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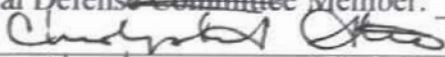
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AUTHOR: Justin A Young

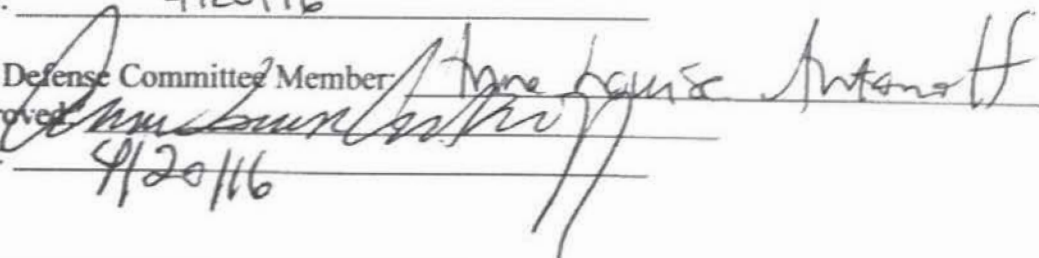
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Executive Summary

Title: The Rising Cost of Developing, Producing, and Maintaining Marine Corps Aircraft.

Author: Major Justin A. Young, United States Marine Corps

Thesis: The Marine Corps should focus on reducing capability requirements, providing greater upward mobility for acquisition Marines, and beginning to train Marines within the acquisitions field earlier in their careers.

Discussion: The cost of military aircraft has outpaced inflation for decades. It is economically unsustainable for the Marine Corps to continue this trend. Many of the variables that affect cost are out of the control of the USMC. It is therefore imperative that the USMC identifies where it has the capability to significantly reduce cost and direct its energy in those areas. Complexity resulting from end-user capability requirements is the largest contributor to cost escalation. It is here that the USMC can make the single largest impact on cost reduction. Additionally, the USMC can ensure the required expertise to navigate a complex acquisitions process is available through greater investment in the Marines that do the job.

Conclusion: If the Marine Corps does not develop a more affordable fleet of aircraft then its future will be at risk.

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Preface

I heard a Marine aviator justify the high cost of modern aircraft by saying that he had never felt that there was too much aircraft strapped to his back when going into combat. I could not help thinking to myself that I have never felt like I had too much car strapped to my back when driving to work in the morning either, but I was not about to bankrupt myself to get one. The best aircraft we can design is one that is capable of accomplishing the mission without spending a penny more than is necessary. Anything beyond that is a waste of taxpayer dollars. I chose to write this paper to examine runaway cost of military aircraft, decisions that have led to these increases and the ability of the Marine Corps to control it. My goal is to give the reader a practical perspective on a complex problem and to lay the foundation for further discussions.

The ideas in this paper were not developed in a vacuum. The origin of many of these arguments began in the ready rooms of the squadrons I have had the privilege of serving. For this I thank all my fellow aviators for their inputs. I would like to give a special thanks to those whose thoughts helped to shape my arguments; LtCol Bradley J. Sams, Maj Ryan “Zero” Pope, Maj Robert “Big Nasty” Gambrell, Maj Andrew “Tramp” Myers, Maj Tyler “Brillo” Burnham, Maj John “Sherm” Moore, Maj Kevin “Hatch” Herrman, and Captain Christian “DQ” Mallamo. I would also like to thank Dr. Christopher Stowe, Dr. Anne Louise Antonoff and Lt Col Winston A. Gould for their mentorship, which made the writing of this paper possible. Last but not least I would like to give thanks to Dr. Linda Di Desidro, Stase Wells and Andrea Hamlen in the Leadership Communication Skills Center in the Gray Research Library for their tutelage.

Introduction

The United States Marine Corps (USMC) is currently transitioning many of its aircraft to newer models to maintain the capability to meet its Title 10 responsibilities. The USMC operates as a Marine Air Ground Task Force (MAGTF), which provides the unique capability of self-supporting action. This capability relies on aircraft that can get Marines to the fight and provide supporting fires once they get there. The dynamic environment in which the Marines operate requires a broad spectrum of capabilities that increase aircraft cost.

The trend of increasing cost for military aircraft is outpacing inflation by approximately three percent per year. Stopping this trend will require sacrifices that are further complicated by shrinking budgets. This translates to purchasing fewer aircraft, finding ways to extend the service of the aircraft already in service, or sacrificing other programs. Studies have shown that the single largest contributor to increasing cost is the complexity of systems designed to meet customer requirements. The MV-22 Osprey and F-35 Joint Strike Fighter (JSF) purchased by the Marine Corps are two stark examples. The costs of development and maintenance for each aircraft are significantly greater than the airframes they replaced. While both are reported to have capabilities that far exceed their predecessors, the increased cost to acquire these capabilities must come from somewhere.

This paper will begin by discussing the structure of the acquisitions process, highlighting the challenges to the organizations involved and how some of these challenges are being addressed. Then it will discuss the cost contributors and analyze which of these factors has the greatest effect on cost increase. Next, it will examine the mission of the US Marine Corps and analyze the decisions made to determine capability requirements. Finally, it will evaluate the

current manning process the USMC uses to fill billets of key decision makers within the acquisitions field.

Although the Marine Corps' ability to affect the cost of the acquisitions process is limited, there are three actions that will have impact. The Marine Corps should focus on reducing capability requirements, providing greater upward mobility for acquisition Marines, and beginning to train Marines within the acquisitions field earlier in their careers. First, identifying less complex requirements and lower capability thresholds on contractors is likely to have the greatest effect on lowering cost. Second, the Marines should change promotion requirements in order to ensure longevity for those who embark upon an acquisition career path. Maintaining current promotion standards provides little incentive to active-duty acquisitions professionals to remain in uniform once eligible for retirement. Third, the Marines should consider opening up the acquisitions field to junior officers at the beginning of their careers, resulting in more seasoned professionals to oversee crucial programs that can cost into the billions. The Marine Corps should focus on these three areas to ensure that they are not priced out of aviation in the future.

The Acquisitions Process

The acquisitions process is a complicated bureaucratic system that can be difficult to understand and more difficult to change. It involves Congress, the Office of the Secretary of Defense (OSD), the Army, Navy, Air Force, civilian contractors, hundreds of billions of dollars, and a large number of American jobs. For fiscal year 2016 alone, the Office of the Under Secretary of Defense (Comptroller) planned \$48.8 billion for aircraft-related systems in its acquisitions budget of \$177.5 billion.¹ The Decision Support System subjects the aviation needs of the Marine Corps to many bureaucratic layers that require approval by multiple stakeholders.

The more complex and innovative the aircraft system requirements are, the more complex and costly the process becomes. The JSF exemplifies this problem; it has been called the most advanced aircraft in the world and the most expensive weapons system ever developed.² There are many barriers the Marine Corps must overcome, beginning with the establishment of a system requirement. Then it must ensure continued funding throughout development. Finally, it must employ and integrate the new weapons system into its fleet forces.

The three major institutions within the acquisition's process, the Executive Branch, Congress, and the Defense Industry, are made up of a wide range of stakeholders. Each institution has its own perspectives, responsibilities and objectives. Any weapons system produced today is a product of these influences.

