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**P-8A Poseidon Multi-mission Maritime Aircraft (MMA) Software Maintenance Organization Concept Analysis**

**21 January 2010**

**by**


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Graduate School of Business & Public Policy

**Naval Postgraduate School**


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# Abstract

The Navy is developing a replacement system, designated as the P-8 Poseidon, for the aging P-3C Orion fleet of aircraft, expanding the mission profile to meet the requirements for its Multi-mission Maritime Aircraft (MMA). The Incremental acquisition approach leverages the Commercial-Off-The-Shelf (COTS) concept, using a modified Boeing 737 aircraft system. The concept integrates the COTS components with Government-Off-The-Shelf (GOTS) elements, including offensive and defensive systems, mission packages, and Operational Flight Profiles (OFP), as well as some newly developed systems. The COTS, GOTS, and newly developed systems are all software-intensive and drive the need for an effective software support architecture that necessarily combines commercial and Governmental entities. This research analyzes potential system software maintenance drivers, and presents advantages and disadvantages for three differing software support management options. The conclusions reached lead the researchers to recommend that an organic (Navy) software support management structure would be most advantageous.

**Keywords:** Intelligence, Surveillance, &Reconnaissance (ISR); Anti-Submarine Warfare (ASW); Commercial-Off-The-Shelf (COTS); Government-Off-The-Shelf (GOTS); Aircraft; Software; Information Assurance (IA)

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# I. Introduction: Background

## A. P-8A Poseidon System Overview/Introduction

Aging aircraft and the associated challenges of supporting older weapon systems continue to plague the Department of Defense with obsolescence issues and increased maintenance costs. There are several acquisition programs underway to replace the aging aircraft fleets—for example, the Joint Strike Fighter (JSF) and procuring additional F/A-18's. Another initiative to replace an aging fleet is the next-generation Maritime Patrol and Reconnaissance (MPR) weapon system: the P-8 Multi-mission Maritime Aircraft (MMA). The United States Navy is replacing the P-3C Orion, which has been in the inventory for 26 years,[1] with a commercial-derivative Boeing 737-800 aircraft.

The system consists of inter-related segments: the Air Vehicle (everything that goes airborne in and on the aircraft) and P-8A MMA product support (including P-8A MMA unique facilities, personnel, training, and support equipment). In other words, this system includes the Air Vehicle and all associated equipment, related unique facilities, materials, software, services, training, manufacturing, disposal, deployment, and support required to ensure that the P-8A MMA System can accomplish its intended operational role. The Tactical Support Center (TSC), while a unique support facility for MPR, is not included in the P-8A MMA System. The P-8A MMA System is required to operate effectively in the context of its external system interfaces and environments (DoN, n.d.).

The P-8A Poseidon will maintain the latest capabilities of the P-3C Orion Anti-Surface Warfare (ASuW) Improvement Program (AIP)—including the Anti-Submarine Warfare Acoustic Display and Control System upgrade (AN/USQ-78 (V)), the Block Modification Upgrade (BMUP), as well as a state-of-the-art flight station

[1] Navy officials said the average age of the 196 aircraft still in the inventory is 26 years (CNN, 2004).

and navigation/communication system. Additionally, the P-8A will incorporate in-flight refueling capabilities, yielding extended ranges and time-on-station previously unavailable in the P-3C fleet (DoN, 2007, March).

For the acquisition strategy, the Navy decided to pursue a Commercial-Off-the-Shelf (COTS) solution to leverage support of the system off the globally deployed aircraft in the commercial sector and to reduce risk across the program. This approach is in line with the most recent Department of Defense acquisition guidance: “To achieve the best possible system solution, emphasis shall be placed on innovation and competition. Existing commercial-off-the-shelf (COTS) functionality and solution drawn from a diversified range of large and small business shall be considered” (DoD, 2008, December 8).

By using the COTS philosophy, Navy leaders are ensuring there will be minimal development costs for the airframe and associated systems. The aircraft airframe has limited design changes, and the parts will be interchangeable with commercial fleets and available from Boeing 737 (B-737) service centers throughout the world. The supportability issues will likely not come from the hardware on the P-8; the challenge will be in the software sustainment and software upgrades for the on-board systems supporting a weapon system scheduled to be in the Navy inventory for 20+ years (CNN, 2004).

The P-8A program was initially an evolutionary acquisition program using spiral development to align the requirements with the acquisition strategy. The acquisition strategy has now been changed to an Incremental Acquisition approach—utilizing enhanced system development to provide mature capability to the Warfighter.

