Chapter 1

1.0 Introduction

The U. S. Navy designed, developed, and built the world's most capable Bathythermograph Recording System more than 30 years ago with the introduction of the AN/SSQ-61 Bathythermograph Recorder. The system contained 1950s vacuum tube technology and 1960s analog componentry. The AN/SSQ-61 recorder was replaced with the AN/BQH-7 (Submarine) Recording System in 1978 and with the AN/BQH-7A (Surface Ship) Recording System in 1980. Even though this new recorder contained digital componentry, the majority of the design remained analog (strip chart drive, cassette tape recorder, etc.). Today, parts obsolescence is a problem of increasing magnitude as vendors either go out of business or eliminate dated components from their production lines.

The purpose of this project was to extend the service life of the aging AN/BQH-7/7A series bathythermograph recorder system by technical insertion of commercial-off-the-shelf (COTS) and non-developmental item (NDI) componentry using open systems architecture and acquisition reform principals. The project was initially proposed as a PMS415 Fleet Support Initiative in March 1995 to resolve the problem of parts obsolescence by re-engineering the recorder before the Fleet was seriously impacted.

This initiative was formalized by the approval of a Preliminary Engineering Change Proposal (PECP) in a PMS415 Configuration Control Board (CCB) Directive letter Ser PMS415L/20 of 12 February 1996. The initiative was formalized contractually by the Appendix C engineering services technical instruction (TI) authorization letter Ser PMS415D2/215 of 12 November 1996.

Several nomenclatures are used initially in Chapter 1 to describe this project. However, beginning in Chapter 2, the project is referred to as "The AN/BQH-7/7A EC-3 Project" or simply as "**AN/BQH-7/7A EC-3**". Other descriptors used include;

The PMS415 AN/BQH-7/7A Fleet Support Initiative (FSI)
PMS415 AN/BQH-7/7A FSI

The AN/BQH-7/7A Service Life Extension Program (SLEP)
AN/BQH-7/7A SLEP

The AN/BQH-7/7A EC-3 COTS & NDI Upgrade Program

The AN/BQH-7/7A EC-3 project and the systems engineering initiatives implemented by this author is the subject of this report. ***Chapter 1*** provides an overview of the project's purpose and then goes into the background of the current AN/BQH-7/7A recorder. The efforts that led to the discovery of the current supportability problem are discussed. The chapter then presents a description of the current recorder and of the proposed "EC-3" upgrade. The body of Chapter 1 establishes the formal need for change.

Chapter 2 discusses where the recorder is now in regard to the overall life-cycle of a typical system. It then proceeds with the specific systems engineering process initiatives implemented with the EC-3 project in relation to the overall life-cycle.

Chapter 3 presents the requirements analysis that began with extensive Fleet user coordination to elicit input. It then proceeds with a discussion of some considerations that led the early preliminary design through requirements and functional analysis, reliability analysis, and trade off studies to a prototype Bill of Material (BOM).

Chapter 4 presents an up-to-date look at the difficulties behind trying to predict Total Life-Cycle Cost (LCC) with systems employing COTS and NDI technologies and componentry. It attempts to answer the question on whether the use of COTS and NDI components is really benefiting programs today in the area of LCC. A successful example is presented. ***Chapter 5*** concludes.

1.1 System Overview

A system overview of the data recording system is provided in the following sections with emphasis on the operational and mission requirements and how these requirements are being met with the current recorder system.

1.1.1 Operational Requirements

As stated in the U. S. Navy Weapon Publications (NWPs) listed in Table 1 below, U. S. Naval Warships are required to have the ability to evaluate the ocean's acoustical environment for ray trace sound propagation paths while underway. The operational requirements in Table 1 are being met today with the AN/BQH-7 series bathythermograph recorder and with the family of expendable probes listed in Table 2. Table 2 also list, in comparison format, the specific probe types used by the AN/BQH-7 submarine recorder, the AN/BQH-7A surface ship recorder, and the proposed AN/BQH-7/7A EC-3 submarine and surface ship recorder. Table 3 is a complete list of expendable probes (and their attributes) available on the market today.

Table 1 - U. S. Navy Operational Requirements Documents for Oceanic Environmental Measurement Systems

NWP 1-10.24	Submarine Sonar Reference Manual
NWP 1-13.1	Evasion Pyrotechnic & Signal Device Reference Manual
NWP 3-31.65.3	Submarine Auxiliary Operations Guidelines
NWP 3-59.1	Tactical Use of the Ocean Environment

1.1.2 Mission Description

The bathythermograph recorder's functional requirement is to be immediately available to support the launch of the expendable probes listed in Table 2, while underway, every two hours (whereas in reality, it is whenever the Commanding Officer (CO) feels a launch is necessary in order to update the sonar performance database in sonar control). The recorder must interface directly with internal shipboard equipment (interfaces listed in Table 8, Chapter 3) and the externally launched probes listed in Table 2. The recorder must have the capability to communicate temperature and/or sound velocity data in real time by "hard copy" as the probe descends through the water column. The recorder must also have the capability to send the collected data electronically to internal shipboard systems. The above stated mission requirement resulted in the stand alone design feature of the current AN/BQH-7 series recorder.

Again, the periodicity of launching a probe is usually determined by the CO after conferring with the weapons and/or sonar officer on duty. On deployers in battlegroups, the operational documents state that the measurements must be taken by a "plane guard" operating forward of the battlegroup, every two hours. This information is then shared with all other ships in the battlegroup.

1.1.3 Functional Description

The recorder measures and displays ocean temperature or sound as a function of depth by using the expendable "over the side" surface or underwater (subsurface) launched probes listed in Table 2. Measurements are obtained in less than five minutes while the ship or submarine is underway. This data is then forwarded to internal shipboard environmental prediction and fire control systems as part of the sound propagation calculation for sonar performance evaluation.

Table 2 - Expendable Probe Types Used by Each Recorder

Probe Types	AN/BQH-7	ANBQH-7A	AN/BQH-7/7A EC-3
T-4		X	X
T-5		X	X
Fast Deep			X
T-6			X
T-7		X	X
Deep Blue			X
T-10			X
T-11			X
SSXBT	X		X
UISSXBT	X		X
XSV-01		X	X
XSV-02		X	X
XSV-03		X	X
SSXSV	X		X
UISSXSV	X		X
XCTD	X		X
SSXCTD	X		X
UISSXCTD	X		X

1.2 Problem Identification

In 1994, the AN/BQH-7/7A team began seeing an alarming trend in supportability issues associated with the AN/BQH-7/7A Bathythermograph Data Recorder System onboard practically every surface ship and submarine in the Fleet. At that point, we began monitoring Fleet casualty reports (CASREPs) and spare part requisitions and use through the Navy Inventory Control Point (NAVICP) Consolidated Ships Allowance Listing (COSAL) database. We discovered an alarming trend leading the program rapidly toward parts obsolescence. This was evident in the large increase in failed electronic circuit card assemblies (CCA) and mechanical assemblies (MA) which required expensive repairs and in some cases major redesigns in order to fix the problem at the Contractor Depot.

