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THESIS

A CASE STUDY OF THE MK 16 MOD 0
UNDERWATER BREATHING APPARATUS PROGRAM

by

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Thesis Advisor: Raymond W. Smith

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A Case Study of the MK 16 MOD 0 Underwater Breathing Apparatus Program

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ABSTRACT

The MK 16 MOD 0 Underwater Breathing Apparatus (UBA) provides life support to EOD divers operating in close proximity to sensitive underwater ordnance. This thesis evaluates the acquisition and logistic strategy used in fielding this acquisition category III system. In addition, current material and logistic support problems were examined and analyzed. The final chapter provides conclusions and recommendations based on the "lessons learned" in fielding this system.

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GLOSSARY OF ACRONYMS

ACAT	Acquisition Category
AFP	Authorized for Full Production
Ai	Inherent Availability
Ao	Operational Availability
APL	Allowance Parts List
ASU	Approval for Service Use
cc	cubic centimeter
CCB	Configuration Control Board
CDRL	Contract Data Requirements List
CFM	Cubic Feet per Minute
CM	Configuration Management
CNET	Chief, Naval Education and Training
CNO	Chief of Naval Operations
CNTT	Chief, Naval Technical Training
CDRL	Contract Data Requirements List
DCAS	Defense Contract Administration Services
DoD	Department of Defense
DT-111	Scheduled TECHEVAL Test Designation
DT&E	Development Test & Evaluation
ECP	Engineering Change Proposal
EOD	Explosive Ordnance Disposal
EODEMDL	EOD Equipment Management Data List
EODGRUONE	Explosive Ordnance Disposal Group One
EODGRUTWO	Explosive Ordnance Disposal Group Two
EODTECHCEN	Explosive Ordnance Disposal Technology Center
FARS	Failure Analysis Reports
FME & CA	Failure Modes Effects and Criticality Analysis
FY	Fiscal Year
GPTE	General Purpose Test Equipment
IAW	In Accordance With
ICP	Inventory Control Point
ILS	Integrated Logistic Support
ILSMT	Integrated Logistic Support Management Team
ILSP	Integrated Logistic Support Plan
IPR	In Process Review
IRP	Interim Repair Parts
IRPL	Interim Repair Parts List
ISEA	In Service Engineering Agent
K	Contract
LCC	Life Cycle Cost
LCD	Liquid Crystal Display
LED	Light Emitting Diode
LEM	Logistic Element Manager
LIS	Low Influence Signature
LSA	Logistic Support Analysis
MDS	Maintenance Data System
MIP	Maintenance Index Page

3-M	Maintenance and Material Management
MOA	Memorandum Of Agreement
MP&TS	Manpower, Personnel, and Training Support
MDT	Mean Down Time
MLDT	Mean Logistic Delay Time
MK	Mark
MRC	Maintenance Requirement Card
MSD	Material Support Date
MSG	Message
MTBF	Mean Time Between Failure
MTFL	Mean Time Fault Locate
MTTR	Mean Time to Repair
NAVSCOLEOD	Naval School Explosive Ordnance Disposal
NAVSEA	Naval Sea Systems Command
NDCP	Navy Decision Coordination Paper
NDI	Nondevelopment Item
NEC	Navy Enlisted Classification
NEDU	Navy Experimental Diving Unit
NPPSO	Navy Publications and Printing Service Office
NTP	Navy Training Plan
O&MN	Operations and Maintenance, Navy
OPEVAL	Operational Evaluation
OPN	Other Procurement, Navy
OPTEVFOR	Operational Test and Evaluation Force
OR	Operational Requirement
OTF P/O	OPTEVFOR Project Office
PHST	Packaging, Handling, Storage, and Transportation
PMO	Program Management Office
PMS	Planned Maintenance System
POA&M	Plan of Action and Milestones
PRS	Provisioning Requirements Statement
PSI	Pounds per Square Inch
PSIG	Pounds per Square Inch Gage
PTD	Provisioning Technical Documentation
QA	Quality Assurance
SCUBA	Self Contained Underwater Breathing Apparatus
SEAL	Sea Air Land Team
SCFM	Standard Cubic Feet per Minute
SIMA	Shore Intermediate Maintenance Activity
SMIC	Special Management Inventory Code
SON	Statement of Need
SOR	Specific Operational Requirement
SPCC	Ship Parts Control Center, Mechanicsburg, Pa
S&TE	Support and Test Equipment
TDEC	Technical Data Element Coordinator
TDP	Technical Data Package
TECHEVAL	Technical Evaluation
TEMP	Test and Evaluation Master Plan
T&E	Test and Evaluation
T&E P/O	Test and Evaluation Project Officer

