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A Review and Analysis of Upgrades to Naval and Air Force Aircraft to Identify Similarities and Trends From Fiscal Year 1998 to Fiscal Year 2013

30 June 2013

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Thanks to Jen, my wife, for her patience with my projects. Thanks as well to my children, Jackson, Chance, and Michele. My family has been patient as I try to balance various aspects of my life.

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LIST OF ACRONYMS AND ABBREVIATIONS

AESA	Active Electronically Scanned Array
AIM	Air Intercept Missile
AIS	Automated Information System
APAF	Aircraft Procurement, Air Force
APN	Aircraft Procurement, Navy
ATFLIR	Advanced Targeting, Forward-Looking Infrared
BA	Budget Activity
BP	Budget Program
CBRN	Chemical, Biological, Radiological, Nuclear
CRS	Congressional Research Service
DAES	Defense Acquisition Executive Summary
DAMIR	Defense Acquisition Management Information Retrieval
DoD	Department of Defense
DoN	Department of the Navy
EA	Evolutionary Acquisition
ECP	Engineering Change Proposal
EOQ	Economic Order Quantity
FY	Fiscal Year
GAO	General Accounting Office (before July 7, 2004) Government Accountability Office (beginning July 7, 2004)
GPS	Global Positioning System
H.R.	House Resolution
IFF	Interrogator, Friend/Foe
IOC	Initial Operational Capacity
IPT	Integrated Product Team
MDAP	Major Defense Acquisition Program
MIDS	Multifunctional Information Distribution System
NACES	Naval Aircrew Ejection Seat
OA	Operational Availability
OUSD(AT&L)	Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics
Pub. L.	Public Law
PMA	Program Management, Air
PRISM	Photo Reconnaissance Intelligence Strike Module or Proxy-Based Inverse Multiplexer
RCPU	Radar Control Power Unit
RWR	Radar Warning Receiver
S.B.	Senate Bill
SSFC	Single Step to Full Capability
TAC	Tactical Air Command
TAMMAC	Tactical Aircraft Moving Map Capability

TMS	Type, Model, and Series
USAF	United States Air Force
USD(AT&L)	Under Secretary of Defense for Acquisition, Technology, and Logistics

I. INTRODUCTION

In 2012, the Government Accountability Office (GAO) detailed that the Department of Defense (DoD) has on its books 96 Major Defense Acquisition Programs (MDAPs), which collectively exceed $1.5 trillion (GAO, 2012). The goal of each program, in the most basic of terms, is to provide the warfighter with increased capability as soon as possible while carefully balancing cost, performance, and schedule. Whether executing the acquisition of Automated Information Systems (AISs), munitions, aircraft, ships, or ground vehicles, some programs are better poised to deliver requirements more rapidly than others through implementation of an evolutionary acquisition (EA) strategy. Although some platforms (e.g., a single aircraft carrier) are limited to delivering their full capability only upon completion of the entire program, larger quantity programs that rely on the production of multiple units have the luxury of pursuing EA. By accepting a product that meets a majority of desired requirements, the warfighter may take advantage of increased capability sooner with the assurance that follow-on production models will continue to build on what has already been delivered. Ultimately, the warfighter will have all requirements met while all along having had the advantage of the infamous but beneficial "80% solution." This time-phased systems improvement approach is typically referred to as block upgrades.

It is common practice for DoD program managers of major weapon systems to implement one or more block upgrades sometime during the life cycle of their respective platforms. Each block upgrade is a dedicated effort that may incorporate a major design change, in terms of either hardware or software, which allows the fleet to receive enhanced capability via incremental delivery. It is quite possible that after multiple iterations, the end product is significantly different from the original. To that end, one may question the delineation between a "block upgrade" and a "new project," a topic that warrants its own study. Because DoD acquisition policy is very focused on controlling life-cycle costs, a modification to achieve greater capability as an alternative to an entirely new platform is an option that is always considered when addressing capability gaps. However, more often than not, new starts come with a hefty and perhaps prohibitive financial price tag, along with a potentially very detailed and lengthy developmental timeline. Considering the DoD's ever-changing operating environments and missions in support of national defense and worldwide peacekeeping initiatives, the use of block upgrades offers an attainable path forward for many key weapon systems in order to increase capabilities, prolong service life, and ensure operational availability of the assets.

The objective of this project is to identify and examine the time-phased upgrades to U.S. Navy F/A-18 and Air Force F-16 aircraft, each of which is an MDAP. I examine timelines to illustrate when the various platform upgrades were requested via the presidential budget for each of the two aircraft. As a result of this project, the Under Secretary of Defense for Acquisition, Technology, and Logistics (USD[AT&L]) will be able to conduct further research to determine an optimal interval between modifications. To be clear, the intent of this project is not so much to determine whether the time-phased implementation of upgrades is feasible or efficient, but rather to identify similarities and capture any trends in the various upgrades implemented within the F/A-18 and F-16 programs.

Following a literature review of GAO reports, Congressional Research Service publications, and published articles that capture various perspectives on evolutionary acquisition and its implementation, I provide a brief overview of each of the platforms investigated for this project. I then describe my methodology for this research and analyze the data I collected. Lastly, I present a summary of conclusions and recommendations for additional research.

II. LITERATURE REVIEW

There is no debating the validity of EA. The benefits are understood and appreciated, and DoD regulation has formally incorporated EA for nearly 10 years in DoD Directive 5000.01 (DoD, 2007a). Although the term *spiral development* has come and gone out of favor, the preference for time-phased incremental improvements remains firmly rooted in the Defense Acquisition System.

In this literature review, I focus on publications that offer insight into the feasibility of and reliance on EA in support of MDAPs. I also focus on capturing (at the most basic level) a trend analysis of aviation-centric upgrades, for which there are currently no published articles on this topic. Therefore, as a starting point, the literature captured here details the DoD's preference of EA as a means of delivering the most capability efficiently to the warfighters.

The practice of a systematic, step-wise acquisition process that delivered products sooner made its DoD debut in the mid-1990s, and by 2001 it was formally adopted as a default weapon system development method (along with spiral development, which later fell out of favor by lack of mention in the 2005 version of DoD 5000.1). Fiscal year (FY) 2003 saw the Department of Defense Authorization Act (§ 2515), which called upon the DoD to detail how it planned to ensure incorporation of EA. A year later, H.R. 1588 (National Defense Authorization Act for Fiscal Year 2004) reinforced the DoD program managers' expectations by requesting that the GAO assess three concerns: whether current policies supported EA, whether the *intent* of the policy was assured by various controls that were in place, and whether the EA policy adequately addressed the concerns of the Senate Armed Services Committee. In 2007, the John Warner National Defense Authorization Act (H.R. 5122) required the DoD to review and further refine current acquisition policies based on greater incorporation of EA (a.k.a., incremental acquisition).

At the start, members of Congress raised concerns as the DoD tried to shift from the paradigm of a single step to full capability (SSFC) acquisition process to that of evolutionary acquisition (EA). The SSFC method relies heavily on successful and accurate long-range forecasting. Ironically, any forecasting beyond the first few fiscal years of any well-laid government acquisition plan tends to become very unreliable for a variety of reasons. With a shift from SSFC to EA, congressional committees expressed concern over the possibility of decreased oversight and how the step-wise process would impact current regular reporting periods (Gertler, 2009). Moreover, EA requires a great deal of trust from all players: first and foremost, trust from the user who agrees to accept earlier-delivered products that are essentially 80% solutions; second, from the program managers and their respective program management offices that their tireless efforts for development and delivery will bear top priority; and third, from the various members of Congress and the DoD acquisition force that clear, concise, and accurate updates will be provided by the cognizant program managers. This interdependent triad of trust (see Figure 1) is a basis for the motivation to invest the resources (people, time, and money) necessary to establish the acquisition building blocks for the time-phased completion and delivery of a product.

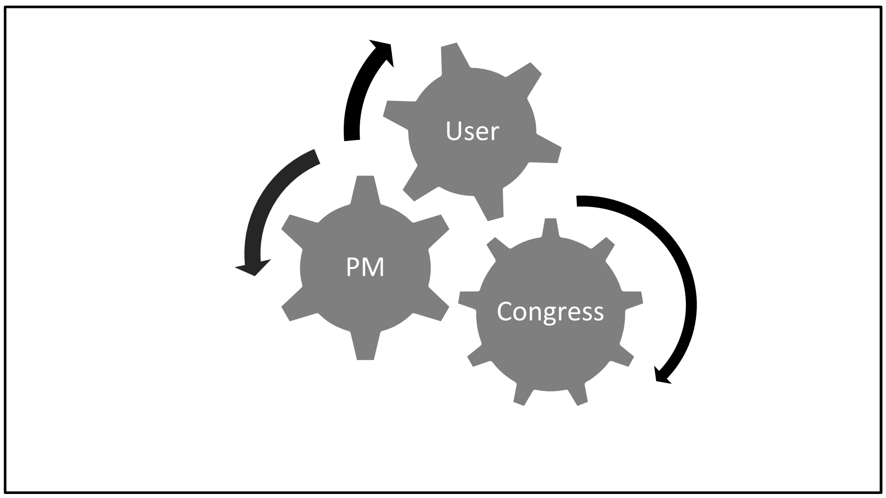

Figure 1. The Evolutionary Acquisition Interdependent Triad of Trust

A. MASTER PLANS AND ROADMAPS

EA serves as a method for the DoD to achieve the end goals detailed in various master plans and roadmaps. Whether it is the *Naval Aviation Vision* (Babb, 2012), *The Air Force Roadmap 2006–2025* (Department of the Air Force, 2006), or *The DoD FY2009–2034*

Unmanned Systems Integrated Roadmap (DoD, 2006), the underlying principle is constant improvement over several years in an incremental fashion.