The acquisition strategy details a method that partners commercial industry and the P-8 fleet, with a goal of delivering the first increment of aircraft to the users in the quickest, most cost efficient manner. During this first increment (the Development Phase), the program will pursue improvement in system capabilities through an incremental development process to keep pace with emerging threats, technologies and strategic requirements of the Navy and Joint Forces (DoN, 2007, March).

## B. Acquisition Strategy

Based on the applicable acquisition regulations at the time, the P-8A program used an Evolutionary Acquisition approach (using a spiral development technique) to align the processes employed for requirements definition, acquisition strategy, and system development into a flexible program to meet the strategic vision of the Navy.

Evolutionary Acquisition is defined as:

> the preferred DoD strategy for rapid acquisition of mature technology for the user. An evolutionary approach delivers capability in increments, recognizing, up front, the need for future capability improvements. The object is to balance the needs and available capability with resources, and to put capability into the hands of the user quickly. The success of the strategy depends on consistent and continuous definition of requirements, and the maturation of technologies that lead to disciplined development and production of systems that provide increasing capability towards a materiel concept. (DoD, 2003, May 12)

The Evolutionary Acquisition approach has been abandoned by the DoD. In fact, the May 2009 version of the *Department of Defense Instruction 5000.02* (*DoDI 5000.02*) dropped the Evolutionary Acquisition approach and the Spiral Development technique. Now, the P-8 MMA Program Office is instead restructuring the program into an Incremental Acquisition approach. The primary difference between the Evolutionary and the Incremental approaches is that the increments within the Incremental approach are much more defined than each typical spiral in the Evolutionary approach. The intent of the well-defined increments is to provide more predictable schedules and budgets, causing less friction with Congress and high-level decision-makers. While the approach changes, the overall strategy remains the same.

The plan for the MMA develops a strategy that provides a partnership between the B-737 commercial industry and the Navy P-8 fleet. The strategy also focuses on delivering the aircraft to the users in the quickest, most cost-efficient manner. At the same time, the program will pursue improvements in system capabilities through spiral development—permitting the system to keep pace with new technologies, emerging threats and requirements of the Navy and Joint Forces (DoN, 2007, March).

The Navy initially selected spiral development based on acquisition policy at program initiation (DoD, 2003, May 12). The revised *Operation of the Defense Acquisition System* (DoD, 2008, December 8) DoD Instruction has deleted spiral development as an evolutionary acquisition approach, identifying only Incremental as a means of achieving rapid acquisition of mature technology. In fact, the revised instruction has established a Configuration Steering Board (CSB). The DoD mandates:

> The Acquisition Executive of each DoD Component shall establish and chair a CSB with broad executive membership including senior representatives from the Office of the USD(AT&L) [Undersecretary of Defense for Acquisition, Technology, and Logistics] and the Joint Staff. Additional executive members shall include representatives from the office of the chief of staff of the Armed Force concerned, and other Armed Forces representatives where appropriate, the military deputy to the CAE and the Program Executive Officer (PEO). (DoD, 2008, December 8)

This board was created by the DoD in an attempt to minimize requirements "creep" and the spiraling costs of new weapon systems acquisition.

> The CSB shall meet at least annually to review all requirements changes and any significant technical configuration changes for ACAT I and ACAT 1A programs in development that have the potential to result in cost and schedule impacts to the program. Such changes will generally be rejected, deferring them to future blocks or increments. Changes shall not be approved unless funds are indentified and schedule impacts mitigated. (DoD, 2008, December 8)

## C. System Support Structure

The current P-8 Support Plan implements a process to leverage existing and worldwide B-737 commercial support, products, and processes with a cost-effective Contractor Logistics Support (CLS) solution for total lifecycle support to the fleet of P-8s worldwide. In addition, the Program Management Office (PMO) will evaluate and incorporate Performance-based Logistics (PBL) concepts into the P-8A maintenance plan to reduce weapon systems cost and improve aircraft readiness (DoN, 2007, March).

The Navy is considering two options for software support:

- Assign the software configuration items to a Weapons System Support Activity (WSSA) to provide software maintenance under a Operation and Maintenance, Navy (O&M,N) level of effort [a contractor or contractors, in lieu of a Government activity, may be used to provide software support where this Software Support Requirements Analysis so justifies]; or
- Not assign the software configuration items to a WSSA, and to treat software changes under alternative contracting procedures. (DoN, 2007, April)

The P-8 acquisition approach combines the use of COTS and Government-Off-The-Shelf (GOTS) products, including software applications. Selecting the most advantageous software support organizational and management structure depends upon properly analyzing the P-8 system software architecture, life cycle plan, and support organizations and facilities. The following sections of this research analyze the advantages and disadvantages of differing software maintenance management options, as well as the impact of likely software maintenance drivers.

