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**IMPLEMENTATION OF THE
ACOUSTIC RAPID COMMERCIAL-OFF-THE-SHELF
INSERTION DEVELOPMENT MODEL
IN THE P-3C ACOUSTIC SYSTEM**

A Thesis
Presented for the
Master of Science
Degree
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John Bruce Gailey, Jr.
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I owe my sincerest admiration and gratitude to the P-3C UIII team, without whom none of this would be possible. Their selfless dedication to the program and commitment to providing the Fleet with the best possible tools to succeed will ensure that even after 57 years as the dominant U.S. Naval Air ASW platform, the P-3 will still be at the top of its game when it retires in 2019.

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Lastly, I would like to thank my wife, Brooke, and my two lovely daughters, Allyson and Anne, for putting up with my long hours and neglected chores while I worked on this degree.

ABSTRACT

The P-3C is a U.S. Navy aircraft designed for the Maritime Patrol and Reconnaissance mission. Although capable in a number of mission areas, the aircraft's Anti-Submarine Warfare capabilities have received much attention lately due to improvements in diesel submarine technology. The acoustic systems on the P-3C needed a better way to more rapidly incorporate new technology while working within a constrained budget environment.

The purpose of this study is to show how the P-3C Acoustic System can be transformed by shifting from the slow, expensive traditional Military Specification (MIL-SPEC) development process to the successful Acoustic Rapid Commercial-Off-The-Shelf (COTS) Insertion (ARCI) process developed for the submarine community. This paper, authored by the Deputy Program Manager for P-3C Acoustic Systems, describes the requirements of the airborne ASW mission and provide the history and architecture of the current acoustic system. It then shows how the constraints of the Department of Defense Acquisition policies present challenges to the incorporation of the latest COTS components, and outline the advantages and disadvantages of using these components.

Using the submarine ARCI Program framework, this paper shows that an Air ARCI program can be made to work with the P-3C acoustic system through the use of Abbreviated Acquisition Programs and periodic technological refreshes to the system. These periodic updates using less expensive COTS components will be combined with an open architecture to ease the incorporation of new software and hardware from across all

platforms. This will allow the system to remain up to date while significantly reducing development costs, weight, power, volume, and cooling requirements.

There are risks inherent in using COTS components that must be managed through the use of comprehensive system-level testing, adherence to schedule and a stabilized funding stream. There must also be a plan in place to manage component End of Life issues and the effects of vendor-initiated hardware revisions. Finally, given the heavy operational use of the aircraft around the world, the use of test assets and Fleet aircraft installations must be balanced with operational needs to provide the best combination of technological currency, cost, configuration management, and supportability and spares reduction.

PREFACE

A portion of the information contained within this thesis was obtained during a Naval Air Systems Command sponsored program in conjunction with the Lockheed Martin Corporation, Maritime Systems and Sensors. The author was the P-3C Update III Deputy Program Manager responsible for the management of the USQ-78(B) program, and all references to this program are a result of personal experience. The research, results, conclusions, and recommendations presented are the opinion of the author and should not be construed as an official position of the United States Department of Defense, the United States Navy, the Naval Air Systems Command, or the Lockheed Martin Corporation.

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LIST OF ABBREVIATIONS

AAP	Abbreviated Acquisition Program
AATAG	Air ASW Technology Advisory Group
ACAT	Acquisition Category
ADAR	Air Deployable Active Receiver
ADB	Acoustic Distribution Box
ADR	Acoustic Digital Recorder
AIP	ASUW Improvement Program
APB	Advanced Processing Build
APN	Aircraft Procurement – Navy
APTR	Acoustic Processor Technology Refresh
ARCI	Acoustic Rapid COTS Insertion
ARTR	Acoustic Receiver Technology Refresh
ASCL	Advanced Sonobuoy Communications Link
ASU	Analyzer Sub-Unit
ASUW	Anti-Surface Warfare
ASW	Anti Submarine Warfare
ATSG	Acoustic Test Signal Generator
AU	Analyzer Unit
BIT	Built-In-Test
BMUP	Block-Modification Upgrade Program
CAPWG	Common Acoustic Processing Working Group
CASS	Command Active Sonobuoy System
CDD	Capability Development Document

CMEP	Commandable Manual Entry Panel
COMOPTEVFOR	Commander, Operational Test and Evaluation Force
COTS	Commercial Off-The-Shelf
CPD	Capability Production Document
CRT	Cathode Ray Tube
DASD	Direct Access Storage Devices
DCU	Display Control Unit
DICASS	Directional Command Active Sonobuoy System
DIFAR	Directional Frequency Analysis and Recording
DON	Department of the Navy
DOTMLPF	Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel and Facilities
DT	Developmental Test
EADR	Embedded Acoustic Digital Recorder
ECP	Engineering Change Proposal
EOL	End of Life
FRP	Full Rate Production
FYDP	Future Years Defense Program
IEER	Improved Extended Echo Ranging
JCIDS	Joint Capabilities Integration and Development System
LRIP	Low-Rate Initial Production
MAD	Magnetic Anomaly Detector
MDA	Milestone Decision Authority
MIL-SPEC	Military Specification
MTBF	Mean Time Between Failure

NADEP	Naval Aviation Depot
NAVAIR	Naval Air Systems Command
NAVSEA	Naval Sea Systems Command
NDI	Non-Developmental Item
NDIA	National Defense Industrial Association
OA	Open Architecture
OMI	Operator Machine Interface
OPEVAL	Operational Evaluation
OT	Operational Test
PDC	Proteus Digital Channel
PDT	Product Direction Team
PEO (A)	Program Executive Office - Air ASW, Assault and Special Mission Programs
POM	Program Objective Memorandum
RDT&E	Research, Development, Test & Evaluation
SASP	Single Advanced Signal Processor
SC	System Controller
SCTR	System Controller Technology Refresh
SDSR	Software-Defined Sonobuoy Receiver
SSI-K	Special Structural Inspection-Kit
SURTASS	Surveillance Towed Array Sonar
TSC	Tactical Support Center
VHF	Very High Frequency
VME	Versa Module Europa

CHAPTER 1: INTRODUCTION

BACKGROUND

The P-3C Orion, shown in figure 1, is a land-based, all-weather, four-engine turboprop aircraft designed for the Maritime Patrol and Reconnaissance mission. Figures A-1 and A-2 depict the general internal arrangement of the P-3C. Although presently used extensively for overland reconnaissance with its Synthetic Aperture Radar and powerful electro-optics, the P-3C aircrew must maintain proficiency in a number of mission areas. These areas include Anti-Surface Warfare (ASUW), Mining, Search and Rescue, and Anti-Submarine Warfare (ASW). It is this last core area, ASW, which has received much attention lately. When the P-3 first entered the Fleet in 1962, the Cold War was in full swing and the primary emphasis was the location of all Soviet Union fast attack submarines which posed a significant threat to U.S. carrier battle groups and all ballistic missile submarines with their load of nuclear ballistic missiles aimed at the United States. The Navy continued to develop the P-3s ASW capabilities, culminating in the P-3C Update III variant that entered the Fleet in 1982.⁽¹⁾ When the Soviet Union collapsed in 1991, it appeared to most that the core P-3 ASW capability was unneeded. As a result, the ASW sensors of the aircraft received little to no funding for improvements, and instead new emphasis was placed on the ASUW Improvement Program (AIP), which dramatically improved the surface and overland capability of the platform.



FIGURE 1
P-3C ORION UPDATE III ⁽¹⁾

The fall of the Soviet Union, however, had simply shifted the ASW threat from relatively large nuclear-powered submarines like the Akula, Oscar, and Typhoon classes, to the much smaller and less expensive diesel submarines such as the Kilo, Dolphin, Type 209, and Collins classes employed by many nations around the world. Due to improvements in technology, these new diesels can be quieter on battery power than most nuclear submarines, and can stay under water much longer than had previously been possible.⁽²⁾ Added to this problem is the fact that most of these smaller, quieter diesel submarines tend to operate in the littoral regions of the ocean close to land. For the ASW systems developed for the deep water, open ocean environment that was the battleground of the Cold War, the shallow, noisy environment of the littorals presents a significant challenge.⁽³⁾ The proliferation of these advanced diesels has led to a renewed focus on ASW capability.

STATEMENT OF THE PROBLEM

Until approximately the late 1990s, most military systems were built to Military Specification (MIL-SPEC), which meant that the manufacturer had to keep a production line open dedicated solely to that system. That line had to be maintained, not just while whole units were being produced, but also just to provide the necessary spares required for maintenance. Given the relatively low numbers of units produced, maintaining that production line significantly increased the per-unit cost of such systems. Additionally, the government paid for all the development costs for the components of those systems.

In today's world of rapidly evolving technology, the development of a single-purpose item is not only cost-prohibitive; it will also likely be technologically obsolescent by the time it is fielded. The solution to this problem has been a movement towards the use of Commercial Off-The-Shelf (COTS) and Non-Developmental Item (NDI) hardware and software components wherever possible. The benefits of this are potentially reduced development costs and schedule, reduced maintenance costs, a wider user base than just the military to identify problems and better characterize the reliability of the component, a better skill base, and an industry-driven investment in advanced technology.⁽⁴⁾ In theory, a program could keep its system technologically updated simply by purchasing the latest version of software and computer cards. There are, however, risks involved with such an acquisition model for a military system in general, and an airborne system specifically. The benefits of COTS must be appropriately managed by the acquisition program to mitigate these risks while still realizing the large potential gains. The purpose of this thesis is to provide an example of one such program, the technological refresh of the P-3C USQ-78(B) Acoustic System, and show how the

successful Acoustic Rapid COTS Insertion (ARCI) program developed for the submarine community has begun to be applied to an aircraft program. This thesis also highlights the program areas that must receive special attention due to the COTS environment, and it analyzes the options for aircraft upgrades to sustain P-3C acoustic capability through 2019.

DESCRIPTION OF THE P-3C ANTI-SUBMARINE WARFARE MISSION

Although the P-3C of today is used for many different missions, the Anti-Submarine Warfare mission remains the most challenging. The P-3C has a typical crew of three pilots, two flight engineers, a Tactical Coordinator, a Navigation/Communication Officer, two acoustic system operators, a non-acoustic sensors operator, and an In-Flight Technician. They are typically tasked to search a particular area of water independently or in concert with other airborne, surface, or subsurface platforms. Their goal for an ASW mission is to find and track any enemy submarines that are in that area, or establish that there are no enemy submarines in that area and it is safe for friendly ships or submarines to transit through. The tactics employed by the aircrew will depend upon the type of submarine they are looking for and the environmental challenges of the search area, and they will employ a number of different sensors both to exploit the vulnerabilities of the submarine and to provide overlapping sensor coverage.

Submarines

In general terms, submarines fall into two categories: nuclear-powered and diesel-powered. Each type has its own advantages and disadvantages.

Nuclear-powered submarines derive their power for propulsion and electricity from a nuclear reactor. The reactor generates high-pressure steam used to turn turbines

coupled to generators and one or more propulsion shafts. These submarines tend to be larger due to the complex equipment, and the large amount of available power also allows them to be designed to travel faster, dive deeper, and carry more sophisticated sensors, equipment, and armament than diesel submarines. Nuclear submarines can stay submerged for as long as the crew has food, since the energy from the reactor is used to generate air from the surrounding sea water and the nuclear cores require refueling only every 10 to 40 years. The size of nuclear submarines can limit their utility in shallow water environments near land, however, and the extreme cost and technical complexity of a nuclear power plant restricts their use to only a handful of countries: the United States, Russia, China, France, and the United Kingdom. In addition, without sophisticated quieting techniques, the pumps and movement of cooling water and steam through the nuclear reactor can lead to additional noise in the water, revealing their position.

Diesel-powered submarines, much like the submarines of World War II, use a diesel engine to provide power. This power can run the propulsion directly, or it can charge batteries that will be used for equipment and propulsion when the submarine is under water. Recent technology advances have made diesels much more efficient and capable, and they can now stay under water running on battery power much longer than before.^(3,7) In addition, there are now a number of new air-independent propulsion systems that use either a stored oxidant or a fuel cell type arrangement to allow extended operation while completely submerged. Endurances under water for the more advanced designs are now measured in days and weeks rather than hours. The primary advantage of this type of submarine design is that they are considerably less expensive and complex than nuclear submarines. This allows countries with modest budgets, training, and

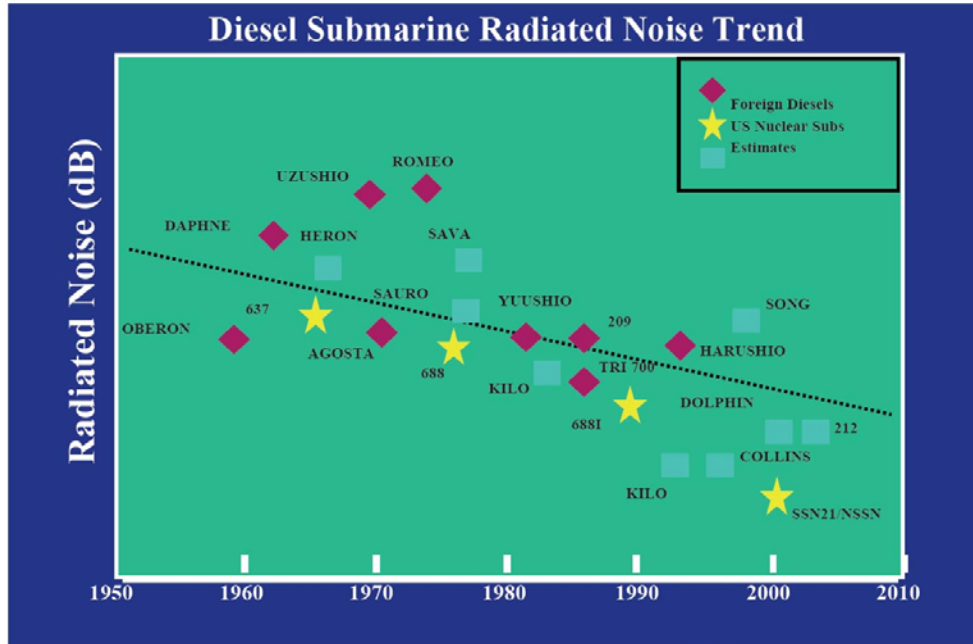


FIGURE 2
DIESEL SUBMARINE NOISE TREND ⁽²⁾

technical capacity to maintain a viable submarine force, and, unlike nuclear submarines, they can simply purchase these diesel submarines from countries that produce them such as Germany, France, Sweden, or Russia. That is why there are currently more than 40 countries that operate diesel submarines with many more considering them. As shown in figure 2, these new submarines can be as quiet as all but the newest nuclear submarines while on battery power, and their smaller size allows them to be utilized closer to land in shallow water. The trade-off is that they do occasionally have to come to the surface to replenish their air and charge their batteries, which exposes them to detection and attack. They also do not have the almost limitless power of nuclear submarines, so their speed and range are much less. When they do make a high-speed run, they do so at the expense of their endurance.

Environment

The primary means of searching for submarines is through acoustic methods, i.e., listening for noise coming from the submarine (passive acoustics) or bouncing a discrete noise (“ping”) off the submarine’s hull and listening for the reflection (active acoustics). The propagation of sound in the water and the ability to actually detect it is greatly affected by the properties of the water between the submarine and the sensor. As the density of the water increases, the speed of sound increases, making that sound refract towards the area of higher density. The daily, seasonal, and geographic variances in the ocean’s temperature profile mean that not only does sound not normally travel in a straight line, it doesn’t even bend the same way if you change locations or just wait a while. Also a factor in detecting sound in the water is the amount of ambient noise caused by seismic, biologic, and man-made sources. Ocean bottom composition and contour can also affect detection ranges due to reflections.⁽⁶⁾ Due to these factors, knowledge of current environmental conditions is extremely important to ASW. As mentioned earlier, up until the end of the Cold War the traditional ASW environment was deep water in the open ocean where the acoustic conditions were much more predictable and benign. The historical data and mapping allowed fairly accurate predictions and ambient noise levels were relatively low due to the great depths involved and lower density shipping. In contrast, the political areas of concern today are in the littoral regions near coastlines, where the ocean environment is more chaotic. The shallow water leads to more variance in temperature profiles and higher ambient noise due to higher density shipping and biological concentration.

Acoustic Sensors

Airborne acoustic sensors are packaged in canister called a sonobuoy. This sonobuoy is dropped by the aircraft. Once in the water, it deploys a float to keep its antenna above the surface of the water, and reels out its sensor package to a set depth. Data from the sonobuoy is then transmitted over one of 99 VHF channels to the aircraft for processing. Sonobuoys are designed to detect submarines through two different means: passive and active.

A passive sonobuoy uses one or more hydrophones to listen for the radiated noise generated by a submarine. During a search, the aircraft will deploy a large field of sonobuoys to cover an area, and the acoustic system and two operators on the aircraft will analyze the incoming data for particular frequencies indicative of a submarine. From the frequencies intercepted, it is possible to classify the type of submarine. If a submarine does a close pass to a sonobuoy, or with multiple sonobuoys in contact, the bearings to the noise reported from each sonobuoy enable the operators to fix the submarine's position. The P-3C must drop the sonobuoys close enough together to get multiple sonobuoys in contact with the submarine, so the range at which the submarine can be detected is important.

That range at which the submarine's noise can be detected is dependent upon the source level (how loud the submarine is), transmission loss (attenuation of the sound in water), ambient noise, directivity index (ability of the acoustic system to reject noise coming from directions other than where the submarine is), and detection threshold (a factor determined by both the expertise of the operator and the ability of the acoustic system to detect a signal in amongst the ambient noise.)⁽⁶⁾ As submarine technology has

progressed, however, their source levels have decreased. From a technical standpoint, there is nothing that can be done to control the transmission loss or ambient noise, so improvements to the acoustic system must come from improvements in the directivity index and lowering the detection threshold through improved signal processing. The main passive sonobuoy currently in use is the AN/SSQ-53 Directional Frequency Analysis and Recording (DIFAR) sonobuoy, which has a single directional hydrophone and is used in standard large passive search patterns of up to 32 sonobuoys.

An active sonobuoy uses a noise generator to create a discrete signal, or “ping”, that will bounce off the hull of the submarine and create an echo that will be detected by a hydrophone. The acoustic processor will then convert this information into a bearing and range to the submarine from the sonobuoy. Traditional active sonobuoys have both the noise generator and hydrophone collocated on the same buoy. Newer methods utilize a multi-static system where there are separate source and receiver buoys, and any submarine echo generated by the source can potentially be detected on one or more receiver buoys. This multi-static method, the latest of which is called Improved Extended Echo Ranging (IEER), also requires a sophisticated acoustic signal processor to discriminate and sort through numerous faint echoes and correlate the results and geometries across a large field of sonobuoys. Although passive methods have been preferred in the past due to the fact that the submarine might not even know it was being tracked, active methods have gained more attention recently due to the improvements submarine manufacturers have made in reducing radiated noise, making passive detection more difficult. The main active sonobuoy in use is the AN/SSQ-62 Directional Command Active Sonobuoy System (DICASS) sonobuoy. The sonobuoys used for IEER

are the AN/SSQ-110 high-source level acoustic source buoy and the AN/SSQ-101 Air Deployable Active Receiver (ADAR) sonobuoy. The ADAR sonobuoy uses a horizontal planar array of 40 hydrophone elements to create 24 horizontal beams.

