

**FLEET INTRODUCTION PROJECT FOR THE  
UNITED STATES NAVY'S  
NEXT GENERATION BATHYTHERMOGRAPH  
RECORDER SYSTEM**

by

**Larry Reynolds Moss**

**Project and Report submitted to the Faculty of the  
Virginia Polytechnic Institute and State University  
in partial fulfillment of the requirements for the degree of**

**MASTER OF SCIENCE**

in

**Systems Engineering**

**APPROVED:**

---

**Professor L. K. Harmon, Chairman**

---

**D. K. Howard**

---

**Dr. K. P. Ellis**

**25 April 1997  
Blacksburg, VA**

# **FLEET INTRODUCTION PROJECT FOR THE UNITED STATES NAVY'S NEXT GENERATION BATHYTHERMOGRAPH RECORDER SYSTEM**

by

Larry Reynolds Moss

Professor L. K. Harmon  
Department of Systems Engineering

(ABSTRACT)

The following report presents the preliminary design and prototype development phase of a technology insertion program implemented by this author to extend the service life and to improve the performance of the United States Navy's Bathythermograph Data Recorder System onboard Submarines (AN/BQH-7) and Surface Ships (AN/BQH-7A). The performance upgrade will increase the Fleet User's ability to measure sonar performance and will provide more accurate salinity measurements used for submarine ballasting and control. This project is unique not necessarily because Commercial-off-the-Shelf (COTS) and Non-Developmental Item (NDI) componentry is being used but because the focus is on developing a systems engineering process model for (1) the implementation of COTS and NDI technologies in an open systems architecture environment, (2) a maintenance, sparing, and life cycle support model for COTS and NDI programs, and (3) a periodic technology insertion plan for keeping pace with COTS and NDI technology advances and configuration changes. It is intended that this report be used in the future as a good example of the successful implementation of Acquisition Reform and DoD 5000.2B initiatives.

## **Keywords:**

Service Life Extension Program (SLEP)

Commercial-off-the Shelf (COTS)

Technology Insertion

Acquisition Reform

Fleet Support Initiative (FSI)

Non-developmental Items (NDI)

Re-engineering / Electronic Re-packaging

Open Systems Architecture (OSA)

## PREFACE



This project was proposed as a Fleet Support Initiative by this author in March 1995 through the Program Executive Office for Undersea Warfare, PEO(USW), Program Office for the Submarine Regional Warfare System, PMS415. PMS415 is a U. S. Navy System Acquisition & Procurement Program Office and is located in Crystal City, Arlington, VA and is part of Commander, Naval Sea Systems Command (COMNAVSEASYSKOM).

Special thanks to those in PMS415 who made this effort possible for without their guidance and support, this effort would not have been possible. May the great systems architect bless you all with high cohesion, low coupling, and hierarchical coparceny.

# TABLE OF CONTENTS

## List of Figures and Tables

List of Figures .....	vi
List of Tables .....	vii

## List of Acronyms

List of Abbreviations/Acronyms .....	viii
--------------------------------------	------

## Chapter 1

1.0 Introduction .....	1
1.1 System Overview .....	2
1.1.1 Operational Requirements .....	2
1.1.2 Mission Description .....	3
1.1.3 Functional Description .....	3
1.2 Problem Identification .....	4
1.3 Description of Proposed Change to Resolve Problem .....	7
1.3.1 AN/BQH-7/7A EC-3 System Description .....	7
1.3.2 AN/BQH-7/7A EC-3 System Goals and Objectives .....	8

## Chapter 2

2.0 Engineering Process and Project Design Methodology .....	10
2.1 Systems Engineering Process .....	10
2.2 Systems Engineering Life-Cycle Process .....	12
2.3 Partitioning of Effort into Manageable Phases .....	12
2.4 Systems Engineering Process Elements .....	15
2.5 Need for Change .....	16
2.6 Processes and Initiatives Implemented .....	19
2.6.1 Acquisition Reform .....	20
2.6.1.1 Integrated Process and Product Development (IPPD) Integrated Product Team (IPT) .....	20
2.6.1.2 Commercial Standards Implementation .....	20
2.6.1.3 Coalition Partnership between Government and Industry .....	21
2.6.1.4 Systems Acquisition Paradigm Shift .....	22
2.6.2 AN/BQH-7/7A EC-3 Open Systems Architecture (OSA) Approach .....	23