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# II. Problem Statement

This research analyzes the most advantageous software-support organization for the P-8 Poseidon ASW Aircraft System, given the known and planned system software architecture and support organizational structures. This analysis will address the following research questions:

a. What are the typical factors affecting software maintainability and support organization?

b. What is the planned P-8 System Software Architecture, and how is that architecture likely to impact the maintenance organization concept decisions?

c. What type of software support organizational structure would be most advantageous for the P-8 system?

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# III. Research Methodology

## A. Analyze Factors Impacting Software Maintainability and Software Support Organization

An initial analysis of the P-8 MMA sub-organizations appears to eliminate the possibility of either a purely Organic or purely CLS support organization option. Boeing and other participating contractors are extremely unlikely to provide data rights or enough access to source code for effective support by a Navy Organic software support activity, even if that activity could find, hire, and retain sufficient quantities of qualified software engineer "maintainers." Conversely, Navy entities responsible for the development and maintenance of mission software are unlikely to provide highly sensitive or classified software to CLS organizations without severe restrictions that would be unattractive to potential CLS contractors. A hybrid of contractor and DoN organic support organizations appears to be the only practical approach.

The leadership and management of the hybrid organization will be analyzed under the same three options: CLS, Organic, or Hybrid management.

There are numerous factors to be considered in planning for the most advantageous support management structure for any system, including the P-8 system. This research will address the following factors:

- Support Concept (including Level of Repair Analysis (LORA))
- Software Architectural Complexity
- Software Design for Maintainability
- Software Lifecycle Support Plan (including planned upgrades, added capabilities, and interoperability with future systems (e.g., net-centric warfare systems)

- Software Size (Software Lines of Code (SLOC))
- Software Safety and Security Considerations

## B. Determine Software Supportability Organization Options

This research will consider three basic software-support organizational structures:

- Organic. All software maintenance management functions are conducted by or under the direct control of the US Government (Department of the Navy (DoN)).
- Contracted Logistics Support (CLS). All software maintenance management functions are conducted by organizations under contract with the DoN.
- Hybrid Organic/CLS Structure. The system software maintenance management support is divided with some management conducted by DoN organic organizations and other functions conducted by CLS organizations.

In addition to P-8 operational concerns, several other factors will impact the software support organizational concept decisions. The P-8 aircraft is based on a Boeing commercial design (B-737), so decision-makers must consider software data rights and issues of proprietary properties. The P-8 is designed to be a Multi-mission Aircraft (MMA)—including Intelligence, Surveillance, and Reconnaissance (ISR) missions that will deal with sensitive and classified data and that will likely employ classified software programs. Naval Air Systems Command (NAVAIR)and the Federal Aviation Administration (FAA) will obviously need to scrutinize the flight software for safety of flight issues and other Naval operational requirements. As communicating mission data is a primary mission, the PMO must ensure that all DoD Information Assurance (IA) requirements, including the *DoD Information Assurance Certification and Accreditation Process* (DoD, 2007, November), are met and maintained. The dynamic nature of the P-8 MMA software support organizations (combined with the DoD and FAA overseeing entities) will likely create a challenging environment for the software support management team.

## C. Analyze P-8 Software Architecture

This research analyzes the planned P-8 software architecture to gain insights into the system design for maintainability. The analysis will include the amount of new software applications, legacy applications, number of different software applications, and the need for differing application interoperability. The planned P-8 software architecture will provide insight into the relative advantages or disadvantages of the organizational alternatives.

## D. Analyze Initially Planned P-8 Software Support Organizational Structure

As part of the initial program documentation, the researchers conducted some analysis to establish the fundamental system supportability concept. The system concept will provide a framework and establish parameters and constraints impacting software support organization analyses.

## E. Analyze Analogous DoD Systems

This research will contrast several DoD systems with similar system software architectures to the P-8 for comparative purposes. Systems researched will include the US Air Force B-1 B bomber, the Air Force KC-135, and Air Force One.