Non-Acoustic Sensors

There are other ways of detecting submarines than by listening for them. A good radar might be able to detect a snorkel or periscope above the surface of the water, although the small radar cross section requires a low grazing angle and therefore low aircraft altitude. In addition, a trained submarine crew will not leave the periscope above the surface for very long, and modern technology has greatly reduced the requirement for diesels to use a snorkel to recharge batteries.

Another non-acoustic sensor is the Magnetic Anomaly Detector (MAD). A very sensitive magnetic sensor detects changes in the Earth's magnetic field due to passing over an object that perturbs that field such as a metal submarine. This sensor is usually placed on a long boom behind the aircraft or trailed on a wire to place it as far as possible from the interfering electromagnetic field of the aircraft itself. Although MAD can be effective, its relatively short range of a few hundred meters means that the aircraft has to fly almost directly over the submarine at low altitude to detect it. MAD is therefore used more as a precise localization sensor when a different sensor such as a sonobuoy has detected the submarine and isolated its location to a small area.

Finally, submarines are still located optically even today. Infrared and electro-optic sensors on the aircraft can detect a periscope, snorkel, or its wake, and occasionally a thermal temperature difference or even bioluminescence caused by the passage of the

submarine's hull can be detected. Many times, a submarine with a poorly trained crew that stays near the surface too long is caught by just the naked eye of a pilot or observer.

DESCRIPTION OF THE P-3C ACOUSTIC SYSTEM

Acoustic System Origins

The origin of the current P-3C acoustic system lies in the P-3C Update III configuration that entered service in 1982. The previous system, the AQA-7, was replaced with a series of components built around the AN/UYS-1 Advanced Signal Processor, which processed incoming acoustic signals through the use of a spectrum analyzer. The development contract was awarded in 1973 to IBM-Manassas (later acquired by Lockheed Martin) by Naval Air Systems Command (NAVAIR).⁽⁸⁾ The Update III acoustic system incorporated dual ARR-78 sonobuoy receivers capable of simultaneously receiving 16 channels of sonobuoy information each, dual acoustic distribution boxes and AQH-4 analog tape recorders, the AN/UYS-1 Single Advanced Signal Processor (SASP) which was also known as the Analyzer Unit (AU), a Commandable Manual Entry Panel (CMEP) and monochrome CRT display for each of the two acoustic operators, and the USQ-78(V) Display Control Unit (DCU), which performed display formatting, post-processing, and system control functions. See figure B-3 for a detailed system diagram. At the time, the AN/UYS-1 was the first programmable signal processor optimized for high speed modularized signal processing applications,⁽⁸⁾ and it became the mandated standard signal processor of the U.S. Navy. Program management of the signal processor was transferred to Naval Sea Systems Command (NAVSEA) in 1985, and it was installed on the P-3C, S-3B, LAMPS Mk III

helicopter and surface vessels, Surveillance Towed Array Sonar (SURTASS), BQQ-5 submarine sonar and BSY-1(V) submarine combat system.

With the exception of software and some minor hardware upgrades, this system remained largely unchanged in the P-3C. In fact, although the P-3C Anti-Surface Warfare Improvement Program begun in 1991 sought to upgrade the acoustic hardware in the aircraft to the USQ-78(A), the use of the AN/UYS-1 for all acoustic signal processing was Navy dictated at that time and Congressional language existed that prevented the program from updating the AN/UYS-1's capability because the AN/UYS-2 was under development by NAVSEA (K. Moore, personal interview, August 23, 2006). Although the technology existed to consolidate the processing of the AN/UYS-1 and the functions of the USQ-78(V), it was not allowed and the architecture of the USQ-78(A) still incorporated the AN/UYS-1 when it was introduced to the Fleet in 1998. Despite the mandate to use the AN/UYS-1, some additional processing capacity was added into the chassis of the USQ-78(A) because of the requirements for what was then the highly classified Extended Echo Ranging program (K. Moore, personal interview, October 5, 2006). By the time the Block-Modification Upgrade Program (BMUP) began development in 1996, however, the AN/UYS-1 requirement had been lifted due to increased costs and risks of the AN/UYS-2. The USQ-78(B) installed on the 25 BMUP aircraft starting in 2002 eliminated the AN/UYS-1, and instead replaced it with a Boeing designed Analyzer Sub-Unit (ASU) composed of 7 VME modules installed within the USQ-78(B) VME chassis. The USQ-78(B) was also incorporated in the remainder of the P-3C AIP-configured aircraft, and a current USQ-78(B) technology refresh program will upgrade all of the previously installed USQ-78(A) systems to the USQ-78(B)

configuration for a common acoustic processor baseline on all 72 AIP and 25 BMUP aircraft.

P-3C Update III Acoustic System Components

As shown in the system diagram depicted in figure B-4, the introduction of the USQ-78(B) not only greatly consolidated the signal processing, display formatting and system control functions, it also replaced the legacy MIL-SPEC components with COTS/NDI components. Due to advances in technology, this resulted in an approximately 14 times increase in performance and 8 times increase in reliability while achieving significant reductions in weight, volume, power, cooling, and number of modules. The upgrade did not, however, address the remainder of the acoustic system, which remained essentially the same. The main components of the acoustic system in the P-3C Update III AIP/BMUP aircraft are as follows:⁽⁹⁾

AN/USQ-78(B) Acoustic Processing Suite– The USQ-78(B) performs all acoustic data processing, display formatting, and system control of all other acoustic subsystem components. It is composed of an 18-slot VME chassis which is still referred to as the DCU. The DCU houses the appropriate interface, converter, CPU, controller and processor cards. Although these VME modules are housed in the same chassis, they can be grouped into two subunits: the Analyzer Sub-Unit (ASU), which performs the high speed signal processing functions required to analyze incoming analog and digital acoustic data, and the System Controller (SC), which provides control over all subsystems, video formatting and drive functions for the dual operator Flat Panel Displays and Programmable Entry Panels, interface between the acoustic system and the aircraft central computer, and routes analog and digital signals between all the

components of the acoustic system. Housed in the same chassis are two Direct Access Storage Devices (DASD). These are computer hard disk drives that load the SC and ASU with the operating program.

ARR-78 Advanced Sonobuoy Communications Link (ASCL/ASCL+) Receiver – The dual ARR-78 ASCLs in the AIP configuration receive and demodulate signals from sonobuoys operating in the VHF band. Each receiver module within the ASCL can be independently tuned to any of the existing 1 to 99 sonobuoy channels, for a total of 32 acoustic channels and 8 additional channels for other functions (16 and 4 per ASCL). The system receives the sonobuoy signals through two line-of-sight antennas located on the underside of the aircraft and distributes the audio via the Acoustic Distribution Boxes. Two-way communication with the SC for control, status, and BIT results is achieved through two Proteus Digital Channel (PDC) pairs. The ASCL+ is a single unit installed in BMUP aircraft that performs identical functions to the two legacy ASCLs installed in the AIP aircraft. Since the MIL-SPEC ARR-78 ASCL was no longer in production when BMUP was implemented, a COTS NDI replacement was procured. There are no significant functionality differences between the dual ASCL system and the single ASCL+ system.

Acoustic Distribution Box (ADB) – The ADBs distribute a total of 32 acoustic signals from the ASCL/ASCL+ receivers to the ASU, Acoustic Recorder, and aircraft ICS system for operator audio.

AQH-4/AQH-13 Acoustic Recorder – The dual AQH-4 analog acoustic recorders installed on older AIP aircraft simultaneously record sonobuoy audio from each ASCL channel as well as ICS, time code and reference tracks on reel-to-reel magnetic tapes for

replay at the Tactical Support Centers (TSC). The AQH-13A Acoustic Digital Recorder (ADR) is a functional replacement for the AQH-4s. A single unit replaces both AQH-4s and records the same acoustic audio onto magnetic cassette tapes in digital format. Many of the AQH-4s and all of the cassette tape AQH-13s are now being replaced with a single AQH-13B ADR-HD, which records the acoustic audio onto a single 146GB removable hard drive, thereby eliminating the reliability problems associated with magnetic tape.

ASA-76A Command Active Sonobuoy System (CASS) Transmitter – The ASA-76A CASS is a one-way VHF-band transmitter which allows the acoustic system to send commands to sonobuoys already deployed in the water. Originally used just to initiate active sonar pings from DICASS buoys, it now also enables the operator to change hydrophone depth, RF channel, on/off status, and send buoy scuttle commands.

Acoustic Test Signal Generator (ATSG) – The ATSG generates simulated acoustic signals for active and passive sonobuoys on all 99 RF channels. It is used to do an end-to-end test of the acoustic system during preflight by transmitting the test signals through an external antenna to the ASCL antennas.

At present, there have been two “technology refreshes”, or insertions of new hardware to mitigate parts obsolescence: the ASU Technology Refresh, and the SC Technology Refresh (SCTR). The ASU Technology Refresh only applied to the existing USQ-78(B)s. Unfortunately, all these upgrades to the USQ-78 have resulted in the three different configurations of acoustic suites shown in figure B-5. The SCTR, which is just beginning Fleet installations, will also upgrade all the USQ-78(V) and USQ-78(A) systems on the AIP aircraft. This will bring all 97 AIP and BMUP aircraft to a common acoustic system.

CHAPTER 2: REVIEW OF THE LITERATURE

GENERAL

The acoustic environment requires advanced signal processing and a continuous effort to lower the detection threshold of the system in order to stay ahead of technological advances in submarine quieting. The rapid pace of technology improvement in the commercial world has driven companies to update their product lines frequently, particularly in areas requiring computer processors and memory. It seems logical that this advance, fueled by the commercial market paying the research and development costs for advanced processors, could be used to the advantage of a military acoustic processing program. The concept of fulfilling a military need with an existing commercial system or component has been around for a number of years, but with decreasing budgets for new acquisitions, a new emphasis has been placed on streamlining the acquisition process and realizing cost savings wherever possible. At times, the term “COTS” has been a buzzword implied to be synonymous with “cost-savings”, and that the easy solution to acquiring modern systems is to simply find it out on the open market. While the potential benefits of a COTS solution are indeed great, the limitations must also be understood from both a programmatic and technical side.

DEPARTMENT OF DEFENSE ACQUISITION

The traditional acquisition cycle, illustrated in figure 3, was developed over many decades of military systems acquisition.⁽¹⁰⁾ Most new-start programs will officially begin at Milestone B, the System Development & Demonstration phase, where the system is

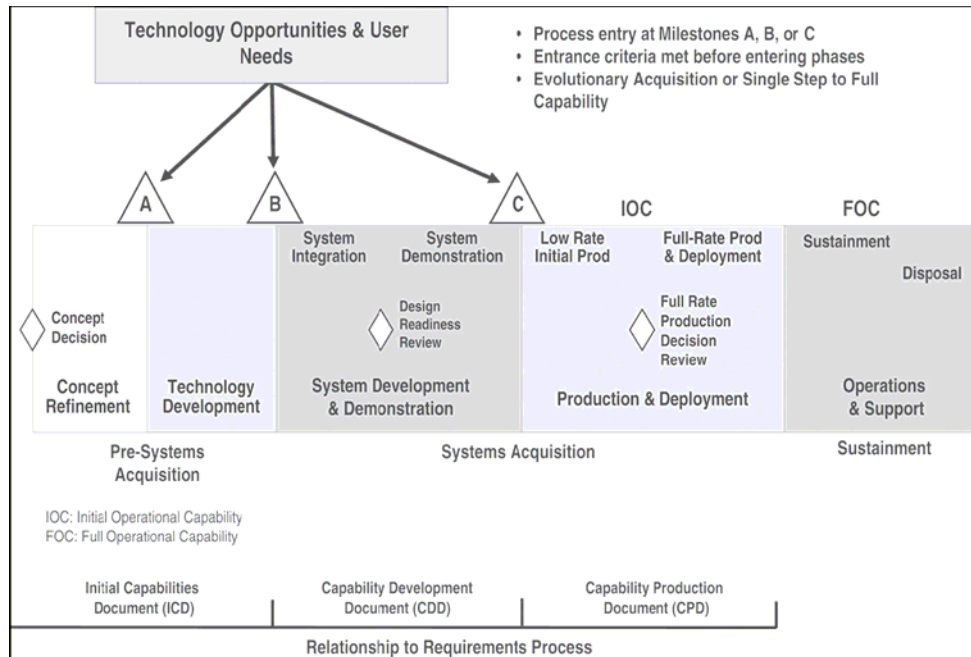


FIGURE 3
DEFENSE ACQUISITION LIFE-CYCLE ⁽¹⁰⁾

initially designed and tested through a number of engineering development models, but a production representative product is not ready yet. A modification to an existing system will typically begin at Milestone C, the Production & Deployment phase, where the changes are minor enough that the system is ready to be produced with a much smaller level of design and test. In addition to major decisions at each Milestone, the acquisition system has a number of checks and balances meant to ensure that the best possible systems are fielded. There are many good examples of why these checks are required, but there has been a realization lately that some degree of tailoring to this model is needed when a particular step does not significantly add to the quality of the product. Use of COTS products require the program to address sparing and periodic technology refresh on a schedule dictated by the pace of the commercial market. Without specific

tailoring, the normal schedule and funding of the defense acquisition cycle are unable to keep pace with the commercial sector.

Schedule

The traditional acquisition cycle for a program should normally start with a need identified by the operational warfighter or warfare analysis. A program is put together and a budget is secured to execute that program. From there, an acquisition strategy must be formally approved by the Milestone Decision Authority (MDA), the entity with the authority to allow a program to proceed through its next milestone. Who the MDA is will be determined by the Acquisition Category (ACAT) level of the program. The different levels of ACAT identify the level of oversight required for that program. In simplified terms, the more expensive, complex, and important the program is, the higher visibility that program generates and more formal planning, documentation, and reviews are required since the consequences of mismanagement are greater. The criteria for each ACAT level is shown in table B-1. The many required documents, briefs, and decision points for an ACAT program are listed in tables B-2 and B-3.^(11,12) Although many of these documents are prepared concurrently, their approval can be a lengthy process.

As an example of how long approvals can take, every ACAT-designated program has to have a Capability Development Document (CDD) or Capability Production Document (CPD) depending upon the maturity of the system design. All CDDs and CPDs must be approved through the Joint Capabilities Integration and Development System (JCIDS). JCIDS is intended to analyze Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel and Facilities (DOTMLPF) in an integrated, collaborative process across the services to define gaps in capability and

identify solutions.⁽¹⁰⁾ While JCIDS seeks to ensure that capabilities added will fill identified gaps in the armed services, the analysis and approval chain is a long one. Even with a smaller program, the JCIDS approval process can take anywhere from 9 months to a year for approval, and the program cannot proceed without that approval.

Once the documentation, engineering, and test objectives for a particular Milestone decision are complete, the program must go back to the MDA for approval to continue on to the next phase. No work that would be considered part of the next phase may be started until that approval is given, which in broad terms means that a contractor cannot be selected and design work commenced until a Milestone B decision is reached, a Low-Rate Initial Production (LRIP) line cannot be opened until a Milestone C decision is reached, and Full Rate Production (FRP) cannot begin until the completion of Operational Evaluation (OPEVAL) and the MDA approves FRP.

Again, there are often good reasons for this oversight. However, the effort to formally get the documentation and decisions approved is lengthy because there are many different levels that need to review a document before it receives its final approval. Program office work on the AN/UYS-1 began in the early 1970s, and it took 8 years from contract award to Full-Rate Production. Likewise, the AIP modifications to the P-3C, which included work on the USQ-78(A) but did not change the AN/UYS-1, took 7 years, and the current acoustic processor, the USQ-78(B), took 6 years. Remember, the USQ-78(A) and USQ-78(B) were not completely new systems; they were modifications to existing systems. Why is this more of a problem now than in the past? The life-cycle of a product in the commercial sector has been getting shorter every year. Many components of the USQ-78(B) system which were first delivered in 2002 are now

obsolescent or completely unsupported, which has driven need for the second set of updated cards that are currently being installed.

Funding

The government defense budget cycle is broken into two year increments, with the total budget, or Future Years Defense Program (FYDP) planned out through the next 5 to 6 years. Even years represent an opportunity to change that plan and the services prepare a Program Objective Memorandum (POM) to submit for the overall defense budget. Odd years (“off-years”) can be used to change the budget as well, but only those changes needed due to “fact-of-life” changes, i.e., unpredicted price or program changes that cannot wait for the next POM cycle. The services begin the process of collecting their budget requirements up to two years in advance of the year of execution because the leadership of each service and the Department of Defense as a whole has to compare all the requirements and decide what items are highest in priority and how much they feel they can successfully justify to Congress. Therefore, planning for any new program realistically has to begin two years in advance of any money spent on engineering. Traditionally, a program justifies funding for its initial creation, and then once the system is fielded and the production line stops, the funding levels drop dramatically until the next program is created to replace what becomes an old system. This cycle creates an unstable funding line of peaks and valleys.

Between the acquisition timeline and the budget timeline, the problem presents itself to any program attempting to stay ahead of the technology curve: 8 to 10 years between identified need and a system rolling off the production line does not match the commercial market.

COMMERCIAL OFF-THE-SHELF

Why try to use commercially available hardware then? The main reasons are time and money. Before the 1980s, there was not a broad commercial market for the type of computing hardware necessary for complex acoustic processing and hence the reason the AN/UYS-1 was developed. In today's information age, however, high-speed processors are used for everything from weather prediction to video game consoles, so why spend the time and money to develop a system from scratch if a suitable product is available now? It took 8 years and \$32.5 million (FY79) just to develop the AN/UYS-1 processor, and that did not include all the other control, display, and receiver hardware to interface it with the aircraft, or the actual costs to produce it.⁽¹³⁾ That development figure, roughly \$90.7 million in today's dollars, also did not include development of any of the software or Signal Processing Language developed specifically by the Naval Research Laboratory for these applications. That software development is just as important and in some ways even more difficult than the hardware. However, nothing comes for free, and, there are benefits and risks in using COTS hardware and software.

Potential Benefits

Some of the potential benefits of using COTS components are ⁽⁴⁾:

1. Reduced development cost and schedule – If the individual hardware components and software language are already available, then the prime contractor becomes a prime integrator.
2. Product updates paid by the vendor – Potentially the product would receive periodic driver updates that were developed by the vendor to keep up with the current market. This could in itself cause problems, though.

3. “Proven” product with a wide user base to identify problems and build operational life – With complex systems and software, it is almost impossible to test all possible failure paths within a reasonable amount of time or budget. Therefore, if a COTS component has been in the market for a while, there is by default that much more operational test time on the component to identify faults.
4. Reduced maintenance costs – This might or might not be true, depending on the application, but the last two benefits should result in a reduced mean time between failure of the part and a reservoir of expertise to identify the cause of failures that are only paid for when there is a problem. Another factor to this is that if the program office schedules in periodic replacement, or technological refresh, of obsolescent components, the cost of doing these “tech” refreshes could be less than the cost of maintaining a stock of obsolescent spare parts.
5. Available skill base – A great amount of concern is placed on maintaining enough work to maintain the worker skill base for critical military technologies such as ship building, high-performance jet engine design, and nuclear power plant engineering. It reduces the burden and cost of a system if the required skill base can be maintained by the commercial market.
6. Industry investment in the technology base – As mentioned in the example of the AN/UYS-1, the Navy paid for all the development of the computing hardware necessary for advanced signal processing and also developed the higher order language to run it. Commercial sector computing requirements

have now grown such that it is the market that drives corporations to invest in the technology base, not the government.