An effective fighting force at its very root is also an efficient fighting force. To that end, the Navy set out to streamline its helicopter fleet by taking a fleet of nine types of helicopters composed of four unique airframes to a fleet of three types of Sikorsky-manufactured helicopters: the MH-60R, MH-60S, and MH-53E. Ultimately, the MH-53E would be replaced by the MH-60S, enabling the Navy to operate a fleet of common helicopters (Babb, 2012). The support and control of logistics, maintenance, and operation of a single airframe are only possible via the methodical implementation of upgrades that allow for multi-mission configurations, which are possible only through step-wise capability improvements.

Even before the formal adoption of the term EA, the Tactical Air Command (TAC), a subset of the Air Force, developed a strategy to reshape the various air wings and squadrons through the incorporation of new aircraft, including the Advanced Tactical Fighter and the A-16, the latter of which never materialized (Department of the Air Force, 2006). The basis for the plan's success was incremental, time-phased capability enhancement. No other means were feasible. The dollar cost alone for the structured force change would be challenging. In addition, the resources to establish enough manufacturing capability to instantly produce the desired end product in a matter of a few years would have been prohibitive. This combination perfectly underscores that EA is the only viable path forward to deliver capable assets while simultaneously positioning the DoD to more readily incorporate technology as it becomes available.

Another example is the DoD's roadmaps for unmanned systems (DoD, 2006; 2007a). There is an effort to greatly enhance and more readily take advantage of the unmanned systems by providing the following war fighting capabilities:

- reconnaissance and surveillance;
- target identification and designation;
- counter-mine and explosive ordnance disposal; and
- chemical, biological, radiological, nuclear (CBRN) reconnaissance.

However, the technology that will allow for success in some of the intended missions has yet to be proven or demonstrated. In order to draft a path forward, the authors of the capability plan first had to evaluate the collective position of the DoD's autonomous technology, and then determine how to achieve the capability within the air, ground, and maritime domains. Table 1 identifies enabling technology in terms of what is available versus what is required. EA is a strategy to incorporate what has yet to be developed.

Table 1. Technology Available Now Versus Technology Required for Autonomous Capabilities
(DoD, 2006)

	2009	2015	2034
	Evolutionary Adaptation	Revolutionary Adaptation	
Power	Battery Powered	Next Gen Power Resource	Bio Mass Reactor Powered/ Opportunistic Power Grazing
Environmental Capability		Sensors to Enable Robust Weather Flexibility	Extreme Weather Capable
Signature Management	Passive	Active	Covert and Self Concealing Behaviors
Architecture	Proprietary	Standard	Standard Unlimited
World Model	Simple	Artificial	Highly Representative
Communication	Relays - Automatically Deployed		High Speed Intelligent Network Comms
Human Detection	Multi-Modal	On the Move	Biomimetic
Human Robot Interaction	Voice Control	Bird Dog/Warfighter's Associate	Hierarchical Collaborative Behaviors
Obstacle Avoidance	Sense and Avoid	Dynamic Obstacle Avoidance	

B. MODERNIZATION ISSUES

A 2007 GAO report stated, "During the next 7 years, the military services plan to spend about $109.3 billion to acquire about 570 new tactical aircraft and to modernize hundreds of operational aircraft" (p. 2).

Aircraft modernization includes the following issues (see Figure 2): required versus actual operational availability (OA) of assets, the ability to counter projected threats, and industry's capability to provide production support. In terms of OA, service chiefs rely on various squadron representatives and requirements officers to provide accurate assumptions regarding expected service life and what is required to safely and effectively extend the service life. An integral part of those assumptions is the predicted threat assessments, which are based on a combination of actual and predicted threat levels together with any relief provided by the delivery of pending new airframes. Specifically, F-16 modernization efforts have been tempered by the expectation of a growing F-22 fleet, and the F/A-18 upgrades are balanced with the progress of the F-35 Joint Strike Fighter.

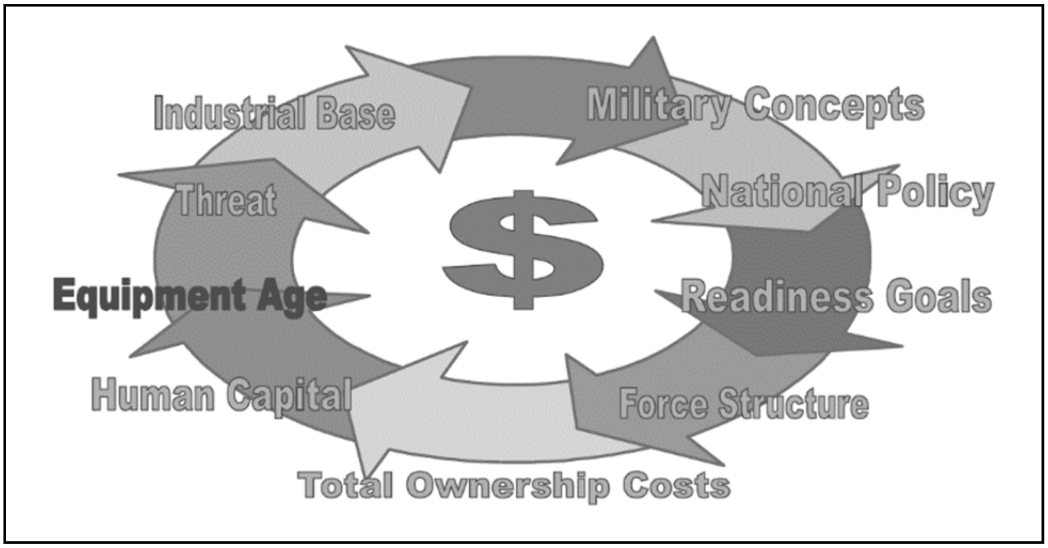

Figure 2. Aircraft Modernization Considerations
(GAO, 2001b)

Cost is also a factor. When accounting for costs, assessment teams need to evaluate previous trends in terms of maintenance, logistics, and training. Projections of future expenditures must also account for an increase in the frequency of repairs as well as upgrades required to meet safety standards (i.e., compliance with new Federal Aviation Administration regulations), for the ability to minimize or eliminate capability gaps, and for any increase in cost/price as impacted by a shifting industrial base. Specifically, the further a type, model, and series (TMS) of aircraft moves beyond full-rate production, the less available spare parts become because tooling, templates, and processes are retired or realigned to other products. The GAO (2007) highlighted the relationship between purchasing new airframes and maintaining legacy assets:

> If quantities of new aircraft are reduced and/or deliveries slip further into future years, significantly more (as yet) unplanned money will be required to sustain, modernize, and extend the life of legacy systems to ensure that the total force is both capable and sufficient in numbers. (p. 2)

The GAO (2007) further added that attempts to effectively plan for and implement modernization projects are stymied by the challenge of accurately predicting the costs associated with new development and production.

Our nation's success in establishing its collective defensive posture is in large part due to the ability of industry to produce the war fighting assets required. A Congressional Research Service (CRS) report (Gertler, 2009) focused on the diligence that must be afforded in terms of maintaining production capability, tooling, and knowledge to mitigate the risk of undermining the ability to maintain a superior air force. But this concern may be juxtaposed against the argument that we can recapitalize on the tooling required to more readily support current in-service aircraft to a higher degree.

Summarizing section 1047 of H.R. 2647 (National Defense Authorization Act for Fiscal Year 2010) as passed by the House, the House Armed Services Committee in a 2009 report detailed the emphasis given to aircraft upgrades/modifications by stating,

> The committee has identified $143.7 million in unjustified program growth in the Air Force operation and maintenance administrative budget, specifically service-wide technical support, service-wide administration, and service-wide other activities. Additionally, the committee has identified $200.9 million in unexecutable peacetime operations due to deployments in the Air Force operating forces, air operations budget activity. The committee recommends that these funds totaling $344.6 be used for the continued operation and maintenance of the 249 legacy fighters that were slated for retirement during fiscal year 2010 until such time as the reporting requirement above is met. In addition, the committee recommends that $10.5 million of funds for aircraft procurement be available for obligations for modifications necessary to sustain the 249 fighter aircraft. (Gertler, 2009, p. 17)

In summary, the FY2010 National Defense Authorization Act authorized approximately $42,000 for each of the 249 United States Air Force (USAF) fighters to be modified.