The stakeholders in the Executive Branch include the President, the Department of Defense (DoD), the Office of Management and Budget (OMB), the Department of State, and the National Security Council (NSC). Some of the responsibilities of the Executive branch include negotiating with Congress, issuing directives and regulations, and contracting with industry. Specifically, the Under Secretary of Defense (USD) for Acquisition, Technology, and Logistics (AT&L) has approval authority of major defense acquisition programs.³ The objectives that must be met include satisfying national security objectives; maintaining a balanced force structure; fielding weapon systems to defeat threats to national security; preventing undue congressional interest and scrutiny; and eliminating fraud, waste, and abuse in federal procurement.⁴ The involvement of the Executive Branch alone clearly presents a significant level of complexity.

The injection of Congress increases the difficulty of the process further. The stakeholders in Congress consist of 100 senators, 435 house representatives and the constituents

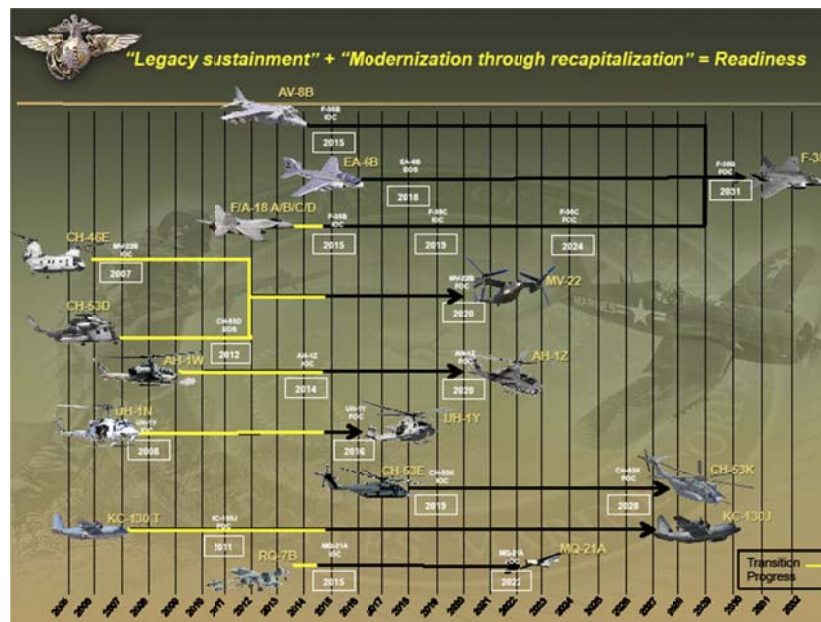
they represent. The Congressional responsibilities in the acquisition process include: conducting hearings; setting resource ceilings; raising revenue; allocating funds; and performing oversight and review.⁵ Their objectives include: balancing national security and social needs; distributing federal dollars by district; maximizing competition; controlling industry profits; and controlling fraud, waste, and abuse.⁶ While some of these Congressional responsibilities and objectives sound the same as those in the executive branch, the methods to accomplish them differ based on several factors to include the political party of each congressman and the interests of their district.

Finally, the Defense Industry--consisting of both American and foreign contractors--supplies the various systems that make up an aircraft that will eventually roll off the assembly line. The primary objectives of the defense industry are to profit and grow; produce cash flow; increase market share; ensure stability; and accomplish technological achievements.⁷ The contractors' responsibilities include responding to solicitations; proposing solutions; conducting independent research and development; and designing, producing, supporting, and upgrading defense systems.⁸ While the defense industry's goals often align with those of the government many are opposing objectives.

The stakeholder of greatest importance within the context of this paper is the Marine Corps. The USMC has been in the process of upgrading the majority of the aircraft in its fleet over the last decade and will continue to do so for the next decade (Figure 1). The USMC invests heavily in the capabilities of its next generation of aircraft to remain the Nation's littoral operations force. It can be argued that the existence of the USMC hinges on the development and successful employment of the capabilities it seeks. In a time of shrinking budgets, Marine

leadership is keenly aware of the importance of squeezing as much capability as possible from every dollar.

Figure 1: USMC Aircraft Transition⁹



Source: Jon D. Davis, "Forward to the Fight," *Marine Corps Gazette*, May 2015, 26,.

By design, the acquisition process incorporates all of the previously discussed stakeholders by processing new weapon-system programs through each of the three major Decision Support Systems. In order, they are the Joint Capabilities Integration and Development System (JCIDS); the Planning, Programing, Budgeting and Execution System (PPBE); and the Defense Acquisition System (DAS). JCIDS identifies, assesses and prioritizes the capabilities that are required for mission accomplishment.¹⁰ These requirements can be addressed by a change in Doctrine, Organization, Training, Materiel, Leadership, Personnel, Facilities and Policy (DOTMPLF-P).¹¹ The PPBE creates the proposed acquisition budget and is the primary resource allocation process.¹² In the DAS, the Department of Defense (DoD) develops and

purchases weapons systems.¹³ The DAS uses milestones, which serve as gates to ensure that statutory requirements, regulatory requirements, and thresholds are met before the program can proceed to the next phase in the process.

US acquisitions programs have often stirred up controversy due to higher-than-expected costs or weapons systems that do not meet the stated requirements. In many cases these issues could have been mitigated early in the process. The tightening of budgets in recent years has led to increased scrutiny of current weapons programs. During his time as USD (AT&L) from 2009 to 2011, Ashton Carter implemented a program he called Better Buying Power (BBP). Secretary Carter designed BBP to reform the acquisition process and make it more efficient.

Frank Kendall, the current USD (AT&L), has built on Secretary Carter's initial versions BBP 1.0 and 2.0, with BBP 3.0. In addition to cost and efficiency, BBP 3.0 focuses on providing dominant capabilities to the warfighter to prevent the closing of the capability gap between the United States and its potential adversaries.¹⁴ In an article for defenseone.com, Kendall uses the replacement of the President's helicopter Marine One to highlight successes of the first two iterations of BBP. The initial attempt to develop a replacement prior to the implementation of BBP ran into significant cost overruns and was eventually cancelled.¹⁵ Therefore, all the money sunk into that program was wasted. BBP instituted practices such as establishing affordability caps for investment and sustainment, controlling life-cycle cost, incentivizing productivity, streamlining competition and focusing on improved professionalism. In the case of V-XX (Marine One replacement prototype), affordability caps gave bidders a realistic assessment of how much money the Navy could expect to be available for the program. Historically, program managers' responsibilities ended with the delivery of a weapons system. The Department of Defense Instruction 5000.02 *Operations of the Defense Acquisition System* now gives program

managers more autonomy to make changes early in the process and assigns them responsibility for the aircraft's entire life-cycle. "Should cost" is a term used that requires program managers to seek and act upon opportunities to save dollars over the life cycle of a program.¹⁶ One example would be spending more money up front to reap savings once the aircraft is in its operations-and-support phase. The government ultimately awarded Sikorsky Aircraft Corporation the engineering and manufacturing development contract for the VH-92A, which is based on its commercial helicopter the S-92A.¹⁷ The U.S. government sought to maximize the use of systems already commercially available prior to BBP, but is placing greater emphasis on the practice in recent years. The leadership in Washington is focusing on improving the acquisitions process, and they are making some progress.