Potential Risks

Some of the potential risks of using COTS components are ⁽⁴⁾:

1. Different lifecycle model – A military system is normally driven by requirements development, whereas reliance on COTS availability could drive technology refreshes faster than the warfighter needs just because that component is no longer produced.
2. Product volatility – A COTS product line can change whenever the vendor chooses based on commercial market drivers. This can cause frequent End of Life (EOL) issues for the system that must be handled quickly through purchasing additional spares or conducting new analysis of alternative parts. A system using COTS components is virtually guaranteed to encounter this, with the current life of a card running 2 to 3 years with product support lasting another 2 years at best.
3. Little or no insight into product or process – If the vendor is supplying a single component to the Prime Integrator, there is a chance that vendor may not have identified all flaws yet, has poor documentation to address failures, and may not wish to provide insight into their internal processes or test reports.
4. System incompatibilities – Although many COTS components are advertised to be compliant with certain industry standards, the standards might be

written vaguely enough that components that can be argued to both meet the standard could still not work properly with each other.

5. Underestimated total program costs – Although the components may be COTS or NDI, the importance of proper systems engineering, integration, and robust system-level testing expenses can be overlooked.
6. Vendor viability – The other side of product volatility. The component may meet all requirements and be cheap, but how stable is the corporation? A vendor that is unstable as a business will not be able to provide support and product stability down the road.

Taking advantage of the benefits while mitigating the risks involves commitment from the program to ensure good systems engineering practices are used, personnel are employed with a good knowledge of the current markets, vendors, and products available, performance verification and system level testing is conducted early and often, and that there is good insight into the processes of the vendor. A good lead system integrator can provide much of this, but the program office still must ensure it has the proper technical expertise to monitor the integrator's performance. The submarine community's Acoustic Rapid COTS Insertion Program has proven to be one of the most successful efforts to harness the COTS potential and make it work.

SUBMARINE ACOUSTIC RAPID COTS INSERTION DEVELOPMENT

In the mid 1990s, the submarine community was falling behind in sonar performance when faced with increasingly quieter foreign submarines and their rapid proliferation around the world. Faced with an estimated \$1.5 billion development cost and \$90 million production unit cost for a new MIL-SPEC system⁽⁵⁾, the U.S. Navy

sought alternatives. In 1995, a panel commissioned by the U.S. Navy recommended replacing the legacy sonar systems with COTS-based processors and implementing an incremental capability fielding process using what they termed Advanced Processing Builds (APB)⁽¹⁴⁾. From this, NAVSEA began the Acoustic Rapid COTS Insertion Program, later designated the AN/BQQ-10(V) with Lockheed Martin's Maritime Systems and Sensors division as the prime contractor. Development costs were driven down to \$100 million and the per unit cost to \$10 million. In addition, the different sonar systems on the various submarine classes were replaced with the common system, greatly reducing the logistical support infrastructure and allowing hardware and software improvements to be shared across the classes.

Simply using COTS hardware and software would not achieve these savings due to some of the potential risks identified earlier. In fact, the first iteration of the ARCI hardware suite used custom VME cards and COTS operating systems and drivers where practical for the given architecture. Although the system was technically COTS, these specialized cards were not reliable, had a high procurement cost, and had limited driver support.⁽⁵⁾ Other factors in the system design were also inconsistent with commercial practices and the system was difficult to support. The ARCI program sought to mitigate these risks in the next iteration through commitment to a Modularized Open System Architecture where the system was broken into separate hardware and software components. A middleware was used to isolate the application code from the hardware and associated drivers and operating system. The middleware solution allowed maximum reuse of previously developed and complex software modules, algorithms, and displays from one hardware build to the next. Follow-on technology insertions migrated

away from the custom VME cards which at the time utilized proprietary operating systems and interfaces, but it wasn't until 2000 that the processing density of mainstream COTS processors could match VME performance for complex signal processing.

The shift was made to Intel Pentium III servers running Linux OS, and due to the large market base for the processors, there was a correspondingly large decrease in system cost. Running Linux also provided the benefit of a broad user base to discover and troubleshoot problems. Since then, the program has maintained a cycle of hardware technology insertions every 2 years, and APB software builds every year. The software builds are distributed and can run on all installed systems so they can take advantage of the latest in algorithm and display updates, but due to the time it takes to pull a submarine in for any kind of retrofit, each individual submarine skips every other hardware update. Therefore, the hardware in each individual submarine receives a leap-frog technology update every 4 years. To more easily incorporate these updates, the server chassis in the submarine was modified to match commercial standards so a new cabinet would not need to be designed every time.

Along with the hardware and software changes, the ARCI program implemented a series of working groups to pull fleet operator experience and initiate a periodic review of developing software and hardware technologies by an expert panel. Inputs from these groups steer the development priorities of the next technology insertion and APB.⁽¹⁴⁾

The success of the ARCI program has been such that the surface and Integrated Undersea Surveillance System communities have begun adopting the same business model and similar hardware, allowing reuse of certain sets of software code across all communities.

CHAPTER 3: METHODOLOGY

GENERAL

The example set by the submarine community has shown that COTS components can be successfully used to keep costs down while providing a consistent, incremental improvement in capability. The goal is to translate that process to the air community to keep the P-3C acoustic processor current and supportable up through the retirement of the aircraft in 2019. The difficulty is that compared to submarines, the P-3C has much more severe power, weight, cooling, and volume restrictions. The budget is also more limited and there are 97 aircraft that the community would like to update with each technology refresh.

ACQUISITION STRATEGY

As mentioned before, the market lifetime of a COTS processor card is approximately 2 to 3 years with 2 more years of support. This timing matches the ARCI model of new hardware being introduced every two years, and each submarine skipping every other build. However, the notion of skipping an equipment upgrade is new to aircraft acquisition in general, and not part of the original concept under which improvements to the P-3C acoustic system were proposed. The original program office concept for acoustic system upgrades was that the system would receive the periodic technology refreshes, but each refresh would go into all 97 AIP/BMUP aircraft before the next technology refresh began. This model, however, posed a problem given the nature of the COTS market.

The problem lay in installation time. Much like the submarine community's move to a standard, easily upgradeable server rack, the first Air ARCI technology refresh will have to encompass extensive physical modifications to the USQ-78(B) chassis and aircraft rack to allow the VME cards and backplane to be easily exchanged in the future. This type of installation can only be performed at certain specialized facilities, so the aircraft will have to be removed from operational use while the installations are performed. These aircraft operate under a high operations tempo due to the current overseas conflicts. As such, they are taken off the flight line for maintenance and installations only when absolutely necessary. Pre-scheduled overhaul periods build into the P-3C maintenance cycle result in an opportunity for approximately 23 to 25 installations per year. Given 97 AIP/BMUP aircraft in the inventory, that number of annual installations means that the initial round of technology installs will take 4 years to complete. As shown in the notional timeline in figure B-6, given a typical 1 year lead time for placing the order for cards, the card sets composing that first technology refresh would be declared EOL by the vendor halfway through the installation period. The program would be installing obsolescent components before they even reach the Fleet.

Because of this, the author felt it was more reasonable to follow the model of installing each technology refresh on half of the 97 AIP/BMUP aircraft in the Fleet. Each half would then skip over a refresh to the next one. As shown in the notional time line in figure B-7, each aircraft would operate with their card sets for 4 years before the next technology refresh opportunity. This would result in a total market and support life for those cards of approximately 5 years when replacement starts, and 7 years by the time the last ones are replaced. This is longer than the anticipated vendor support period, but the

final support during those last two years could be accommodated with good logistics decisions which will be discussed later.

Given the time it takes to follow the traditional acquisition path of milestone decision, contractor design and test, government Developmental Test (DT), independent Operational Testing (OT), formal report, and next milestone decision, a more streamlined approach was needed.

The author decided on pursuing an Abbreviated Acquisition Program (AAP) using concurrent development and production. Integrated contractor and DT testing would be conducted with OT personnel participating in all events and providing an informal Operational Assessment known as a DT Assist.

The key to implementing the program quickly lies in the AAP. When defining the different levels of program acquisition categories, Secretary of the Navy Instruction (SECNAVINST) 5000.2C identifies the AAP this way:

“Small DON [Department of the Navy] acquisitions and modifications may be designated an AAP if they do not require OT&E [Operational Test & Evaluation] and they meet dollar threshold and other criteria in Table E2T1 below. The OTA [Operational Test Authority] must concur in writing that OT&E is not required.”⁽¹²⁾

That “Table E2T1” is duplicated in table B-1. What is important about an AAP is that the program is not subject to the same level of formal documentation (and timeline) as an ACAT program. The program is limited to \$10 million in Research, Development, Test & Evaluation (RDT&E) dollars, \$50 million in Aircraft Procurement – Navy (APN) dollars, and the Operational Test Authority (Commander, Operational Test and

Evaluation Force in Norfolk) must concur that a formal Operational Evaluation is not required. The OTA will only agree to that if they feel that the new system or modifications to an existing system are not high risk and do not involve a large change in Fleet capability. That description fits the Air ARCI concept perfectly, since the whole idea is that the primary driver is the periodic replacement of obsolescent COTS components and small insertions of proven code and algorithms. Any improvements in capability are due to the natural advancement in commercial technology. Operational Testers would be involved in every aspect of testing on the system to provide valuable Fleet operator inputs, but they simply would not conduct a formal independent Operational Evaluation. An Operational Evaluation can run as long as 6 months with another month to generate the report.

Each technology refresh would be installed on half of the AIP/BMUP aircraft over a two year period, followed by the next technology refresh on the other half. In addition, much like the submarine community, there would be yearly Advanced Processing Builds where improvements to the acoustic system software can be inserted.

Independent of the acquisition category and number of installations per technology refresh, the first Air ARCI technology refresh had been identified as the Acoustic Receiver Technology Refresh (ARTR) for reasons outlined in the next section. The P-3C Program is currently procuring USQ-78(B)s from Lockheed Martin Corporation in Manassas, Virginia to update all of the AIP aircraft to a common USQ-78(B) baseline. The previously mentioned technology refreshes for the ASU and the SC have also been procured from Lockheed Martin. Likewise, ARTR will be procured on the same contract. Lockheed Martin Manassas not only has the technical and

programmatic experience gained from over 30 years of developing the P-3C acoustic system, they are also the prime integrators for the successful submarine community's ARCI upon which this change is built.

The cornerstone of ARTR is the replacement of the ASCL receivers with a Software-Defined Sonobuoy Receiver (SDSR). The SDSR is manufactured by Ultra-Flightline, a subcontractor to Lockheed Martin for SDSR integration work. The ARTR research and development effort and associated DT effort will be conducted throughout FY07 with final DT scheduled for completion by 2nd QTR FY08. Initial SDSR/ARTR kit procurements are scheduled for 3rd QTR FY07. Deliveries will include an engineering change proposal (ECP) detailing the installation, associated source data, technical publication data, training courseware modifications, and prototype and production A and B kits.

TECHNICAL SOLUTION

As can be seen on the diagram of the USQ-78(B) shown in figure B-4, the acoustic system equipment most needing an update are the legacy MIL-SPEC ASCL receivers, ADBs, ATRs, CASS transmitter, and ATSG. Together, these systems are not only difficult to support, the legacy late 1970s design and 65-year old analog signal distribution architecture forced many unnecessary analog to digital and digital to analog conversions within the system. A National Defense Industrial Association (NDIA) study completed in 2003 concluded that the use of an open COTS digital architecture using a modern digital receiver that was common across all Maritime Patrol and Reconnaissance Aircraft and helicopters would lead to significant cost avoidance through hardware commonality, parts reduction, increased performance, and power, cooling, volume and

weight reductions.^(15,16) The simplification to the acoustic processing signal flow is shown in figure B-8.

The Ultra-Flightline SDSR was selected as that receiver by the Multi-Mission Maritime Aircraft Program developing the P-8A, the replacement for the P-3C, beginning in late 2013. To simplify logistics and conduct risk mitigation for the P-8A, that same receiver has been selected for the first Air ARCI technology refresh to the P-3C. The MH-60R helicopter also selected the same receiver, although it will be slightly modified to fit within the even greater physical constraints of a helicopter.

At the same time, modifications to the USQ-78(B) will be performed to eliminate the separate acoustic recorders, bring the DCU to an almost 100% COTS content, improve open architecture, and perform configuration changes that will allow future technology refreshes to be more easily incorporated.⁽¹⁸⁾ The actual changes incorporated in ARTR are:

Software Defined Sonobuoy Receiver – Replace the obsolete ARR-78 ASCL receivers, acoustic distribution boxes, and ASA-76A CASS Transmitter with the Ultra-Flightline SDSR system. The P-3C SDSR hardware is a commercial VME chassis populated with a single board computer, receiver support module, and a receiver processor card. The SDSR will provide the same functions as the obsolete ASCLs, but the hardware is fully digital, eliminating the numerous unnecessary analog-to-digital / digital-to-analog conversions, and is easily upgradeable for increased functionality in the future. The ASCL system only allowed the use of 8 DIFAR/ADAR and 4 DICASS sonobuoys at any one time, but the increased throughput of the SDSR will allow up to 64 DIFAR/DICASS sonobuoys to be used at once or 32 or more ADAR sonobuoys, or some

combination thereof. Although ARTR will restrict ADAR use to 16 sonobuoys because of processing capacity and Operator Machine Interface (OMI) issues with using that much data, the next technology refresh will allow this capability to be used. The SDSR is also capable of performing notch filtering to improve reception in noisy RF environments. When coupled with a four-antenna configuration and with replacing the single receiver card with four receiver cards it will also perform RF beamforming as an additional method to improve reception in noisy RF environments. This four-antenna configuration will also allow the system to provide sonobuoy position information through phase differences. ARTR will not implement the RF beamforming or sonobuoy position system due to budget and technical risk given the second quarter FY08 date for completion of testing. However, the four antennas will be installed on the aircraft at the same time as ARTR so that the Fleet AIP/BMUP P-3Cs will not have to be brought back to a modification site when this functionality will be implemented with the follow-on technology refresh.

Embedded Acoustic Digital Recorder (EADR) – One of the two DASD hard drives presently in use by the USQ-78(B) will be modified to provide an embedded acoustic recorder capability in the DCU. This DASD will be designed to serve as a functional replacement for all AQH-4 and AQH-13 recorder variants and will use the same 146GB hard drive utilized by the AQH-13B ADR-HD. The acoustic recording to DASD will greatly simplify logistics and reliability by allowing all aircraft to have a common recorder and eliminating the separate acoustic recorder and associated wiring and interfaces.

USQ-78(B) Display Control Unit Modifications – Chassis and card modifications will be made to allow the USQ-78(B) to interface with the new SDSR. In addition, changes internal to the USQ-78(B) DCU are designed to replace obsolescent components and move the system towards an open architecture. Proprietary interfaces and obsolescent software code will also be eliminated, such as the replacing the PDC interface needed for the ASCLs with a Gig Ethernet interface to the SDSR and replacing the proprietary Lynx OS with the more open Linux OS and use of some object-oriented code. The VME64 backplane will be replaced with a commercial standard 18-slot VITA 41 backplane with 10 of those slots being utilized. Eight cards will be removed due to obsolescence and because they are no longer needed due to the fact that the SDSR will interface with the DCU over the Gig Ethernet connection instead of the old analog interface. Three new CPU cards will be added for display, ICS, and EADR control. The power supply will be updated and the chassis modified to allow all future card modifications to be completed from the front of the DCU while installed in the aircraft. In addition to mitigating obsolescence issues, these hardware and software modifications will provide the necessary open architecture to more easily facilitate any future capability improvements. After the modification, any future replacement of the USQ-78(B) VME cards will be through simple card insertions/removals not requiring physical removal of the DCU for shipment back to the manufacturer.

Because each technology refresh needs to happen at least every two years, initial planning for the follow-on technology refresh has started. It will be called Acoustic Processor Technology Refresh (APTR) and will add the four receiver cards, firmware and software upgrades to the SDSR to implement RF beamforming and sonobuoy

position location, upgrade all the processor cards to current technology, implement full object-oriented code, add a windows OMI, increase operator automation, and expand ADAR buoy monitoring capability to 32 or more due to increased processing capacity. Aside from adding the four receiver cards and refreshing the card set in the DCU, the main emphasis of APTR is the full implementation of a software open architecture that will allow use of displays, code, and algorithms developed for any ASW platform.

The projected system diagram is shown in figure B-9. When compared to the original P-3C Update III acoustic system, the reduction in components is remarkable. Yet, as shown in figure B-10 and table A-4, the system will have roughly 38 times the performance of the old system with corresponding improvements in every characteristic.

WORKING GROUPS

Like the submarine community, the Air ARCI process will depend upon inputs from a number of working groups to help focus the development areas and assess the value and maturity of new technologies as they emerge.

Air ASW Technology Advisory Group (AATAG) – The AATAG is a collaborative group chaired by PMA-264, PMA-290, and PMA-299. Its goal is to encourage collaborative efforts across air ASW platforms and sharing of technology, evaluate new technology for insertion and lead the Air ARCI process with regards to performance improvement in multi-static and other acoustic system algorithms. Participation is encouraged from across NAVAIR, industry, academia, OPNAV, PEO-A, IWS, and Fleet operators. Figure B-11 illustrates how the AATAG will provide input to the P-3C Air ARCI development process through assessments at key points in development and recommendations to the program office.⁽¹⁸⁾

Common Acoustic Processing Working Group (CAPWG) – The CAPWG’s draft charter states that “The group will assess algorithms and OMI features with the goal of achieving a common acoustic ASW application software source code baseline, together with a common software engineering toolset. Given the substantially different operating environments of the various platforms, a common processing hardware solution will not be mandated. However, in order to facilitate achievement of our goal of common software, the group will seek compatible compute environments.” PEO(IWS 5) and PMA-264 co-chair the CAPWG. CAPWG is supported by expert representation from PEO(IWS 5), PMA-290, PMA-264, PMA-299, NAWC-AD, NUWC and others.

Product Direction Team (PDT) – The PDT manages the development of the APB software builds. It receives recommendations and assessments from the AATAG and supports the AATAG in assessment of new technologies. The team determines what content will be implemented in the next annual software build release based on technical maturity and Fleet requirements, and tracks the progress of its development.

There are other working groups as well, and all the groups interface with each other regularly both within the air ASW community and across the entire ASW community. In fact, many times the members of one group are also members on one or more other groups at the same time. Figure B-12 lists these other groups and illustrates their relation to the AATAG.

TESTING

As mentioned under COTS potential risks, components that are both individually compliant with an industry standard can still be incompatible with each other. One way to reduce this risk is a comprehensive test strategy.