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# IV. Data and Analysis

## A. System Acquisition Strategy

The P-8 acquisition strategy was one of Evolutionary Approach using Spiral Development techniques. This strategy was designed to provide the warfighter with initial capability as early as possible, with additional functions and capabilities added as needed. With such an approach, there would necessarily be numerous planned and unplanned changes that would impact the system software and Post-deployment Software Support (PDSS)—including significant software development as well as sustainment type activities. The evolutionary approach also indicated that the final, objective system configuration was not known; thus, current Software Lines of Code (SLOC) estimates and final system software architectural complexity were likely to be underestimated.

With the change of acquisition approach from the Evolutionary to Incremental, decision-makers conducted a more detailed analysis in order to more fully define the work to be accomplished in each increment. This approach should provide more accurate estimates (of both SLOC and the required software engineering effort) for the development of each increment, allowing a better understanding of the objective software size and structure. In turn, the PDSS estimates should be more accurately estimable. The actual P-8 MMA Incremental Approach was not available for this research effort. Without the actual, updated data, the researchers conducted more generalized analyses based upon the data provided. Resulting conclusions and recommendations are based on the generalized analysis approach.

The current Software Support Requirements Analysis does address computer source code for either commercial or military unique software developed in support of the P-8 program, addresses access to contractor developed source code, and includes just one statement regarding obsolescence. Unlike the programs of the past, computer resources hardware obsolescence issues are not expected to require many accompanying software upgrades due to the inclusion of portability layers in the architecture.

How does this “built in” obsolescence affect military weapon systems? With software transistor density doubling every two years (Moore’s Law), each Program Office must ensure that proposed budgets for its program reflect accurate costs and that the budget justification documents clearly articulate the criticality of upgrading weapon system software. The Government Accountability Office (GAO) explains, “Unless DOD assesses and secures its right for the use of technical data early in the weapon systems acquisition process when it has the great leverage to negotiate, DOD may face latter challenges in sustaining weapon systems over their life cycle” GAO, 2005, October).

## B. P-8 System Software Architecture

The system software architecture is based on an open-systems approach with designed portability layers supporting the Incremental Acquisition strategy. The starting point for the architecture is the reuse of several Navy-managed, mission-oriented software applications migrating to the new platform. These applications will be combined with existing weapon systems planned for integration on the P-8, as well as the Boeing avionics package developed for the airframe that has been modified for the anticipated mission flight envelopes envisioned for the P-8. This initial architecture is designed to leverage existing software applications and focuses on adapting those to meet functional mission requirements of the P-8. The P-8 systems and programs involve at least four major contractors (Boeing, Raytheon, Northrop-Grumman, and Smiths) and their numerous associated subcontractors, as well as at least two major Navy-controlled mission systems. While many of these mission applications have no doubt been working together for some time, others will be newly integrated into the P-8’s architecture. The supportability aspects of this software architecture are incidental to the system’s design, as at least some of these major software components have not been designed to be integrated together. This architectural approach is likely to require the development of software middleware if it is to allow dissimilar applications to communicate or share data and resources; however, adding middleware will increase the software supportability burden of the P-8 system. In addition, this type of architecture adds to the difficulty of maintaining software because problems or integration challenges often happen between applications supported by different organizations—thus increasing the likelihood that more software maintainers will be needed to support the system than would be likely in an integrated architecture that was designed for supportability and under the control of a single entity. In addition, integration of this entire architecture into a net-centric warfighting system (such as the Navy's ForceNet), will add to the system software supportability challenges immensely. The challenge is exacerbated by —program managers trying to maintain all of the required Information Assurance (IA) *DIACAP* certifications.

It is not clear, from the documentation provided, how the P-8's system software supportability performance was planned or communicated with the contractors or Government software engineering organizations. Performance specifications addressing Maintainability, Upgradeability, Interoperability/Interfaces, Reliability, Safety & Security (MUIRS) performance attributes (Naegle, 2006) of the system software drive the system architecture toward a more supportable, flexible design. The degree to which the MUIRS elements were specified as performance attributes in the original contract is unknown, but it is likely they were difficult to attain due to the P-8 acquisition approach that includes existing software applications and procurement of commercial avionics applications embedded with the air platform. There are several models that correlate the system software architecture to expected supportability costs that may apply to the P-8 Program. Jan Bosch and PerOlof Bengtsson (Bosch & Bengtsson, 2001) have developed a quantitative model assessing the maintainability aspects (quality attributes) of a particular software architecture based on specified, stakeholder-based operational scenarios. This model requires scenario development and recommends the Software Engineering Institute (SEI)-developed Architecture Tradeoff Analysis Method (ATAM) (Kazman, Klein, & Clements, 2000). (The ATAM approach is taught and recommended in NPS software acquisition courses). The stakeholder-based scenarios resulting from an ATAM analysis would provide great insight to the operational needs for supportability attributes and the planned P-8 software architecture design effectiveness in meeting those operational needs. It is designed to be used prior to the software architectural design process to influence the design towards supportability performance attributes. The PMO conducted an ATAM evaluation on the P-8 MMA, but results of the analysis were not available for this research. Because the ATAM data was not available, it is unknown whether the architectural tradeoffs considered the supportability aspects of the alternative designs. As the P-8 software architecture has been substantially set, the Bosch and Bengtsson quantitative approach would be limited to gaining a more accurate estimate of software support costs.