TM	Technical Manual
UBA	Underwater Breathing Apparatus
UDT	Underwater Demolition Team

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I. INTRODUCTION

A. OBJECTIVES OF THE RESEARCH

The acquisition strategy for obtaining a new weapon system to satisfy an approved mission need is "the conceptual basis of the overall plan that a Program Manager follows in program execution." [Ref. 1:p. 3-1]

The purpose of this thesis is to examine the acquisition strategy used in developing and fielding the MK 16 MOD 0 Underwater Breathing Apparatus (UBA). It will evaluate the decisions made in formulating this strategy and their effect upon current design and material support. In addition, it will also examine and evaluate the Integrated Logistics Support Plan (ILSP), which is an important by-product of the acquisition strategy.

B. RESEARCH QUESTIONS

The primary research question was: What "lessons learned" could be used to improve the development and fielding of future systems by the Explosive Ordnance Disposal (EOD) Program Office?

Secondary research questions were:

1. What were the acquisition and logistic decisions that resulted in the current system?
2. What material support problems were encountered in the fielding of this system?

3. What additional resources are needed by the EOD Program Office and other activities in developing and fielding future systems in an effective manner?

C. RESEARCH METHODLOGY

The research for this thesis was done in three parts. First, a review of the literature pertaining to the fielding of an ACAT III system was done. Current Department of Defense (DoD) instructions, regulations and policy were reviewed. Second, interviews with personnel from the EOD Program Office, EOD Technology Center and other DoD agencies were conducted. Third, information and data gathered from steps one and two were analyzed and evaluated.

D. THESIS STRUCTURE

This thesis is divided into five chapters. Chapter I provides an introduction and describes how the UBA hardware operates. This description will help the reader to understand concepts discussed in the remainder of this thesis. Chapter II provides a general history of the UBAs that were in use before the MK 16 and discusses why development of the MK 16 was required. In addition, the acquisition history of the MK 16 is described. Chapter III examines the acquisition strategy and integrated logistics plan used in developing the MK 16 MOD 0 UBA. A baseline is established from which the MK 16 acquisition strategy and the integrated logistic support plan can be discussed. In addition, an integrated logistics support planning process is described for the conceptual development of an ILSP. Chapter IV discusses the "lessons learned" from the research for this thesis. Chapter V presents the author's observations, conclusions and recommendations.

E. GENERAL DESCRIPTION

The MK 16 MOD 0 UBA is a low-influence signature (LIS), closed-circuit, mixed-gas, constant partial pressure of oxygen, underwater life-support system. It was developed to support the low magnetic and acoustic signature requirements of EOD operations. The MK 16 MOD 0 UBA is illustrated in Figures 1 and 2. Figure 1 is a drawing of the UBA itself and Figure 2 is a picture of the equipment as worn by a diver.

The breathing medium of this new equipment is kept at a predetermined partial pressure of oxygen by oxygen sensors that monitor, evaluate, and control the oxygen level via a battery-operated electronic module. The apparatus controls the oxygen partial pressure in the diver's breathing mix at a preset level independent of depth. It incorporates manual overrides (shutoff and bypass valves) for the automatic system as an added safety feature.

The MK 16 MOD 0 UBA with the necessary auxiliary equipment provides life support to EOD divers to a maximum depth of 300 feet (91.44 meters). The UBA is designed for EOD divers for