The concept of a fully integrated test team should be applied with contractor, DT, and OT test personnel present at test events. Integration and testing should commence early, with demonstrations of the SDSR in both the contractor and government test facilities. Flight demonstrations are already scheduled to occur early, even before the rest of the DCU hardware will have been assembled, by comparing SDSR performance side-by-side with the legacy ASCL system on a P-3C towards the end of this year. The government lab test facilities also have the capability to stimulate the complete system with rooftop antennas, allowing much more extensive end-to-end testing prior to initiating expensive flight test.

Another factor in the test strategy is the level of involvement by Operational Testers. The AAP requires that Commander, Operational Test and Evaluation Force (COMOPTEVFOR) agree that no independent OT is required. While this paper was being written, COMOPTEVFOR agreed to this strategy under the stipulation that their testers will have full involvement in all the contractor and DT tests, and always reserve the right to require a separate operational test if they deem it necessary.

An undefined benefit to the program is the proximity of the prime contractor, Lockheed Martin in Manassas, VA to the NAVAIR headquarters and primary DT and OT test squadrons at NAS Patuxent River, MD. A contractor's development and production facilities could potentially be anywhere in the country, and indeed there are other P-3C programs with contractor locations all across the U.S. While technology and air travel make distance manageable, there is no substitute for the ability to get in a car and drive over to the contractor facilities at any time to observe the latest test or meet face-to-face to resolve an issue with a test procedure. Likewise, the contractor can quickly pull any

engineering support personnel they need over to the government test facilities to observe any test results. This synergy between contractor and government test facilities has been demonstrated repeatedly when the assets of the test facility at one location were lacking, the equipment under test could easily be moved to the other facility to complete testing. In fact, there have been cost savings due to deliberate avoidance of duplication in certain capabilities at each lab because the facilities of the other were so readily accessible.

INSTALLATION

The modifications to the C-1 rack and DCU chassis, and the installation of the SDSR system and four antennas will require the aircraft to be brought in to a specialized facility with the proper equipment and personnel to do the installation. The AIP/BMUP aircraft are in heavy demand throughout the world to satisfy current U.S. military requirements and other new or upgraded systems need to be installed in addition to the acoustic system, so the amount of time the aircraft spends in modifications must be minimized. Ideally, all these modifications should be completed at the same time.

Since most of the P-3C airframes flying today were built between 1969 and 1990 and are expected to reach the end of their fatigue life well before 2019, the aircraft are required to go through a Special Structural Inspection-Kit (SSI-K) program where the aircraft are brought in for a series of inspections and preemptive airframe component replacements. The work is being performed by either L3 COMM in Greenville, TX or Lockheed Martin in Greenville, SC. Since all the aircraft are required to go through SSI-K, this presents an opportunity to install the ARTR without impacting Fleet use. In addition, the Naval Aviation Depot (NADEP) in Jacksonville, FL also has the required

facilities and expertise to install ARTR, so any aircraft requiring depot-level maintenance could potentially also have ARTR installed at the same time.

This is the current installation strategy used for the System Controller Technology Refresh. A proposal is received from all three sources and an installation price is negotiated. When an aircraft then goes in for SSI-K or depot work, that pre-negotiated price is used and the necessary hardware is shipped from Lockheed Martin Manassas to the installation site.

Subsequent technology refreshes such as APTR will not require special facilities because the design modifications for ARTR will be such that future card upgrades can be completed with just access to the front of the DCU. Installations for APTR should therefore complete much more quickly, since technicians with the new cards will be able to travel to the P-3C home base and perform the upgrade quickly on multiple aircraft onsite.

LOGISTICS

The logistics concept for supporting the ARCI-developed systems on board the submarines has evolved beyond the traditional military supply system practice of ensuring a constant supply production line or stockpiling enough repair components to last the expected lifetime of the system. Their present concept involves pre-planned maintenance and upgrade periods, embedded spares, remote diagnostics and contractor supply chain management and maintenance support. By embedding spare hardware within the acoustic systems, they are extending their maintenance free operating period beyond the length of a deployment. This minimizes unscheduled maintenance and allows preventative maintenance to be performed while the submarine is on its home cycle. In

addition, each submarine has a pre-planned technology upgrade every four years, so the hardware stays relatively new and reliable. What spares and failure diagnostics are required are conducted under a support contract by Lockheed Martin. Support technicians can diagnose problems remotely over SIPRNET and send repair parts if necessary.

Portions of this model can be used for P-3C acoustic system sustainment, while others are impractical. The deployment patterns for individual P-3C aircraft are less predictable than submarines. A particular aircraft may be left in theatre for the next squadron to use, or it may return home to the U.S., depending entirely upon the present operational tempo. P-3Cs regularly travel on detachments to remote locations that can be primitive, with little connectivity to outside networks. This variance coupled with the weight restrictions imposed on aircraft make embedding sufficient spares and relying on remote diagnostics difficult. However, the aircraft acoustic system is less complex than the submarine system, so a robust Built-In-Test (BIT) should allow the Navy maintenance personnel to identify individual replaceable failed components. There are presently no plans to change how parts are obtained, but choosing the right upgrade number and frequency could lead to a couple simplifications to the logistics requirements as will be shown.

A continuous cycle of upgrades would mean that any one aircraft would only go for a maximum of four years before its acoustic system underwent a technology refresh. As shown in figure B-13, this would mean that replacement parts would be needed for only those four years. Once those aircraft begin their next technology refresh, most of those replaced components would be available for reuse as spares to support the rest of

the old technology refresh until they could be updated as well. This should minimize the need to maintain a large inventory of parts. The lead time required from component purchase to delivery will depend on how widely used the component is in the commercial world, but as long as the part is in production, there should only be a need to maintain a stock of enough components to last through that lead time. When the part is declared EOL by the vendor, enough spares will need to be purchased to last for the period left in that technology refresh cycle. Another consideration when it comes to support is the fact that each unit would be in service for a maximum of four years before it receives an upgrade. The reliability should be higher for these systems than one that has been around for a decade or more, as is the case with the UYS-1. An additional item for analysis is the effect on sparing if the cycle time for each aircraft is reduced and the effect of retiring aircraft beyond FY14 returning components to the supply chain. This could result in very little sparing due to EOL issues, and will be examined later as different options in the acoustic system roadmap.

CHAPTER 4: RESULTS AND DISCUSSION

GENERAL

At the time of the writing of this thesis, COMOPTEVFOR has concurred with the assessment that no independent OT is required for the Acoustic Receiver Technology Refresh program, satisfying that requirement for an Abbreviated Acquisition Program. Based on initial estimates, sufficient budget has been secured to fully fund ARTR development and installation on half of the 97 AIP/BMUP as planned. This estimate is less than the annual and total expenditure limits for an AAP as outlined in SECNAVINST 5000.2C. Having satisfied the requirements, the AAP request for ARTR has been submitted to PEO(A) for approval and is awaiting a decision.

Although the program is ongoing and there are no final results, the previous experience with the large percentage of COTS components in the original USQ-78(B) system, the subsequent ASU and SC technology refreshes, and the design of the ARTR and APTR upgrades have shown that the use of COTS components in a military aircraft application is feasible and the significant gains shown in figure B-10 can be realized. In the 15 years between the introduction of the USQ-78(V)/SASP and the USQ-78(B), performance of the acoustic system increased by a factor of 7. In the 10 years between introduction of the USQ-78(B) and APTR, acoustic system performance will have increased by a factor of 30. Although the submarine community can claim a greater improvement in performance over their own legacy systems, the submarines are not as subject to power, space, weight, and cooling limitations as aircraft. Even so, the

submarines have reached their limit for cooling capacity using their present architecture. In contrast, along with the increase in performance, APTR will yield a power and weight savings of nearly 80%, a volume savings of over 50%, a reduction in total modules by 92%, and an increase in Mean Time Between Failure (MTBF) by a factor of over 41.

Along with these gains, there are a number of risks that have been identified both through the initial work on ARTR and through the experience gained working on SCTR. These risks almost completely match those identified earlier by Kohl⁽⁴⁾, which were listed in Chapter 2 of this paper and are discussed below.

RISKS

Different lifecycle model and Product volatility – SCTR has already received 3 EOL notices before installation could even begin on Fleet aircraft. Once Fleet installs begin near the end of this year, the USQ-78(B) will have retained only 4 of the original 14 VME cards introduced in 2002. The follow-on technology refresh will replace those remaining cards as well.

Little or no insight into product or process – Although this has not been a major problem at the prime integrator level, there have been issues at the sub-vendor level. A sub-vendor did not inform the prime integrator that certain capabilities in its component would not be available for test until late in the design process. This partially contributed to the functionality of that capability being deferred to the next technology refresh cycle. Also, the prime frequently has had little warning that an EOL notice was coming from the sub-vendors. There have also been issues with a sub-vendor changing the revision of the component without full visibility into the consequences of those changes. The revision may have been created due to problems with another user or a change in materials

vendors, and although the component still met specification, the changes led to product failure.

System incompatibilities – There was an issue where one component proved incompatible with another, leading to part failure. Both supposedly met the VME specification, yet a modification had to be made to one of the parts, resulting in program delays and additional testing.

Underestimated total program costs – Estimates of component costs have proven to be late or underestimated due to the advanced nature of the component. An inaccurate cost estimate can lead to budget shortfalls during the program since the Defense Department budget is set years in advance and there is no guarantee that additional funds can be acquired to cover a cost overrun. Frequently a budget shortfall translates into a reduction in performance or quantity of the system.

Vendor viability – A smaller vendor was purchased by another corporation, which then led to a move in the center of operations and a period of internal adjustment while the new management took over. Contract deliverable items fell behind schedule during the transition.

As discussed in the previous section, these risks are inherent to the COTS environment, and the Program Office will continue to have to manage them through robust systems engineering, system-level testing, and frequent, detailed communication with the Prime Integrator.

TECHNOLOGY REFRESH ROADMAP

A remaining question is the sequencing and numbers of subsequent technology refreshes to carry the P-3C to its retirement in 2019. While this thesis was being written,

the Program Office made the decision to install ARTR on only half of the 97 AIP/BMUP aircraft, and that APTR will continue to install those chassis and sonobuoy receiver improvements in addition to its own new set of processor cards in the remaining half. This decision was based on the previously mentioned installation time and component life. What must now be determined is how the upgrades proceed from there. Six different paths are examined here.

Options

1. Install each technology refresh in all 97 aircraft prior to commencing the next technology refresh. This was discarded early on, but will be shown here for comparison. The notional roadmap is shown in figure B-13.

2. Install each technology refresh in half of the 97 aircraft each for ARTR & APTR. Follow-on Air ARCI TR #3 will be installed in all aircraft not due to retire within the year and no additional technology refreshes will be conducted before aircraft retirement. The notional roadmap is shown in figure B-14.

3. Install each technology refresh in half of the 97 aircraft for ARTR. APTR and follow-on Air ARCI TR #3 and #4 will be installed in all aircraft not due to retire within the year. The notional roadmap is shown in figure B-15.

4. Install each technology refresh in half of the 97 aircraft each for ARTR & APTR. Follow-on Air ARCI TR #3 and #4 will be installed in all aircraft not due to retire within the year. The notional roadmap is shown in figure B-16.

5. Install each technology refresh in half of the 97 aircraft until Air ARCI TR #4, which then installs in all aircraft not due to retire within the year. The notional roadmap is shown in figure B-17.

6. Same as option #3, but with TR #4 to be delayed 1 year in an effort to reduce overall cost. The notional roadmap is shown in figure B-18.

Assumptions

Some simplifying assumptions were made to bound the problem, but the results are valid as a means to show the relative magnitude of advantage between the options:

1. Costs associated with modifications to the DCU, aircraft rack, and incorporation of the SDSR are not included, since they are necessary to ensure ease of future upgrades and therefore would be part of any option.
2. Each technology refresh is assumed to be composed of 10 new replacement VME cards costing \$10,000 each. This value may be high for some cards, such as a switching card, or low for others such as digital signal processor cards. The card count number is an average, as well, since the final configurations for APTR and beyond are not yet set. There are 9 cards in the ARTR configuration DCU, and although 6 of those are left over from the SC technology refresh, replacement and sparing for those cards will be even more difficult over time because they are older. There is also 1 card in the SDSR unique to the ARTR installation.
3. An annual failure rate of 5% was assumed, and applied across all cards.
4. Non-Recurring Expenses associated with design and integration of each technology refresh were set at \$6 million each for ARTR and APTR due to the extensive hardware design for ARTR and extensive software work in open architecture and OMI. Air ARCI TR #3 was set at \$5 million, and #4 was set at \$4 million. These figures, as well as the card costs, are Rough Order of Magnitude estimates only, with a variance of

approximately 30%. They are based on the author's experience with P-3C acoustic system development programs, but are not actual Program Office figures.

When evaluating the options, the weighting factors to be considered are: Does the spacing and number of the refreshes keep pace with the submarine threat described in the original Statement of Problem? Does the option reduce sparing? How many concurrent configurations of aircraft does the option yield? (Smaller is better for the Fleet operators.) Which is least expensive? The first factor must be satisfied since the rate of improvements to foreign submarines is the original driver for these updates. The remaining factors must be balanced to be acceptable.

Evaluations

The results of the analysis on total cost are shown in table A-5 and figure B-19. The breakdown by option is as follows:

Option 1 – As mentioned before, due to the initial length of installation this option would result in two years wasted installing obsolescent parts. In addition, a portion of the cards in ARTR re-use the older SCTR cards. Some of these cards have already exceeded EOL, so supporting the system until the end of FY12 may be impossible. Cost is average and no more than 2 configurations of acoustic system exist at any one time.

Option 2 – The least expensive option, but by stopping the technology refresh cycles at 3, this option lags the other options by two years in keeping pace with the submarine threat. The design that must last until the end of FY19 will have been finalized early in FY11, an interval of almost 9 years. Average sparing will be required, with aircraft retirements providing the bulk of supporting parts during the last 5 years.

There are a maximum of 3 configurations from the end of FY12 to the end of FY13, but just the one configuration for the remaining 6 years.

Option 3 – The most expensive option, due to keeping all aircraft updated from APTR onward through a total of 4 technology refreshes. Very little to no sparing is required because the components begin replacement when the cards go EOL. No more than 2 configurations of acoustic system exist at any one time, the current installation configuration and the previous configuration being replaced.

Option 4 – This option is a little higher than average in cost. Sparing is relatively low. There are three configurations early on, which then reduce to two by FY13.

Option 5 – This option is average in cost. There is a fairly high amount of sparing necessary due to the need to have each technology refresh remain in operation for an additional 2 years beyond card EOL prior to beginning replacement through the next refresh. This also means that there are always 3 configurations in the Fleet; the one being phased out, the last refresh installed, and the current refresh being installed.

Option 6 – This option is slightly lower than average in cost, but it has the highest requirement for sparing due to extending the amount of time Air ARCI TR #3 is used prior to being replaced. Like Option 5, there are always 3 configurations in the Fleet, so although the fourth refresh is the most up to date of all the options by the time the P-3Cs retire, many of the aircraft never get the most current refresh due to the rate of retirement and the fact that only half of the aircraft are updated at any given time.

Each option was ranked against one another for each of the four grading criteria, with equal grades assigned where there was no advantage. A weighting factor of 3 for

technical currency, 2 for cost, and 1 for configurations and logistics/sparing was then applied. The results are shown in Table A-6.

Despite the fact that Option 3, which installs on half of the 97 aircraft for ARTR and then all aircraft for each subsequent refresh, is the most expensive, it scores higher than all the other options. This is due to the number of aircraft kept technologically current, reduction in spares, and a minimum of multiple configurations. In fact, even if the weighting is lowered for technical currency to the same as or lower than cost, Option 3 still scores the highest. If Option 2 is discarded because it fails to come close to the other options in currency, Option 3 is \$7.41 million more than the least expensive viable option, Option 6. Over the 7 years of acquisition from FY10 to FY16, this represents an investment of approximately \$1.06 million per year for the added advantages of this option. If the budget simply cannot afford the additional funds, then Option 6 remains a good alternative, although there will be added complexity due to multiple configurations, fewer aircraft with the most current capabilities, and greater sparing of parts.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

The goal of this study was to identify the issues facing the implementation of the successful submarine Acoustic Rapid COTS Insertion program to the P-3C acoustic system and identify a possible path forward to sustain that capability up to the retirement of the P-3C in 2019. The driving force behind this investigation is the advancement in submarine quieting technology and the need to be able to rapidly incorporate new technology. Given the advanced capabilities of current commercial technology and the prohibitive cost of developing the same capabilities from the ground up as part of a military development program, the incorporation of COTS components is the only economical way to proceed while still being able to pace the threat.

The foundation for the first steps in the Air ARCI process has been laid. An Abbreviated Acquisition Program is being approved to allow for a shortened development cycle that better fits into the short lifespan of commercial components. A series of working groups have been established or are being set up to ensure that there is an established review procedure to steer future software and hardware developments. A hardware solution for the first technology refresh, Acoustic Receiver Technology Refresh, has been designed and is beginning lab testing. This first refresh is primarily designed to enhance the hardware aspects of open architecture, allowing the system to more easily incorporate new hardware with each successive refresh.

To continue successful implementation of the Air ARCI process, there are a number of steps the Program Office must follow. If possible, the AAP structure should

be maintained for each of the following technology refreshes. The reduction in documentation and approval chain length is better suited to meeting the shortened development cycle necessary to keep pace with the limited life of commercial components. If a refresh looks like it will exceed either the cost limits or require a dedicated Operation Test period, planning and commencement of required documentation must start immediately to even begin to attempt to stay on the two-year ARCI hardware cycle. More Program Office personnel will also be required to complete the ACAT requirements.

The main emphasis on the second refresh should be enhancing the software aspects of open architecture such that the best software code and algorithms across all ASW platforms can be more easily incorporated with each successive annual software build and each follow on hardware cycle.

Given both the potential benefits and risks of COTS technology incorporation, continued emphasis should be placed on comprehensive system level testing as early as possible in the development cycle. The fact that these COTS components should already be proven in the commercial marketplace just means that they almost assuredly meet their own stated specifications, not that they will work well when combined with other vendor's components.

Frequent communication with the Prime Integrator and visibility into all development processes, including the management of sub-vendors, is absolutely necessary to ensure the Program Office has as much time as possible to prepare for any unplanned changes that could affect schedule or budget. The Prime Integrator should

periodically poll its vendors to seek out any indications that a component will soon be discontinued or replaced with a new revision or model number.

Finally, a funding structure should be pursued that enables adoption of the Option 3 roadmap, where ARTR will be installed in half of the 97 aircraft and APTR and follow-on Air ARCI TR #3 and #4 will be installed in all aircraft not due to retire within the year (figure B-15). This will minimize the problems associated with frequent, short notice End of Life notices such as unplanned purchases of spares or additional testing and qualification of new sources.

The information presented in this thesis was gathered from both official Navy and Lockheed Martin public-releasable information and independent research and interviews. Although all analysis conducted as part of this study was completed independently by the author during personal time, the results bear direct applicability to the P-3C acoustic program and have already influenced future planning by the Program Office.