Mr. Julian Gibbs (Gibbs, 2001) created a software support cost model titled *A Software Support Cost Model for Military Systems.* This model focused on military systems in the United Kingdom (UK) and North Atlantic Treaty Organization (NATO) and might provide a simpler approach to estimating supportability costs compared to the Bosch and Bengtsson quantitative approach. Mr. Gibbs created a model by researching over 120 software-intensive systems and then selecting 48 of them for detailed analysis. The analysis focused on research statistics that had high correlation to the empirical system software supportability cost. Surprisingly, several factors traditionally used in predicting software supportability costs (software size (SLOC), number of users, number of sites, etc.) showed low correlation to the costs experienced. The significant factors were the system's military essentiality, the operational environment, the age of the software used, and the type of contract. All of these parameters had a correlation of 0.9 or higher with regard to software supportability costs. Data required for this analysis was not available for this research; however, the application of this model appears to require minimal effort and might provide additional insight to the probable P-8 software support costs.

## C. P-8 Software Support Architecture

The P-8 is designed in a two-level maintenance concept with no intermediate maintenance support planned between the Organizational level and the Depot level (an O-to-D, two-level concept). While the following is not delineated in the reference documents, the researchers assume that Organizational-level software maintenance actions would be limited (immediate action, problem recording, reboot, etc.)—with nearly all other software maintenance actions deferred to the Depot level. The controlling organization of those Depot-level support activities is the subject of this research and consists of three options: Organic, CLS, or Hybrid Organic-CLS.

Maintainability, Upgradeability, Interoperability, Reliability, and Safety/Security (MUIRS) software support functions will be almost exclusively performed at the depot level under this two-level concept. The P-8 MUIRS software analysis will be conducted in four different software testing facilities: The Mission Systems Software Development Laboratory (SDL), the Mission Systems Integration Laboratory (MSIL), the Weapons Systems Integration Laboratory (WSIL), and the Patuxent River System Integration Laboratory (PAXSIL). The SDL, MSIL, and WSIL are existing facilities, and the PAXSIL is a deliverable under the P-8 contract. The SDL and MSIL facilities are used by Navy organic entities to develop, integrate and test the mission software applications. Once complete, the Navy provides the developed Operational Flight Programs (OFPs) to the WSIL and PAXSIL for integration testing with the armament/ordnance control subsystems, flight deck, flight station avionics, and mission system avionics. Boeing and other primary contractors will have access to the WSIL and PAXSIL for testing of system-level integration, specification compliance verification, and to support airworthiness certification. The PAXSIL will not support software sustainment development activities, as it is a test-only laboratory.

Any discussions about sustainment, whether hardware or software, must address constraints and compliance imposed by Public Law. The *Limitations on Performance of Depot Level Maintenance* legislation (Section 2466, Title 10 *USC*)—

otherwise known as the "50/50 Rule"—stipulates that not more than 50% of the funds made available in a fiscal year to a military department or defense agency for depot-level maintenance and repair may be used for work performed by private-sector contractors." This "50/50" rule includes software maintenance. This becomes one of the drivers in decisions regarding organic versus contractor sustainment; the proper estimation of PDSS costs becomes critical as cost increases can rapidly impact the 50/50 distribution of funding.