In March 1995 at Sippican Incorporated (the Navy's AN/BQH-7/7A Contractor Depot) in Marion, Massachusetts, an Integrated Product and Process Development (IPPD) Integrated Product Team (IPT) was established to study the feasibility of and resources available for the development of an Engineering Change (EC) Kit. The proposed IPT members were to consist of personnel from Commander, Submarine Force Atlantic Fleet (COMSUBLANT), Commander, Submarine Development Squadron 12

(COMSUBDEVRON 12), NAVICP's Inventory Manager and PMS415's AN/BQH-7/7A Technical Design Agent (TDA) and In-Service Engineering Agent (ISEA) from Naval Undersea Warfare Center (NAVUNSEAWARCEN). Sippican Incorporated and Techmatics Incorporated (NAVSEA support) participated as non-voting members.

We immediately began communicating with various Fleet offices to inform them of the problem and for the need for corrective action. After several Fleet meetings and conferences we received a written endorsement from Commander, Submarine Force U.S. Atlantic Fleet (COMSUBLANT) [see Appendix A] and were featured in a Fleet newsletter put out by Commander, Submarine Force U.S. Pacific Fleet (COMSUBPAC) [see Appendix B]. In addition to these endorsements, LCDR Jessie Carmen, Oceanographer for Commander, Submarine Development Squadron 12 (COMSUBDEVRON 12) wrote an article in the DEVRON 12 newsletter that said;

> ***"Fresh water eddies exist in many areas of the world. As we have experienced recently in the Gulf of Mexico using the Tactical Oceanographic Monitoring System (TOMS), there exist very distinct surface ducts that causes the Submarine Fleet Mission Program Library (SFMPL) sonar prediction to be unreliable. Accurate bathythermic information is paramount and a precursor for accurate sonar predictions."***

In a follow-on phone call with LCDR Carmen after this article was published, she unanimously endorsed the AN/BQH-7/7A EC-3 effort by stating;

> ***"We at DEVRON 12 fully endorse the AN/BQH-7/7A EC-3 Program which not only extends the service life of this valuable Fleet system but also addresses this problem (addressed in her article) head on."***

Likewise, in a report back to PMS415 from Commander, Naval Undersea Warfare Center Detachment (NAVUNSEAWARCEN DET) Arctic Submarine Laboratory (ASL) on their experiences with the performance of the (UI)SSXCTD submarine conductivity probe they used extensively in a recent expedition "under the ice" Al Hyasheda wrote;

> ***"ASL agrees strongly with the need for change and fully endorses the capability and operability of the Sippican Mk-12 Data Acquisition System chosen for use in the AN/BQH-7/7A EC-3 SLEP Program".*** *(See Figure ??, Chapter 2)*

With these endorsements in hand, the IPT team unanimously endorsed the proposal to develop the Engineering Change (EC) Kit in a meeting later that same year. A Preliminary Engineering Change Proposal (PECP) was developed, submitted, revised, and resubmitted to the NAVSEA PMS415 Configuration Control Board (CCB) for approval. The PECP was subsequently approved by the CCB on 12 February 1996 by CCB Directive letter Ser PMS415L/20.

The IPT team is now proceeding with the development of ECP PM-BQH7-P0003 with plans to submit it to the CCB this summer (17 months after the original PECP was approved by the CCB). ***The outcome of this summer's CCB will be EC-3 to the AN/BQH-7 Series Bathythermograph Recorder (referred to hereon as AN/BQH-7/7A EC-3).***

The main goal and objective of the proposal was to extend the service life of the recorder and improve the performance by initiating an affordable technology insertion upgrade program using COTs and NDI componentry. Our forecast predictions showed that we could reduce the extent of the eminent parts obsolescence problem before the Fleet was severely impacted if we could be ready for full implementation in early 1998. By combining desire, initiative, and creative programmatics with acquisition reform and rapid prototyping principals; we believed this goal was achievable even without an identified budget with which to work with.

Since our budget for this effort was literally zero, we knew it would also take some hard work to make the program successful. We achieved success in this endeavor by auditing several contracts to identify unexpired dollars that remained. We then backtracked to the source of the funds to the appropriate NAVSEA offices and approached them with the EC-3 proposal. Written concurrence was eventually received in all cases. The program began with a formal proposal to the IPT team in March 1995. With the IPT in place, the preliminary design work began. A high level program timeline is depicted graphically in Figure 1 below.