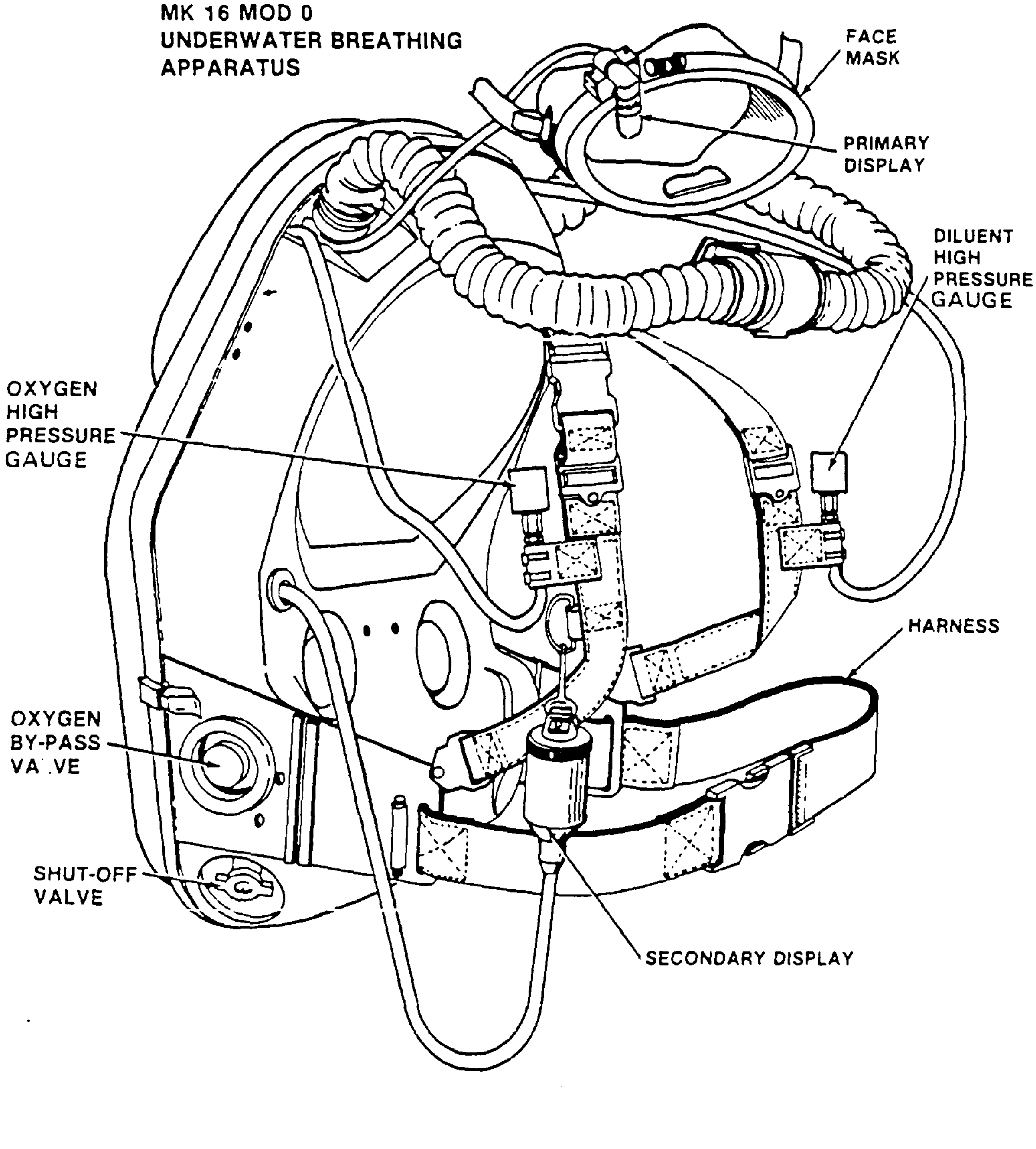

Figure 1
Equipment Interrelation Diagram
(Courtesy of EOD Program Office)