While the O-to-D, two-level concept appears to be a streamlined approach to P-8 system support, the Depot-level software support structure appears to be very cumbersome. There are not less than five different software-developing entities, including four lead contractors and organic Navy developers. There are four planned Software Integration Laboratories (SILs) with final integration and contractor access planned for two of the SILs, one of which is designed to be test-only. Emerging software problems identified by the WSIL, PAXSIL, or by the operational fleet would necessarily be addressed by one or more of at least five differing (and possibly competing) organizations for resolution and retesting through one or more of the SILs. Integration or other software problems involving two or more of the application developers requires the cooperation of both, which may be complicated by issues of contract language, proprietary rights or—in the case of the Navy-developed applications—security clearance and need-to-know concerns. Regression testing of reengineered or patched software components is likely to be significant, and in the case of airworthiness or Information Assurance (IA)-related actions, regression testing will likely be onerous.

With the numerous software-developing entities anticipated for the P-8 software architecture, the personnel support structure is likely to be significantly higher than with a similar-sized organization supporting an integrated engineering architecture with a unified development staff. Each of the five organizations will have developers, QA personnel, managers, and support personnel operating in at least two different environments—one environment designed to handle immediate maintenance actions on the fielded version, and a second developing/integrating the next upgrade increment planned. In addition, the manning of four SILs will likely add support personnel to the requirement, as will the inclusion of the planned software library.

The P-8 support architecture is significantly driven by the planned P-8 System Software Architecture, which is leveraging existing applications, development expertise, organizations, and facilities—including SILs. This approach is likely to significantly reduce the development cost when compared to newly developed, wholly engineered, integrated software architecture for the P-8 MMA system. However, the software acquisition plan supports the acquisition and was not designed for maintainability. The cost of PDSS is likely to be significant because of the resulting support structures, organizations, and personnel. Each corrective action, upgraded capability, new interface, or other software maintenance action has the potential to be processed through a labyrinth of structures, organizations, laboratories, tests, certifications, and management before being operational on the P-8 system.

As explained above, the contractual structure of the planned P-8 support architecture appears to be complex with prime contractors, numerous subcontractors, and vendors providing software products and services. In addition, as system integration continues, it is likely that middleware will be required creating the probability that additional entities will be needed to support the system. This situation has the potential of creating a confusing array of contracts that must be managed by the support organization selected.

## D. Software Size

Software size, measured in Software Lines of Code (SLOC), is one indicator of expected maintainability costs. The P-8 is currently estimating 2.657 million SLOC for the system as initially deployed. A study conducted by Professors Lientz and Swanson from UCLA indicated that, on average, one software maintainer maintained approximately 16,500 SLOC per year (Data processing organizations) (Lientz & Swanson, 1980). This is obviously not completely applicable to an integrated weapon system such as the P-8 MMA, but may provide a rough indication of the order of magnitude and of the level of support that might be expected. Using the Lientz and Swanson model (1980), the P-8 would require 161 full-time software maintainers across all applications. As the vast majority would likely be contractors, a conservative estimate of a burdened annual rate would be about $150,000 per maintainer. The annual cost for 161 maintainers would be approximately $24.15 million. As additional spirals of capability would likely be developed, the SLOC count would increase, and the cost would increase accordingly. Given the P-8 software architecture envisioned and the associated organizational structures identified earlier, there would likely be more software support personnel per 16.5 KSLOC rather than less due to the complexity of the system software architecture. There are numerous other predictive models that may give more accurate estimates, but they would need to have more detailed parameters and data than were available with the documentation provided.

Surprisingly, the UK research and resulting model (Gibbs, 2001) did not include the software size because the research indicated that there was very low correlation between the software size and the software supportability costs. This lack of correlation indicates that the size of the software may not be a significant driver of support costs, or more likely, that other factors are more dominant in the supportability cost-estimation process. Mr. Gibbs' research did indicate that the mission criticality, software age, complexity, and volatility of the environment (planned changes, upgrades, new interoperability requirements, etc.) were significant drivers of the supportability costs in defense systems.

## E. P-8 Lifecycle Management

In 2007, the National Defense Industrial Association (NDIA) listed two of the Top Software Issues impacting software sustainment:

- Software Lifecycle planning and management by acquirers and suppliers is ineffective.
- Inadequate attention is given to total lifecycle issues for COTS/NDI impacts on lifecycle costs and risk. (Baldwin, 2007)

The documents provided did not detail the P-8 system lifecycle management plan, but it is anticipated that the P-8 will have a long life-span, with numerous planned and unplanned software updates and upgrades. Planned updates/upgrades for mission modules, avionics, defensive weapon software, ForceNet (or other networks) interoperability, and other major systems likely have been scheduled and planned into the P-8 lifecycle. There will also be numerous unplanned update and upgrade requirements for emerging mission software, Information Assurance, threat countermeasures, network interoperability, safety of flight, and other unforeseen requirements. By combining the planned and unplanned software changes, we can see there will be a continuing need for a significant amount of software support throughout the P-8 lifecycle.