## Chapter 3

3.0 Requirements Analysis .....	25
3.1 Operational Requirements Analysis .....	25

3.2	Maintenance and Supportability Requirements .....	26
3.2.1	Organizational Level (O-Level) Maintenance .....	26
3.2.2	Depot Level Support .....	27
3.2.3	Depot Level Maintenance .....	27
3.2.4	Technical Design Agent (TDA) and In-Service Engineering Agent (ISEA) .....	27
3.2.5	Ship Yard .....	28
3.3	Human Factors Considerations .....	28
3.4	Functional Requirements Analysis .....	28
3.4.1	Quality Function Deployment (QFD) and Analytic Hierarchy Process (AHP) Analysis .....	28
3.4.2	AN/BQH-7/7A EC-3 Requirements Synthesis .....	30
3.4.3	AN/BQH-7/7A EC-3 Requirements Allocation to Current Requirements .....	31
3.4.4	AN/BQH-7/7A EC-3 Functional Flow Requirement .....	31
3.4.5	Interface Requirements Analysis .....	33
3.5	Preliminary Reliability Analysis .....	34
3.6	Component Tradeoff Analysis .....	36
3.6.1	Component Tradeoffs .....	36
3.6.2	Component Selection .....	37
3.6.2.1	Hardware .....	38
3.6.2.2	Software .....	40
3.6.2.3	EC-3 Prototype Bill of Material (BOM) .....	41
3.7	Pre-Production Unit (PPU) Prototype .....	43
3.8	Updated Reliability Analysis and Verification .....	46
3.9	Validation Test Requirements Analysis .....	48
3.9.1	Laboratory Test .....	48
3.9.2	At-Sea Test .....	48
 <b>Chapter 4</b>		
4.0	Life Cycle Support and Cost Analysis .....	49
4.1	COTS versus Build-to-Print (MILSPEC) Systems .....	50
4.2	Example of Operation and Support Cost Savings (AN/SQQ-89 Program) .....	55
4.3	AN/BQH-7/7A EC-3 Life-Cycle Cost (LCC) .....	58
 <b>Chapter 5</b>		
5.0	Summary .....	60
5.1	Conclusions .....	61
 <b>Notes and References</b> .....		62

## **Appendices**

Appendix A - Commander Submarine Force U.S. Atlantic Fleet Endorsement .....	A-1
Appendix B - Commander Submarine Force U.S. Pacific Fleet Sonar Newsletter .....	B-1
Appendix C - Engineering Services Authorization Letter.....	C-1
Appendix D - Proposed Program Schedule .....	D-1
Appendix E - AN/BQH-7/7A EC-3 Requirements Allocation Matrix .....	E-1
Appendix F - AN/BQH-7/7A EC-3 Hardware Functional Allocation Matrix .....	F-1
Appendix G - Tradeoff Analysis Tables .....	G-1
Appendix H - Mk-12 Marketing Specification Sheet .....	H-1