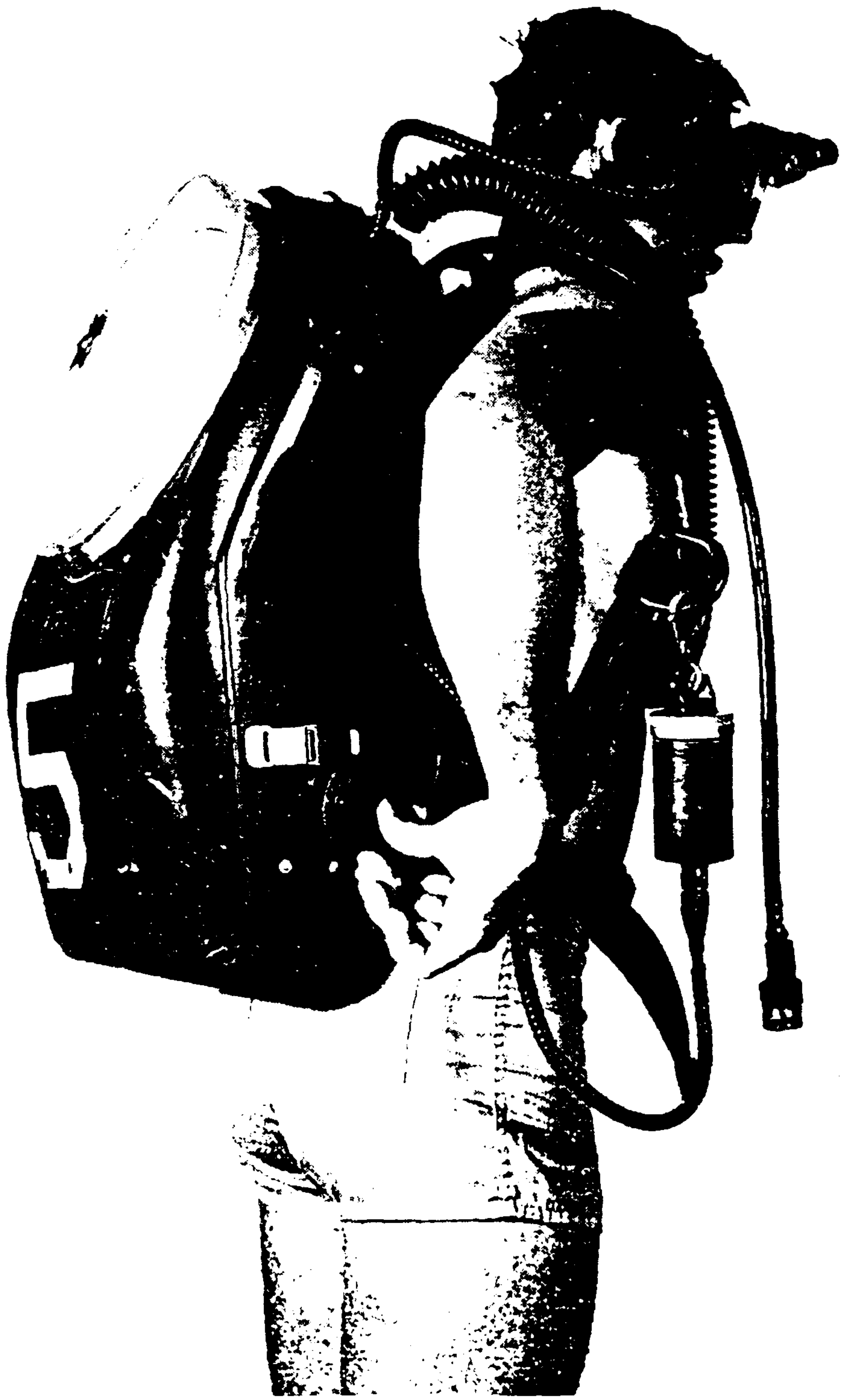

Figure 2
MK 16 MOD O UBA WORN BY DIVER
(Courtesy of EOD Office)

the purpose of performing ordnance disposal or recovery tasks against mines that are activated either magnetically or acoustically. [Ref. 2:pp. 1-5]

F. FUNCTIONAL DESCRIPTION

The MK 16 is a closed circuit system which recirculates the diver's respiratory gas. A scrubber assembly removes CO_2 exhaled with each breath. The breathing gas is retained within the equipment except during ascent; or when the diver has manually added gas; or during normal operation when the breathing loop pressure is greater than the surrounding atmospheric/water pressure, at which time excess pressure is vented. Oxygen (O_2) is mixed with a diluent gas (air(N_2O_2)) or helium/oxygen (HeO_2) to maintain a preset partial pressure of oxygen (PPO_2) of 0.75 ATM.

The normal working dive limit is 150 feet (46 meters) of seawater when N_2O_2 is used as the breathing medium and 300 feet (91 meters) of seawater when HeO_2 is used as the breathing medium.