In 2001, Allen Li (GAO, 2001b), the director of acquisition and sourcing management, wrote a letter to the Secretary of Defense to introduce GAO Report 01-163 supported by Table 2. In the letter, he stated,

> We project that in 2011, the average age of the Air Force's tactical aircraft will grow from 13 to 21 years; for the Navy, it will increase from 10 to 11 years. By 2025, we project that the average age of Navy aircraft will be about 10 years but that Air Force aircraft will have an average age of 16 years…We

also observed that DOD and the services' approved financial plans for 2001 and future years do not include funding for structural modifications that the services believe are essential for maintaining certain tactical aircraft in the force. These modifications, estimated to cost about $1,344 million through fiscal year 2014, are necessary, according to the Navy and the Air Force, to extend the useful lives of about 1,542 F/A-18C/D and F-16 aircraft. These modifications are essential for DOD to maintain sufficient numbers of tactical aircraft to respond to the current defense policy to fight in two nearly simultaneous major theater wars.

Table 2. Examples of Average Aircraft Age and Expected Life
(GAO, 2001b)

Current Aircraft	1999 Average Age	Expected Remaining Years in the Inventory
F-14 A/B/D	15 years old	4-9 years
F/A-18 A/B	13 years old	16 years
F-16 C/D	10 years old	At least 20 years

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III. OVERVIEW OF THE F/A-18 HORNET, F-16 FIGHTING FALCON, AND ASSOCIATED UPGRADES

A. F/A-18 HORNET

In 2009, there were 1,000 F/A-18s in the Naval inventory (GAO, 2010). The F/A-18 Hornet got its start in the latter half of the 1970s with the A/B series. Full-rate production was authorized in 1975, and the fleet had initial operational capability (IOC) in January 1983. The C/D series followed shortly thereafter with IOC 1987, and, by mid-FY1994, there was a critical design review for the E/F model. The first flight for the F/A-18 E/F was in 1997, and it has since come to be operated by the following seven nations, in addition to the United States: Australia, Canada, Finland, Kuwait, Malaysia, Spain, and Switzerland. Since its inception, there have been four major block upgrades. Regarding the time phasing between block upgrades for the F/A-18 A/B/C/D/E/F, there is little systematic correlation other than adherence to a predefined plan in support of the *Naval Aviation Vision* (Babb, 2012). Figure 3 illustrates the block-wise progression of the F/A-18 from 1980 through 2014.

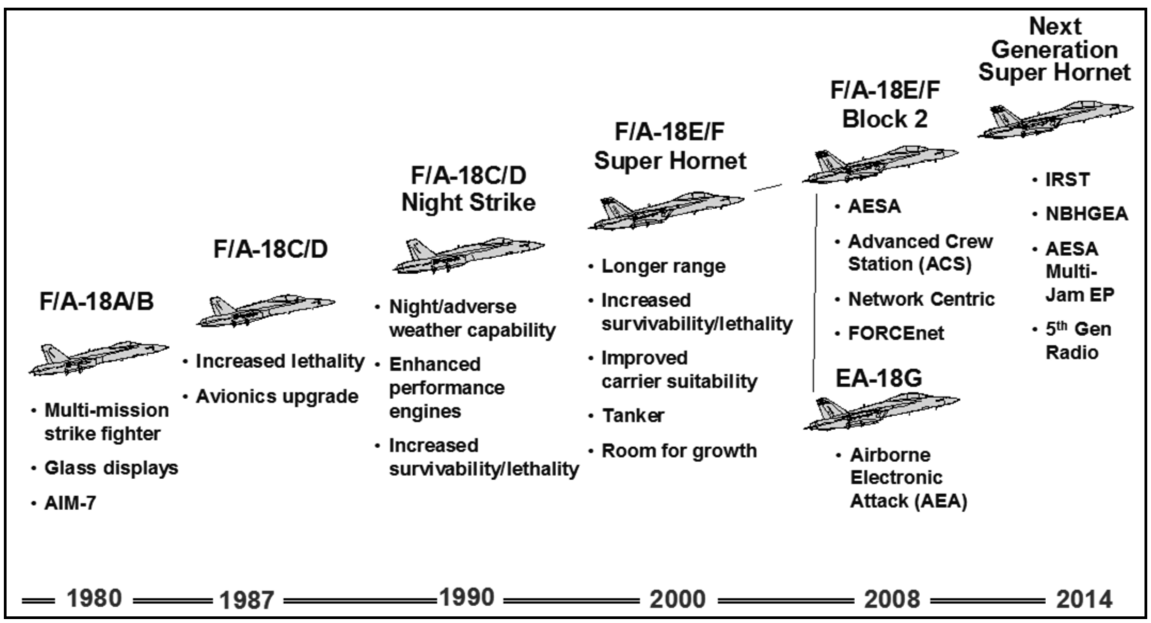

Figure 3. F/A-18 Block Progression History
(Helper, 2009)

B. F-16 FIGHTING FALCON

In 2009, there were 1,200 F-16s in the Air Force inventory (GAO, 2010). First reaching IOC in 1979, the Fighting Falcon was upgraded in 1981 to the C/D model (a.k.a., block 25/32), then in 1989 to blocks 40/42. In 1994, the F-16 block 50/52 became operational. There was a two-, seven-, and five-year gap, respectively, between the various upgrades. The Air Force continues to upgrade the F-16 in order to increase capability and extend its service life through the end of FY2025. Figure 4 depicts a planned decrease in the quantity of F-16s as EA is expected to impact its efficiency and effectiveness.

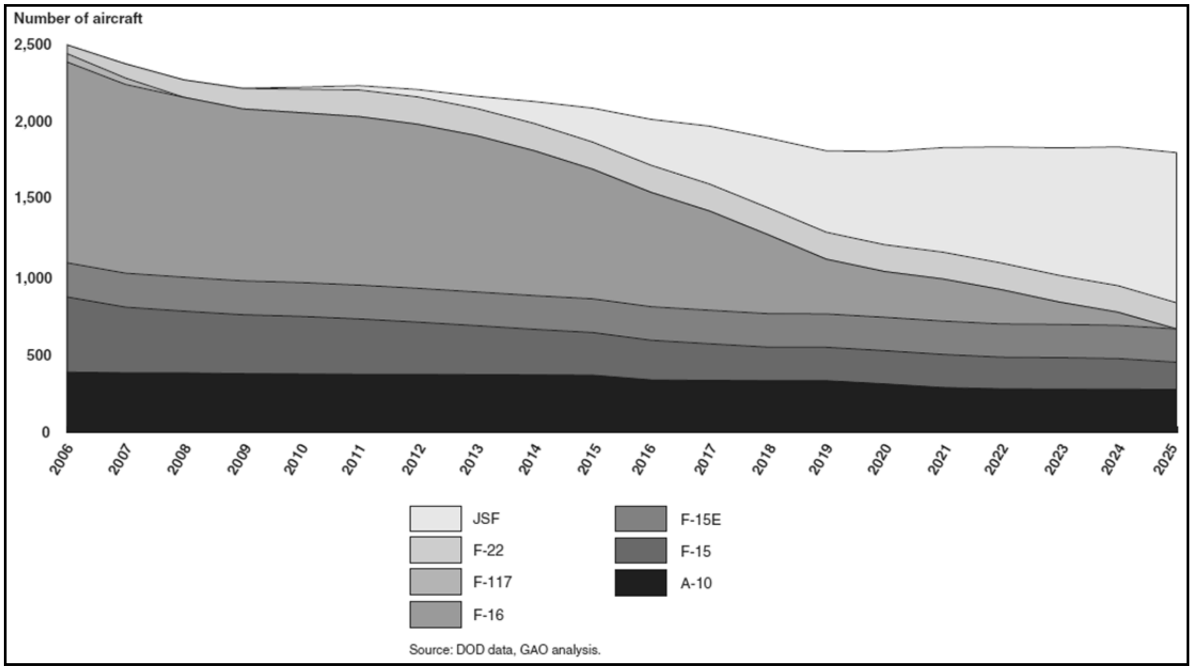

Figure 4. Projection of Aircraft Quantity Required Through FY2025
(GAO, 2007)

IV. METHODOLOGY AND ANALYSIS

This research relied on information reported annually to Congress as per the various submissions in support of the presidential budget submission to Congress. By using the Defense Acquisition Management Information Repository (DAMIR), the Air Force Financial Management & Comptroller website (http://www.saffm.hq.af.mil/budget/index.asp), and the Department of Navy Budget Materials website (http://www.finance.hq.navy.mil/fmb/13pres/books.htm), I was able to access the archived budget materials from FY1998 through FY2013 for the Navy and Air Force. Specifically, I focused on the records that capture Aircraft Procurement, Navy (APN) and Aircraft Procurement, Air Force (APAF). Table 3 lists the volumes of the seven budget activities (BAs) within the DoD.