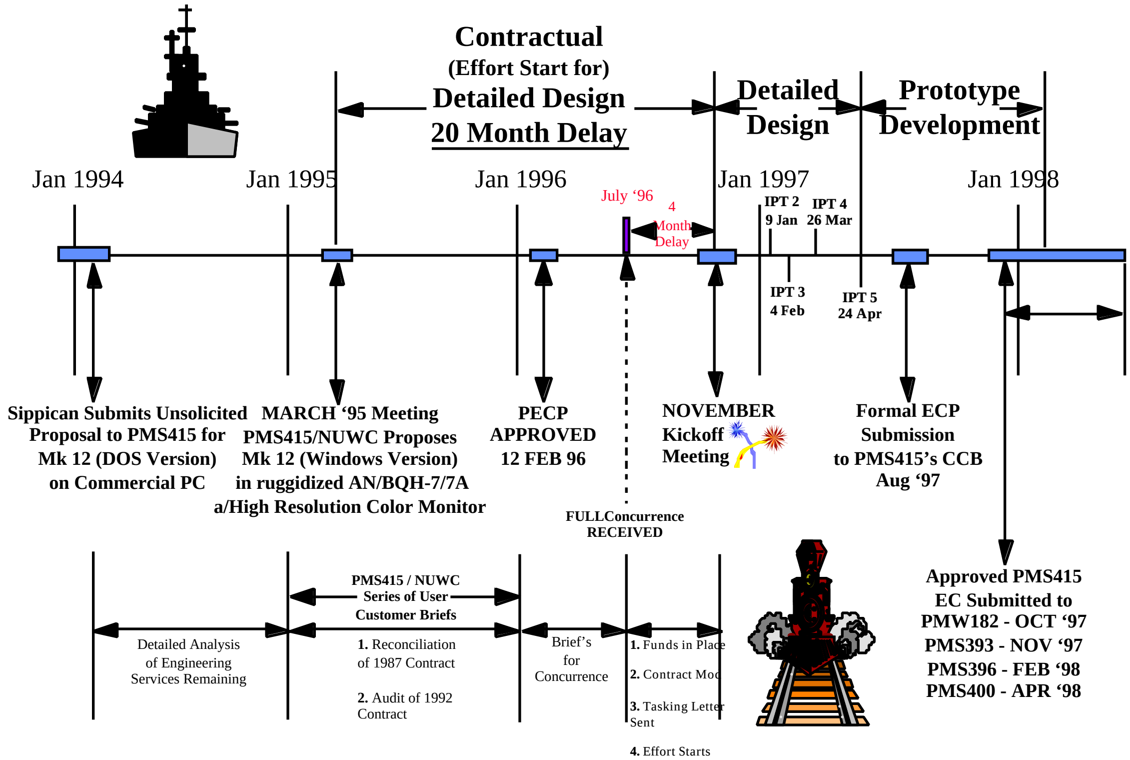


Figure 1 - AN/BQH-7/7A EC-3 Program Timeline and Milestones

1.3 Description of Proposed Change to Resolve Problem

The IPT team proposed that the strip chart recorder, printed circuit card chassis, and magnetic tape recorder (built with 1960s and 1970s technology) be removed and replaced with commercial off the shelf (COTS) and non-developmental item (NDI) IBM PC compatible components in an open system modular architecture using acquisition reform contractual implementation methods.

1.3.1 AN/BQH-7/7A EC-3 System Description

The proposed system had to meet all current Fleet requirements. A Functional Requirements Allocation Matrix was created for traceability of COTS and NDI hardware to original requirements and is presented in Appendix F. A critical requirement that was tracked was the interface and performance compatibility function with the expendable probes and the specific performance attributes associated with each (listed in Table 3 below).

Table 3 - Launched Expendable Probe Types and Attributes

Probe Type	Range Max Depth (ft.)	Rated Ship Speed (knots)	Resolution Vertical Distance Between Data Points (ft)	Part Number	Depth Accuracy	Accuracy
T-4	1,500	30	2.2	207592-1	+/- 2%	± 0.2C
T-5	6,000	6	2.2	211105-1	+/- 2%	± 0.2C
Fast Deep	3,280	20	2.2	211105-2	+/- 2%	± 0.2C
T-6	1,500	15	2.2	211965-1	+/- 2%	± 0.2C
T-7	2,500	15	2.2	210883-1	+/- 2%	± 0.2C
Deep Blue	2,500	20	2.2	300686-1	+/- 2%	± 0.2C
T-10	660	10	2.2	213412-1	+/- 2%	± 0.2C
T-11	1,500	6	0.7	213713-1	+/- 2%	± 0.2C
SSXBT	2,500	3	2.2	212867-1	+/- 2%	± 0.2C
UISSXBT	2,500	3	2.2	214673-1	+/- 2%	± 0.2C
XSV-01	2,790	15	1.3	213796-1	+/- 2%	± 0.25 m/sec
XSV-02	6,560	8	1.3	300023-1	+/- 2%	± 0.25 m/sec
XSV-03	2,790	5	0.4	300817-1	+/- 2%	± 0.25 m/sec
SSXSV	2,790	3	1.3	300708-1	+/- 2%	± 0.25 m/sec
UISSXSV	2,790	3	1.3	300648-1	+/- 2%	
XCTD	3,280	10	3.2	305039-1	+/- 2%	± 0.035° C ± 0.035 mS/cm ± 0.05 PSU
SSXCTD	3,280	3	3.2		+/- 2%	± 0.035° C ± 0.035 mS/cm ± 0.05 PSU
UISSXCTD	3,280	3	3.2		+/- 2%	± 0.035° C ± 0.035 mS/cm ± 0.05 PSU

1.3.2 AN/BQH-7/7A EC-3 System Goals and Objectives

The IPT team agreed on the following design goals with the Fleet user in mind. The overarching goal was to develop an affordable easy to operate (and support) EC Kit that would extend the service life while improving the performance of the current AN/BQH-7/7A recorder.

- Design Simplification - Reduction in number of circuit cards. Implementation of open systems architecture (OSA) modular design in architecture.

- Decreased Maintenance Cost - Reduce if not eliminate the need for a large number of Maintenance Assist Modules (MAMs).

- Increase in Reliability - Increase reliability by approximately 3 fold.

- Reduced Manpower Requirements - Simplify maintenance and troubleshooting procedures to reduce preventive and general maintenance manning level requirements while increasing Mean Time Between Maintenance (MTBM) and decreasing the Mean Time To Repair (MTTR).

- Future Growth - Implementing open systems architecture design for ease of future technology insertions.

- Performance Upgrade - Improve data acquisition performance by adding capability to launch and receive data from high resolution expendable probes (XBTs & XSVs) and expendable conductivity/temperature/depth (XCTD) probes which will improve the submarine forces ballasting capability but will also enhance the Fleet's sonar performance and prediction ability in;
  - littoral waters
  - regional areas with fresh water eddies
  - open ocean salinity fronts
  - near ice flows

- Easier to Use - Replace high maintenance analog strip chart recorder with a ruggedized high resolution color monitor. Add zoom, overlay, and side by side trace comparison capability in software.

Chapter 2

2.0 Engineering Process and Project Design Methodology

The purpose of this chapter is to present the AN/BQH-7/7A EC-3 IPT design and management processes implemented to date. These processes are discussed and presented in reference to the overarching systems engineering process presented in Figure 2. Section 2.5 presents the “Need for Change”. Section 2.6 presents the methodology used in implementing the change and briefly discusses the acquisition reform measures used. The Integrated Process and Product Development (IPPD) Integrated Product Team (IPT) approach is presented as the manner in which resources were organized to accomplish the tasks.

2.1 Systems Engineering Process

The Systems Engineering Process is presented in Figure 2 in terms of the life cycle of the system. The current AN/BQH-7/7A recorder is close to 20 years old and therefore very clearly in Phase V of the system’s life cycle. The bold arrows leading from Phase V show the systems engineering processes and life cycle phases that were revisited prior to formally proposing the AN/BQH-7/7A EC-3 project in final Engineering Change Proposal (ECP) format. Note that the bold arrows proceed out to Phase I, Phase II, and Phase III. After EC-3 kit development and laboratory and at-sea “proof-of-concept” testing, the EC-3 project will enter production (Phase IV). Various input-output and value-added feedback loops could be further discussed in this chapter to further illustrate the management and systems engineering processes implemented in the EC-3 project. For brevity sake, the feedback loops illustrated in Figures 2 and 4 were considered adequate when combined with the additional exhibits presented and discussed in this Chapter.

The overarching system engineering process in Figure 2 was partitioned into manageable (easy to implement) phases as presented in Figure 3. The task or process flow used to accomplish each of the work tasks in each of the phases in Figure 3 were then further broken down (or partitioned). An example of this further partitioning is shown in Figure 4. The work flow (or task flow) presented Figure 4 was that used to accomplish the work in Phase II of Figure 3 where the end products were the final Bill of Material (BOM) and Engineering Change Proposal (ECP). The engineering studies and project “deliverables” implemented by the IPPD IPT and required to ensure compliance with the systems engineering process are presented in Figure 5 and explained in detail in the Technical Instruction Statement of Work in Appendix C, Enclosure 1.