Cost

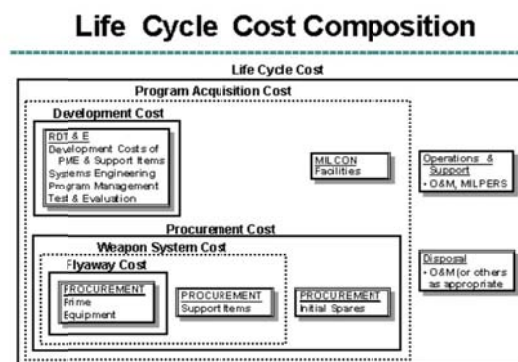
Acquiring, operating and supporting military aircraft that meet mission requirements have resulted in unsustainable cost increases over time. There are many factors to consider when analyzing the total cost of an aircraft from initial development until its end of life. The Life-Cycle Cost (LCC) or "total cost" of any weapons system consists of Program Acquisition Cost (PAC), Operating and Support (O&S) Cost and the Disposal Cost for the system (see Figure 2).¹⁸

The program acquisition cost is made up of all costs associated with developing, procuring, and housing a weapon system; it is the complete cost of acquiring a weapon system that is ready to operate.¹⁹ The decisions in the program acquisition phase are often the most critical, since in addition to affecting PAC they may have significant cost consequences later in the O&S phase.

O&S cost is the sum of personnel, equipment, and supply costs associated with operating, modifying, maintaining, and supporting a weapon system while it is in the DoD inventory.²⁰ These factors each contribute to a weapon-systems readiness. The end user often provides readiness requirements at the beginning of the acquisition process. The readiness of the aircraft will depend on its reliability, the ease of maintenance, and the logistics plan's ability to provide replacement parts and the aircraft itself.

The demilitarization and disposal of a weapon system makes up the disposal cost.²¹ The disposal cost is typically a relatively small portion of the total cost of a weapons system. Thus, the focus of this paper will be on PAC and O&S costs.

Figure 2: Life Cycle Cost Composition



Source: "Acquimedia: Cost Terms," Defense Acquisition University, 2016, <https://dap.dau.mil/acquimedia/Pages/ArticleDetails.aspx?aid=e8a6d81f-3798-4cd3-ae18-d1abafaacf9f>.

Discussing weapon-systems cost in terms of PAC can be misleading; the greatest portion of LCC comes from O&S. Mark Taylor and Joseph Murphy estimate that O&S can be 60% to 80% of the total LCC. The longer an airframe remains in service the greater the ratio of O&S cost to PAC.²² The JSF program provides a current example. Zachary Cohen points out that

while the PAC for 2,457 aircraft is near \$400 billion, the Pentagon expects to lay out \$1 trillion for O&S costs over the program's lifetime.²³ Considering that the \$400 billion for PAC is nearly double its original estimate, it should not be surprising if and when the O&S cost exceeds the \$1 trillion mark. Even if it does not, O&S will be 60% of the cost not accounting for disposal cost.

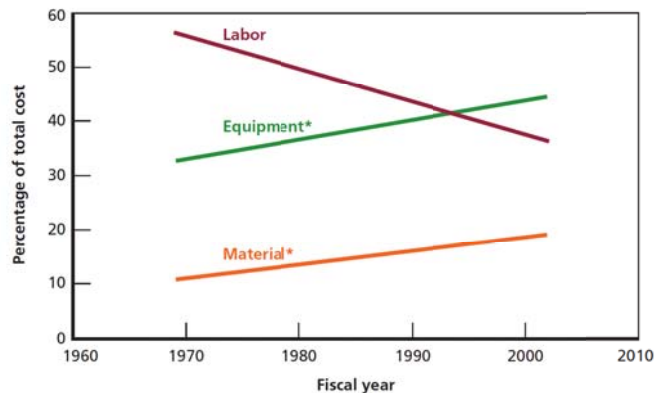
It is also important to understand the key factors contributing to cost. In 2008, Mark V. Arena, Obaid Younossi, et al., of the Research and Development (RAND) Corporation conducted a study of rising military aircraft costs over the past few decades, titled *Why Has the Cost of Fixed-Wing Aircraft Risen?* In their study the authors found that the greatest contributors to cost increase were economic- and customer-driven variables. Customer-driven factors have made up two thirds of this increase, while economic factors have made up the remaining third.²⁴

Economic costs are those primarily associated with labor, material, and equipment. Arena, Younossi, et al., discovered an interesting trend during the period analyzed (1969 to 2003). When looking at the total aircraft system procurement cost, the percentage of labor decreased while both equipment and material costs increased. The obvious question is, what forces drove these two trends?

Arena, Younossi, et al., found that aircraft manufacturing labor rates increased much faster than other measures of inflation, but were balanced by increased productivity and lean manufacturing practices at the same time, resulting in total labor cost that grew only slightly faster than inflation. This, coupled with the outsourcing of manufacturing and a shift to advanced computer-aided design systems, is believed to have contributed to the overall decreasing proportion of labor cost.²⁵ Figure 3 represents the relationship of labor, materials and equipment with respect to total cost of a weapons system from 1969 to 2003; it shows that the growth in material and equipment costs have outpaced that of labor.

Figure 3: Labor, Equipment and Material proportions of total cost

Labor, Equipment, and Material Percentages of Weapon System Cost, 1969 to 2003



Source: Arena et al., *Why Has the Cost of Fixed-Wing Aircraft Risen?*, 19.

The graph in Figure 3 clearly illustrates that the growth of equipment and material costs have become a more significant portion of the total economic cost. However, from an economic standpoint it does not explain the magnitude of growth in aircraft cost over time. There are many factors that affect the costs of materials and equipment. One causal factor is the design of modern aircraft requiring the use of high-strength, low-weight materials that translate to increased performance, maneuverability, range, and cargo-weight capacity. Steel and aluminum have long been the standard for aircraft, but titanium and thermosetting resin/plastics are increasingly taking their place. Arena, Younossi, et al., analyzed cost increases in these four materials from 1986 to 2004, comparing the increase in each with the Consumer Price Index (CPI), which takes the average of the cost increase of a “basket of goods” in order to assess changes in the cost of living.²⁶ The authors also compared their data to the DoD procurement

deflator, which is a tool used to predict future procurement cost based on the prices in the economy as a whole.²⁷

The RAND data was recalculated using the Consumer Average Growth Rate (CAGR) of the Producer Price Index (PPI) data published for steel (Series Id: WPU1017), aluminum (Series Id: PCU331315331315), titanium (Series Id: WPU102505), thermosetting resins/plastics (Series Id: PCU3252113252114), aircraft parts (Series Id: PCU336413336413), aircraft engines (Series Id: PCU336412336412), and navigation equipment (Series Id: PCU3345113345111) on the Bureau of Labor and Statistic's website. Each series id identifies the specific item for which data is given. CAGR is calculated using Equation 1, where PI is the Price Index taken from the Bureau of Labor Statistics (BLS).