Table 3. Budget Activities, APN, and APAF Budget Documentation
(Roberts, 2011)

Budget Activity	**Title**
BA-1.	Combat Aircraft
BA-2.	Airlift Aircraft
BA-3.	Trainer Aircraft
BA-4.	Other Aircraft
BA-5.	Modification of In-Service Aircraft
BA-6.	Aircraft Spares and Repair Parts
BA-7.	Aircraft Support Equipment & Facilities

I paid particular attention to the justification of estimates detailed in the B-5 budget activities for the modification of in-service aircraft.

Table 4 details a subset of Navy aircraft procurement categories. The Navy uses a combination of the acronym for APN and the number of the corresponding budget activity (1–7) to yield terms APN-1 through APN-7.

Table 4. Navy Procurement Categories
(Roberts, 2011)

Navy Procurement Categories	Description
Aircraft Procurement, Navy 1 (APN-1)	Provides for fabricating and procuring combat aircraft
Aircraft Procurement, Navy 5 (APN-5)	Provides for modifications of aircraft
Aircraft Procurement, Navy 6 (APN-6)	Provides for aircraft spares and repair parts
Aircraft Procurement, Navy 7 (APN-7)	Provides for aircraft support equipment and facilities

The Air Force references uniquely numbered budget programs (BP), with each number identifying what the funds are intended to procure (see Table 5).

Table 5. United States Air Force Budget Programs
(Department of the Air Force, 2012)

Air Force Budget Programs	Description
Budget Program 10 (BP-10)	Provides for fabricating and procuring complete aircraft
Budget Program 11 (BP-11)	Provides for permanent modifications of in-service aircraft
Budget Program 12 (BP-12)	Provides for replacement of organizational- and intermediate-level support equipment (common and peculiar) for all out-of-production aircraft
Budget Program 13 (BP-13)	Provides for post-production costs in support of the following: (1) production-line close-down costs, (2) deferred support equipment, (3) interim contractor support (until the date specified in the acquisition program baseline), and (4) procurement-related contractor support
Budget Program 16 (BP-16)	Provides for procuring investment-type initial spares and repair parts

For both the Air Force and the Navy, the budget submissions included details and justification in support of all aircraft appropriations, but in this project, I honed in on the data captured specifically within Air Force BP-11 and Navy APN-5 because they are both intended to capture modifications. I specifically avoided inclusion of APN-1 and/or BP-10 because the intent of those categories is to capture the procurement of production-line aircraft. This paper has a narrow focus on retrofit of post-production aircraft.

Further narrowing the focus, I considered only Air Force F-16s and Navy F/A-18s. It is important to highlight that U.S. Marine Corps F/A-18 are captured as a subset of the Department of the Navy (DoN). I determined the specific Navy and Air Force aircraft by noting which aircraft were prominent within budget activity-5 between FY1997 and FY2013. The intent was to capture aircraft that are now, in some capacity, being modified versus simply produced. After reviewing the data, I discovered numerous variations of the same airframe, which indicate the DoD's attempt to provide specialized platforms for mission-specific tasking. For the sake of the paper, I have identified the baseline model of each aircraft and then followed each subsequent variation as a capability-enhancing upgrade. This is a very important point that bears repeating. If an airframe does not include the phrase *Block I* or *Block II*, I did not necessarily discount it from my list of observable data.

To discern which updates were funded (not necessarily completed), I used the data captured in two unique budget forms, P-40 and P-3a, both of which support the P-1. The P-1 is an overarching summary form that captures (at the service component level) the line-item procurement request for each appropriation within the presidential budget request. The P-40 details each line item captured within the P-1 that is equal to or in excess of $5 million. Likewise, the supporting documentation for each individual modification is then captured within P-3a. Figure 5 displays the hierarchy of these three budget forms.

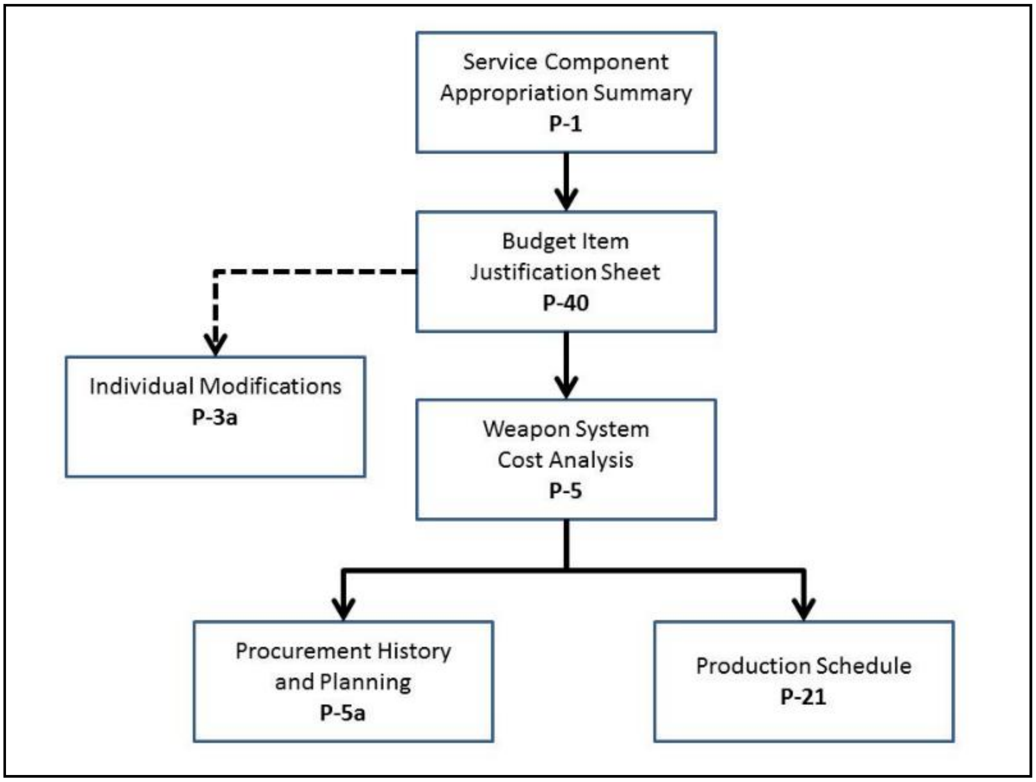

Figure 5. P-Form Flow Chart
(Roberts, 2011)

A. F-16 TRENDS IN UPGRADES

Between FY1998 and FY2013, the F-16 program cited 28 unique efforts that were either supporting or central to a capability improvement. Table 6 depicts the number of times these 28 unique efforts were requested by the F-16 program over a 15-year span (1998–2013) of the presidential budget submissions. Nine of the upgrade modifications were budgeted for a period of eight or more years during the 16-year timeframe that I investigated. The efforts that consistently requested funding were global positioning system (GPS; 13 years), modular mission computer (12 years), and smart weapons support infrastructure (12 years).

Table 6. Number of Air Force Budget Requests Across Presidential Budgets, FY1998–FY2013

Number of Years Captured in Presidential Budgets From FY1998 Through FY2013	Effort
13	Global Positioning System
12	Modular Mission Computer
12	Smart Weapons Support Infrastructure
11	Color Displays
11	Joint Helmet-Mounted Cueing System
11	Link 16
10	F110 Digital Engine Control
9	Air-to-Air Interrogator
8	Mode 5 Identification
7	ALE-47 Auto/Semi-Auto & Chaff and Flare System
6	ALQ-213 Countermeasure Set
6	Falcon 229 Engine Upgrade
6	Improved Data Modem
6	Night-Vision Imaging System
4	Beyond Line-of-Sight Radio
4	Commercial Central Interface Unit
4	Enhanced Fire Control Computer
4	Tactical Data Link
3	600-Gallon External Fuel Tanks
3	Advanced Data Transfer Equipment
3	Advanced Interrogator, Friend/Foe (IFF)
3	ALR-56M Radar Control Power Unit (RCPU) Upgrade
3	Digital Flight Control Computer
3	Secure Line-of-Sight Radio
2	Color Airborne Video Tape Recording System
2	Commercial Flight Control Computer
1	Main Aircraft Battery
1	Radar Warning Receiver Update

Of the 28 efforts, two were budgeted to impact all blocks of the F-16 (25/30/32/40/42/50/52) and were submitted in FY1998 and then again in FY2007 (see Table 7).

Table 7. Efforts Spanning All Blocks FY1998–FY2013

Blocks	Effort	Budget Year
25/30/32/40/42/50/52	Night-Vision Imaging System	1998
25/30/32/40/42/50/52	Secure Line-of-Sight Radio	2007

Nine efforts captured the earlier blocks (25/30/32) within the budget requests for FY1998, FY1999, FY2000, FY2003, FY2005, and FY2007 (see Table 8).

Table 8. Efforts Focusing on Blocks 25/30/32

Blocks	Effort	Budget Year
25/30/32	ALQ-213 Countermeasure Set	1998
25/30/32	GPS	1998
25/30/32	Night-Vision Imaging System	1998
25/30/32	Smart Weapons Support Infrastructure	1998
25/30/32	Enhanced Fire Control Computer	1999
25/30/32	Main Aircraft Battery	2000
25/30/32	Commercial Central Interface Unit	2003
25/30/32	Color Displays	2005
25/30/32	Secure Line-of-Sight Radio	2007

Twelve efforts targeted all of the mid-block aircraft (40/42/50/52) and were included in FY1998, FY2000, FY2001, FY2003, FY2006, and FY2008 (see Table 9).