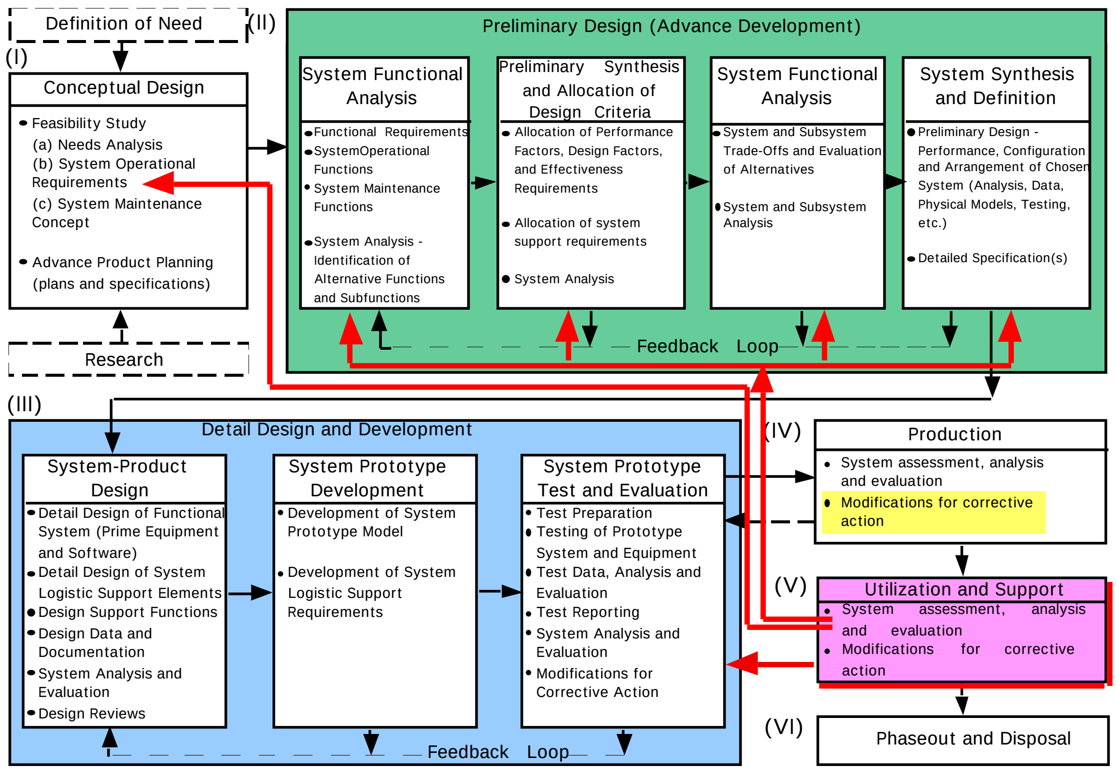


Figure 2 - Systems Engineering Life-Cycle Process

2.2 Systems Engineering Life-Cycle Process

The systems engineering process phases addressed in this report are illustrated by the bold arrows in Figure 2.[1] As mentioned earlier, the current AN/BQH-7/7A system has been fielded in the Fleet for close to 20 years and is therefore in Phase V of the AN/BQH-7/7A system's life cycle. The bold arrows show the system life-cycle phases that were revisited during the progression through concept design to detailed design and prototype development of the future AN/BQH-7/7A EC-3 recorder.

As stated in the first paragraph of Section 1.2, Problem Identification; several metrics or indicators bought our attention to the support problems facing the fielded AN/BQH-7/7A recorder. The Need for the current recorder's Phase V "Modification for Corrective Action" was based upon support issues brought to light by monitoring the following metrics;

- Fleet Causality Reports (CASREPs)
- Spare Part Requisitions
- COSAL Database Spare Part Usage
- Number of ECNs Presented over time at our Contractor Depot

The most valuable, readily assessable, and visible metric was the number of ECNs presented over time due to parts obsolescence. This information along with other data obtained showed a clear need for the IPT to take immediate action.

2.3 Partitioning of Effort into Manageable Phases

As stated in Section 2.1, "The Systems Engineering Process"; the overarching systems engineering process illustrated in Figure 2 was partitioned (or broken down) into manageable phases as presented in Figure 3. The work in each of these managed phases were further partitioned into task or work flow processes. Figure 4 is the work flow process associated with Phase II of Figure 3 and shows the steps implemented by the IPT in conducting the engineering studies and analysis required in obtaining a final Bill of Material (BOM) and ECP while at the same time ensuring that each of the steps in the systems engineering process was followed. The approach was contractually implemented through the Technical Instruction (TI) in Appendix C.

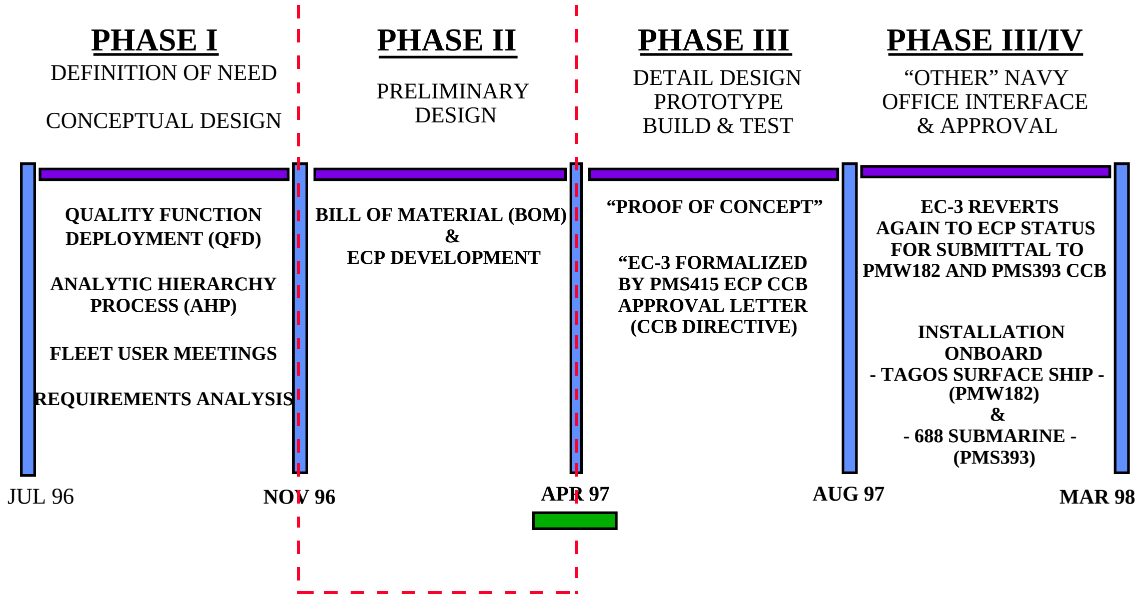


Figure 3 - EC-3 Recorder Design-to-Fielding Phasing Plan

The phases at the top of Figure 3 represent the system life-cycle phases of the future AN/BQH-7/7A EC-3 recorder system. The vertical bars in the center of Figure 3 divides the EC-3 conceptual design - detailed design - prototype development effort into four manageable phases. Phase I represents the early conceptual design considerations of the future EC-3 recorder. Phase II represents the preliminary design, Phase III represents the detailed design, and Phase III/IV represents the effort required prior to transitioning into production.