An adult usually consumes between 0.25 and 3.0 liters of oxygen per minute, depending on activity level. Tests have shown over an extended period of time, a hard working diver will consume an average 1.2 liters of oxygen per minute. Therefore, for a six-hour dive, a closed circuit system need only supply approximately 15 cubic feet (424 liters) of oxygen to meet diver respiratory needs. The MK 16 can store approximately 21 cubic feet (594 liters) of oxygen at 3,000 psig (20,684 kPa), providing an adequate supply for a six-hour dive. The major limiting factor for the MK 16 is the CO2 absorbent capability. The absorbent duration is directly related to the environmental operating temperature and depth. Absorbent duration decreases as temperature decreases and depth increases. [Ref. 3:p. 4]

G. RECIRCULATION SYSTEM

Figure 3 is a functional block diagram of the MK 16. The diver exhales into the mouthpiece (1), the exhaled gas passes through the exhalation hose (2), through a moisture absorber and support screen (3) and through a bed of absorbent granules in the scrubber (4), where CO_2 is removed. The gas then passes through a second moisture absorber and support screen (5), over the oxygen sensor assembly (6), into the diaphragm assembly (7) and back to the diver through the inhalation hose (8).

H. ANALYSIS AND CONTROL

The primary electronics assembly (9), powered by the battery (10), monitors the PPO_2 in the recirculating gas by means of three oxygen sensors (refer to Figure 3). This information appears on the primary display (11) to indicate a low, normal or high level of oxygen. Once every five seconds, the electronic assembly compares the average PPO_2 value with