Equation 1

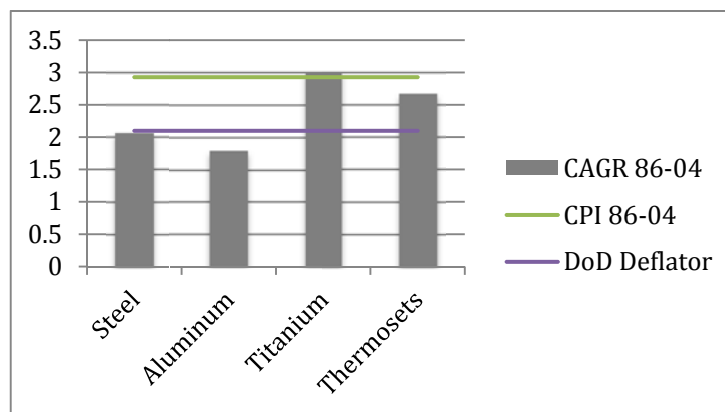
$$CAGR = \left[\left(\frac{PI_{last\ year}}{PI_{first\ year}} \right)^{\frac{1}{\#yrs}} - 1 \right] \times 100$$

Figure 4 and 5 depict CAGR of the PPI for each material compared with the CAGR of the CPI and DoD deflator for the same period. Equation 1 was used to calculate the growth rate of CPI for all urban consumers (Series Id: CPIAUCSL) using data from the BLS.²⁸ Figure 4 indicates that cost growth for steel, aluminum, and thermosetting resins/plastics was lower than for CPI from 1986 to 2004, and the cost growth for titanium in line with the CPI for the same period. The CPI here represents inflation, therefore the cost of the materials analyzed during the period 1986 to 2004 actually decreased relative to inflation with the exception of titanium, which remained constant. Examining the same data with respect to the DoD deflator implies a slight

increase in cost for titanium and thermosets. While each of these techniques are only estimates, for the period examined material cost clearly does not account for the cost increase of aircraft.

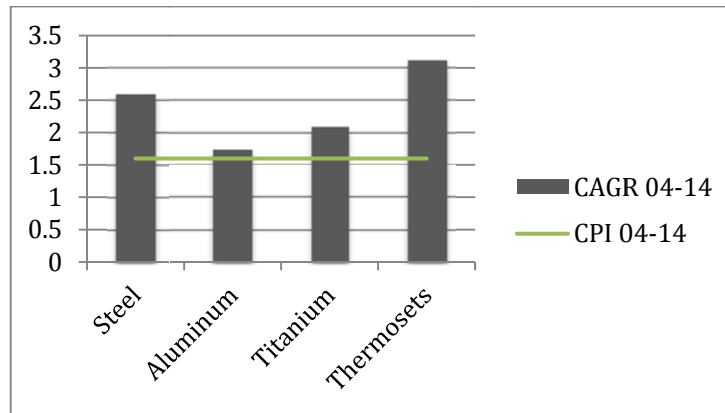
In order to evaluate the continued growth of material cost beyond the period used by Arena, Younossi, et al., Figure 5 presents the PPI material growth rates from 2004 to 2014 as compared to the growth rate of CPI for the same period. During the period in Figure 5 the CPI growth rate is almost half the value found by Arena, Younossi, et al., in Figure 4. During the same period, the growth rates for the cost of steel and thermosets increased, while titanium decreased and aluminum remained the same. This implies that from 2004 to the present material costs have actually increased over time. Modern aircraft are increasingly designed with greater quantities of thermosets/resins, which experienced the greatest material cost growth.

Figure 4: Material Price Escalation (1986-2004)



Source: Data retrieved from the Bureau of Labor and Statistics, www.bls.gov, 20 February 2016.

Figure 5: Material Price Escalation (2004-2014)



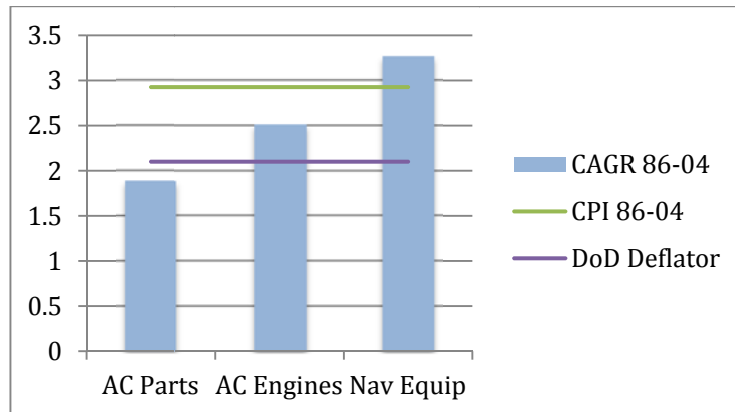
Source: Data retrieved from the Bureau of Labor and Statistics, www.bls.gov, 20 February 2016.

Equipment makes up the third economic factor contributing to overall cost. The individual systems of an aircraft comprise the equipment category. They include but are not limited to avionics systems, navigation systems, sensors, weapons systems, communications, and propulsion systems. Arena, Younossi, et al., also analyzed the CAGRs of PPI for a few key components compared to CPI and the procurement deflator. The equipment cost growth in Figure 6 and 7 are similar to the material growth previously discussed. Figure 6 and 7 depict the same relationships for common aircraft equipment as seen in Figures 4 and 5.

Arena, Younossi, et al. showed that the cost growth of aircraft parts and engines decreased from 1986 to 2004, while navigation equipment increased slightly. Like the data analyzed for material cost growth this accounts for only a small portion of the increased cost of aircraft during the same period. For comparison Figure 7 examines the same data from 2004 to

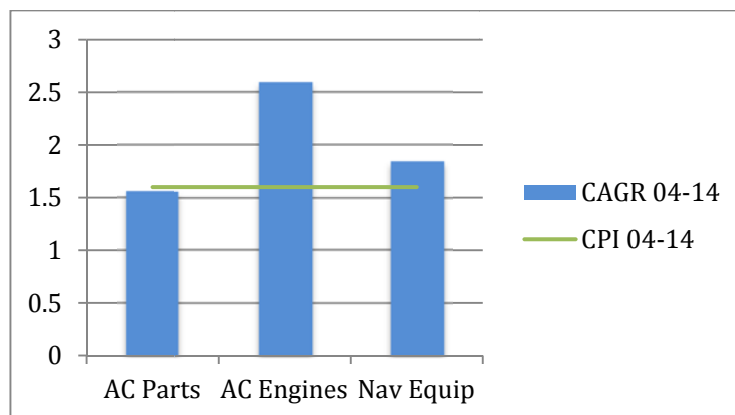
2014, with similar results except aircraft-engine cost increased and navigation equipment decreased during this period when compared to CPI.

Figure 6: Equipment Price Escalation (1986-2004)



Source: Data retrieved from the Bureau of Labor and Statistics, www.bls.gov, 20 February 2016.

Figure 7: Equipment Price Escalation (2004-2014)



Source: Data retrieved from the Bureau of Labor and Statistics, www.bls.gov, 20 February 2016.

There are two customer-driven factors to consider. First, the end-user determines the capability requirement of a new aircraft. Second, the end-user also has control over the number

of units purchased and to some extent the rate of production. Unlike economic factors, the Marine Corps can affect these costs. While the capabilities and number of aircraft purchased are derived in response to perceived threats, there exists flexibility in how these threats are countered. It will require innovative solutions to take advantage of the circumstances in these areas.