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APPENDICES

APPENDIX A TABLES

Table A-1: Description and Decision Authority for ACAT I-IV and AAP Programs ⁽¹²⁾

Acquisition Category	Criteria for ACAT or AAP Designation	Decision Authority
ACAT I	- Major Defense Acquisition Programs (MDAPs) (10 USC 2430) - RDT&E total expenditure > \$365 M in FY 2000 const. dollars, or - Procurement total expenditure > \$2.190 B in FY 2000 const. dollars, or - USD(AT&L) designation as special interest	ACAT ID: USD(AT&L) ACAT IC: SECNAV, or if delegated, ASN (RD&A) as the CAE
ACAT IA	- Major Automated Information Systems (MAISs) - Program costs/year (all appropriations) > \$32 M in FY 2000 const. dollars, or - Total program costs > \$126 M in FY 2000 const. dollars, or - Total life-cycle costs > \$378 M in FY 2000 const. dollars - ASD(NII) designation as special interest	ACAT IAM: ASD(NII)/DoD CIO ACAT IAC: ASN(RD&A), as delegated by DoD CIO
ACAT II	- Does not meet the criteria for ACAT I - Major Systems (10 USC 2302(5)) - RDT&E total expenditure > \$140 M in FY 2000 const. dollars, or - Procurement total expenditure > \$660 M in FY 2000 const. dollars, or - ASN(RD&A) designation as special interest - Not applicable to IT system programs	ASN(RD&A), or the individual designated by ASN(RD&A)
ACAT III	- Does not meet the criteria for ACAT II or above - Weapon system programs: - RDT&E total expenditure ≤ \$140 M in FY 2000 const. dollars, or - Procurement total expenditure ≤ \$660 M in FY 2000 const. dollars, and - Affects mission characteristics of ships or aircraft or combat capability - IT system programs: - Program costs/year ≥ \$15 M ≤ \$32 M in FY 2000 const. dollars, or - Total program costs ≥ \$30 M ≤ \$126 M in FY 2000 const. dollars, or - Total life-cycle costs ≤ \$378 M in FY 2000 const. dollars	Cognizant PEO, SYSCOM Commander, DRPM, or designated flag officer or senior executive service (SES) official. ASN(RD&A), or designee, for programs not assigned to a PEO, SYSCOM, or DRPM.
ACAT IVT	- Does not meet the criteria for ACAT III or above - Requires operational test and evaluation - Weapon system programs: - RDT&E total expenditure ≤ \$140 M in FY 2000 const. dollars, or - Procurement total expenditure ≤ \$660 M in FY 2000 const. dollars - IT system programs: - Program costs/year < \$15 M, or - Total program costs < \$30 M, or - Total life-cycle costs ≤ \$378 M in FY 2000 const. dollars	Cognizant PEO, SYSCOM Commander, DRPM, or designated flag officer, SES official, or PM. ASN(RD&A), or designee, for programs not assigned to a PEO, SYSCOM, or DRPM.
ACAT IVM	- Does not meet the criteria for ACAT III or above - Does not require operational test and evaluation as concurred with by OTA - Weapon system programs: - RDT&E total expenditure ≥ \$10 M ≤ \$140 M in FY 2000 const. dollars, or - Procurement expenditure ≥ \$25 M/year ≥ \$50 M total ≤ \$660 M total in FY 2000 const. dollars - Not applicable to IT system programs	Cognizant PEO, SYSCOM Commander, DRPM, or designated flag officer, SES official, or PM.
Abbreviated Acquisition Program	- Does not meet the criteria for ACAT IV or above - Does not require operational test and evaluation as concurred with by OTA - Weapon system programs: - Development total expenditure < \$10 M, and - Production or services expenditure < \$25 M/year, < \$50 M total - IT system programs: - Program costs/year < \$15 M, and - Total program costs < \$30 M	Cognizant PEO, SYSCOM Commander, DRPM, or designated flag officer, SES official, or PM.

Table A-2: Statutory Information and Milestone Requirements ⁽¹²⁾

Program Information and Reports	Presentation Medium	ACAT	Applicability	Prepared By	Approved By
OSD PREPARED					
Beyond-LRIP Report ^{1/}	Optional	I, IA + OSD T&E oversight pgms designated by DOT&E	Full-Rate Production Decision Review (FRP DR)	DOT&E	DOT&E
Electronic Warfare (EW) T&E Report Report Control Symbol (RCS) DD-AT&L(A)2137 *	Optional	EW pgms on OSD T&E oversight	Annually	Dir Def Systems DOT&E	Dir Def Systems DOT&E
Independent Cost Estimate *	MDA option	I	Pgm Initiation for Ships (cost assessment only pre-MS B for ships) MS B/C FRP DR	CAIG/NCAD ^{2/}	CAIG/NCAD ^{2/}
LFT&E Report * RCS: DD-OT&E(AR)1845	Optional	LFT&E programs	FRP DR	DOT&E	DOT&E via SECDEF
COMPONENT PREPARED					
Acquisition Program Baseline *	See DAG	I	Pgm Initiation for Ships MS B/C (updated as nec) FRP DR	PM	MDA
Analysis of Alternatives (AoA)	Optional	IA	MS A MS B/FRP DR (or equiv)	Indep Activity	CAE/CNO/CM C
Benefit Analysis and Determination (applicable to bundled acquisitions)	Acqn Strat	I, IA, II, III, IV	MS B MS C (if no MS B)	PM	MDA
Certification of compliance with the Financial Management Enterprise Architecture	Acqn Strat	IA (Financial Mngt MAIS only)	MS A/B MS C (if FRP equivalent) FRP DR	PM	MDA
Clinger-Cohen Act (CCA) Compliance (all IT - including NSS)	See DoDI 5000.2, Encl 4, Table E4T1	I, IA, II, III, IV	MS A (MAIS only) Pgm Initiation for Ships MS B MS C (if FRP equivalent) FRP DR or equivalent	PM (coordinated with DASN(Space & C4I) for ACAT I/IA/II)	DOD CIO (ACAT IA) DON CIO (ACAT I/IA/II) Cmd IO (ACAT III/IV)
Competition Analysis * (Depot-level Maintenance \$3M rule)	Acqn Strat	I, II, III, IV	MS B MS C (if no MS B)	PM	MDA
Consideration of Technology Issues	Acqn Strat	I, IA, II, III, IV	MS A/B/C	PM	MDA
Cooperative Opportunities *	Acqn Strat	I, II, III, IV	MS B/C	PM	MDA
Core Logistics Analysis/ Source of Repair Analysis *	Acqn Strat	I, II, III, IV	MS B MS C (if no MS B)	PM	MDA
Economic Analysis (EA)	Optional	IA	MS A (may be combined with AoA) MS B/FRP DR (or equiv)	PM	PM
Industrial Capabilities *	Acqn Strat	I, II, III, IV	MS B/C	PM	MDA
Information Assurance Strategy (all IT - including NSS)	DON CIO Template, see Encl (4), para 4.4	I, IA, II, III, IV	MS A (MAIS only) Pgm Initiation for Ships MS B MS C (if FRP equivalent) FRP DR or equivalent	PM	DON CIO (ACAT I/IA/II) Cmd IO (ACAT III/IV)

* Not statutorily required for ACAT IA programs. DAG is the Defense Acquisition Guidebook.

Table A-2: Continued

Program Information and Reports	Presentation Medium	ACAT	Applicability	Prepared By	Approved By
COMPONENT PREPARED (cont'd)					
LFT&E Waiver and Alternate LFT&E plan *	MDA option	LFT&E programs	MS B	PM	USD(AT&L) (ACAT ID) CAE (ACAT IC/II/III/IV) DOT&E
LRIP Quantities *	ADM	I, II, III, IV	MS B	PM	MDA
Manpower Estimate * (reviewed by OUSD(P&R))	See ref (e) sample format	I	MS B/C FRP DR	CNO/CMC	CNO/CMC
Market Research	Acqn Strat	I, IA, II, III, IV	MS A/B	PM	MDA
Operational Test Plan *	OTA option	I + DOT&E oversight pgms	Prior to start of OT&E	OTA	DOT&E
Post-Deployment Performance Review	MDA option	I, IA	FRP DR (submit plan) IOC + 1 yr (assessment) 3 yr intervals (repeat) or as determined by MDA	PM	MDA
Program Deviation Report *	PM option	I	Immediately upon a program deviation	PM	PM
Programmatic Environmental, Safety, & Health Evaluation (PESHE) (including NEPA Compliance Schedule)	MDA option, Summary in Acqn Strat	I, IA, II, III, IV	Pgm Initiation for Ships MS B/C FRP DR	PM	PM (PESHE) MDA (Acqn Strat)
Registration of mission-critical and mission-essential information systems RCS: DD-C3I(AR)2096	See DAG	I, IA, II, III, IV (all MC or ME IT systems - including NSS)	Program Initiation (after initial registration, update quarterly)	PM	PM
Selected Acquisition Report (SAR) - RCS: DD-AT&L(Q&A)823	See DAG	I	Pgm Initiation for Ships MS B, annually thereafter End of quarter following: MS C FRP DR Breach	PM	CAE/PEO/SYS COM USD(AT&L)
Spectrum Certification Compliance (applicable to all systems/equipment that require use of the electromagnetic spectrum)	DD Form 1494	I, IA, II, III, IV	MS B MS C (if no MS B)	PM	USN - CNO (N6) USMC - HQMC (C4)
Technology Development Strategy	MDA option	potential I, IA I, IA	MS A MS B/C	PM	MDA
Unit Cost Report- RCS: DD-AT&L(Q&R)1591	See DAG	I	Quarterly	PM	CAE/PEO/SYS COM USD(AT&L)

* Not statutorily required for ACAT IA programs. DAG is the Defense Acquisition Guidebook.

Table A-3: Regulatory Information and Milestone Requirements ⁽¹²⁾

Program Information and Reports	Presentation Medium	ACAT	Applicability	Prepared By	Approved By
<i>OSD/JOINT STAFF.DISA PREPARED</i>					
Acquisition Decision Memorandum	MDA option	ID, IAM	Pgm Initiation for Ships MS A/B/C, Each Review	MDA staff	MDA
C4I Supportability Certification	Optional	I, IA, II, III, IV	FRP DR	Joint Staff	Joint Staff (J-6)
Independent Technology (Readiness) Assessment	Optional	ID (if required by DUSD(S&T))	MS B/C	DUSD(S&T), or designee	DUSD(S&T)
Interoperability Certification	Optional	I, IA, II, III, IV	FRP DR	DISA	Joint Staff (J-6)
<i>COMPONENT PREPARED</i>					
Acquisition Decision Memorandum	MDA option	IC, IAC II, III, IV	Pgm Initiation for Ships MS A/B/C, Each Review	MDA staff	MDA
Acquisition Program Baseline	See DAG	IA, II, III, IV	Pgm Initiation for Ships MS B/C (updated as nec) FRP DR	PM	MDA
Acquisition Strategy	MDA option	I, IA, II, III, IV	Pgm Initiation for Ships MS B/C, and FRP DR	PM	MDA
Affordability Assessment	Optional	I, IA, II, III, IV	Pgm Initiation for Ships MS B/C	CNO/CMC	CNO/CMC
Analysis of Alternatives Plan	Optional	I, IA, II, III, IV	Concept Decision	Indep Activity	CAE/MDA/CNO/CMC
Analysis of Alternatives (AoA)	Optional	I, II, III, IV	MDAPs/non-MDAPs Pgm Initiation for Ships MS A/B MS C (updated as nec) non-MAISs MS A MS B/FRP DR (or equiv)	Indep Activity	CAE/MDA/CNO/CMC
C4I/Information Support Plan (also summarized in acquisition strategy)	See DAG	I, IA, II, III, IV	Pgm Initiation for Ships MS B/C	PM	PEO/SYSCOM/DRPM, or designee
Component Cost Analysis	Optional	IA I (CAE option)	MDAPs (CAE option) Pgm Initiation for Ships MS B/FRP DR MAISs (to support EA MS A/B/FRP DR	NCAD	NCAD
Component LFT&E Report	Optional	LFT&E prog.	Completion of LFT&E	DT&E Activity	DT&E Activity
Cooperative Opportunities	Acqn Strat	IA	MS B/C	PM	MDA
Cost Analysis Requirements Description	Optional see DoDI 5000.2, Encl 6	I IA (when an EA is required)	Pgm Initiation for Ships MS A (MAIS only) MS B/FRP DR MS C (MDAP only)	PM (coordinated with OSD CAIG (ACAT ID) and NCAD (ACAT IC/IA))	PEO/SYSCOM/DRPM

Table A-3: Continued

Program Information and Reports	Presentation Medium	ACAT	Applicability	Prepared By	Approved By
<i>COMPONENT PREPARED (cont'd)</i>					
Defense Acquisition Executive Summary (DAES), RCS: DD-AT&L(Q)1429	See DAG	I, IA	Quarterly Upon POM or BES submission Upon unit cost breach	PM	PM
DT&E Report	Optional	I, selected IAM, + DOT&E pgms	MS B/C and FRP DR	DT&E Activity	DT&E Activity
Earned Value Management Systems (EVMSs)	See DAG, OMB Circular A-11, Part 7	I, IA, II, III, IV	Implement EVMS guidelines in ANSI/EIA-748-1998 and conduct Integrated Baseline Reviews (IBRs) (applies to contracts/agreements for RDT&E over \$73 million and procurement/O&M over \$315 million, both in FY 2000 const. dollars)	Contractor implements EVMS PM conducts IBRs	PM
Exit Criteria	ADM	I, IA, II, III, IV	Pgm Initiation for Ships MS A/B/C Each Review	PM	MDA
Independent Cost Estimate/Assessment	MDA option	II	MS B/C FRP DR	SYSKOM/PEO Cost Estimating Office	SYSKOM/PEO Cost Estimating Office
Independent Logistics Assessment (ILA) and Logistics Certification	See ref (f)	I, IA, II, III, IV	MS B/C FRP DR	ILA team leader	ILA (ILA team leader) Logistics Certification (PEO/SYSKOM/DRP M)
Initial Capabilities Document (ICD) Capability Development Document (CDD) Capability Production Document (CPD)	See CJCSM 3170 series	I, IA, II, III, IV	Concept Decision (ICD) MS A/B/C (if init) (ICD) Pgm Init - Ships (CDD) ^{7/} MS B (CDD) ^{7/} MS C (CPD) ^{7/}	Program Sponsor	JROC (JROC Interest) CNO/CMC (Joint Integration and Independent)
Manpower Estimate	See ref (e) sample format	IA, II, III, IV	MS B/C FRP DR	CNO/CMC	CNO/CMC
Operational Test Agency Report of OT&E Results	Optional	I, IA, II, III, IVT	MS B/C FRP DR	OPTEVFOR MCOTEA	OPTEVFOR MCOTEA
Operational Test Plan	OTA option	IA + DOT&E oversight pgms	Prior to start of OT&E	OTA	DOT&E
Program Deviation Report	PM option	IA, II, III, IV	Immediately upon a program deviation	PM	PM

Table A-3: Continued

Program Information and Reports	Presentation Medium	ACAT	Applicability	Prepared By	Approved By
<i>COMPONENT PREPARED (cont'd)</i>					
Program Life-Cycle Cost Estimate	MDA option	I, IA, II, III, IV	Pgm Initiation for Ships MS B/C, and FRP DR	PM	PM
Program Protection Plan (for programs with critical program information) (includes Anti-Tamper Annex) (also summarized in acquisition strategy)	Optional	I, IA, II, III, IV	MS B (based on approved requirements in CDD) MS C	PM (Annex requires CHENG's technical concurrence)	PM
Risk Assessment	Acqn Strat	I, IA, II, III, IV	Pgm Initiation for Ships MS A/B/C, and FRP DR	PM	MDA
Systems Engineering Plan	Acqn Strat	I, IA, II, III, IV	Pgm Initiation for Ships MS B/C, and FRP DR	PM	MDA
System Threat Assessment (Information technology programs use published Capstone Information Operations System Threat Assessment)	Optional	I, IA, II, III, IV	Pgm Initiation for Ships MS B/C	Intell Activity (ONI or MCIA)	Intell Activity (ONI or MCIA) DIA validates ACAT ID
Technology Readiness Assessment	Optional	I, IA, II, III, IV	Pgm Initiation for Ships (preliminary assessment pre-MS B for ships) MS B/C	PM	CNR (ACAT I/IA/II) PEO/SYSCOM (ACAT III/IV)
Test and Evaluation Master Plan	see DAG	I, IA, II, III, IV	MS A (test and evaluation strategy only) MS B MS C (update, if nec) FRP DR	PM OPTEVFOR MCOTEA	CNO/CMC ^{9/} CAE/MDA DOT&E/Cognizant OIPT Leader
Training System Plan		I, IA, II, III, IV	MS B (preliminary) Phase B midpoint (final) MS C (update, if nec)	PM	CNO/CMC

Table A-4: P-3C Acoustic Processor Technical Performance Measure Changes ⁽¹⁸⁾

	Relative Performance	Power (W)	Weight (lbs)	Volume (cu ft)	Total Modules	MTBF (hrs)
SASP/USQ-78(V)	1	5510	1841	39	262	27
SASP/USQ-78(A)	2	4665	1848	38	200	30
USQ-78B	8	1810	984	23	58	310
USQ-78B w/APTR	37.9	1135	401	19	22	1124

Table A-5: Notional Life Cycle Costs by Option

	Card Sets Required				Spare Cards Required	NRE	Total Life Cycle Cost
	ARTR	APTR	TR #3	TR #4			
Option 1	97	97	40	N/A	85	\$17,000,000	\$41,250,000
Option 2	48	49	75	N/A	71	\$17,000,000	\$34,910,000
Option 3	48	97	75	40	0	\$21,000,000	\$47,000,000
Option 4	48	49	75	40	36	\$21,000,000	\$42,560,000
Option 5	48	49	48	40	85	\$21,000,000	\$40,350,000
Option 6	48	49	48	30	109	\$21,000,000	\$39,590,000

Table A-6: Scoring of Options

	Tech Currency (Weight = 3)	Cost (Weight = 2)	Configurations (Weight = 1)	Logistics/Sparing (Weight = 1)	Total
Option 1	2	3	6	2	20
Option 2	1	6	4	3	22
Option 3	6	1	6	6	32
Option 4	4	2	4	5	25
Option 5	3	4	1	2	20
Option 6	5	5	2	1	28