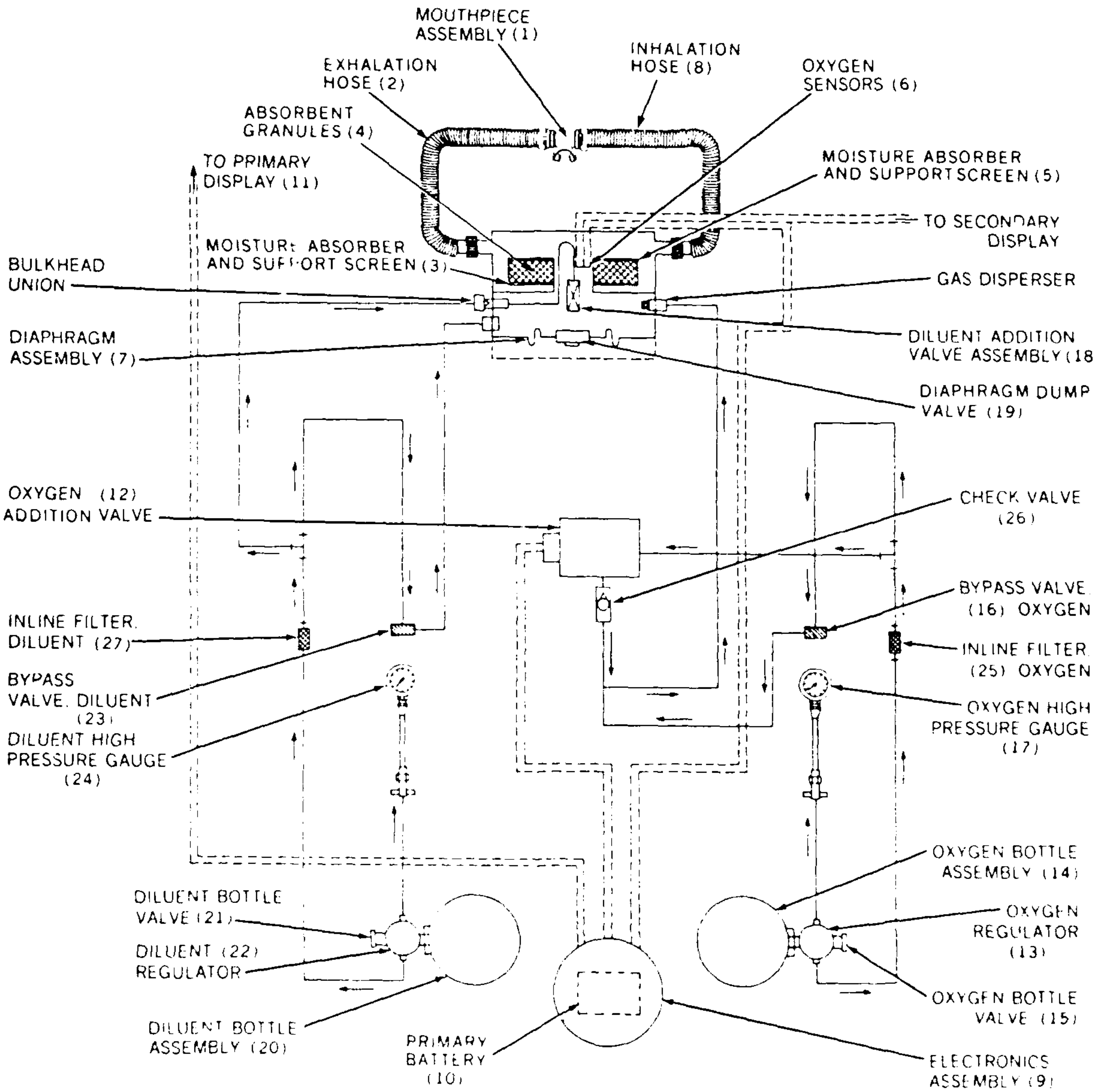

Figure 3
MK 16 MOD O UBA Functional Block Diagram
(Courtesy of EOD Program Office)

the set-point value. A PPO_2 value less than the set-point value automatically opens the oxygen addition valve (12) in the oxygen supply line to admit oxygen to the system. The regulator (13) maintains the preset pressure level. Oxygen is stored in a spherical bottle (14), fitted with a manual shutoff valve (15). The oxygen bypass valve (16) allows manual addition of oxygen to the breathing gas when required. The oxygen pressure gauge (17) displays oxygen bottle pressure.

I. DILUENT GAS SUPPLY

As the diver descends (See Figure 3), increased water pressure causes the diaphragm to partially collapse, which activates the diluent addition valve (18). Diluent gas enters the breathing loop equalizing the pressure differential existing between the gas in the recirculating system and the ambient water. During ascent, water pressure decreases causing the gas inside the diaphragm to expand. The dump valve (19) opens to relieve the excess pressure within the breathing loop, thus equalizing the pressure differential between the breathing loop and the ambient water. The diluent gas is contained in a spherical bottle (20), fitted with a manual shutoff valve (21) and regulator (22). A bypass valve (23) allows direct addition of diluent to the breathing loop when required. A pressure gauge (24) provides visual indication of diluent gas bottle pressure.

J. PRIMARY DISPLAY

The primary display assembly provides qualitative data indications to the diver relative to the PPO_2 in the breathing loop and primary battery condition through coded red and green light signals. The primary display consists of two light emitting diodes (red and green) and a clear cylindrical housing is connected to the electronics assembly by a cable and connector. The display is normally mounted on the right side of the nonmagnetic face mask by means of a detachable mounting bracket.

K. SECONDARY DISPLAY ASSEMBLY

The secondary display assembly is normally attached to the divers harness assembly. It consists of a back-lighted liquid crystal display, electronic circuits, four 1.5 volt batteries, a cylindrical housing and is connected directly to the oxygen sensors and primary electronics assembly by a cable and connector. Its function is to provide quantitative information to the diver by presenting the PPO_2 numerically for each of the three oxygen sensors, the primary battery's percentage of remaining usable power, and indicates the secondary batteries' condition. [Ref. 3:pp. 4-7]

II. BACKGROUND

A. GENERAL HISTORY

Prior to the introduction of the MK 16, EOD Groups One and Two were using the MK VI, a semi-closed circuit UBA. This UBA, introduced in 1963, emitted gas bubbles and provided borderline magnetic and acoustic safety for the diver. In addition, the MK VI breathing resistance, canister duration, and decompression profiles provided minimal safety for the diver. In 1979 logistic support was stopped for the MK VI and marginal mission capability was being maintained through cannibalization of fleet assets.

The MK 16 was designed to replace the MK VI. The MK 16 is a nonmagnetic, acoustically quiet, closed circuit, mixed gas underwater breathing apparatus, born of a complete redesign of its military predecessor, the MK 15 and its commercial counterpart, the CCR-1000. The MK 15 is similar to the MK 16, however, it is a magnetic vice nonmagnetic UBA. It is used by Navy Seal teams for specialized operations in support of their mission. The MK 16's primary application is in mine countermeasure diving. Because the UBA is nonmagnetic and acoustically quiet, its primary mission is to allow divers to render safe, recover or dispose of influence (magnetically or acoustically) detonated mines.