Table 9. Efforts Focusing on Blocks 40/42/50/52

Blocks	Effort	Budget Year
40/42/50/52	ALE-47 Auto/Semi-Auto & Chaff System	1997
40/42/50/52	Smart Weapons Support Infrastructure	1998
40/42/50/52	ALR-56M RCPU Upgrade	2000
40/42/50/52	Color Displays	2001
40/42/50/52	Link 16	2001
40/42/50/52	Modular Mission Computer	2001
40/42/50/52	Tactical Data Link	2003
40/42/50/52	GPS	2006
40/42/50/52	Mode 5 Identification	2006
40/42/50/52	Advanced Data Transfer Equipment	2008
40/42/50/52	Digital Flight Control Computer	2008
40/42/50/52	Beyond Line-of-Sight Radio	2009

The latter-most blocks (50/52) were captured by requests in FY1998, FY1999, FY2000, and then again in FY2010 (see Table 10).

Table 10. Efforts Focusing on Blocks 50/52

Blocks	Effort	Budget Year
50	600-Gallon External Fuel Tanks	1998
50/52	Color Displays	1999
50/52	Link 16	1999
50/52	Air-to-Air Interrogator	2000
50/52	Color Airborne Video Tape Recording System	2000
50/52	Joint Helmet Mounted Cueing System	2000
50/52	Modular Mission Computer	2000
50/52	Mode 5 Identification	2010

Figure 6 graphically depicts the top six recurring modification requests in terms of number of times requested over the period of time included in my research (FY1998–FY2013). Tables 11 and 12 provide additional insight into the annual budget requests, showing which modifications were requested for airframes over the years.

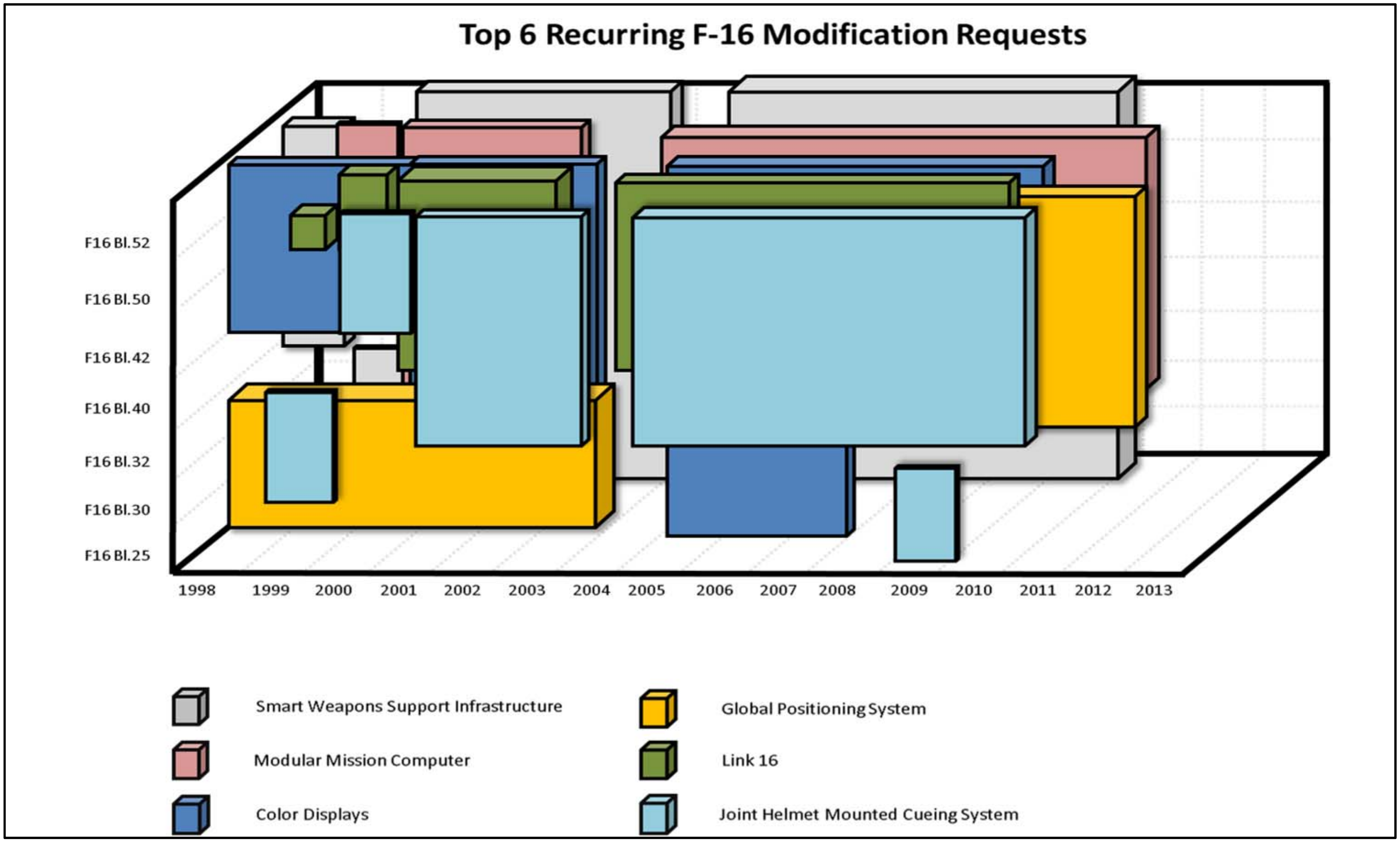

Figure 6. Top Six Recurring F-16 Modification Requests

Note. During the research for this project, budget activity-5 for the United States Air Force FY2004 budget was not available. This is the reason for the one-year break in continuity.

Table 11. BP-11 Modification Request Data From FY1998 to FY2013 (Part 1 of 2)

BP-11 Upgrade Title	F-16 Blocks Affected							Fiscal Years Included in Presidential Budget															No. of Fiscal Years Authorized
Modular Mission Computer				40	42	50	52				2001	2002	2003		2005	2006	2007	2008	2009	2010	2011	2012	11
Smart weapons support infrastructure	25	30	32						1999	2000	2001	2002	2003		2005	2006	2007	2008	2009	2010			11
Smart weapons support infrastructure				40	42	50	52	1998		2000	2001	2002	2003		2005	2006	2007	2008	2009	2010			11
F110 Digital Engine Control		30		40				1998	1999	2000	2001	2002	2003		2005	2006	2007	2008					10
Joint Helmet-Mounted Cueing System						50	52			2000	2001	2002	2003		2005	2006	2007	2008	2009	2010			10
Joint Helmet-Mounted Cueing System				40	42				1999		2001	2002	2003		2005	2006	2007	2008	2009	2010			10
Air to Air Interrogator						50	52			2000	2001	2002	2003		2005	2006	2007		2009	2010			9
Color Displays				40	42	50	52				2001	2002	2003		2005	2006	2007	2008	2009	2010			9
Link 16				40	42	50	52				2001	2002	2003		2005	2006	2007	2008	2009	2010			9
ALE-47 Auto/Semi-Aauto & Chaff System				40	42	50	52	1998	1999	2000	2001	2002	2003		2005								7
GPS				40	42	50	52									2006	2007	2008	2009	2010	2011	2012	7
ALQ-213 Countermeasure Set	25	30	32					1998	1999	2000	2001	2002	2003										6
Falcon 229 Engine Upgrade							52	1998	1999	2000	2001	2002	2003										6
GPS	25	30	32					1998	1999	2000	2001	2002	2003										6
Improved Data Modem				40				1998	1999	2000	2001	2002	2003										6
Night Vision Imaging System	25	30	32	40	42	50	52	1998	1999	2000	2001	2002	2003										6
Improved Data Modem					42				1999	2000	2001	2002	2003										5
Beyond Line-of-Sight radio				40	42	50	52												2009	2010	2011	2012	4
Commercial Central Interface Unit	25	30	32										2003			2006	2007	2008					4
Tactical Data Link				40	42	50	52						2003		2005		2007		2009				4
600-Gallon External Fuel Tanks						50		1998	1999	2000													3
Advanced Data Transfer Equipment				40	42	50	52											2008	2009	2010			3

Note. During the research for this project, budget activity-5 for the United States Air Force FY2004 budget was not available. This is the reason for the one-year break in continuity.