Note: Total = sum of grading criteria x weighting factor

APPENDIX B FIGURES

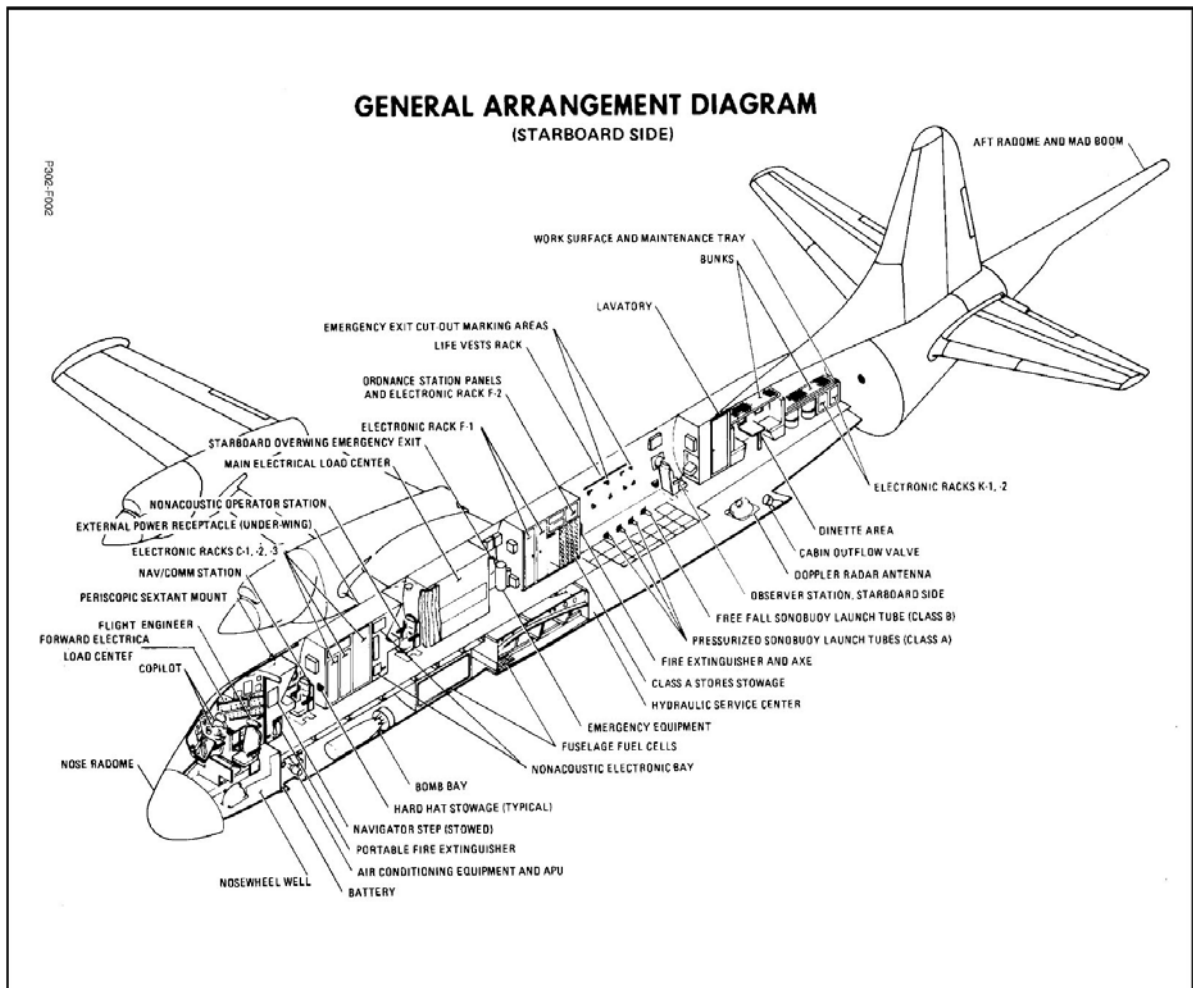


FIGURE B-1
P-3C UPDATE III GENERAL ARRANGEMENT (STARBOARD)⁽⁹⁾

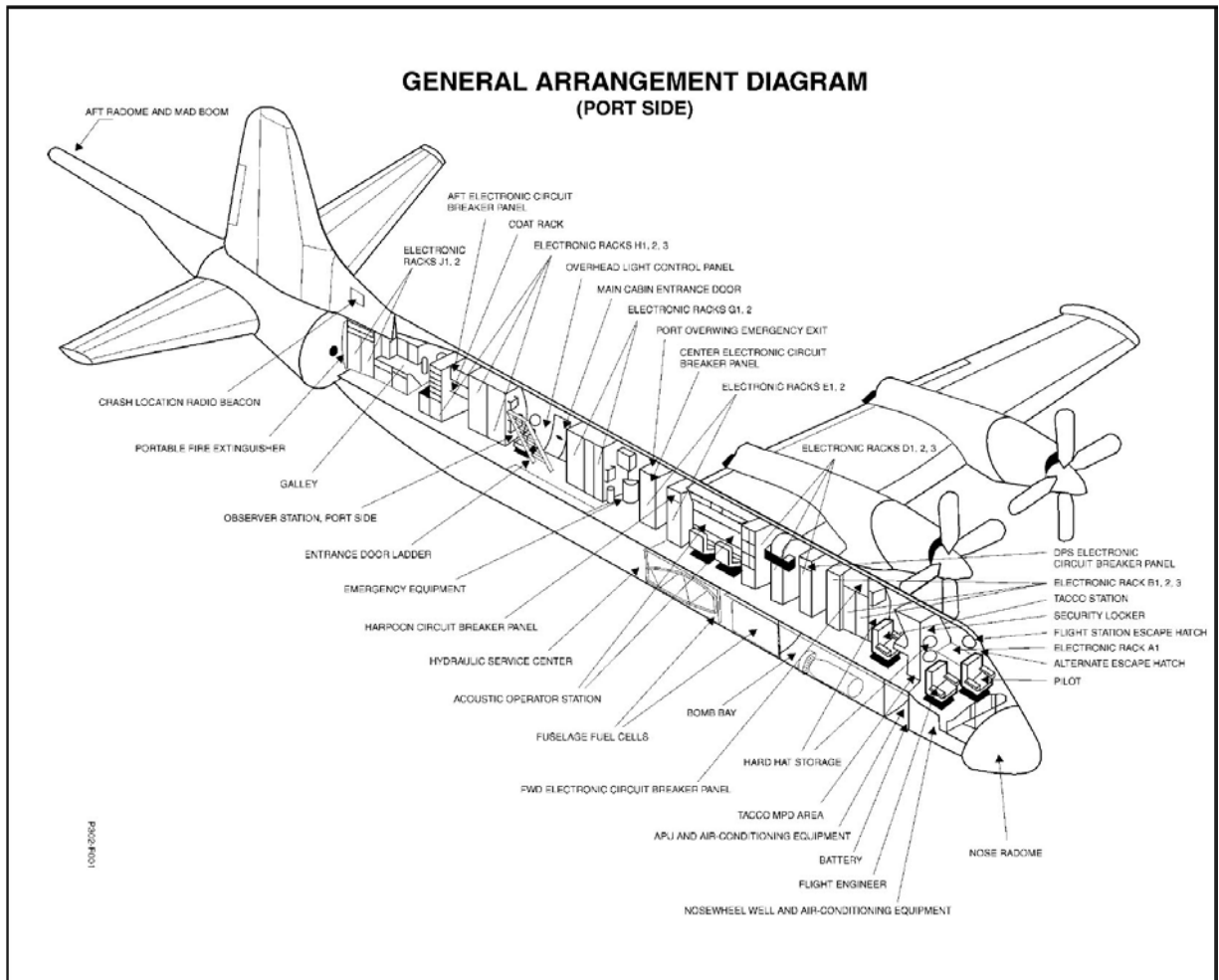


FIGURE B-2
P-3C UPDATE III GENERAL ARRANGEMENT (PORT)⁽⁹⁾

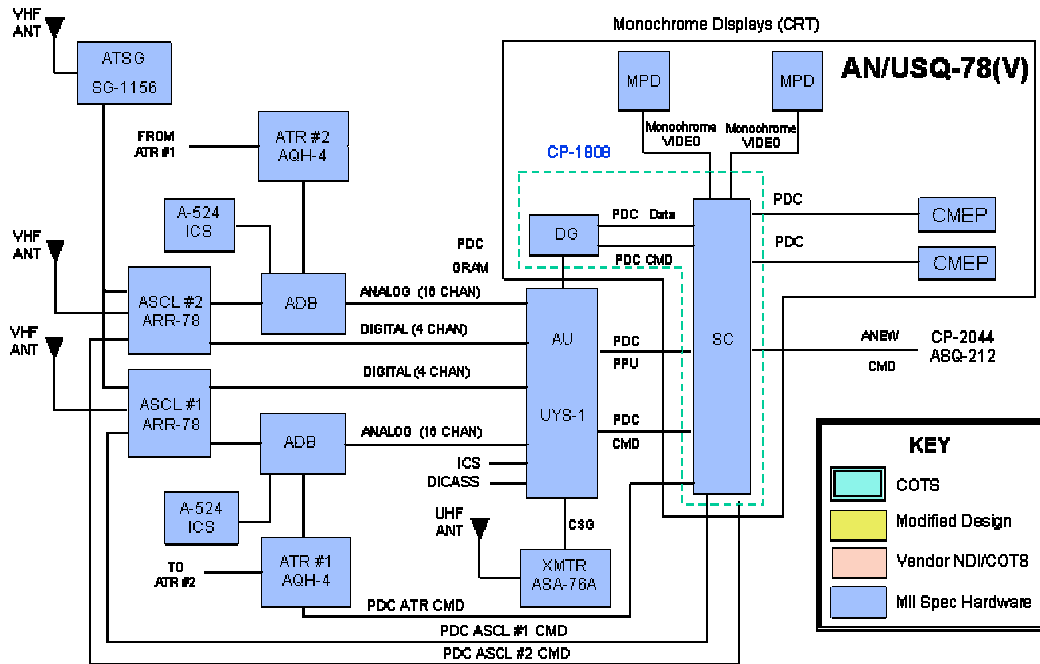


FIGURE B-3
USQ-78(V) LEGACY CONFIGURATION⁽¹⁸⁾

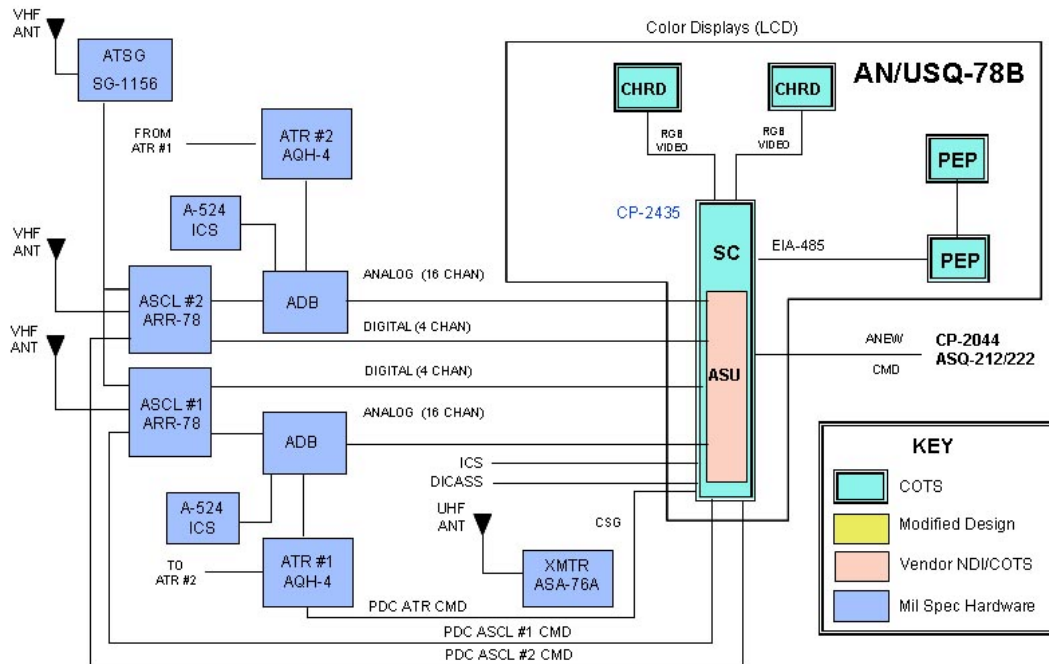


FIGURE B-4
USQ-78(B) BASELINE CONFIGURATION⁽¹⁵⁾

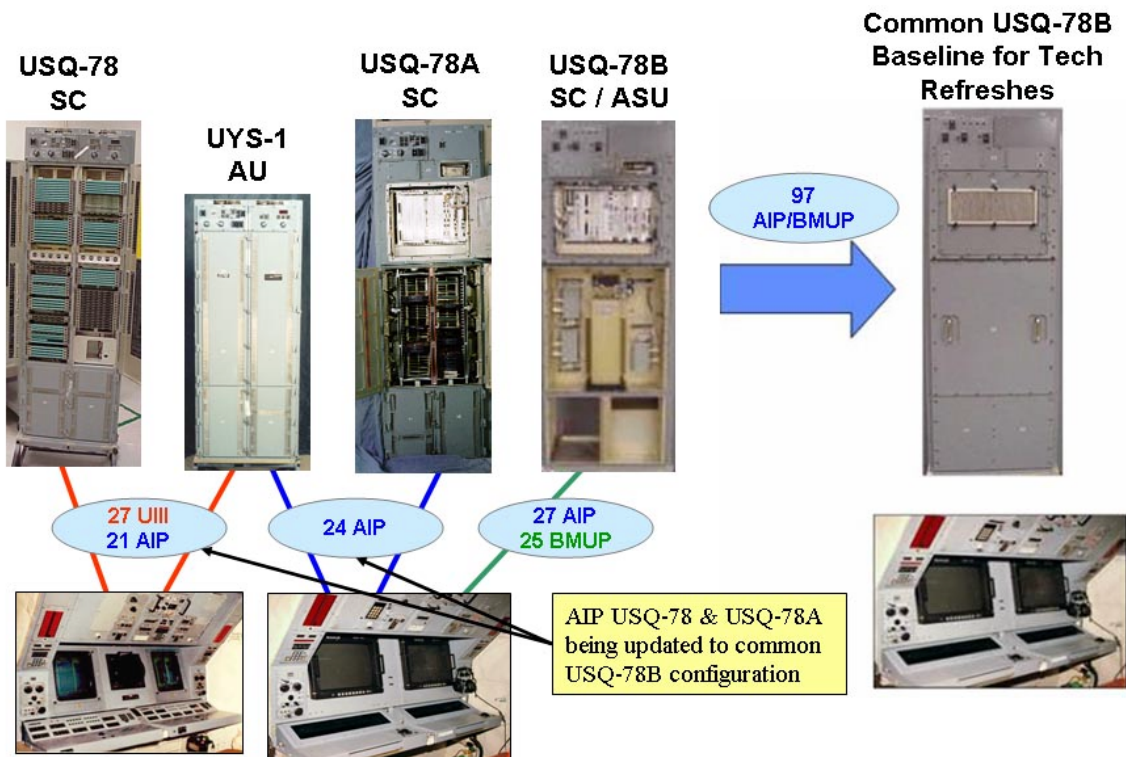


FIGURE B-5
P-3C ACOUSTIC SYSTEM CONFIGURATIONS⁽¹⁸⁾

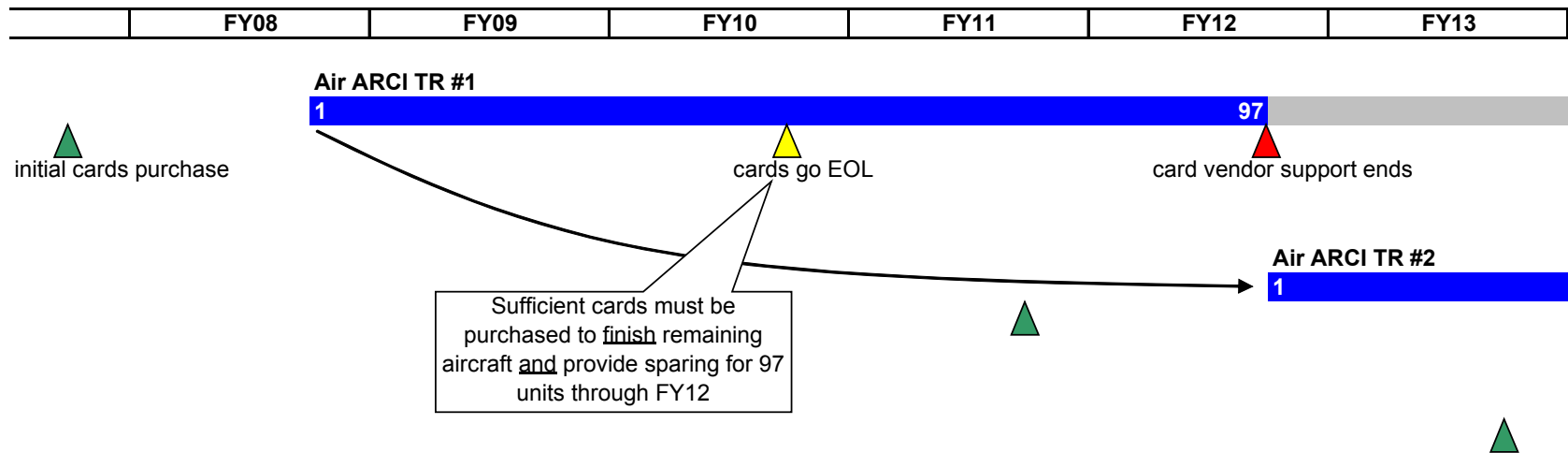


FIGURE B-6
NOTIONAL ACOUSTIC REFRESH TIME LINE (INSTALL IN ALL)

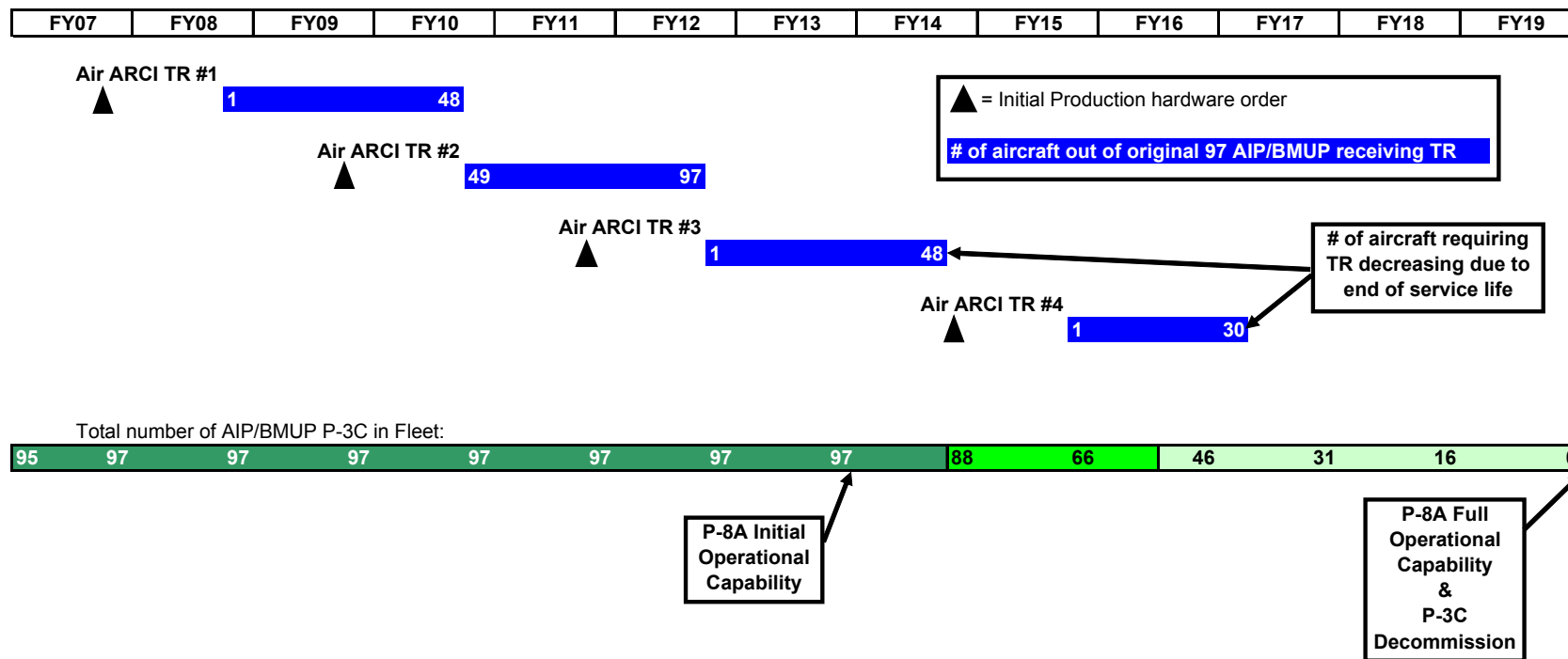


FIGURE B-7
NOTIONAL ACOUSTIC REFRESH TIME LINE (INSTALL HALF)