## List of Figures

Figure 1 - AN/BQH-7/7A EC-3 Program Timeline and Milestones .....	7
Figure 2 - Systems Engineering Life-Cycle Process .....	11
Figure 3 - EC-3 Recorder Design-to-Fielding Phasing Plan .....	13
Figure 4 - Work Process/Task Flow Chart for Phase II .....	14
Figure 5 - Allocation of Systems Engineering SubTasks .....	15
Figure 6 - Systems Engineering Process Elements .....	16
Figure 7 - Illustration of Benefits of Using Open Systems Architecture and Intended Ease of Technology Insertions .....	24
Figure 8 - Quality Function Deployment (QFD) Process .....	29
Figure 9 - Analytic Hierarchy Process .....	30
Figure 10 - AN/BQH-7/7A EC-3 Functional Flow Diagram .....	32
Figure 11 - AN/BQH-7/7A EC-3 System/Subsystem Interface Diagram .....	34
Figure 12 - AN/BQH-7/7A EC-3 Keyboard Design .....	38
Figure 13 - Sippican Mk-12 Data Acquisition Card .....	39
Figure 14 - AN/BQH-7/7A EC-3 Pre-Production Unit (PPU) Prototype Block Diagram .....	44
Figure 15 - Picture of the AN/BQH-7/7A (Current Recorder) .....	45
Figure 16 - Computer Generated Picture Composite of the AN/BQH-7/7A EC-3 (Future Recorder).....	45
Figure 17 - Final AN/BQH-7/7A EC-3 Reliability Model .....	47
Figure 18 - Commercial versus MILSPEC Procurement Comparison .....	50
Figure 19 - Cartoon Depicting the Rapid Pace of Technology Changes .....	51
Figure 20 - Hard Drive Evolution - Typical PC Hard Drive Capacity by Year .....	52
Figure 21 - Nominal Life Cycle Support Comparison between Build-to-Print and COTS Based Systems .....	53
Figure 22 - System Technology Assessment Process .....	54
Figure 23 - Board Availability and Support Curve Example .....	56
Figure 24 - Product Life Cycles Identified from Market Survey .....	57
Figure 25 - Collective Technical Refresh in Year 2001, Cost vs. Time .....	58

## List of Tables

Table 1 - U. S. Navy Operational Requirements Documents for Oceanic Environmental Measurement Systems .....	3
Table 2 - Expendable Probe Types Used by Each Recorder .....	4
Table 3 - Launched Expendable Probe Types and Attributes .....	8
Table 4 - Correlation of Parts Obsolescence Impact to Number of Engineering Change Notices (ECNs) Over Time .....	17
Table 5 - Vendor Supportability Survey for Current AN/BQH-7/7A Recorder Components .....	18
Table 6 - AN/BQH-7/7A EC-3 External Shipboard Interface Requirements .....	33
Table 7 - Actual versus Predicted Reliability Comparison (AN/BQH-7/7A versus AN/BQH-7/7A EC-3) .....	35
Table 8 - AN/BQH-7/7A EC-3 Display Options .....	37
Table 9 - Selected AN/BQH-7/7A EC-3 Pre-Production Unit (PPU) Prototype Bill of Material (BOM) .....	42
Table 10 - AN/SQQ-89 Total Product Replacement Cost .....	55



## **List of Abbreviations/Acronyms**

AHP - Analytic Hierarchy Process  
ANSI - American National Standard Institute  
APL - Allowance Parts List  
A-RCI - Acoustics, Rapid COTS Insertion  
ASL - Arctic Submarine Laboratory  
ASQC - American Society Quality Control  
ASW - Anti-Submarine Warfare  
BOA - Basic Order Agreement  
BOM - Bill of Material  
BSME - Bachelors of Science in Mechanical Engineering  
CASREP - Casualty Report  
CCA - Circuit Card Assembly  
CCB - Configuration Change Board  
C<sup>3</sup>I - Command, Control, Communications, Intelligence  
CO - Commanding Officer  
COMSUBDEVRON - Commander, Submarine Development Squadron  
COMSUBLANT - Commander, Submarine Force U. S. Atlantic Fleet  
COMSUBPAC - Commander, Submarine Force U. S. Pacific Fleet  
COMSURFLANT - Commander, Surface Force U. S. Atlantic Fleet  
COMSURFPAC - Commander, Surface Force U. S. Pacific Fleet  
COSAL - Consolidated Ship's Allowance List  
COTS - Commercial off the Shelf  
CPU - Central Processor Unit  
DET - Detachment  
DEVRON 12 - Development Squadron 12  
DoD - Department of Defense  
DRAM - Dynamic Random Access Memory  
EC - Engineering Change  
ECN - Engineering Change Notice  
ECP - Engineering Change Proposal  
EDM - Engineering Development Model  
EIA - Engineering Institute of America  
E-Mail - Electronic Mail  
ENGR - Engineering  
ETC - et cetera  
FAT - Factory Acceptance Test  
FAU - Florida Atlantic University  
FDDI - Fiber Distributed Data Interface  
FSI - Fleet Support Initiative