Just as Figure 3 took a partitioning (phasing) approach to the management effort behind the EC-3 project in relation to the overarching systems engineering process in Figure 2, Figure 4 took a similar partitioning approach by partitioning the overarching systems engineering process efforts (or taskings) into work flow or task flow phases. Figure 4 represents only one phase of the overall systems engineering process and covers pre-Phase II to post-Phase II of the future EC-3 recorder effort. Another way of saying this is that the Figure 4 work flow phase is specific to Phase I, II, and III of the EC-3 project (with a strong focus on Phase II). Note the Input/Output and Value Added Feedback Loops.

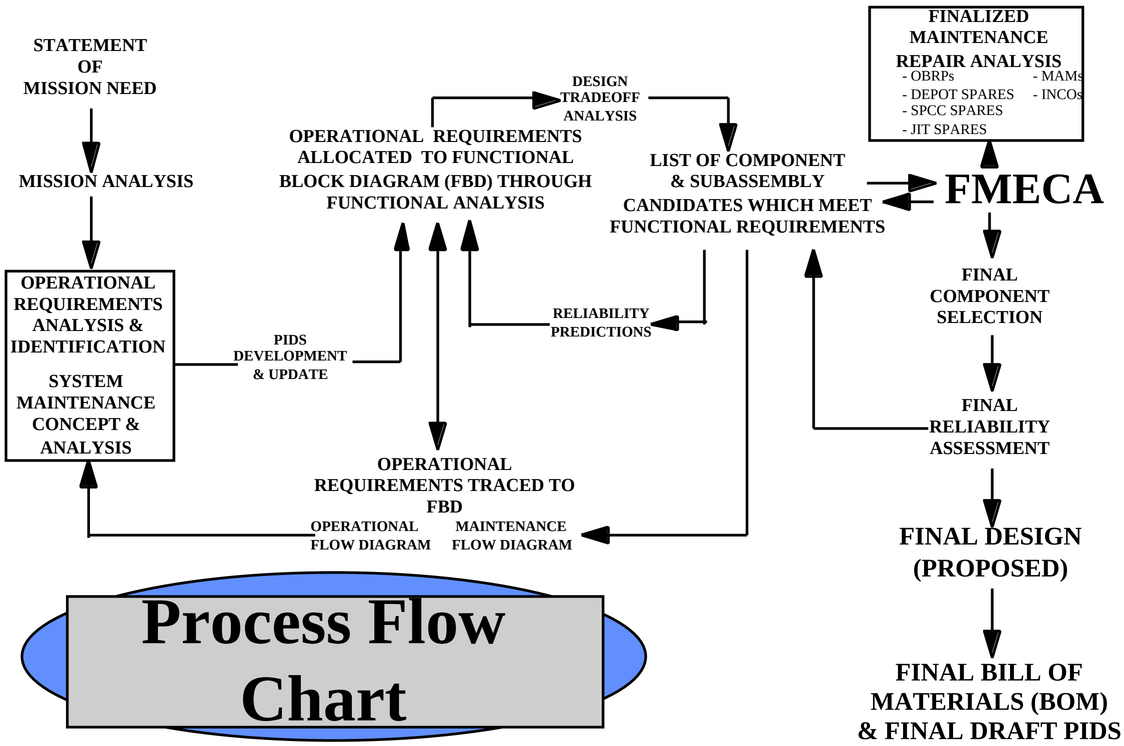
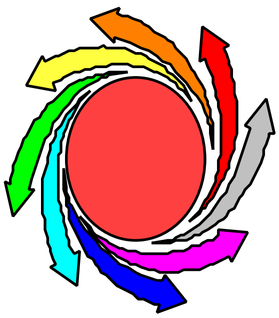


Figure 4 - Work Process/Task Flow Chart for Phase II

The AN/BQH-7/7A EC-3 program was "formalized" contractually on 12 November 1996 with the engineering services technical instruction (TI) authorization letter (Ser PMS415D2/215) in Appendix C. Figure 5 shows a high level look at how the TI effort was broken down into easily manageable systems engineering subtasks with associated "deliverables". The engineering studies and project deliverables are explained in detail in the Technical Instruction Statement of Work in Enclosure 1 to Appendix C.

2.2 PIDS

- Operational Requirements
  - Performance Requirements
  - Functional Requirements
- Maintainability Requirements
- Sparing Requirements
- Test Requirements



2.3 PDD

- 2.3.1 Update PEA Analysis
  - Include PESHA
- 2.3.2 Functional Block Diagram
  - Operational Flow/Sequence Diagram
- 2.3.3 Reliability / FMECA Analysis
  - Document Trade Off Analysis
  - Ruggidization Assessment
- 2.3.4 Top Level Breakdown of BOM
  - Reference Designators
  - Component Name and Quantity
  - Vendor Name/Phone No. & Part Number
  - Projected Manufacturing End Date
  - Fully Loaded Cost (Component/SubAssembly/Unit)
- 2.3.5 Maintenance Flow Diagram (MFD)
  - MTBF Analysis
- 2.3.6 PTD w/Recommended Sparing Candidates
- 2.3.7 MTTR and M-Demo Procedures
- 2.3.8 SW Description
- 2.3.9 Hull Specific/Unique Variant Description/Analysis
- 2.3.10 Top Level Assembly/Subassembly Dwgs

2.4 PTD

2.5 SUPPORT

2.6 PIDS V&V

2.7 ECP

2.8 PSD

2.9 TM

2.10 TMD

Figure 5 - Allocation of Systems Engineering Sub-Tasks

Several reasons can be given for using the approaches discussed thus far. However, by far the main reasons for this particular partitioning and implementation approach was for;

- Optimum Implementation of Design Using Systems Engineering Processes,
- To Enhance Communication Between the IPT Members and Fleet Users,
- Simplicity and Ease of Program Implementation,
- Program Accountability and Traceability.

2.4 Systems Engineering Process Elements

Figure 6 shows the systems engineering process elements used in breaking down the EC-3 Phase II process into manageable elements that could be easily measured and tracked. Measurability is an important principal. Just as the systems engineer should be able to validate requirements through tests (bench test, environmental test, at-sea test), systems engineering processes should be measurable to validate progress, effectiveness or need for change.