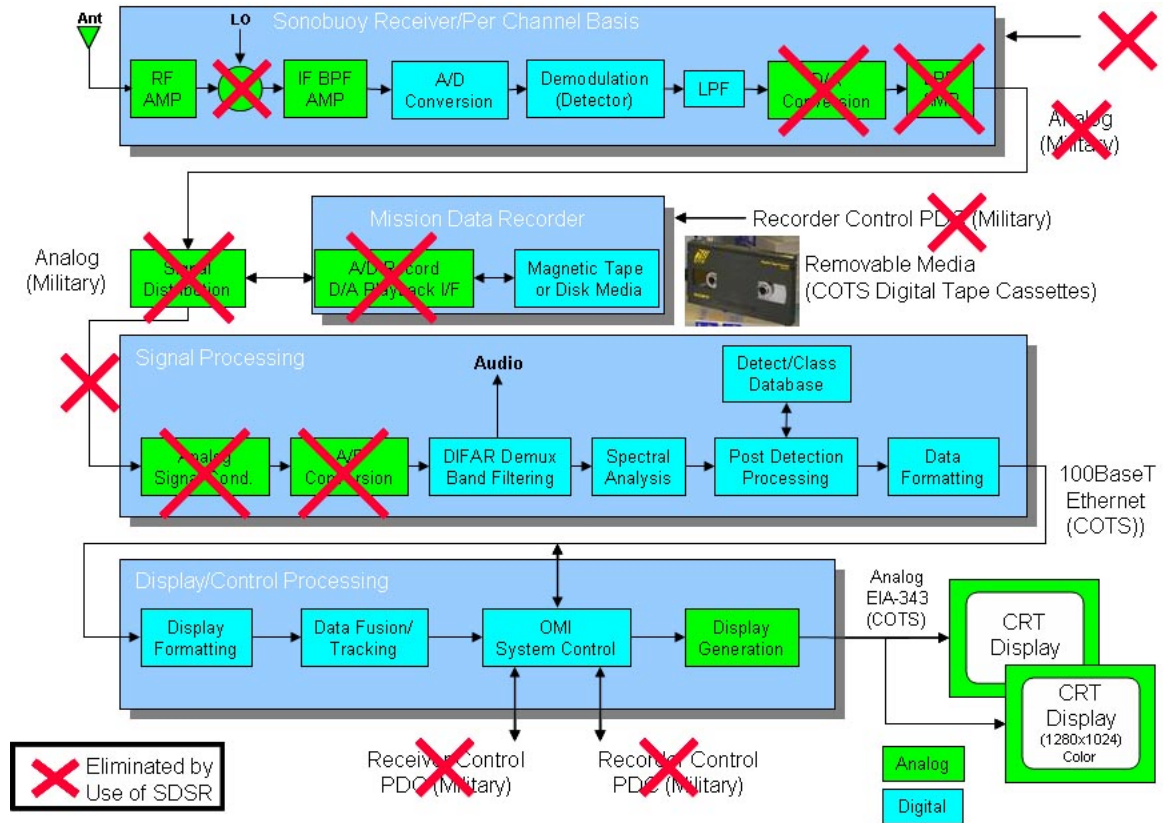


FIGURE B-8
P-3C BMUP ACOUSTIC PROCESSING FLOW⁽¹⁶⁾

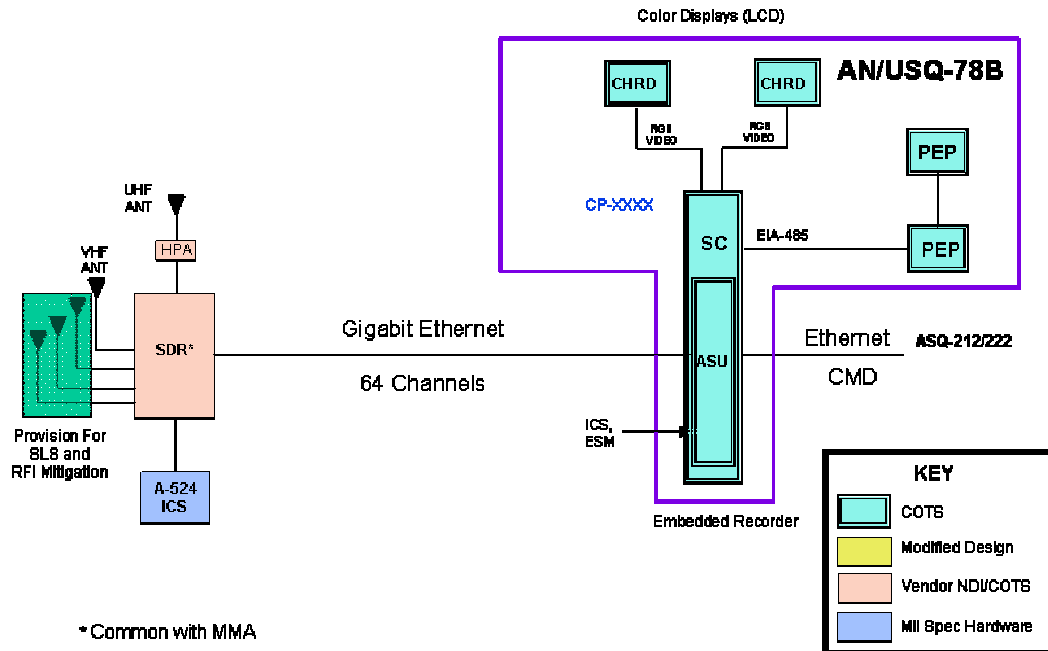


FIGURE B-9
USQ-78(B) APTR CONFIGURATION⁽¹⁸⁾

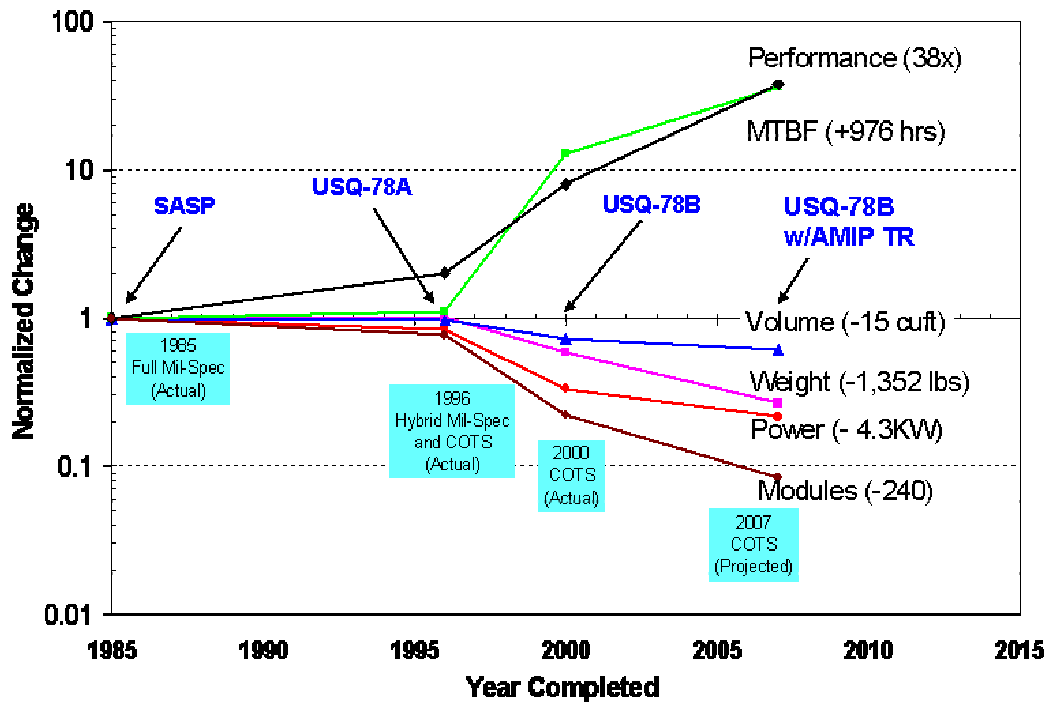


FIGURE B-10
P-3C ACOUSTIC SUBSYSTEM CHANGE PER YEAR⁽¹⁸⁾

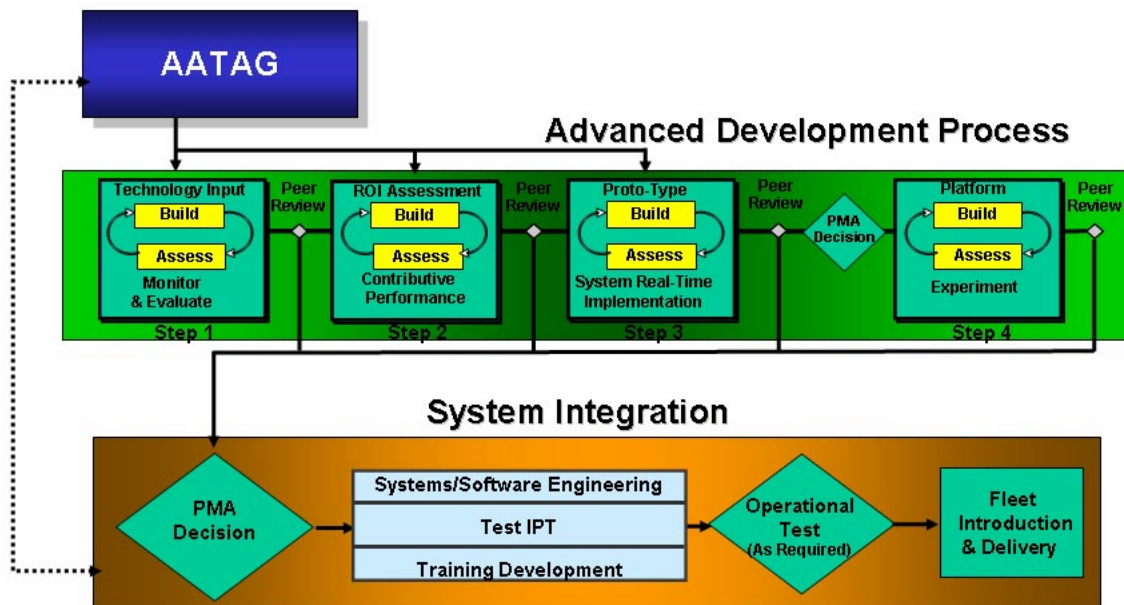


FIGURE B-11
AATAG INFLUENCE ON P-3C AIR ARCI DEVELOPMENT⁽¹⁸⁾

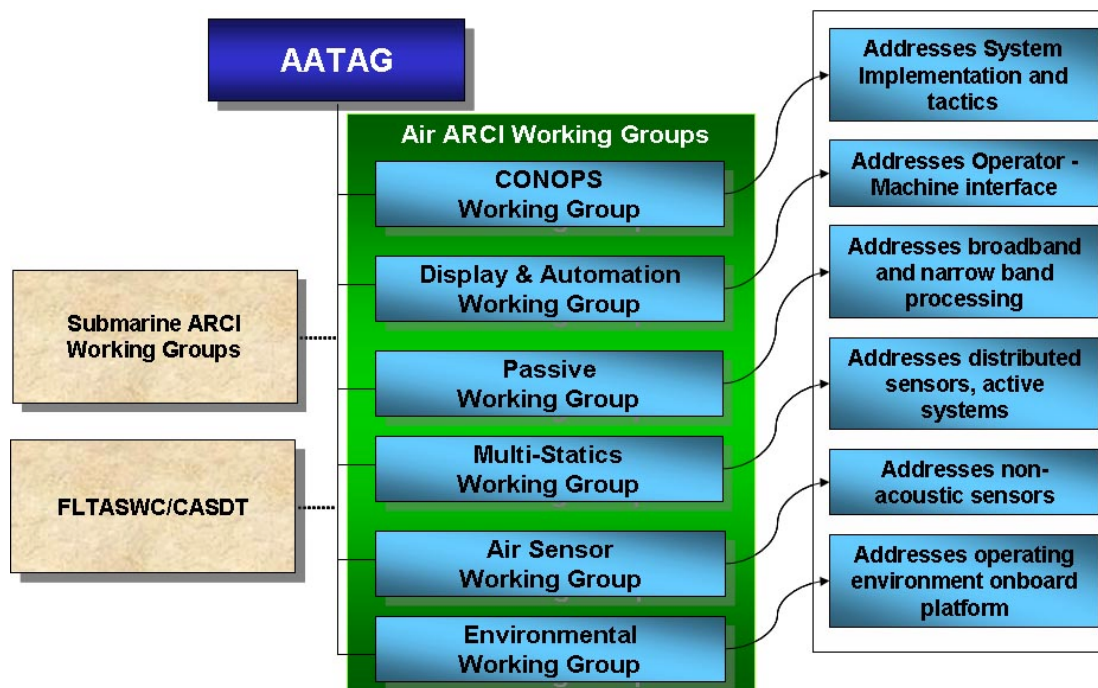


FIGURE B-12
AATAG RELATION TO OTHER WORKING GROUPS⁽¹⁸⁾

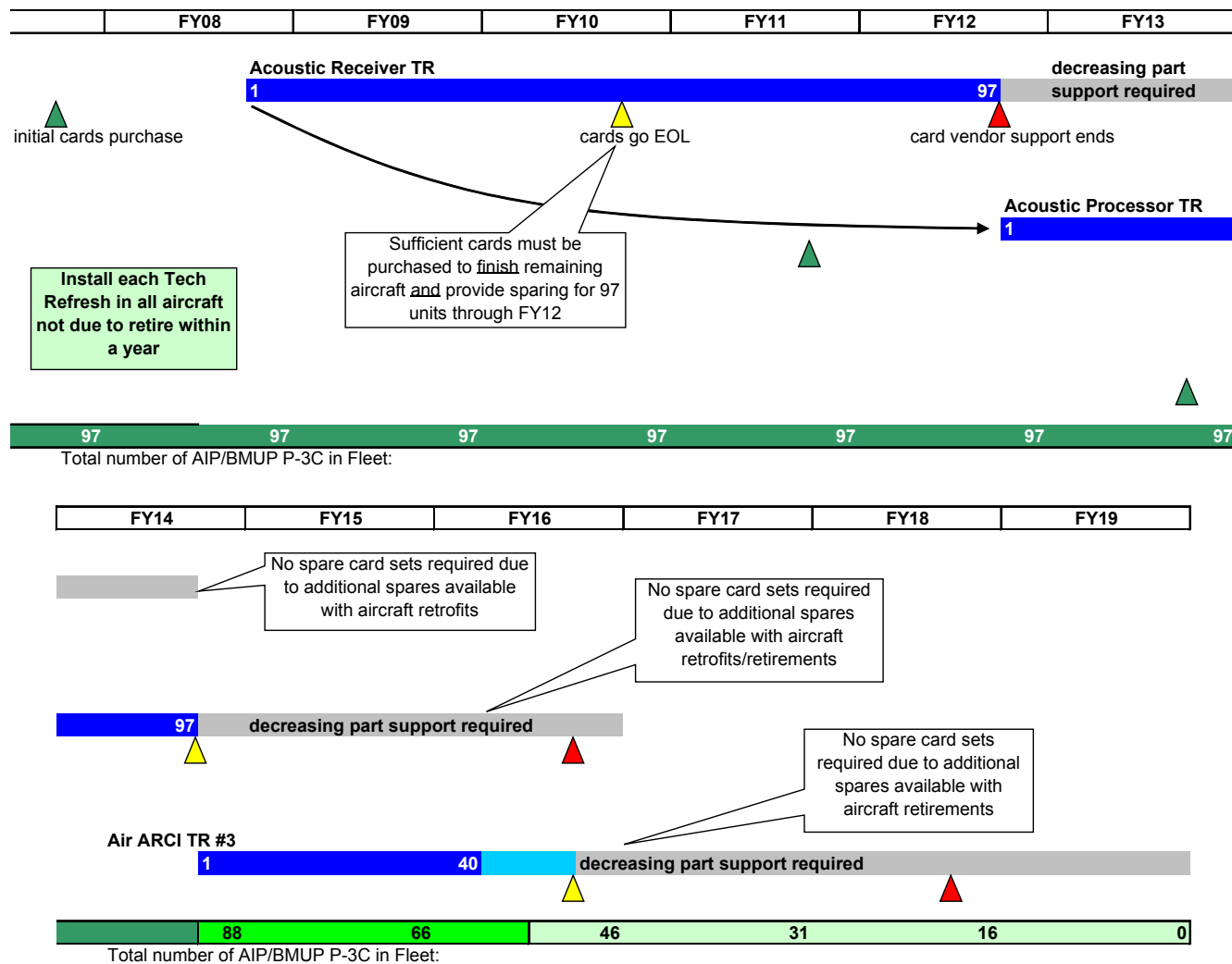


FIGURE B-13
NOTIONAL P-3C ACOUSTIC SYSTEM ROADMAP, OPTION 1

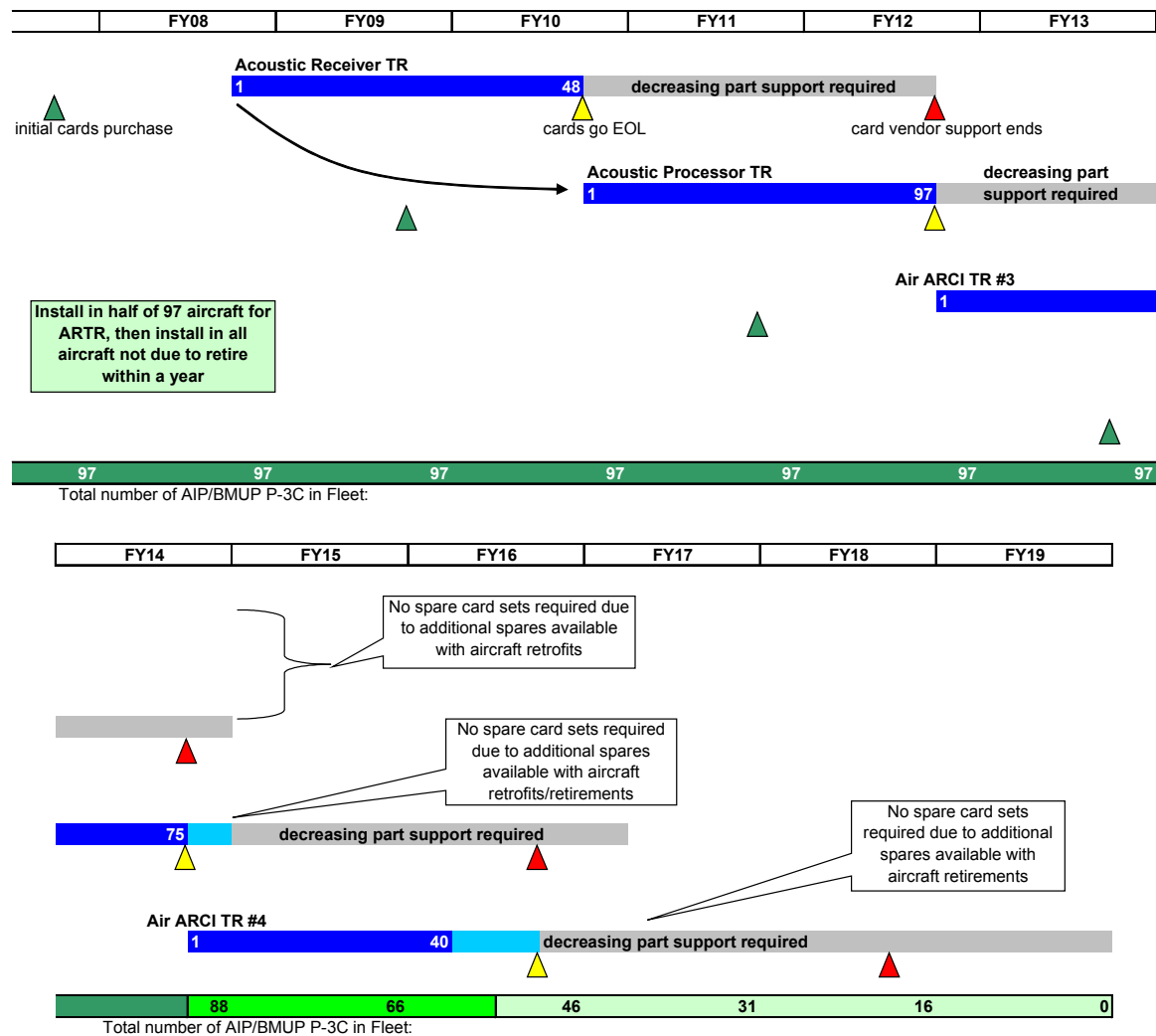


FIGURE B-15
NOTIONAL P-3C ACOUSTIC SYSTEM ROADMAP, OPTION 3

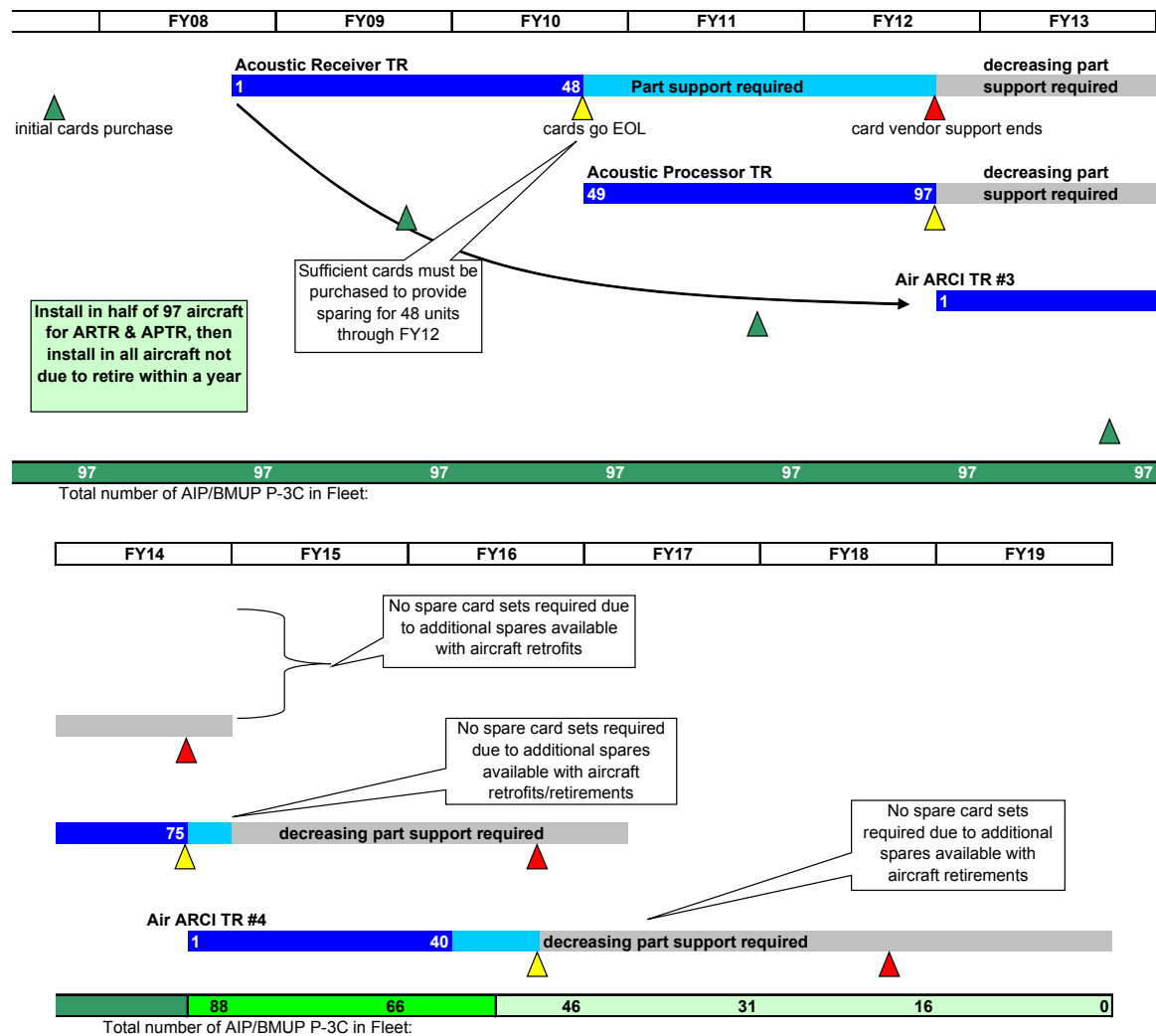


FIGURE B-16
NOTIONAL P-3C ACOUSTIC SYSTEM ROADMAP, OPTION 4

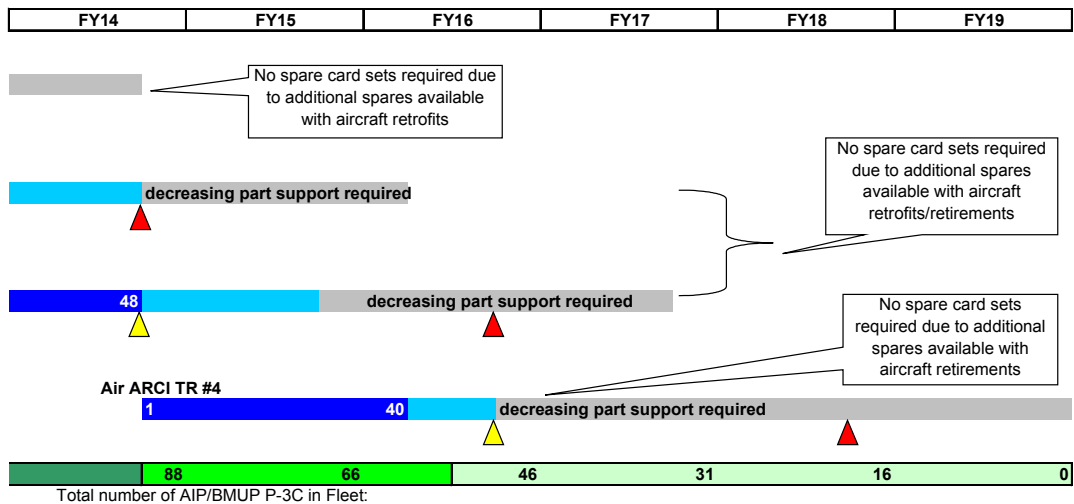
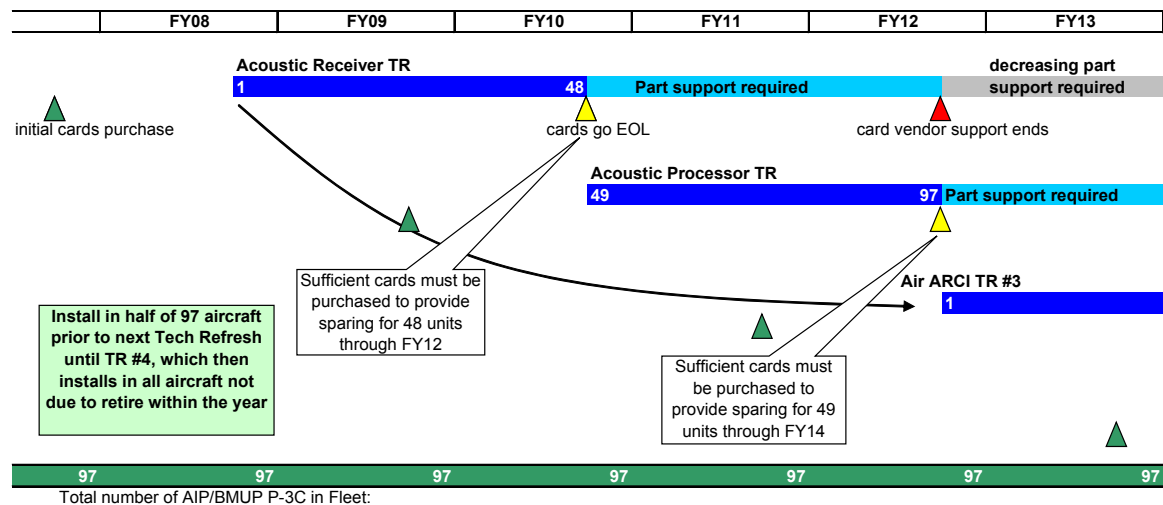


FIGURE B-17
 NOTIONAL P-3C ACOUSTIC SYSTEM ROADMAP, OPTION 5

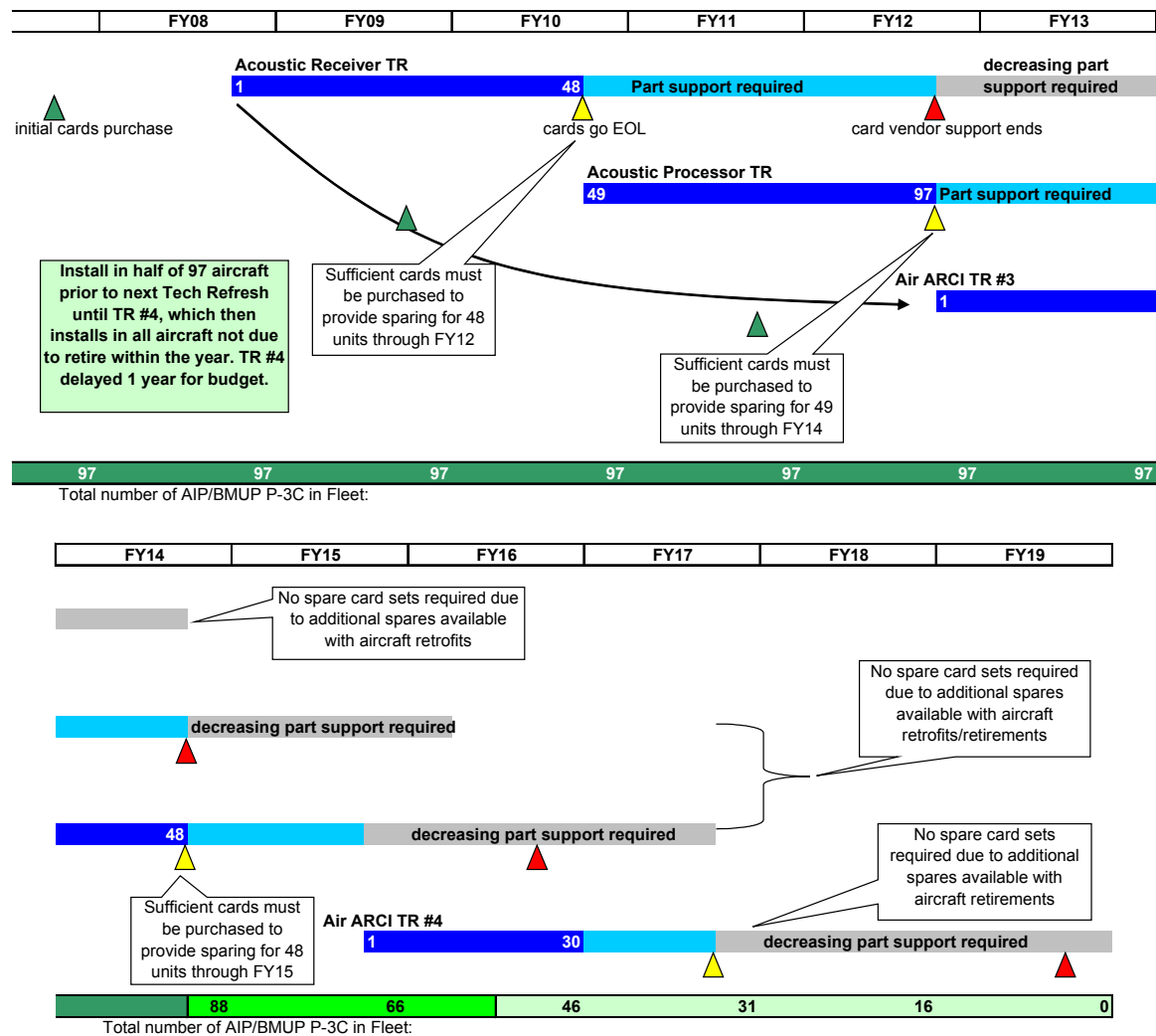


FIGURE B-18
NOTIONAL P-3C ACOUSTIC SYSTEM ROADMAP, OPTION 6

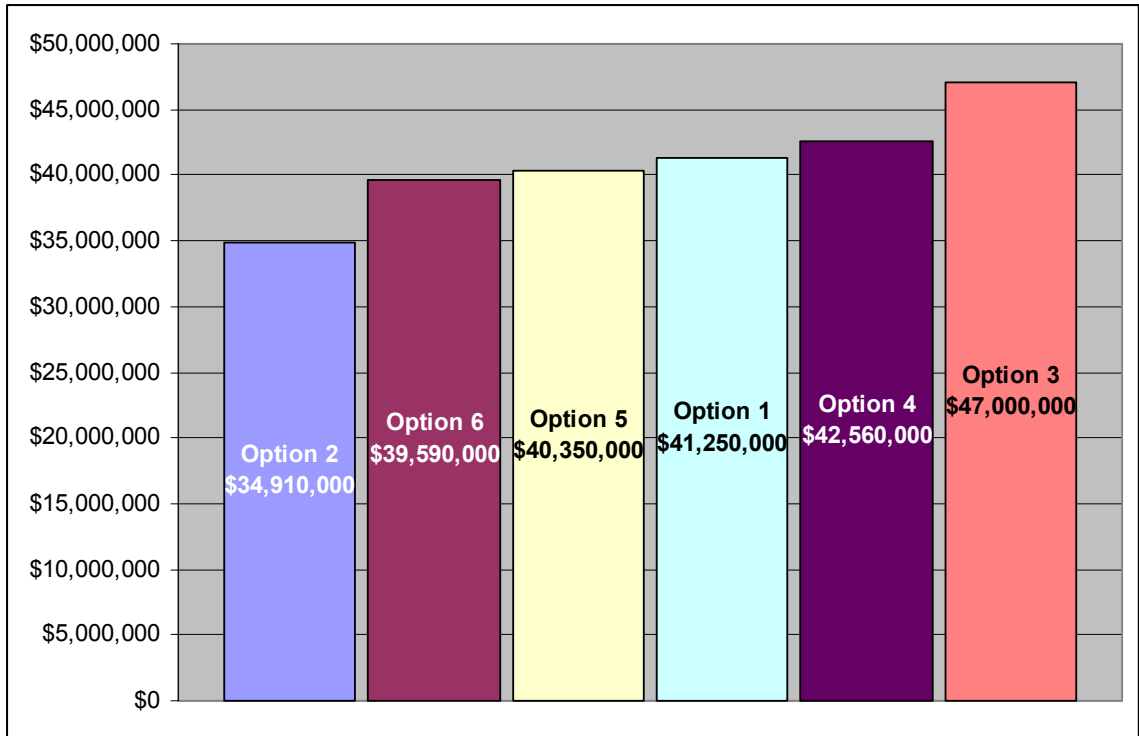


FIGURE B-19
NOTIONAL LIFE-CYCLE COSTS BY INSTALLATION OPTION

VITA

CDR John B. Gailey was born in Fresno, CA on August 14, 1969 and graduated from Marysville-Pilchuck High School in Washington State in 1987. John attended the University of Washington in Seattle and graduated in June 1991 with a B.S. in Aeronautical and Astronautical Engineering. Following commissioning in the United States