid degraded capabilities due to an inability to fulfill needed defense procurements.

The prosperity and security of the U.S. is inextricably tied to the health of industry and industry is likewise inextricably tied to the need for international access to technology, materials, and labor in the form of multinational corporations and strategic foreign partnerships. In light of today's realities, the need for remodeling of government's relationship with the defense industry is critical. But in order to realize change, leaders must first understand what is at stake. They must also understand that government policies profoundly affect the ability of U.S. industry to remain healthy and viable in today's market.[164] Without this realization, change cannot happen.

ENDNOTES

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[6] Ibid, 2.

[7] Ibid.

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[14] R. Johnson, "Russian Air Force set to Receive First Su-35s," *Jane's Defence Weekly* (March 13, 2012).

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[18] J. Lyons, "U.S. Seeks an Ally In Brazil," *Wall Street Journal*, (April 9, 2012), 16.

[19] Jane's Data Search, "South Korea: Combat Aircraft," http://search.janes.com, accessed March 16, 2012: 1.

[20] Jane's Data Search, "Japan: Combat Aircraft," http://search.janes.com, accessed March 16, 2012: 1.

[21] R. Aboulafia, 2.

[22] Ibid, 5. Related to Singapore one should also mention the two letters of offer relating to the F-16C/D Block 52 program that were released to the US Congress in 2009, a $250 million project on pilot training and logistics support and a $75 million pilot proficiency training program. In February 1998, Singapore began discussion with the US over becoming observers on the JSF strike program, and officially joined the program as "Security Cooperation Participants" in March 2004.

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[25] Teal Group Corporation. *"Unmanned Aerial Vehicles Market Overview."* World Missiles and UAVs Briefing. Jan 2011. Page 6.

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[27] Department of Defense. *"Annual Aviation Inventory and Funding Plan Fiscal Years (FY) 2013-2042."* March 2012. Page 6

[28] Fulghum.

[29] Teal Group Corporation. *"Unmanned Aerial Vehicles Market Overview."* Page 6.

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[35] Wall, Robert; Nativi, Andy; Flottau, Jens. "Europe's Defense Industrial Landscape in Flux." Aviation Week and Space Technology, 20 Feb 2012. Page 53.

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[50] IHS Jane's. Latin America: Brazil: Embraer. Jane's Defence Industry & Markets. Jane's World Defence Industry. Date Posted: 19 Jul 2011.

[51] Ibid.

[52] Teal Group Corporation. *"World UAV Forecast."* Page 1.

[53] Fulghum.

[54] Ibid.

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[58] Wall, Robert; Nativi, Andy; Flottau, Jens. "Europe's Defense Industrial Landscape in Flux." Aviation Week and Space Technology, 20 Feb 2012. Page 53.

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[65] Ibid, 5.

[66] Ibid, 3.

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[68] *United States Department of Defense Fiscal Year 2013 Budget Request*, Office of the Under Secretary of Defense (Comptroller) / Chief Financial Officer, February 2012, (Washington, DC: US Government Printing Office, February 2012), page 1-3.

Relevant section direct from budget document follows:

Figure 1-3 shows below the proposed FY 2013 – FY 2017 DoD topline in this President's Budget, as compared to last year's FY 2012 President's Budget. The FY 2013 topline for the years FY 2013 to FY 2017 is reduced by $259.4 billion.

Figure 1-3. DoD Proposed Outyear Topline for the Base Budget

$ in Billions	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY13-17 Total
FY 2012 PB	**570.7**	**586.4**	**598.2**	**610.6**	**621.6**	**2,987.5**
FY 2013 PB	**525.4**	**533.6**	**545.9**	**555.9**	**567.3**	**2,728.1**
Delta	**-45.3**	**-52.8**	**-52.3**	**-54.7**	**-54.3**	**-259.4**
Real Growth	***-2.5%**	**0.0%**	**+0.8%**	**+0.2%**	**+0.2%**	****-0.3%**

**Real growth calculated from the FY 2012 appropriation ($530.6 billion).*
***Average annual real growth for FY 2013 – FY 2017.*

[69] Robert Burns and Donna Cassata, The Associated Press, "Pentagon outlines plan to absorb $487B in defense cuts," *The Daily Breeze*, http://www.dailybreeze.com/ci_19831484, posted 26 January 2012.

[70] Mark A. Gunzinger, Center for Strategic and Budgetary Assessments, briefing slides: *Sustaining America's Strategic Advantage in Long-Range Strike—Toward the next long-range strike family of systems*, slide 32.

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[83] "More Cost Growth Would Cut F-35 Buy: Air Force," *Reuters Online*, March 20, 2012, http://www.reuters.com/article/2012/03/20/us-lockheed-fighter-idUSBRE82J0TY20120320 (accessed March 30, 2012).

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[85] "More Cost Growth Would Cut F-35 Buy: Air Force"

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Purpose. The purpose of the EMD Phase is to develop a system or an increment of capability; complete full system integration (technology risk reduction occurs during Technology Development); develop an affordable and executable manufacturing process; ensure operational supportability with particular attention to minimizing the logistics footprint; implement human systems integration (HSI); design for producibility; ensure affordability; protect CPI by implementing appropriate techniques such as anti-tamper; and demonstrate system integration, interoperability, safety, and utility.

[87] *Assessments of Selected Weapons Programs*, *29 March 2012*, page 77.

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[91] Ibid, 16.