The Marine Corps establishes the capabilities and thresholds of performance that it needs. An Initial Capabilities Document (ICD) is produced to document the “need for a material approach (or an approach that combines material and non-material solution sets) to satisfy specific capability gaps.”²⁹ The aircraft that are currently in service are significantly more complex than previous generations. This is apparent when comparing the Air Force’s original F-16 to the F-35. The F-16 had 15 subsystems, thousands of interfaces, and its software managed less than 40 percent of its functions. The F-35 has 130 subsystems, hundreds of thousands of interfaces, and its software manages more than 90 percent of its functions.³⁰ This produces both a stark difference in capability and cost.

Arena, Younossi, et al.. analyzed the effects of changes in personnel complement, empty weight, ceiling, range, thrust, top speed, and airframe material complexity on the cost of aircraft.³¹ They found that airframe weight, maximum speed, and material composition correlate strongly to unit price.³² End users control the stated capability requirement of each of these variables. An aircraft that can fly farther, faster, and carry larger payloads will always be desirable, but may not always be necessary. Developing new lighter-composite materials to replace the steel and aluminum parts traditionally used is key to limiting an aircraft’s weight. Using stronger-lighter materials in the airframes is partially driven by the need to offset the increasing weight of the numerous additional systems required by modern aircraft. The total

weight of additional electronics required for fly-by-wire capabilities, and advanced radar, weapons, and navigation-systems have steadily risen over time.³³ Essentially, cost must rise to produce those additional components and then rise even more to develop a means to reduce the weight in other areas to maintain required performance.

Incorporating stealth design into aircraft has also led to increasing complexity resulting in rising costs. According to Arena, Younossi et al., producing an aircraft like the F-22 or F-35 requires “additional nonrecurring design labor costs as well as recurring labor and materials costs.”³⁴ These costs result from smaller tolerance for aircraft parts, more expensive radar absorbing materials (RAM), and heavy reliance on computer aided design (CAD).³⁵ In today’s environment, possessing stealth aircraft is imperative for the United States, but one could argue against its necessity to the mission of the Marine Corps.

The quantity of units and the rates at which they are purchased affects the total cost per aircraft. The cost improvement effect often called “the learning curve” is one factor that causes this effect. It is a decrease in cost proportional to the number of units purchased that results from an accumulation of experience. The mathematical relationship used with learning-curve theory states that doubling the number of units, results in the man-hours or recurring cost of each unit being reduced by a constant percentage.³⁶ This is expressed in Equation 2 where: “ y_x is the man-hours or costs of unit x ”; “ a is the man-hours or costs of the first unit”; “ x is the unit number”; and “ b is the logarithm (base 10 or natural) of the slope divided by the same logarithm type of 2”.³⁷ A similar benefit occurs when purchasing a greater number of units with respect to time, which occurs due to greater operating efficiency and spreading fixed costs over additional units.

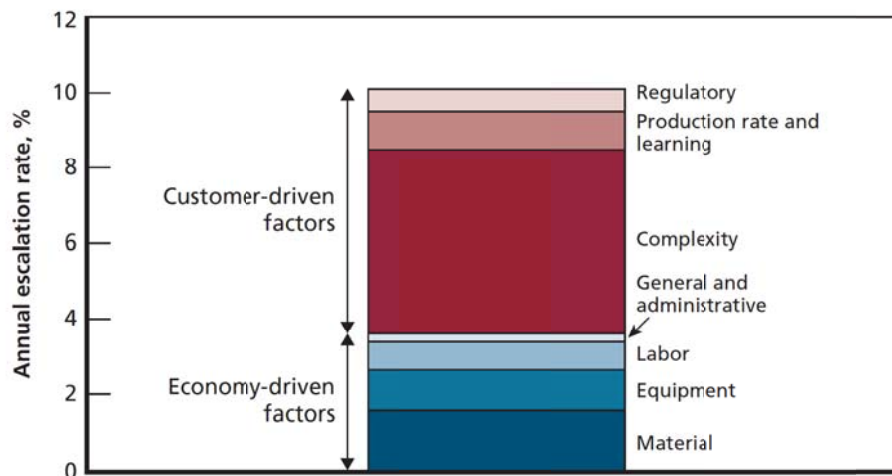
Equation 2

$$y_x = ax^b$$

Source: Equation is from the Marine Corps Systems Command, Cost Analysis Guidebook, 14 May 2013.

Reduced cost through increased volume has driven the efforts to develop joint aircraft, and sell them to partner nations. Eight partner countries helped the United States fund the JSF- Australia, Britain, Canada, Denmark, Italy, the Netherlands, Norway and Turkey.³⁸ The high cost, resulting from its complexity, discouraged the United States from development of the JSF without partners. Lt. Gen. Chris Bogdan (JSF Program Executive Officer) claims that the F-35A will cost \$80 to \$85 million by 2019 and he expects it to be even lower once it hits multi-year procurement. This is less than any existing fourth-generation fighter according to Colin Clark.³⁹

Figure 8: Contributors to Price Escalation from the F-15A (1975) to the F-22A (2005)



Source: Arena et al., *Why Has the Cost of Fixed-Wing Aircraft Risen?*, xvii.

As a result of increased technical requirements, greater capability requirements and the militaries expressed desire for stealth capable aircraft, customer-driven factors make up the greatest contributor to cost escalation. As discussed, material and equipment cost growth

occurred at a rate at or below inflation over the same period of time. While labor costs increased at a rate greater than inflation they were offset by gains in productivity. Arena, Younossi et al., determined that customer-driven factors were responsible for about two-thirds of the total escalation in cost from 1975 to 2005 between the F-15A and the F-22A (see Figure 8).

Cost can also be negatively affected by poor processes. In the past, the acquisition process did not consider O&S costs carefully in its early stages. It was, in a sense, “someone else’s problem.” Fortunately, the USD(AT&L) identified this problem and steps were taken to minimize runaway O&S costs that could be addressed early in the acquisition process. Leadership reorganized the acquisition process to look forward and anticipate O&S cost by assigning the Program Manager (PM) responsibility of the program throughout its entire life-cycle. This new approach improves the process, but does not resolve the problem entirely.

A PM billet is usually filled by a military O-6 or a civilian GS-15. Military personnel fill the majority of these billets and only remain in the position for 3 years. While adjusting the process to account for O&S costs certainly alleviates issues down the road, it is difficult to see how a PM can be held accountable for a problem that may not be realized until long after that individual has moved on to another job or retired. The JSF program has been under development for approximately fifteen years, therefore it can be assumed that it has seen five or more PMs thus far, and the program has just entered the O&S phase.

As previously discussed, the development of joint programs, are viewed favorably as a result of the greater quantity of units produced. The DoD has developed several joint aircraft throughout history; the JSF is the most recent. Cost savings is advertised as a principal benefit behind developing aircraft jointly. It is reasoned that LCCs are reduced by eliminating duplication of research, development, test, and evaluation (RDT&E), in addition to the benefit of

economies of scale during the procurement and O&S phases.⁴⁰ While this appears to be a sound argument, history tells a different story.