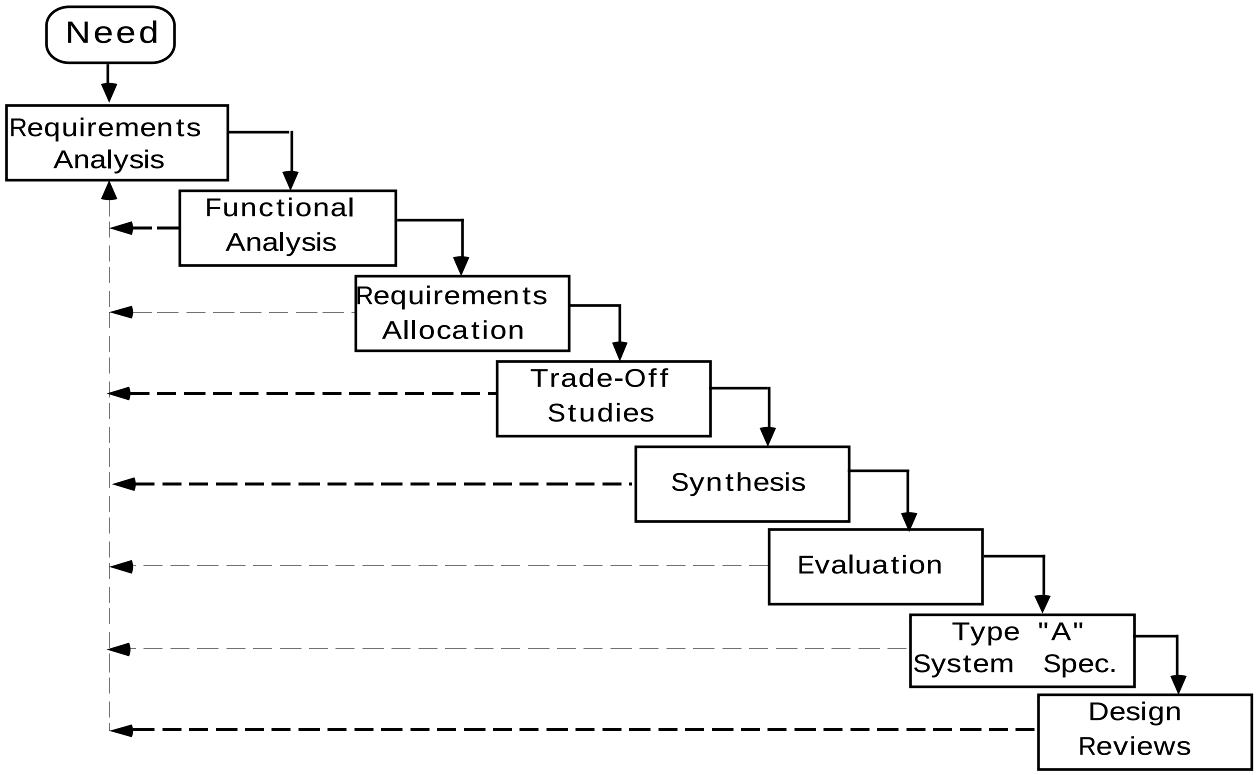


Figure 6 - Systems Engineering Process Elements [2]

2.5 Need for Change

As discussed in Section 1.2 "Problem Identification" and presented in Section 2.2 "Systems Engineering Life-Cycle Process", several indicators showed the IPT team that there was a real problem with parts obsolescence and with a lack of vendor support. In an attempt to better define the apparant trend, the IPT team went back in time and documented the number of ECNs presented over a given period. Table 4 shows the number of ECNs presented as a direct result of parts obsolescence over the last several years. The ECN activity includs both simple changes, where a direct replacement part had been identified and qualified, and complex changes, where extensive redesign and qualification was required.

Table 4 - Correlation of Parts Obsolescence Impact to Number of Engineering Change Notices (ECNs) Over Time

Year	Design Modifications	Change of Vendor	Change of Component	Total ECNs Per Year
1987		2	1	3
1988		3		3
1989		3	1	4
1990		2	5	7
1991		4	1	5
1992			2	2
1993			2	2
1994	1	4	6	11
1995		5	5	10
Total	1	23	23	47

Table 4 shows that a higher number of ECNs were presented in more recent years than past years. Whereas most of the ECNs were relatively low in cost (projected at approximately $4,000 per ECN), the design modification in 1994 cost the program $125,000. This cost was due to the need for a new circuit board layout because of the inability in finding a direct pin for pin replacement for a major component of the system. In this case, the component vendor had stopped manufacturing and even supporting (through inventory) this component many years prior. The next logical step was to conduct a vendor's survey on some of the most likely component candidates in the current AN/BQH-7/7A design which were believed to be on the verge of parts obsolescence. The vendor manufacturers were queried as to how much longer the parts would be in production and their plans for supporting their product once production was halted. Table 5 below documents the results of this survey.

Table 5 - Vendor Supportability Survey for Current AN/BQH-7/7A Recorder Components

PART NO.	DESCRIPTION	COMMENTS	TIME TO OBSOLESCENCE	DIRECT REPLACEMENT
115753	IC, FLIP FLOP, M38510/05102BEX (CD4027A)	OLD 4000 SERIES “A” REVISION	2 TO 3 YEARS	YES
115151	IC, NAND GATE, M38510/05001BCB (CD4011A)	OLD 4000 SERIES "A" REVISION	2 TO 3 YEARS	YES
115146	IC, NAND GATE, M38510/05003BCB (CD4023A)	OLD 4000 SERIES "A" REVISION	2 TO 3 YEARS	YES
115150	IC, AND/OR GATE, M38510/05302BEA (CD4019A)	OLD 4000 SERIES "A" REVISION	2 TO 3 YEARS	YES
115152	IC, BUFFER, M38510/05503BEB (CD4049A)	OLD 4000 SERIES "A" REVISION	2 TO 3 YEARS	YES
115754	IC, COUNTER, M38510/05601BEX (CD4017A)	OLD 4000 SERIES "A" REVISION	2 TO 3 YEARS	YES
115147	IC, REGISTER, M38510/05703BEB (CD4105A)	OLD 4000 SERIES "A" REVISION	2 TO 3 YEARS	YES
115148	IC, REGISTER, M38510/05704BEB (CD4021A)	OLD 4000 SERIES "A" REVISION	2 TO 3 YEARS	YES
115095	IC, INVERTER, M38510/00105BCB (5404)	OLD LOGIC DEVICE	2 TO 3 YEARS	NO
115002	IC, FLIP FLOP, M38510/00205BCB (5474)	OLD LOGIC DEVICE	2 TO 3 YEARS	NO
115093	IC, BUFFER, M38510/00803BCB (5407)	OLD LOGIC DEVICE	2 TO 3 YEARS	NO
410121-1	IC, INTERFACE (MD8255)	OLD LOGIC DEVICE	2 TO 3 YEARS	NO
410178-1	IC, EPROM (MD2732A-25/B)	OLD LOGIC DEVICE	2 TO 3 YEARS	NO
410177-1	IC, MICROPROCESSOR (MD8085AH/B)	OLD LOGIC DEVICE	2 TO 3 YEARS	NO
115801	IC, STATIC RAM, M38510/23804BVB (MD2114)	OLD STATIC RAM	2 TO 3 YEARS	NO