The PMO utilized a systems engineering approach to develop a Support Concept that employs logistic support solutions such as centralized contractor maintenance, performance-based Supply Chain Management (SCM), reliability-improvement incentives, and spiral development in order to meet the requirements established in the Performance-based Specification (PBS). The PMO has implemented or will implement Government-approved commercial processes that fulfill the requirements of Supportability Analyses (SA)—such as Failure Modes Effects and Criticality Analyses (FMECA), Reverse Logistics Association (RLA), and Reliability Centered Maintenance (RCM)—in the P-8A Maintenance Management Plan (MMP). Utilizing legacy and newly developed data, the contractor is required to populate and maintain a Supportability database containing the maintenance, engineering, and provisioning data necessary to conduct initial maintenance planning. Once matured, the P-8 software support group can utilize the Supportability database to update the Support Concept as necessary to meet Readiness and O&S cost goals.

Interim Contractor Support (ICS) will be established with The Boeing Company CLS services for maintenance, support, and SCM. The Interim Support period will bridge the gap between System Development and Demonstration (SDD) and Navy Support Date (NSD)—defined as Initial Operational Capability (IOC) plus two years. The Interim Support contract, or bridge contract, will provide for the establishment of the initial P-8A Main Operating Bases (MOBs) and Primary Deployment Sites (PDSs). The interim support period not only provides support for initial aircraft, but also system and support data required to facilitate the competition and implementation of the eventual long-term support PBL contract. The Interim Support period will provide a risk-mitigation period, in which NAVAIR will further evaluate the support system's performance and capability (DoD, 2007, March).

## F. P-8 PDSS Support Management

With the existing software applications, organizations, and facilities, it is unlikely that the development and initial maintainability could be performed by Navy Organic organizations or by a purely CLS contract. The proprietary software associated with the aircraft and other subsystems would be too costly to acquire, if available at all. The classified and sensitive nature of some mission modules severely complicates the use of contractors for maintenance. There will most probably be a Navy official who is charged with the PDSS responsibilities, but the organization that performs the management may be one of three options. Options and advantages/disadvantages for the overall management of the PDSS effort are discussed below.

### 1. Organic Management

- **Advantages**
  - Organic Management provides unity of the software support function.
  - It facilitates positive control under Navy leadership.

- It is likely to be the most cost-effective approach after procuring access to contractor software.
- It focuses on improving system reliability and availability.

- **Disadvantages**

  - Organic Management could be very costly and difficult to gain access to all contractor software code, future updates/upgrades, and access to contractor testing/SILs, requiring skillful contract negotiations.
  - It requires the establishment of a robust Navy organic management team.
  - It requires leaders to attract and retain qualified software professionals for needed support activities.
  - It requires leaders to gain and maintain software licensing agreements, which may be challenging.

**2. CLS Management**

- **Advantages**

  - CLS Management provides unity of the software support function.
  - The size of the effort in terms of funding levels is likely to incentivize the contractor competition for CLS contract.
  - CLS is likely to provide the highest degree of flexibility as the contractor is able to expand or contract more rapidly than the Government workforce.
  - It maintains the ability to access contractor updates/upgrades without separate contract actions.

- **Disadvantages**

  - CLS contract must be carefully crafted to ensure that the contractor's motivation (money) is linked with the Navy's supportability goals (Reliability, Availability, Flexibility, Upgradability, Cost-effectiveness, etc.).
  - Navy's needs outside of the scope of the contract are likely to be very expensive (Unilateral Change Orders).

- o CLS contract control over Navy-produced mission software and Navy-organic support personnel, SILs, and other facilities are likely to be difficult, especially if shared with other, non-P-8 program entities.
- o The focus on profitability may detract from system reliability and availability unless the contractor is carefully incentivized by the contract.

### 3. Hybrid Management

- **Advantages**
  - o Hybrid Management maintains the chains of Authority for Navy-organic and Contractor-proprietary software products, personnel, and facilities is maintained.
  - o It provides the ability to access contractor updates/upgrades.
  - o It enhances flexibility by providing access to contractors via support-contract agreements.
- **Disadvantages**
  - o Unity of effort is lost with a hybrid approach.
  - o The hybrid organization is likely to have numerous supportability contracts with participating contractors and vendors.
  - o Financial management is likely to be difficult with numerous organic and contract funding streams.
  - o It is difficult to manage conflicts between the various support entities.