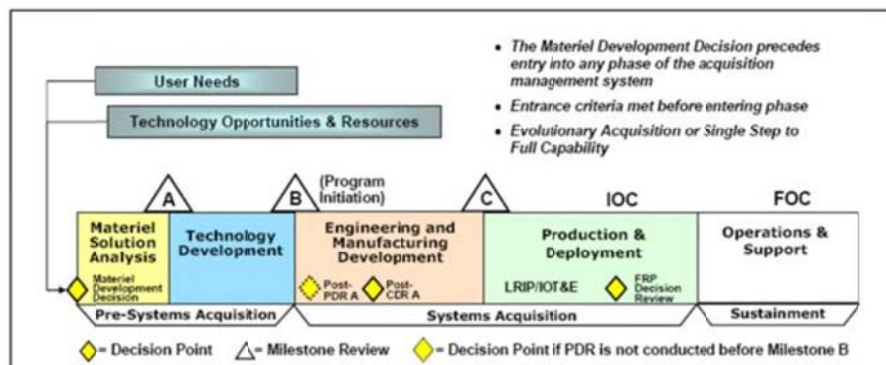
Mark Lorell, Michael Kennedy, et al., analyzed the cost to produce several jointly developed aircraft (including the JSF), and compared them to the costs of aircraft developed independently by each service. The results are made clear in the title; *The Department of Defense Should Avoid a Joint Acquisition Approach to Sixth-Generation Fighter*. The authors of the study found that dissimilar service requirements have historically led to greater costs in joint programs throughout the overall life-cycle.⁴¹ The attempts to design individual requirements into the same airframe has proven more costly than designing each airframe from the ground up. It has the added negative effect of increasing weights required by one or more of the services, which results in a net cost increase and performance decrease.

The authors looked at four joint-fighter programs that began with a goal of 100 percent commonality: the Tactical Fighter Experimental (TFX), the F-4, the A-7, and the Air Combat Fighter (ACF). Each program resulted in distinct aircraft with little-to-no commonality, and in the case of the F-111 (a product of TFX), both the Navy and Air Force pulled out of the program.⁴² The study then focused on the JSF concluding that it is exhibiting similar cost trends to the previous joint programs.

Milestone B (see Figure 9) is the start of the engineering, manufacturing and development (EMD) phase in the acquisitions life cycle. From DoD instruction 5000.02 *Operation of the Defense Acquisitions System*, “The purpose of the EMD Phase is to develop, build, and test a product to verify that all operational and derived requirements have been met, and to support production or deployment decisions.”⁴³ At Milestone B, the JSF cost was 16 percent lower than the RAND estimate of three notional single-service fighters (modeled off the

F-22 program). In the nine years following Milestone B, the O&S cost of the JSF grew substantially. The result was the JSF cost estimate being 37 percent higher than the notional single-service programs.⁴⁴

Figure 9: Acquisition Process



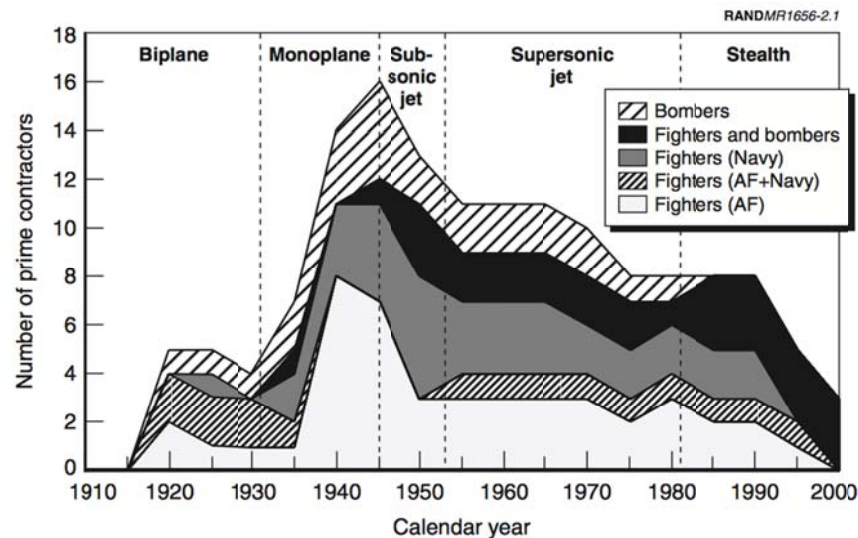
Source: "Acquisition Process", *Defense Acquisition University*, last updated March 31, 2015, <https://acc.dau.mil/CommunityBrowser.aspx?id=650767>

Competition is a pillar of innovation and cost control. Joint programs have the unintended consequence of limiting the available contractors capable of building aircraft the DoD needs. In the case of the JSF, Lockheed Martin was awarded the contract to build replacement fighter aircraft for the Navy, Air Force and Marine Corps, making it difficult for other contractors to survive. In 1945, the U.S. military aviation industry consisted of sixteen prime contractors. In 1990 this number had declined to eight, and currently only Lockheed-Martin, Boeing, and Northrop Grumman remain.⁴⁵

The graph in Figure 10 depicts the number of U.S. combat-aircraft prime contractors with respect to time and capability requirements. As capability requirements have increased, costs have risen and fewer prime contractors capable of producing the necessary weapons systems remain. The development of a jointly developed airframe like the JSF that has a single prime

contractor producing a planned 2,457 aircraft contributes to likelihood of an eventual fighter-attack aircraft monopoly in the industry.

Figure 10: U.S. Combat-Aircraft Prime Contractors



Source: Birkler et al., *Competition and Innovation in the U.S. Fixed-Wing Military Aircraft Industry*, 13.

Marine Corps Mission and Capability Requirements

Each of the services has a specific mission to meet and therefore must develop equipment that best suits those needs. Title 10 requires the USMC to maintain its capability to provide “defense of advanced naval bases and for the conduct of such land operations as may be essential to the prosecution of a naval campaign.”⁴⁶ The Marines must also maintain the ability to conduct “amphibious operations that pertain to the tactics, technique, and equipment used by landing forces.”⁴⁷ The USMC has traditionally focused on the development of aircraft capable of operating from US Navy ships and expeditionary airfields. These capabilities are inherent in rotary-wing aviation, but require more deliberate thought with fixed-wing aviation, especially

fighter and attack aircraft. The swept wing design of modern fighter/attack aircraft provide increased speed and maneuverability, but sacrifice control at low airspeeds. The result is the need for longer runways.

The British Company, Hawker-Siddeley initiated development of the AV-8A Harrier to resolve this problem. The USMC ordered 102 AV-8As in 1970, but later worked a deal with Hawker-Siddeley to allow McDonald Douglas to develop the AV-8B Harrier II.⁴⁸ The Harrier II is currently operating in the Marine Corps. It provides a unique capability to the Marines, but not without costs. The Harrier II's primary role is to provide close-air-support (CAS) to Marines on the ground. Its short take-off and landing capabilities allow the pilots to remain close to the units they will be supporting. Unfortunately, the Harrier II is more limited in both payload and range than the Marine Corps' alternate fixed wing attack aircraft, the F/A-18. Therefore, it cannot remain on station for long, which results in gaps in the coverage it can provide. It is also significantly more vulnerable to Foreign Object Debris (FOD) than other aircraft due to its intake, which is large and low to the ground. This poses problems for operations from expeditionary airfields.