Table 5 shows that a number of older components will be due for replacement soon. The manufacturers have indicated that only about 50% of these parts will have direct replacements. This means that the other 50% of the time, expensive design modifications like the one in 1994 may be required. Armed with this information, it because apparent that a long term solution needed to be pursued in order to keep this capability in the Fleet. Whereas some newer ship classes were incorporating this capability into the open systems architecture of new COTS equipment, the rate at which the consolidation of function was occureing showed that the AN/BQH-7/7A recorder would remain in the Fleet for many years to come. To do nothing was not an option.

The IPT then began a detailed cost analysis to show the impact of parts obsolescence on the Fleet users (i.e., AEGIS & Minehunter surface ships and 688/688I & Trident submarines). Four cost categories were analyzed;

(1) the cost of engineering associated with the search for replacement parts and the redesign and requalification required when replacement parts could not be found,

(2) the cost of implementing the EC-3 upgrade to the AN/BQH-7/7A,

(3) the cost of repairs for the old system,

(4) the cost of repairs for the new EC-3 system.

The cost of parts obsolescence along with operability and maintainability benefits to the proposed EC-3 design were then assembled and presented to various Fleet organizations and users. The maintainability and operability benefits (discussed at the end of Chapter 1 and in Chapter 3) were nearly as persuasive as the cost benefits. This was because the mechanized components and subassemblies, which were to be replaced by digitized functions in the new EC-3 design, were high maintenance items. These mechanized components included the cassette drive and cassettes, chart drive and chart paper, chart assembly, panel switches, and lights. The Fleet realized that the high maintainability requirements would be reduced and simplified in the EC-3 design thereby eliminating the need for constant operator calibration and maintenance. Currently, the chart drive often needs adjustment when the paper is replaced and the two calibration potentiometers require constant adjusting due to varying humidity. In addition, the cassette transport head must be kept clean to assure reliable data storage.

As discussed in detail in Section 1.2 “Problem Identification”, extensive user briefs continued over time with the Fleet. The end result was a direct endorsement by Submarine Force U.S. Atlantic Fleet (see Appendix A) and an indirect endorsement by Submarine Force U.S. Pacific Fleet (see Appendix B).

2.6 Processes and Initiatives Implemented

This section presents a brief look at some of the DoD 5000.2 initiatives implemented in the AN/BQH-7/7A EC-3 program. The processes for implementing these initiatives will be tailored (or fine tuned) as the program matures and as more lessons are learned.

2.6.1 Acquisition Reform

Acquisition Reform is a relatively new initiative (required by the new DoD 5000.2 Instruction) for conducting government business in the future. The guidance includes key elements of a strategy for integrating the military and commercial industrial base to increase innovation, foster managed risk, encourage empowerment and to establish cross-functional teams using world-class commercial practices. In other words, there is much that can be discussed on the topic of Acquisition Reform. The discussion in this section is limited to a few key areas specially used in the implementation of the EC-3 project.

2.6.1.1 Integrated Process and Product Development (IPPD) Integrated Product Team (IPT)

The DoD 5000.2 Instruction principals were implemented as the preferred management approach by the AN/BQH-7/7A EC-3 IPT by incorporating a IPPD management philosophy as guidance for the business practices implemented in the EC-3 program which should be evident in this paper though the business decisions discussed.

The AN/BQH-7/7A EC-3 leadership implemented a IPT cross-functional team approach to integrate and benefit from the knowledge and experiences of a cross-functional team in building an affordable product (the EC-3 Kit) for our Fleet customer.

2.6.1.2 Commercial Standards Implementation

In the Appendix C TI letter, all Military Standards were discarded and replaced with commercial standards. As stated in the letter;

> "All work is to be performed in accordance with the enclosure (1) Statement of Work (SOW) and using the Systems Engineering Interim Commercial Standard ***EIA/IS-632***, ISO-9001 procedures and processes, and other best commercial practices as guidance."

While most people are now aware of the purpose and content behind ISO standards, most people are just now beginning to understand the purpose and need for another standard like EIA/IS-632. The following briefly describes the purpose of the standard along with the history and current status of it's development and implementation.[4] EIA/IS-632 and ISO-9001 was chosen for the AN/BQH-7/7A EC-3 project because of the good general guidance provided for implementing a systems engineering program and process.

What is EIA/IS-632?

EIA/IS-632 is intended be a top-level standard for the engineering of a system. It is expected that second tier standards and guides will be developed for specific technology domains, industry sectors, etc (similar to the evolution of ISO standards). An example of a second tier "standard" is the IEEE Trial-Use Standard 1220-1994 and covers the electrical and electronics industry. An example of a second tier "guide" is the SAE 4754 which covers certification of aircraft in meeting safety regulations. The final version of EIA 632 is intended to be used as a top-level standard for the processes behind engineering a system. These processes include;

- Acquirer-Supplier Agreement Process
- Planning Process
- Control Process
- System Design Process
- System Qualification Process

History and Status of EIA/IS-632

The EIA Interim Standard 632 is in the final stages of revision to a full EIA standard. The development of this standard began in April 1995 as a joint project sponsored by EIA, IEEE, and INCOSE. A final draft was planned for released to EIA in early January 1997 for distribution to EIA, INCOSE, and IEEE for final review and for balloting. The drafts of this standard have been through two extensive reviews by the Systems Engineering Working Group made up of EIA, IEEE, and INCOSE members. The ballot version will have incorporated comments from the working group reviews.

2.6.1.3 Coalition Partnership between Government and Industry

Coalition Partnership is the working together with defense contractors through cross-functional integrated product teams (IPTs) to resolve programmatic or design problems in partnership as a team rather than through the adversarial approach practiced in the past.

Success Story Example

From the beginning of the EC-3 effort, our IPT team chose to leverage off of the more than thirty years of experience that Sippican had in developing bathythermograph equipment and systems. The coalition partnership with Sippican has been fairly successful in the initial development of the AN/BQH-7/7A EC-3 Kit thus far. One reason for the success was the IPT's ability to temper and balance the decisions and progress with sound and creative thinking from the cross functional IPT members.