Table 12. BP-11 Modification Request Data From FY 1998 to FY 2013 (Part 2 of 2)

BP-11 Upgrade Title	F-16 Blocks Affected							Fiscal Years Included in Presidential Budget															No. of Fiscal Years Authorized
ALR-56M RCPU Upgrade				40	42	50	52			2000	2001	2002											3
Color Displays	25	30	32												2005	2006	2007						3
Digital Flight Control Computer				40	42	50	52											2008	2009	2010			3
Enhanced Fire Control Computer	25	30	32							2000	2001	2002											3
Mode 5 Identification						50	52													2010	2011	2012	3
Mode 5 Identification				40	42												2007	2008	2009				3
Secure Line of Sight Radio	25	30	32	40	42	50	52										2007	2008	2009				3
Advanced IFF		30	32														2007			2010			2
Color Airborne Video Tape Recording System						50	52			2000	2001												2
Color Displays						50	52		1999	2000													2
Commecial Flight Control Computer		30	32																2009	2010			2
Advanced IFF		30														2006							1
Beyond Line-of-Sight radio		30	32																	2010			1
Enhanced Fire Control Computer	25	30	32						1999														1
Joint Helmet-Mounted Cueing System		30	32																2009				1
Link 16						50	52			2000													1
Link 16						50			1999														1
Main aircraft Battery	25	30	32							2000													1
Mode 5 Identification				40	42	50	52									2006							1
Mode 5 Identification				40	42															2010			1
Modular Mission Computer						50	52			2000													1
Radar Warning Receiver Update				40				1998															1

Note. During the research for this project, budget activity-5 for the United States Air Force FY2004 budget was not available. This is the reason for the one-year break in continuity.

Figure 7 shows the trend of costs associated with the Air Force budget requests for modifications and procurement. Specifically, there are two trend lines depicted. The lower curve shows the costs for F-16 modifications as a percentage of the total cost of all Air Force aircraft modifications. The graph depicts a decreasing trend since FY2005 for costs of modifying the F-16. The upper curve shows the cost of all Air Force aircraft modifications as a percentage of the entire Air Force aircraft procurement budget. In contrast to the former trend, here we notice an increase in overall modification costs since FY2005.

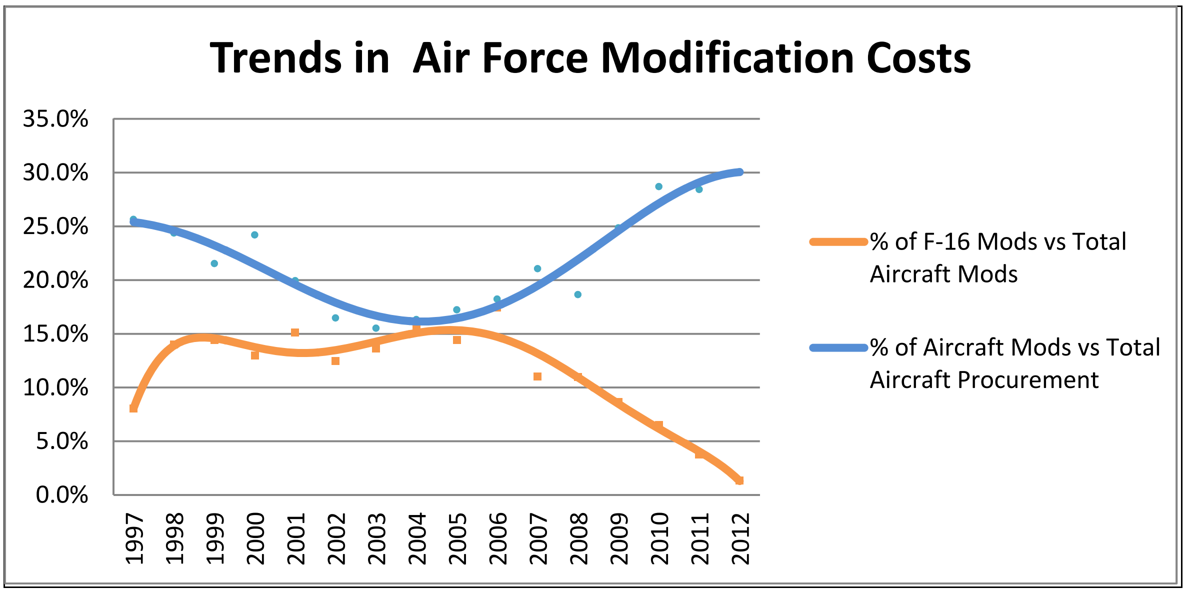

Figure 7. Trends in Air Force Modification Costs

B. F-18 TRENDS IN UPGRADES

The F-18 program has introduced several variants of the aircraft that benefited from the EA strategy. From FY1998 through FY2013, 24 distinct efforts were essential for aircraft modernization and overall mission success (see Table 13). Of the 24 unique efforts, 14 were included in the presidential budget request for eight or more years within the 15-year research window of this project. Two of the efforts (a digital communications system and a multifunctional information distribution system) received funding for 15 consecutive years. The next four largest annual inclusions were avionics upgrades for the U.S. Marine Corps (14 consecutive years); a positive identification system (13 years); a joint helmet-mounted cueing system (13 consecutive years); and advanced targeting, forward-looking infrared (ATFLIR; 13 consecutive years).

Table 13. Number of Navy Budget Requests Across Presidential Budgets, FY1998–FY2013

Number of Years Captured in Presidential Budgets, FY1998–FY2013	Effort
15	Digital Communications System
15	Multifunctional Information Distribution System (MIDS)
14	U.S. Marine Corps Avionics Upgrade
13	Positive ID System
13	Joint Helmet-Mounted Cueing System
13	ATFLIR
11	GPS
10	Air Intercept Missile (AIM)-9X Compatibility
9	Common Configuration
9	AN/APG-73 Radar Upgrade
9	AN/ARC-210 Electronic Protection Comb Radio
9	Naval Aircrew Ejection Seat (NACES) Ejection Seat
8	Advanced Tactical Airborne Recon System
8	Core Avionics Upgrades
6	Link 4A Replacement
5	Mk XIIA Mode 5 IFF
5	Litening (AN/AAQ-28)
6	Active Electronically Scanned Array (AESA)
4	Net-Centric Ops
4	ALR-67 Radar Warning Receiver (RWR) Systems
3	ALR-67 Advanced Special Receiver
2	Photo Reconnaissance Intelligence Strike Module or Proxy-Based Inverse Multiplexer (PRISM)
3	Fast Tactical Imagery II
2	Tactical Aircraft Moving Map Capability (TAMMAC)

Of the 24 Navy upgrade efforts, two were budgeted to impact all series of the F/A-18 (A/B/C/D/E/F). The core avionics upgrade was requested in FY2005, followed by the active electronically scanned array (AESA) in FY2007 (see Table 14).

Table 14. Efforts Spanning all Series of F/A-18 Blocks, FY1998–FY 2013

Series	Effort	Budget Year
A/B/C/D/E/F	Core Avionics Upgrades	2005
A/B/C/D/E/F	AESA	2007

Four efforts captured the early series aircraft (A/B) with the budget requests in FY1998, FY1999, and FY2005 (see Table 15).

Table 15. Efforts Incorporating the Early Series of the F/A-18 (A/B/C/D)

Series	Effort	Budget Year
A/B/C/D	GPS	1998
A/B/C/D	Common Configuration	1998
A	U.S. Marine Corps Avionics Upgrade	1999
A/D	Litening (AN/AAQ-28)	2005

Twelve efforts included the mid-block aircraft (C/D) and were included in FY1998, FY2000, FY2001, FY2002, and FY2009 (see Table 16).

Table 16. Efforts Focusing on Mid Series (C/D)

Series	Effort	Budget Year
C/D	Digital Communications System	1998
C/D	Positive ID System	1998
C/D	AN/APG-73 Radar Upgrade	1998
C/D	AN/ARC-210 Electronic Protection Comb Radio	1998
C	Advanced Tactical Airborne Recon System	1998
C/D	ALR-67 Advanced Special Receiver	1998
C/D	Joint Helmet Mounted Cueing System	2000
C/D	ATFLIR	2000
C/D	AIM-9X Compatibility	2001
C/D	TAMMAC	2001
C/D	Mk XIIA Mode 5 IFF	2002
C/D	ALR-67 RWR Systems	2009

And the latter series F/A-18 aircraft (E/F/G) were captured by requests in FY2005, FY2006, and FY2009 (see Table 17).

Table 17. Efforts Focusing on the Latter Series (E/F/G)

Series	Effort	Budget Year
E/F/G	Link 4A Replacement	2005
E/F	AESA	2006
E/F	Net-Centric Ops	2009

Figure 8 graphically depicts the top six recurring modification requests in terms of number of times requested over the period of time included in my research (FY1998–FY2013). Table 18 provides additional insight into the annual budget requests, showing which modifications were requested for airframes over the years.

In both Figures 6 and 8, it is interesting to note the recurrence of the modification requests. Beyond question, the program offices for the F-16 and F/A-18 are working hard to continuously deliver upgraded products to the warfighter. But with such a constant repetition of modifications, the question needs to be asked whether they are receiving the financial support needed to achieve efficient upgrades. It is hard to correlate efficient modifications with budget requests that drag out over a decade. Are all aircraft and aircrews equally reaping the intended benefits of the collective upgrades? I contend that the piecemeal budgetary requests for modifications highlights a systemic challenge in the bureaucracy of government funding, which in itself forces each program office to operate with extreme inefficiency. But they do so very well as they have no other choice.