# V. Other US Defense Systems Software Supportability Costs

An analysis of the P-3C Orion system software supportability costs is warranted because the P-8A Poseidon directly replaces the overage P-3 fleet; indeed, most P-3 missions will be migrated to the P-8. Unfortunately, the P-3 system software supportability costs were not available for this research.

## A. US Air Force B-1 B Bomber

The B-1 multi-mission system software architecture is very similar to that of the P-8. The B-1 software architecture, similar to the P-8's, consists of multiple applications consisting of both common military procured and uniquely developed software, supported by three **www.opm.gov/e-qip/** organizations. There are numerous software vendors and entities arranged in a hybrid support organization and coordinated by an Air Force support Program Management Office (PMO). The B-1 PMO budgets approximately $100 million annually for software sustainment—including software repairs, updates, upgrades, new functionality, interoperability, and safety/security/Information Assurance compliance. At a time when the Air Force is accomplishing major software upgrades to the system, the budget is $227 million for 2010. (R. Owens, personal communication, May 14, 2009 and Terri Wells, Feb 2, 2010).

## B. US Air Force KC-135 Aerial Refueling Tanker

The KC-135 system software is not comparable to the P-8's because it is an older system with one primary mission. The KC-135's software consists of approximately 2.6 million software lines of code (KSLOC) and budgets approximately $12 million annually for software support. The KC-135 supportability is managed through an organic Air Force PMO and includes contracted software-support arrangements. In planning for necessary software updates, the 2010 through 2014 budgets are rapidly expanding to approximately $140 million annually (E. Guttery, personal communication, June 18, 2009).

## C. Air Force One

Air Force One has approximately 5.75 million SLOC arranged in an architecture that is not similar to that of the P-8. Air Force One is supported through a CLS contract with Boeing Corporation. The annual software support budget for Air Force One is approximately $5 million. Planned software upgrades will accelerate the annual software support budget to approximately $25 million for a fleet of two aircraft (E. Guttery, personal communication, June 18, 2009).

By examining other US aircraft software-supportability costs, it is clear that complex software architectures can be very expensive to support (as demonstrated by the B1 B bomber above). With the information provided by all three of the systems, we can see that the costs to upgrade software can rapidly inflate the need for software supportability funding in fielded systems.

# VI. Conclusions and Recommendations

## A. Conclusions

- This research clearly indicates that a hybrid Organic/CLS software-support structure provides the most advantageous, and possibly the only practicable support-organization concept. Proprietary software associated with the commercially based aircraft would be extremely expensive to procure, if available at all—virtually eliminating an all-Organic support organization. Classified and sensitive Navy-controlled data and software programs (combined with planned use of legacy programs currently supported by organic support elements) make it impractical, overly costly, or impossible to contract out all software maintenance in a wholly CLS support concept.

- There does appear to be an opportunity to opt for differing methodologies for managing the software supportability effort. Each of the three options has advantages and disadvantages that may influence the decision, and the recommendation provided by this research was based on the degree of control and the likely cost of managing the effort.

- The software supportability cost control will be challenging. The mission-critical nature of the P-8, the complex structure, software size, and the anticipated number of significant upgrades, changed/added missions, Information Assurance/countering of new threats, and eventual networking of the system into the Navy's ForceNet or other DoD net-centric warfighting structures, indicates that there will be the need for significant software updates and upgrades in the future. As illustrated by the KC-135 and Air Force One programs, software upgrades can often rapidly accelerate the need for supportability funding.

## B. Recommendations

While it is clear that the P-8 software support organization must certainly be a hybrid of Navy and contractor entities, the Organic (Navy) support management option appears to provide the Navy with the highest degree of control in terms of both support services and cost and, thus, is the recommended approach.

It is highly recommended that the contractor and Navy decision-makers negotiate the access to all software for supportability purposes prior to any contracting actions in order to provide the Navy with the maximum leverage possible in gaining supportability access at the most economical cost.

With the Evolutionary acquisition approach using spiral development processes losing DoD and Congressional support, a reassessment of the P-8 program into a well-defined incremental approach seems warranted.  If possible, such a re-evaluation may provide an opportunity for decision-makers to more precisely estimate the P-8 system supportability costs for future budget considerations.  In addition, there may be an opportunity for some system software reengineering toward a more supportable software architecture, reducing the costs of future upgrades.

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