In order to maintain competition in future EC-3 efforts and to ensure that the government would not be "locked in" to sole source in future procurements, the IPT first developed a Prime Item Development Specification (PIDS). The PIDS (or Performance Specification) was developed during the early phases of the EC-3 effort (Phases I & II) as illustrated in Figures 4 and 5 in Section 2.3 and in the Appendix C TI SOW. This document set the stage for the development of detailed performance requirements that the EC-3 Kit would be tested to during final factory acceptance test (FAT).

Key to Success is Cooperation and Open Communication

A quick example of a contractor “working against the new paradigm” in the area of coalition partnership between government and contractor entities in a major COTS/NDI development effort can be seen in the real life example of the NSSN COTS/NDI C^3I, A-RCI, and BQQ-5 WAA programs (submarine combat systems being procured by the Navy in coalition partnership with industry. In this one case, a subcontractor (referred to as Contractor 2) under the C^3I contract built and delivered a system called the multi-purpose processor (MPP) to the main contractor in charge (referred to as Contractor 1). The MPP was to be accepted by the government from Contractor 2 and in turn provided to Contractor 1 as government furnished property (GFP) under the A-RCI contract. But since the MPPs were not yet accepted by the government (for mutually beneficial reason between all three parties), Contractor 1 asked for consideration due to late delivery - even though the MPPs had been sitting in Contractor 1’s plant for some time! Contractor 1 also started blaming other A-RCI delays on the late delivery of the MPPs even though all three parties had fully agreed on the GFP delivery schedule at an earlier date.

Point

New initiatives like acquisition reform’s “new way of doing business” takes hard work and requires cooperation and communication between all parties involved with a sincere desire to make the new initiative work. Otherwise, we can easily find ourselves back in the old adversarial relationship with industry rather than a coalition partnership.

2.6.1.4 Systems Acquisition Paradigm Shift

Old-way of Systems Acquisition

Government leads the three major tasks of (1) selecting the specifications and standards, (2) selecting the products that meet those standards and (3) integrating the products into a larger system.

New-way - Open Systems Architecture (OSA) Approach

Contractor assumes the three major tasks of (1) selecting and tailoring the open systems specifications and standards, (2) buying the products and (3) integrating the subsystems.

Benefits of Open Systems Acquisition Approach

The commercial marketplace bears the cost burden of product design, product marketing, and in some cases, product support infrastructure. The clear advantage common to both the contractor and government alike is the reduced and shorter development schedules.

2.6.2AN/BQH-7/7A EC-3 Open Systems Architecture (OSA) Approach

The term *open systems* has many definitions and interpretations. Though the various definitions have common elements, no formal agreement on one definition of the term exists. The key common points in most open system definitions are vendor independence, non-proprietary, public availability, and wide-acceptance. Other properties exhibited in an open system include:

Interoperability - The ability of two or more systems to exchange information and to mutually use the information that has been exchanged.

Portability - The ease with which application software and data can be transferred from one information system to another without code changes.

Our open systems architecture approach was driven by our system goals and objectives discussed in Section 1.3 entitled "Description of Proposed Change to Resolve Problem". From an OSA paradigm, the OSA program goals were to;

- achieve low development costs,
- allow for the purchase of subsystem components at relatively low cost, now and in the future,
- maintain long term availability of subsystem components,
- maintain multivendor interchangeable components,
- maintain upward compatibility of subsystem components in the future.

By calling out industry standards, we allowed ourselves to take advantage of system components that had been fully developed and debugged or "proofed out" in the commercial marketplace. We also assured ourselves of the latest technological and support processes since these standards and components were in common use everyday by millions of users, and were being continuously improved, maintained and updated at no additional cost to ourselves or our future Fleet customers. Figure 9 illustrates the expected benefits to the program by being able to rapidly respond to the latest in technological advances in commercial technologies and the ease in which the technologies can be inserted into the system when using an OSA approach.

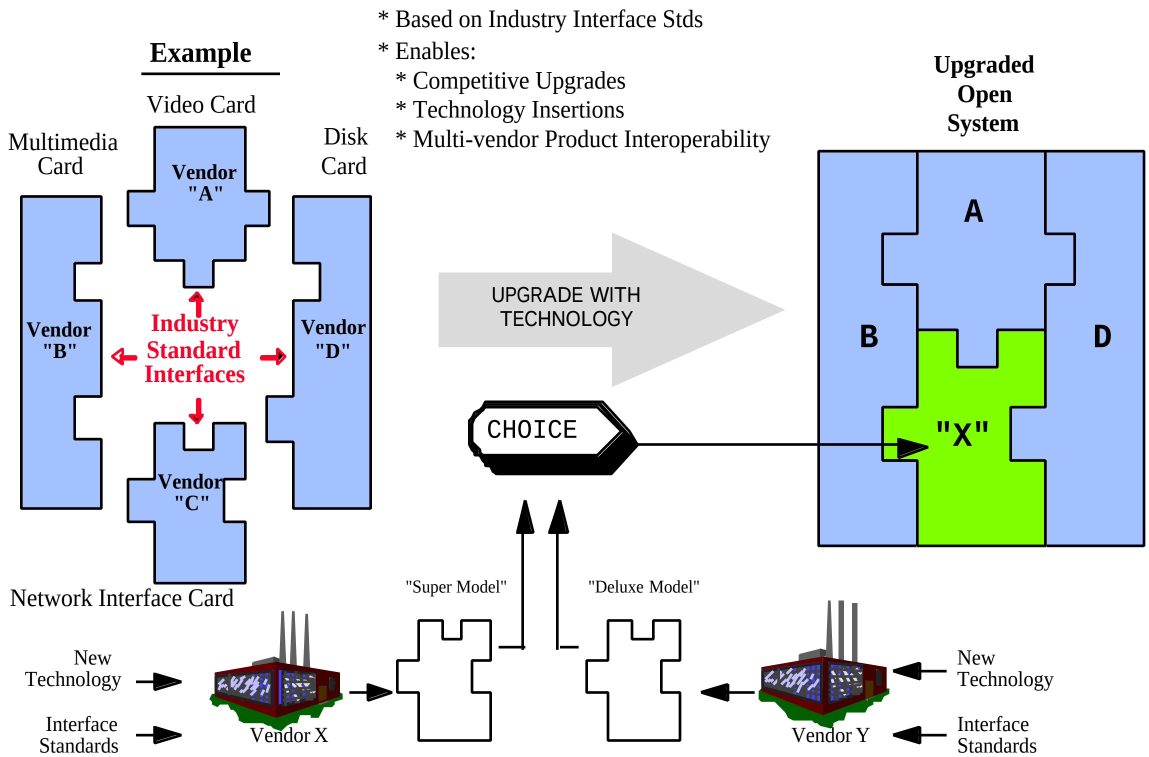


Figure 7 - Illustration of Benefits of Using Open Systems Architecture and Intended Ease of Technology Insertions

Specific OSA issues associated with the AN/BQH-7/7A EC-3 effort are discussed further in Section 3.6.2 entitled “Component Selection”.