Navy, he commenced flight training in Pensacola, FL and San Antonio, TX, which culminated in his designation as a Naval Flight Officer (NFO). Following a six month training period at the P-3C Fleet Replacement Squadron (VP-30), he was assigned to Patrol Squadron One (VP-1) from June 1994 to December 1997. During his three and one-half year tour he completed two six-month deployments: one to Japan and one to the Arabian Gulf region. He was next assigned as an instructor at VP-30 at NAS Jacksonville from December 1997 to December 1999. He served as an instructor for new first and second tour NFOs, preparing them for their Fleet squadrons. In January 2000, John reported to the U. S. Naval Test Pilot School (USNTPS) and graduated from the systems curriculum in December 2000 (Class 118). Upon completion, he was transferred to Naval Force Aircraft Test Squadron (NFATS), now Air Test and Evaluation Squadron TWO ZERO (VX-20), Patuxent River, MD, as a test NFO. While at VX-20, he was primarily involved as a Project Officer and lead test NFO for ACAT Level 1C and ACAT Level II CNO Special Programs. Redesignated an Aerospace Engineering Duty Officer, John reported to the Unmanned Aerial Vehicles Program Office (PMA-263) in August 2003, where he was the Mission Systems IPT Lead working on the Broad Area Maritime Surveillance UAV. He is currently assigned to the Maritime Patrol and Reconnaissance Aircraft Program Office (PMA-290) as the P-3C Update III Deputy Program Manager.