[92] Frank Kendall, "The Acquisition Implications of the DoD Strategic Guidance and the FY2013 Budget," Speech to the Center for Strategic and International Studies Defense-Industrial Initiatives Group, (2012): 21.

[93] Ahern, 1.

[94] Government Accountability Office, *KC-46 Tanker Aircraft—Acquisition Plans Have Good Features but Contain Schedule Risk, GAO-12-366*, (Washington, DC: US Government Printing Office, March 2012), page 17. These three technologies are:

- **Three-Dimensional Display.** The display screens at boom operator stations inside the KC-46 aircraft provide the visual cues needed for the operator to monitor the aircraft being refueled before and after contact with the refueling boom or drogue. The images of the aircraft on the screens are captured by a pair of cameras outside that aircraft that are meant to replicate the binocular aspect of human vision by supplying an image from two separate points of view, replicating how humans see two points of view, one for each eye. The resulting image separation provides the boom operator with greater fidelity and a more realistic impression of depth, or a third dimension. Similar technology has been used on two foreign-operated refueling aircraft and a representative model in tests with other Boeing tankers.

- **Airborne ESTAR.** This software module is planned to have an algorithm that allows for automatically re-routing and constructing new flight paths for the aircraft that are safe, flyable, and avoid potential threats. The algorithm is new and novel technology, critical to meeting operational requirements. Airborne ESTAR has been tested in a simulation that provided data on its performance, interfaces, and functionality.

- **Threat Correlation Software.** Somewhat similar to Airborne ESTAR, this new software module serves to correlate tracks from multiple potential threats and automatically help re-route the tanker's flight path to avoid them.

[95] Ibid, 35.

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[103] Ethan B. Kapstein, "Smart Defense Acquisition: Learning from French Procurement Reform," Center for New American Security Policy Brief, December 2009, 2-3, http://www.cnas.org/files/documents/publications/CNAS%20Policy%20Brief%20-%20defense%20acquisition_1.pdf (accessed March 20, 2012).

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[105] Mahon,Terry. Personal email correspondence with Lt Col Wilbourne. March 7, 2012.

[106] Ibid.

[107] Kapstein, 2.

[108] Ibid, 3.

[109] Terry Mahon, personal email correspondence with Lt Col Wilbourne.

[110] Kapstein, 3.

[111] Terry Mahon, personal email correspondence with Lt Col Wilbourne.

[112] Kapstein, 3.

[113] TRLs are defined in the redundantly-named *DAG Guidebook* published online by the Defense Acquisition University. The following summary of TRLs is taken from the *Guidebook.*

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. Applications are speculative and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic 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 they will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of "ad hoc" hardware in the laboratory.
5	Component and/or breadboard validation in relevant environment.	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so it can be tested in a simulated environment. Examples include "high fidelity" laboratory integration of components.
6	System/subsystem model or prototype demonstration in a relevant environment.	Representative model or prototype system, which is well beyond that of 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 demonstration of an actual system prototype in an operational environment such as an aircraft, vehicle, or space. Examples include testing the prototype in a test bed aircraft.
8	Actual system completed and 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 in its intended weapon system to determine if it meets design specifications.

9	Actual system 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. Examples include using the system under operational mission conditions.

[114] US Code Title 10—Armed Forces § 2366b part (a). Reprinted below for context.

§ 2366b. Major defense acquisition programs: certification required before Milestone B or Key Decision Point B approval

(a) CERTIFICATION.—A major defense acquisition program may not receive Milestone B approval, or Key Decision Point B approval in the case of a space program, until the milestone decision authority—

(1) has received a business case analysis and certifies on the basis of the analysis that—

(A) the program is affordable when considering the ability of the Department of Defense to accomplish the program's mission using alternative systems;

(B) appropriate trade-offs among cost, schedule, and performance objectives have been made to ensure that the program is affordable when considering the per unit cost and the total acquisition cost in the context of the total resources available during the period covered by the future-years defense program submitted during the fiscal year in which the certification is made;

(C) reasonable cost and schedule estimates have been developed to execute, with the concurrence of the Director of Cost Assessment and Program Evaluation, the product development and production plan under the program; and

(D) funding is available to execute the product development and production plan under the program, through the period covered by the future-years defense program submitted during the fiscal year in which the certification is made, consistent with the estimates described in subparagraph (C) for the program;

(2) has received a preliminary design review and conducted a formal post-preliminary design review assessment, and certifies on the basis of such assessment that the program demonstrates a high likelihood of accomplishing its intended mission; and

(3) further certifies that—

(A) appropriate market research has been conducted prior to technology development to reduce duplication of existing technology and products;

(B) the Department of Defense has completed an analysis of alternatives with respect to the program;

(C) the Joint Requirements Oversight Council has accomplished its duties with respect to the program pursuant to section 181(b) of this title, including an analysis of the operational requirements for the program;

(D) the technology in the program has been demonstrated in a relevant environment, as determined by the Milestone Decision Authority on the basis of an independent review and assessment by the Assistant Secretary of Defense for Research and Engineering; and

(E) the program complies with all relevant policies, regulations, and directives of the Department of Defense.

[115] DODI 5000.02, page 19.

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[133] Gregory Suchan, "US and Multilateral Export Controls on UAS Transfers," November 15, 2011, 8.

[134] Ibid, 11.

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[139] Missile Technology Control Regime Equipment Software and Technology Annex, November 18, 2011, 13.

[140] Ibid, 11-12.

[141] Ibid.

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