## **List of Abbreviations/Acronyms - Continued**

GByte - Giga-Byte  
GFP - Government Furnished Property  
GPS - Global Positioning Satellite  
HRS - Hours  
INCO - Installation and Checkout  
INCOSE - International Council on Systems Engineering  
IPPD - Integrated Process and Product Development  
IPT - Integrated Process Team  
IS - Industrial Standard  
ISEA - In-Service Engineering Agent  
ISA - Industry Standard Architecture  
ISO - International Standards Organization  
LCC - Life Cycle Cost  
LCD - Liquid Crystal Display  
LCDR - Lieutenant Commander  
LSA - Logistics Support Analysis  
MA - Mechanical Assemblies  
MAMs - Maintenance Assist Modules  
MByte - Mega-Byte  
MEA - Masters of Engineering in Acoustics  
MHz - Mega-Hertz  
MILSPEC - Military Specification  
Mk - Mark  
MPP - Multi-Purpose Processor  
MSSE - Masters of Science in Systems Engineering  
MTBF - Mean Time Between Failure  
MTBM - Mean Time Between Maintenance  
MTTR - Mean Time to Repair  
NAVICP - Navy Inventory Control Point  
NAVSEASYSKOM - Naval Sea Systems Command (also referred to as NAVSEA)  
NAVSEACOMBATSYSSENGSTA - Naval Sea Combat Systems Engineering Station  
NAVUNSEAWARCEN - Naval Undersea Warfare Center (also referred to a NUWC)  
NDI - Non-Developmental Item  
NSSN - New Ship Submersible, Nuclear (also referred to as “New Attack Submarine”)  
NSPCC - Navy Ship Parts Control Center  
NTDS - Naval Tactical Data Systems  
NWP - Navy Weapon Publication  
OBRP - On Board Repair Part  
OSA - Open Systems Architecture

## **List of Abbreviations/Acronyms - Continued**

PAL - Preliminary Allowance List  
PARM - Program Acquisition Review Manager  
PDD - Program Design Document  
PECP - Preliminary Engineering Change Proposal  
PEO(USW) - Program Executive Office for Undersea Warfare  
PIDS - Prime Item Development Specification  
PMS415 - Program Manager, Sea (for NAVSEA)  
PMW - Program Manger, Space and Naval Warfare (also see SPAWAR)  
PPU - Pre-Production Unit  
PSD - Product Specification Description  
PTD - Provisioning Technical Documentation  
QFD - Quality Functional Deployment  
RAM - Random Access Memory  
RDT&E - Research, Development, Test & Evaluation  
ROM - Read Only Memory  
SCSI - Small Computer Systems Interface  
SER - Serial  
SEWG - Systems Engineering Working Group  
SFMPL - Submarine Fleet Mission Program Library  
SHAPM - Ship's Acquisition Program Manager  
SLEP - Service Life Extension Program  
SPAWAR - Space and Naval Warfare  
SPCC - Ship's Parts Control Center  
SSN - Ship Submersible, Nuclear  
SSXBT - Sub-Surface Expendable Bathythermograph  
SSXCTD - Sub-Surface Conductivity Temperature Depth  
SUBLANT - Commander Submarine Force U.S. Atlantic Fleet  
SUBPAC - Commander Submarine Force U.S. Pacific Fleet  
SURFLANT - Commander Surface Force U.S. Atlantic Fleet  
SURFPAC - Commander Surface Force U.S. Pacific Fleet  
SURTASS - Surface Towed Array Sonar Suite  
SVGA - Super Video Graphics Array  
S.W. - Software  
TDA - Technical Design Agent  
TI - Technical Instruction  
TM - Technical Manual  
TMCR - Technical Manual Contract Requirement  
TMD - Training Material Documents  
UISSXBT - Under Ice Sub-Surface Expendable Bathythermograph Temperature

## **List of Abbreviations/Acronyms - Continued**

UISSXSV - Under Ice Sub-Surface Expendable Sound Velocimeter

UISSXCTD - Under Ice Sub-Surface Expendable Conductivity Temperature Depth

U. S. - United States

USS - United States Submarine

USW - Undersea Warfare

VGA - Video Graphics Array

V&V - Verification and Validation

WWA - Wide Aperture Array

XBT - Expendable Bathythermograph

XSV - Expendable Sound Velocity

XCTD - Expendable Conductivity Temperature Depth