The Harrier II will soon be replaced by the F-35B Joint Strike Fighter, while the USMC's aging F/A-18s will be replaced by the F-35C. The JSF brings superior capabilities to the airframes it will replace to include stealth technology, but it has also been described as the most expensive weapons system program ever developed. The JSF's advantages are apparent: survivability, interoperability, and Short Takeoff Vertical Landing in the case of the F-35B. The JSF is a multirole fighter attack aircraft, which means it is not ideal for any one mission. Therefore, the Marines should expect limitations in capability as a CAS platform relative to an aircraft like the A-10 that was designed to serve as a ground-attack system.

Like the Harrier, the MV-22 Osprey is designed to provide a unique capability for the USMC. Its ability to take off and land vertically allows operations from US Navy small-deck ships like the CH-46 Sea Knight that it replaced, but in fixed-wing mode it can fly much faster and cover longer distances. In addition, the Osprey's ability to refuel in the air and fly similar speeds to the Marines KC-130 air-to-air refueler significantly extends its range. The MV-22 is a significant technological advance over the CH-46, but has created a gap in the USMC's ability to provide CAS for the Osprey during landing zone (LZ) operations.

The Marine Air Ground Task Force (MAGTF) is the foundational concept on which the USMC relies to meet its Title 10 obligations. A common phrase (uttered by Marine aviators) is, you can't spell MAGTF without the A. According to current leadership, the JSF and the Osprey are necessary for providing the MAGTF the ability to conduct expeditionary operations while maintaining a tactical and technological edge over foreign belligerents. The ability to launch and recover from ships coupled with the increased speed and range of the Osprey provides MAGTF commanders increased options. The stealth capabilities of the JSF result in survivability that allows it to penetrate enemy anti-access/aerial denial (A2/D2) defenses and to strike key defensive targets, thus allowing the insertion of Marines where necessary. Once the enemy air defenses are destroyed the JSF would transition to a CAS role in support of marines on the ground.

While the new technology brought by these weapons systems present advantages, it also creates dilemmas. The MV-22 outpaces and outranges traditional helicopter gunship support, which results in increased risk to the Osprey, its crew, and its passengers during landing-zone operations. To bridge this gap the Marine Corps is testing the MV-22 with the Advanced Precision Kill Weapon System (APKWS) and AGM-176 Griffin-B missile system. In theory

this will allow the Osprey to protect itself or be escorted by another MV-22. Senior officials have claimed that this is a solution. It could be argued that if simply strapping missiles to a utility aircraft is an adequate solution then why continue to develop and pay for gunships. The fact is missiles on the MV-22 are not a sufficient solution to the problem. The Osprey cannot provide adequate protection for itself while it is on approach to landing, on the deck, and departing the landing zone. Sourcing additional Ospreys as escorts will likely be difficult to support considering the MV-22's low readiness rates (see Figure 11).

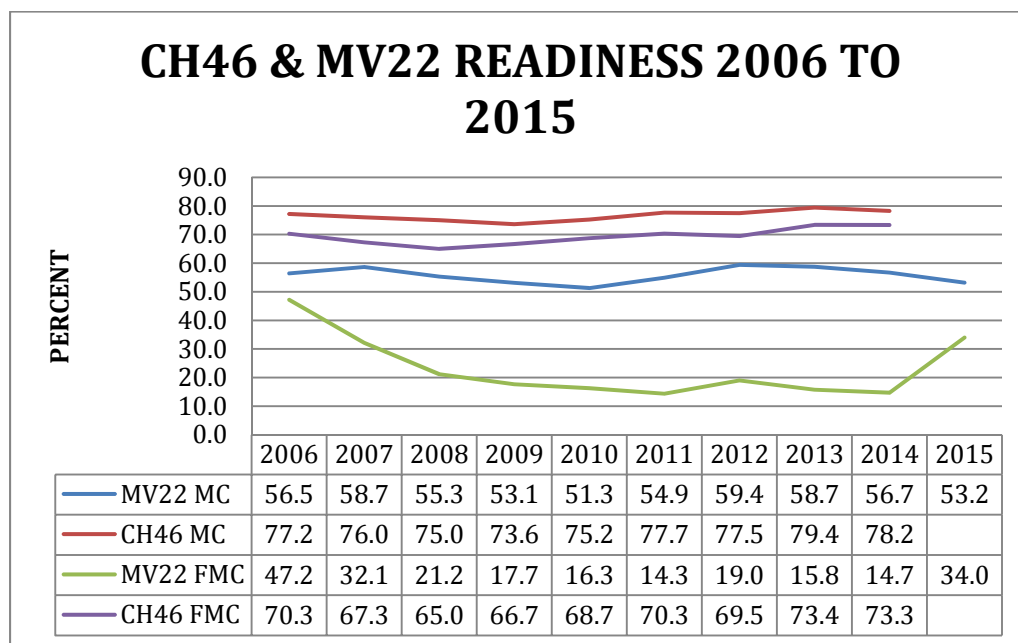
Aircraft readiness is critical to a commander's ability to conduct operations. When comparing the Marine Corps' readiness data for the CH-46 and the MV-22 it is clear that the more sophisticated MV-22's readiness is considerably lower (2006-2014). The mission capable (MC) data represents the percentage of aircraft that are flyable. This means there is something wrong with the aircraft, but it will not prevent the execution of certain missions. The full mission capable data (FMC) represents the percentage of aircraft that are capable of performing all missions. For example the MV-22 has issues with its anti-icing system that require a large number of them to be classified as MC instead of FMC. The CH-46 does not have an anti-ice system at all, so for this reason the FMC data gives the appearance of a greater disparity than really exists. Focusing on the MC data shows there is still roughly a 20 percent difference in readiness, which is a significant number.

Maintenance-man-hours per flight hour are another key metric used in aviation. Generally, a higher ratio of maintenance-man-hours per flight-hour, leads to a lower readiness of the airframe. Increasing the footprint (quantity of maintenance personnel, equipment and spare parts) is one method to adjust to this issue. This results in greater cost and is often not an option for expeditionary operations, which rely on the capability to operate with a smaller footprint.

Similar data is not yet available for the JSF due to infancy of the program. The complexity of the JSF suggests that a similar trend will appear once it is fully operational.