It is a commonly held misconception that the MK 16 is a nonmagnetic version of the MK 15. The MK 16 resembles the Mk 15 in outward appearance only. The MK 15 UBA was developed for Navy Special Warfare forces and its mission is entirely different from that of the MK 16. In addition, the MK 15 did not meet the magnetic signature requirements of a system to be used in a mine countermeasure environment. Both the MK 15 and MK 16 function by maintaining a constant partial pressure of oxygen (PPO_2) through the breathing loop; but the MK 16 is a significant advance over the MK 15 and is without a doubt the most advanced UBA in the world today. [Ref. 4:pp. 7-9]

B. ACQUISITION HISTORY

The MK 16 UBA was developed in response to Operational Requirement (OR) SSL-01 and as an integral part of the EOD Underwater Support System (NDCP S1317-SW) dated 30 July 1979. Figure 4, shows the MK 16 MOD 0 program schedule. Naval Explosive Ordnance Disposal Technology Center (NAVEODTECHCEN), Indian Head, Maryland conducted exploratory development of an underwater breathing apparatus using closed-circuit constant partial pressure of oxygen (PPO_2) technology. Initial research was conducted under R&D funding in 1968 and 1972 by General Electric and Westinghouse respectively. In years 1975 through 1977 Rexnord took over the primary Research and Development.

Summary

Milestones:	Planned Comp. Date:	Actual Comp. Date:
Request for Proposal:	1974	1974
Concept Exploration Phase:	1978	1978
Validation/Demo. Phase:	1980	1980
Complete DT-III TECHEVAL:	June 1980	June 1980
Complete OT-III OPEVAL:	November 1980	November 1980
Approval for Service use:	March 1981	October 1981
First Production Contract Award:	March 1981	October 1982
Provisioning Conference:	July 1981	March 1985
Complete 1st Prod. Deliveries:	December 1981	October 1985
Commence Training at NAVSCOLEOD:	February 1982	July 1985
2nd Production Contract Award:	February 1982	April 1986
2nd "K" Delivered:	December 1982	May 1989
Navy Support Date:	February 1983	*1991 (Proposed)*
3rd Prod."K" Award:	February 1983	*TBD*
Deliv. 3rd Prod."K":	December 1983	*TBD*

Figure 4
MK 16 MOD 0 Program Structure
(Courtesy of EOD Program Office)

Development of the first successful rebreather started at General Electric (GE) around June of 1968 and was successfully completed at Duke University before the end of the year. During January of 1969 all of the key members of General Electric left to form a new company called Marine Systems International which was later renamed Rexnord. One of the first developments of Rexnord was the design of a completely new rebreather called the CCR-1000. The first three units went to the Army special forces in 1969 for test and evaluation.

In 1970, Rexnord designed and built the first closed circuit rebreather for Westinghouse Inc. An objective of this effort was to design a unit to resemble the Westinghouse MK II Abalone semi-closed unit which Westinghouse was then building for the Navy. Early in 1972, the Navy tested all of the commercially available models (the Rexnord CCR-1000, the Westinghouse unit designed by Rexnord, the General Electric unit and the Beckman Electro-Lung). The Navy determined that all, with the exception of the Beckman unit, were potentially acceptable for Navy use. Based on these evaluations and developmental testing, the Navy prepared a specification.

In August of 1972, it came to the attention of Rexnord that the Navy was contemplating a sole source procurement of the GE unit for deep diving use. Rexnord objected to this, as they felt their UBA was technically superior to the GE unit and less expensive. In 1974, the Naval Sea Systems Command included

Rexnord, GE and Westinghouse in a competition for a closed circuit mixed gas rebreather to be used for in-shore warfare. Both Westinghouse and GE decided to get out of the closed circuit rebreather business and elected not to bid. As a result of this decision by Westinghouse and GE to withdraw from bidding, Rexnord was the only contractor to submit a proposal. Two prototypes were acquired from Rexnord under contract N00174-77C-0187. NAVEODTECHCEN completed test and evaluation of the feasibility models in 1978. The total amount for this R&D effort was approximately $1,095,430.00 dollars (hardware cost only).

A contract specification was then prepared for the acquisition of seven full scale development models. Contract N00024-79-C-6170 was awarded to Rexnord, Inc. on 25 May 1979 for their fabrication. The resulting life support equipment was designated the MK 16 MOD O UBA. Delivery of the seven models was completed by the end of April 1980. DT-111 TECHEVAL was completed in June and OT-111 OPEVAL was conducted in October 1980.