The concept of the DAMIR (Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics [OUSD[AT&L], 2011) is great, but, unfortunately, seems to be falling short of its potential. The message on its front page reads as follows:

> **DAMIR** is a DoD initiative that provides enterprise visibility to Acquisition program information. DAMIR streamlines acquisition management and oversight by leveraging web services, authoritative data sources, data collection, and data repository capabilities. DAMIR identifies various data sources that the Acquisition community uses to manage Major Defense Acquisition Programs (MDAP) and Major Automated Information Systems (MAIS) programs and provides a unified web-based interface through which to present that information. DAMIR is the authoritative source for Selected Acquisition Reports (SAR), SAR Baseline, Acquisition Program Baselines (APB), and Assessments. It is a powerful reporting and analysis tool with robust data checks, validation, standardization and workflow leveling. It has extensive security capabilities as well as both classified and unclassified

> versions. One component of DAMIR, Purview, is an executive information system that displays program information such as mission and description, cost, funding and schedule. It is OSD's solution for structured acquisition data presentation and uses web services to obtain and display Defense Acquisition Executive Summary (DAES) data directly from the Service acquisition databases.

As of June 2013, this statement had last been updated on October 4, 2011. Although there are several interesting and useful links on the site, there are also several outdated documents that serve to undermine the credibility of the site as a whole. Perhaps an additional link could be made within DAMIR that sheds light specifically on the concept I present in this research by showing a trend in the types of modifications requested along with the status of their implementation to better identify any common thread across all programs.

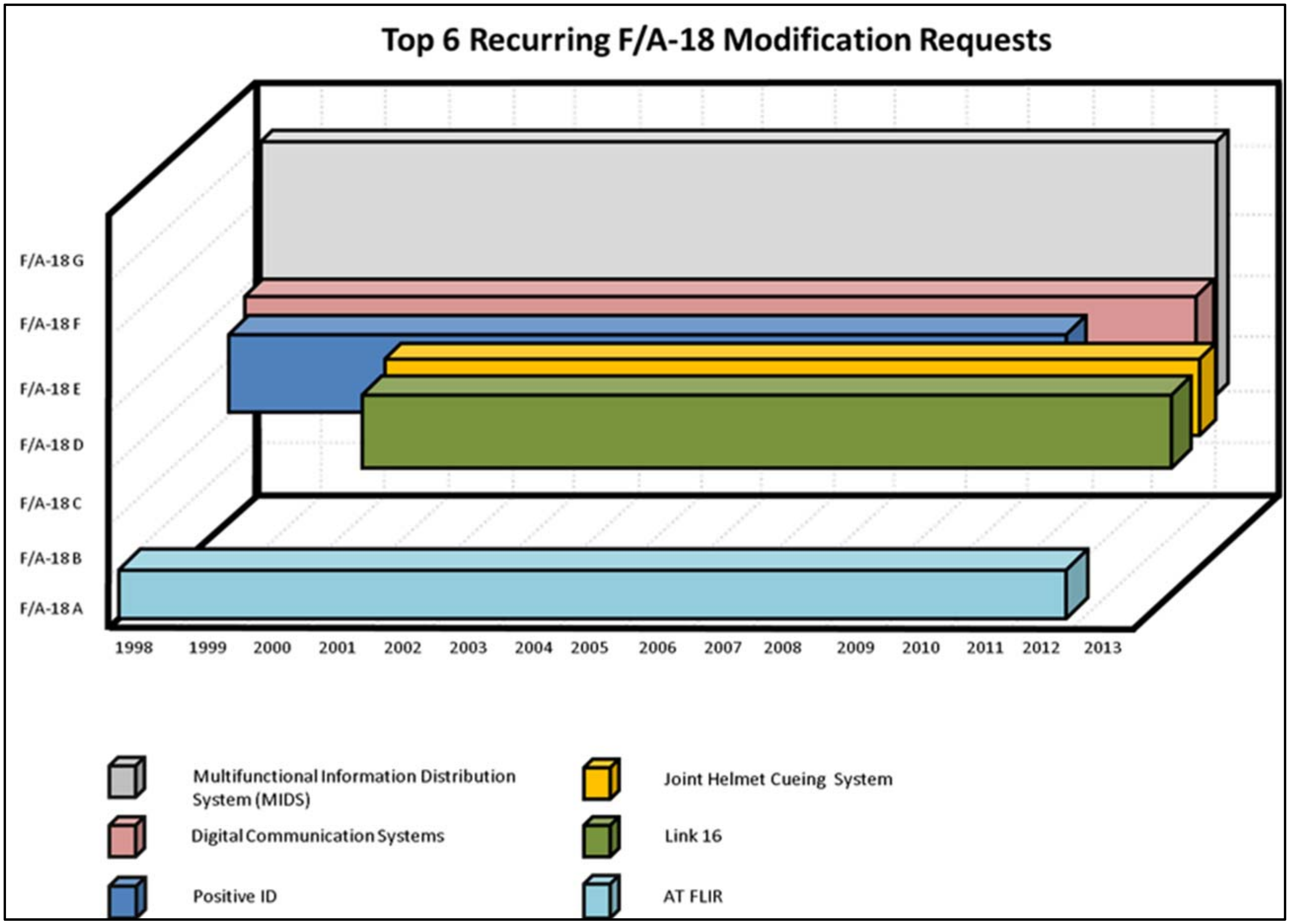

Figure 8. Top Six Recurring F/A-18 Modification Requests

Table 18. APN-5 Modification Request Data From FY1998 to FY2013

APN-5 Upgrade Title	F/A-18 Blocks Affected							Fiscal Years Included in Presidential Budget															No. of Fiscal Years Authorized
Digital Communications System			C	D				1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	15
Multifunctional Information Distribution System (MIDS)			C	D	E	F		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	15
USMC Avionics Upgrade	A								1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	14
Positive ID System			C	D				1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010			13
Joint Helmet-Mounted Cueing System			C	D						2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	13
ATFLIR			C	D						2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	13
GPS	A	B	C	D				1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008					11
AIM-9X Compatibility			C	D							2001	2002	2003	2004	2005	2006	2007	2008	2009	2010			10
Common Configuration	A	B	C	D				1998	1999	2000	2001	2002	2003	2004	2005	2006							9
AN/APG-73 Radar Upgrade			C	D				1998	1999	2000	2001	2002	2003	2004	2005	2006							9
AN/ARC-210 Electronic Protection Comb Radio			C	D				1998	1999	2000	2001	2002	2003	2004	2005	2006							9
NACES Ejection Seat			C	D	E	F		1998	1999	2000	2001	2002	2003	2004	2005	2006							9
Adv Tactical Airborne Recon System				D				1998	1999	2000	2001	2002		2004	2005	2006							8
Core Avionics Upgrades	A	B	C	D	E	F									2005	2006	2007	2008	2009	2010	2011	2012	8
Link 4A Replacement					E	F	G								2005	2006	2007	2008	2009	2010			6
Mk XIIA Mode 5 IFF												2002	2003	2004	2005	2006							5
Litening (AN/AAQ-28)	A			D											2005	2006	2007	2008	2009				5
AESA	A	B	C	D	E	F											2007	2008	2009	2010	2011		5
Net-Centric Ops					E	F													2009	2010	2011	2012	4
ALR-67 RWR Systems			C	D															2009	2010	2011	2012	4
ALR-67 Adv Special Receiver			C	D				1998	1999	2000													3
Fast Tactical Imagery II			C	D	E	F								2004	2005	2006							3
TAMMAC			C	D							2001	2002											2
PRISM			C	D	E	F						2002	2003										2
AESA					E	F										2006	2007						2

Figure 9 shows the trends in costs associated with the Navy budget requests for modifications and procurement. As with Figure 7, two trend lines are depicted. The curve that shows a decreasing trend corresponds with a decrease in costs for all DoN aircraft modifications (APN-5) as a percentage of all Navy aircraft procurement (APN-1). The curve that shows a slight increasing trend denotes the cost of all F/A-18 aircraft modifications as a percentage of the all Navy aircraft modifications. The peak of F/A-18 modification requests were between 2003 and 2006.