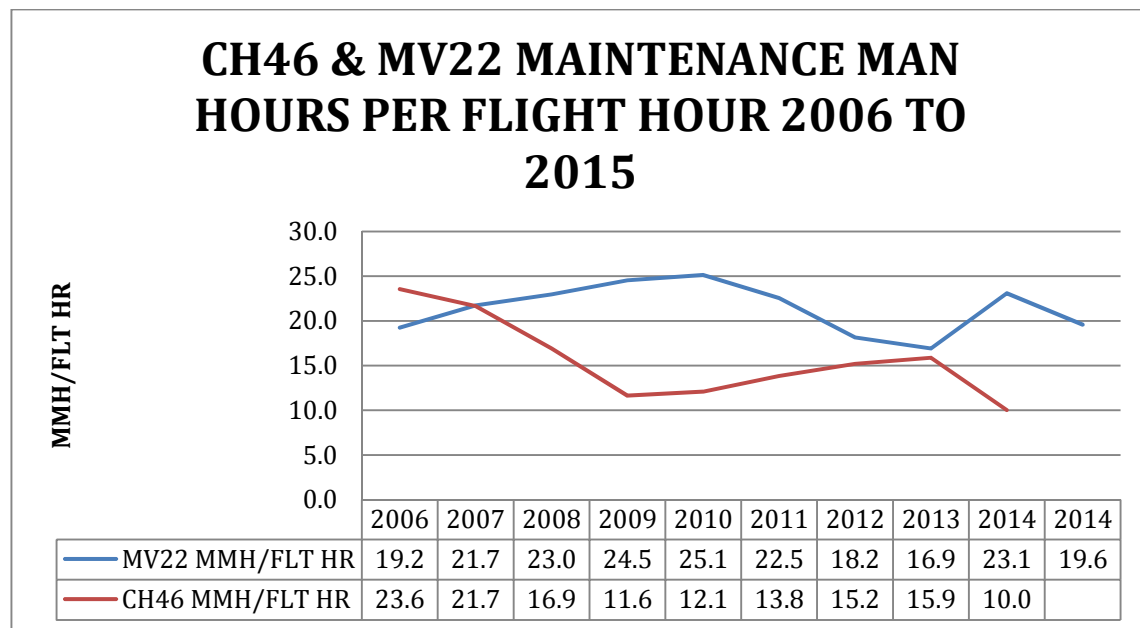
In the case of the MV-22 The Marine Corps focused on the technology itself, but failed to consider the changes that the new capabilities required operationally. As a result commanders must accept more risk for long-range missions for which the MV-22 was designed. This additional risk has led to the cancelation of missions in Operation Enduring Freedom.

Figure 11: Aircraft Readiness Comparison



Source: Data received in an email from Amee N. Patton, Office of Marine Aviation, HQMC, February 26, 2016.

Figure 12: Aircraft Maintenance Comparison



Source: Data received in an email from Amee N. Patton, Office of Marine Aviation, HQMC, February 26, 2016.

Marine Corps Acquisition's Manning

The Marine Corps' success in controlling the cost of advanced weapons systems will require a greater investment in the individuals it chooses to manage the process. There are three areas the Marine Corps can influence to create a more experienced acquisitions force. The first is, the point in an officer's career he or she is eligible to transition into to the field. The second is the length of time spent in an acquisition's billet. The third is the loss of experience to the private sector.

The USMC established the Marine Corps Systems Command (MCSC) on January 1, 1992, to "Streamline the acquisition and life cycle management processes to improve readiness of the Fleet Marine Force (FMF), increase responsiveness and support for the FMF, and reduce costs."⁴⁹ Currently, a board selects the military occupational specialty (MOS) 8059 or 8061(Acquisition Professional Officer) each year from a pool of eligible majors and lieutenant

colonels in the Marine Corps. A promotion board selects a Marine officer to the rank of major at 10-12 years from the date of his or her commission. Unlike in other MOSs, acquisitions majors will not have 10-12 years of experience behind them in their field. Acquisitions Professional Officers will be expected to negotiate with seasoned contractors where the outcomes can be the difference of millions of dollars. The result of less experience representing the interests of the USMC should be obvious.

Like most USMC billets, acquisition billets typically last only 3 years before the Marine moves to his or her next assignment. Therefore, a project like the JSF program sees continuous turnover of the individuals that are representing the interests of the Marine Corps. When considering the value of “corporate knowledge,” working relationships, and stability in a workplace, this system is terribly inefficient. The complexity of the acquisition process requires years to understand and even longer to master. In the case of aircraft development, there are billions of dollars, hundreds of thousands of jobs, and the Marine Corps’ future at stake. The way the USMC mans its acquisition process is an investment in its future. Training Marines in this trade early and providing greater stability in program manning will lead to a more efficient process.

Finally, working in acquisitions is often a stepping-stone into a civilian job for one of the many defense contractors. Culminating relationships for future jobs with contractors creates a conflict of interest for individuals working within DoD acquisition’s fields. Providing incentives and disincentives to counter these trends would help to minimize the issue. The USMC provides bonuses to retain talent in several MOSs. Bonuses should also be considered for acquisitions. Also, many industries require non-compete clauses to be signed by employees. Preventing

senior decision makers from having the option of retiring directly into a position with a contractor that is providing goods or services to the USMC should also be examined.

Conclusion

The Marine Corps' role in acquisitions is small relative to the size of the process as a whole. This fact limits the actions that can be taken to affect the cost of new aircraft. There are areas that the Marines do have influence. First and foremost the USMC must take a harder look at the capability requirements versus cost in both dollars and readiness. It should avoid joint programs in the future wherever feasible. Then it should reevaluate the structuring of its acquisitions fields. The USMC should bring junior officers into the MOS, and ensure incentives for retention as they move through the ranks, opportunity for continued promotions being one of these.

Arenas, Younossi et al, concluded that end-user capability requirements are often the largest contributing factor to the growth in cost.⁵⁰ The JSF is the most expensive weapons system ever developed, but will have many limitations providing CAS to the Marines on the ground when compared to an airframe designed specifically for that purpose. The airframe is designed to survive in a high-threat environment, which require tradeoffs that limit its value to combat troops. In an interview with Christian Sundsdal, Air Force F-35 pilot, Maj John Wilson stated that the A-10 "will always be better in CAS than the F-35 because it was designed to perform that kind of mission."⁵¹ The USMC can choose to purchase less-expensive aircraft to fulfill the roles it requires. The Air Force and the Navy possess the capability to penetrate and strike enemies air defenses, therefore Marine Corps is purchasing a duplicate capability.

The Marine Corps should focus on affordable technologies that provide enhanced capabilities where there exist shortfalls in the joint environment. The Marines argue that its air wing is necessary because Marine aviators provide a unique capability to the Marines fighting on the ground. If better CAS is the foundation of the Marine's argument, then developing a fixed wing CAS platform that is better suited for deep strikes, and air-to-air engagements undercuts that argument.

Joint Programs do not save money. In fact, history has shown that they are more expensive than developing aircraft independently. The next fixed wing fighter/attack program the Marine Corps endeavors to create must keep these facts in mind. Aircraft are not expeditionary simply because they can take-off and land vertically. They must be supportable within those same environments. The supportability requirements of the JSF are yet to be seen on an operational scale, but like the Osprey it is a significantly more complex machine than its predecessor. Therefore, it is not overreaching to expect similar issues regarding the logistics required to keep it in the air.

The progression of Marine officers is often dependent upon accomplishing specific tours of duty. Pilots are encouraged to strive to fill billets as a Forward Air Controller when not filling a squadron billet. There is no encouragement to fill billets in acquisitions. Many senior leaders are trumpeting the role of aircraft and the importance of having the best technology, yet a detour into an acquisitions job can derail a pilot's career progression. Additionally, an officer cannot even submit to transition into an acquisition's MOS until he or she is selected for major. If the USMC wants to ensure that it is doing all that it can to acquire the best weapons systems obtainable, it should invest more in the people that are responsible for the process.

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