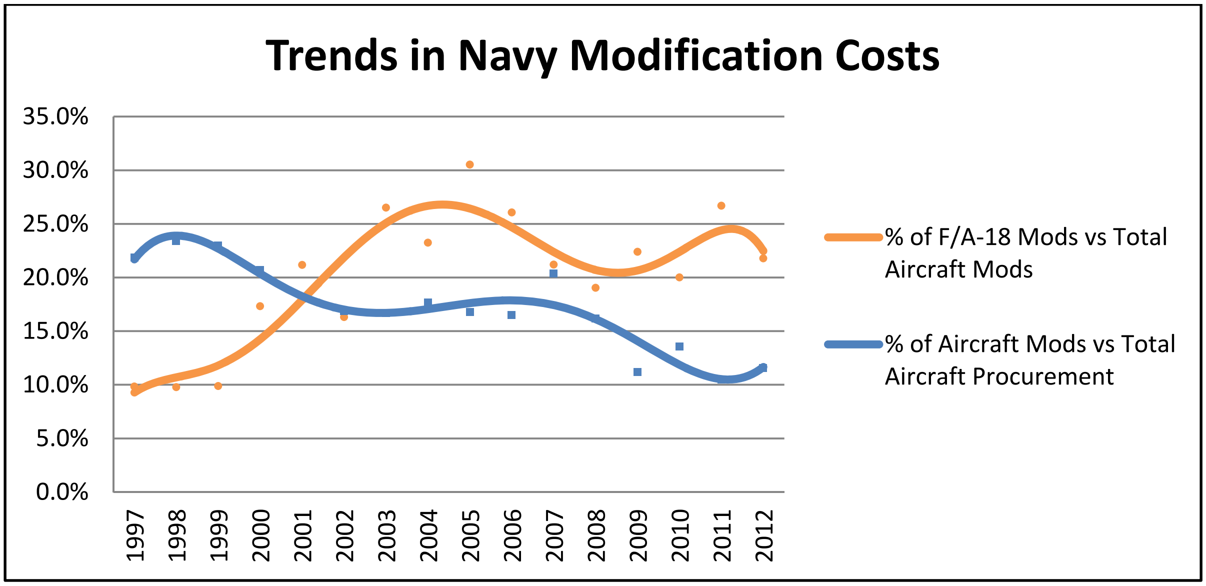

Figure 9. Trends in Navy Modification Costs

V. CONCLUSIONS AND RECOMMENDATIONS

For both the Air Force and the Navy, the archived budget submissions included details and justification in support of all aircraft appropriations, but this project hones in on the data captured specifically within the Air Force F-16 BP-11 and the Navy F/A-18 APN-5 because they are both intended to capture modifications. I specifically avoided inclusion of APN-1 or BP-10 (procurement funding) because the intent of those categories is to capture the procurement of production-line aircraft. However, discounting both APN-1 and BP-10 also disregards budget requests for any modifications that are simultaneously implemented on production-line assets and retrofitted on the previously delivered fleet aircraft. It is legal to absorb APN-5 and BP-11 requirements within the procurement funding. The separation of funds is an important point to consider in any follow-on research. This concept alone warrants its own study to understand how much of the fleet is modified with procurement funds. Left unchecked, this funding strategy may prove to be a slippery slope and compromise overall program success. It is very feasible that as a production line comes to a close, any program relying on the procurement funds for modification as well as production may find itself instantly operating in a deficit status and unable to adequately continue planned modifications either in support of capability enhancements or for necessary rework.

Additionally narrowing the focus, I considered only one type/model of airframe for Air Force and Navy aircraft. However, it is important to highlight that U.S. Marine Corps assets are captured as a subset of the DoN, hence the inclusion of the Marine Corps F/A-18 within the subset of naval aircraft (although not specifically called out).

I recommend additional research to further delineate trends in presidential budget requests. Specifically, researchers may capture and categorize all requests for individual modifications. Moreover, it is not enough simply to annotate the title of each budgetary request. It is more important to read the actual description of what is to be implemented and why. Through the review of the presidential budget requests, I learned that several titles changed while the descriptions remained the same. Additionally, along with specific airframes, it is important to capture any attempt of a single program office to leverage its purchasing power via an economic order quantity in support of multiple airframes. During the fact finding for this project, I learned, via the Navy budget archives, that this practice was becoming more popular annually and could very well impact any resulting compilation of data. Specifically, within Naval Aviation Systems Command, there are program offices dedicated to the procurement of common equipment (Program Management Air [PMA]-202 Aircrew Systems, PMA-260 Common Ground Support Equipment and Automatic Test Equipment, and PMA-209 Common Avionics). In addition, my research has found that between FY1998 and FY2013, the Navy spent $1.9 billion on common avionics upgrades alone. This is in *addition* to other aircraft modifications listed within BA-5.

In FY2003–FY2006, the Assistant Secretary of the Navy for Research, Development, and Acquisition commissioned a series of reports to provide analysis of economic order quantity (EOQ) at the airframe level. Individual program data were submitted via a common single source price investment model database that was accessible online. The data facilitated the generation of standard quad charts that detailed such information as the minimum per-unit cost for a given EOQ and the maximum per-unit cost per EOQ, both of which are compared to the current per-unit rate. In addition, a graph that shows unit cost as a function of quantity ordered denoted zones of "inefficiency," "efficiency," and "diminishing returns." As a result of the continually requested upgrades, I propose that a similar analysis be ongoing for the wide variety of recurring subsystems. Regardless of service affiliation, there simply has to be a better way to strengthen the overall buying power across the board within the DoD (and perhaps the federal government). Moreover, the concept of a program office that is charged with making common purchases (e.g., PMA-260, Common Aviation Support Equipment) might well be expanded to a DoD-wide level. A military clearinghouse for all issues of GPS (for example) or beyond line-of-sight radios could serve to enhance a ready and consistent production base, and ultimately a quicker turnaround on desired platform upgrades. It is a disservice for any program office to feel compelled to request the same type of upgrade for a decade. At that pace, the latest retrofit is most assuredly different that the first installation. With the implementation of a common subsystem acquisition office, resources across DoD program offices would regain much-needed bandwidth in order to address a variety of competing issues.

Lastly, in concert with follow-on, higher fidelity analysis of what program offices have requested and continue to request for a budget, a breakdown of the various engineering change proposals (ECPs, often submitted en masse) might prove to offer insight into what levels of efficiency exist at the program (and integrated product team [IPT]) level. Without any specific examples, I saw an enormous number of ECPs that were included in the presidential budget request on a recurring basis. Considering our current fiscal environment and the pending reduction of manpower, it is valid to ask whether such a workload is feasible. The requests for funding such a large, recurring quantity of ECPs portray a well-intentioned but unsustainable roadmap. There are undoubtedly extra costs rooted within countless inefficiencies; specifically, the funds required to maintain our industry counterpart while the DoD attacks several different projects simultaneously, each constantly reprioritized in an effort to focus on the "alligator closest to the boat" and confront queuing inefficiencies as a result of multitasking.

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- MOSA Contracting Implications
- Portfolio Optimization via KVA + RO
- Private Military Sector
- Software Requirements for OA
- Spiral Development
- Strategy for Defense Acquisition Research
- The Software, Hardware Asset Reuse Enterprise (SHARE) Repository

Contract Management

- Commodity Sourcing Strategies
- Contracting Government Procurement Functions
- Contractors in a 21st-Century Combat Zone
- Joint Contingency Contracting
- Model for Optimizing Contingency Contracting, Planning, and Execution
- Navy Contract Writing Guide
- Past Performance in Source Selection
- Strategic Contingency Contracting
- Transforming DoD Contract Closeout
- USAF Energy Savings Performance Contracts
- USAF IT Commodity Council
- USMC Contingency Contracting

Financial Management

- Acquisitions via Leasing: MPS Case
- Budget Scoring
- Budgeting for Capabilities-Based Planning
- Capital Budgeting for the DoD
- Energy Saving Contracts/DoD Mobile Assets
- Financing DoD Budget via PPPs
- Lessons from Private-Sector Capital Budgeting for DoD Acquisition Budgeting Reform
- PPPs and Government Financing
- ROI of Information Warfare Systems
- Special Termination Liability in MDAPs
- Strategic Sourcing
- Transaction Cost Economics (TCE) to Improve Cost Estimates

Human Resources

- Indefinite Reenlistment
- Individual Augmentation
- Learning Management Systems
- Moral Conduct Waivers and First-Term Attrition
- Retention
- The Navy's Selective Reenlistment Bonus (SRB) Management System
- Tuition Assistance

Logistics Management

- Analysis of LAV Depot Maintenance
- Army LOG MOD
- ASDS Product Support Analysis
- Cold-Chain Logistics
- Contractors Supporting Military Operations
- Diffusion/Variability on Vendor Performance Evaluation
- Evolutionary Acquisition
- Lean Six Sigma to Reduce Costs and Improve Readiness

- Naval Aviation Maintenance and Process Improvement (2)
- Optimizing CIWS Lifecycle Support (LCS)
- Outsourcing the Pearl Harbor MK-48 Intermediate Maintenance Activity
- Pallet Management System
- PBL (4)
- Privatization-NOSL/NAWCI
- RFID (6)
- Risk Analysis for Performance-Based Logistics
- R-TOC AEGIS Microwave Power Tubes
- Sense-and-Respond Logistics Network
- Strategic Sourcing

Program Management

- Building Collaborative Capacity
- Business Process Reengineering (BPR) for LCS Mission Module Acquisition
- Collaborative IT Tools Leveraging Competence
- Contractor vs. Organic Support
- Knowledge, Responsibilities, and Decision Rights in MDAPs
- KVA Applied to AEGIS and SSDS
- Managing the Service Supply Chain
- Measuring Uncertainty in Earned Value
- Organizational Modeling and Simulation
- Public–Private Partnership
- Terminating Your Own Program
- Utilizing Collaborative and Three-Dimensional Imaging Technology

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