CHNAVMAT approved the MK 16 for service use (ASU) in October 1981. This was documented in ASU Action Sheet File No. 80-00152 and satisfied the requirements at that time for full production (AFP).

Initial procurement of the MK 16 MOD 0 UBA occurred on 29 October 1982 under contract N00024-83-C-4077. This was a sole source procurement order awarded to Rexnord Process Control Division for 96 units. The contract price for these 96 units was $3,024,000.00 dollars ($31,500 per unit).

Toward the latter part of 1984 a major problem was discovered which delayed production of the MK 16. In December 1984, Lee Valve Company, the major supplier of the piezoelectric oxygen addition valve, ceased manufacturing the part after it failed to meet Navy specifications during government testing. The MK 16 UBA production program resumed six months later, when the first components were delivered from the new valve supplier, Grindley Manufacturing Company to Rexnord. Due to this delay first article testing didn't start until 17 April 1985. NAVSCOLEOD commenced training in July 1985 and delivery of the first operational MK 16 units to the fleet started in October 1985. [Ref. 5:pp. 1-10]

III. ACQUISITION STRATEGY

A. INTRODUCTION

The purpose of this chapter is to evaluate the acquisition strategy and integrated logistics support plan (ILSP) used in fielding this ACAT III system. However, before the acquisition strategy or the ILSP are discussed, an understanding of the following concepts is essential:

1. Acquisition Strategy Purpose.
2. Acquisition Strategy Development.
3. Acquisition Strategy Structure.
4. Acquisition Strategic Concerns.
5. Acquisition Technical Concerns.
6. Acquisition Resource Concerns.
7. Acquisition Strategy Criteria.
8. Acquisition Strategy Constraints and Limitations.

An understanding of the above concepts will help the reader establish a baseline from which the MK 16 program can be evaluated. In addition, an understanding of these concepts will help the reader understand the many variables the Program Manager has to deal with in the development and execution of an acquisition strategy and ILSP. During the research for this thesis, one article clearly stood out from the others on how to develop an acquisition strategy. The article was written by Dr. David V. Lamm (Associate Professor, Naval Postgraduate

School), and is entitled, "Acquisition Strategy". The material from his article is used extensively in the following sections to develop a baseline from which to discuss the MK 16 acquisition strategy and ILSP.

B. PRIMARY PURPOSE OF AN ACQUISITION STRATEGY

The primary purpose of an acquisition strategy is to, "prioritize and integrate many diverse functional requirements, to evaluate and select from among the important issue alternatives, to identify the opportunities and times for critical decisions (decision windows), and to provide a coordinated approach to achieving program objectives economically and effectively." [Ref. 1:p. 3-2]

Every program acquisition strategy is developed on an individual basis. Each one is different from the other. The acquisition strategy is used as a road map for program planning and execution. It is a living document that changes as new information is obtained during the conduct of the program. [Ref. 1:p. 3-2]

C. ACQUISTITION STRATEGY DEVELOPMENT

In recent years, the policy regarding the development and use of an acquisition strategy has become more specific and more demanding. However, this acquisition development process has not resulted in a clear definition of acquisition strategy, nor has it resulted in a uniform application of DoD policy guidelines. Dr. Lamm found that all successful acquisition strategies must contain certain characteristics. He stated that the acquisition strategy must be: (1) a reflection of the management concepts used in the execution of the program: (2) realistic; (3) comprehensive; (4) integrated and internally consistent; (5) flexible, and; (6) serve as a formal agreement. [Ref. 6:p. 91]

The process of developing an acquisition strategy involves; (1) determining guidance, the Program Manager will assimilate, integrate and implement planning guidance received from formal and informal sources; (2) identifying what is to be accomplished, why and when it must be completed and by whom; (3) identifying and evaluating strategic alternatives; (4) selecting an appropriate strategy, and; (5) developing contingent strategies. [Ref. 6:p. 91]

Acquisition strategies must be initiated during the early part of the Concept Exploration phase when very little is known regarding system configuration, integrated logistics support requirements, costs, and many other important factors. [Ref. 6:p. 91] It is noteworthy to add that decisions made very early in a program determine the costs throughout the life of the system. Figure 5 shows the impact of decisions on life-cycle costs compared against actual expenditures. Decisions made during the concept exploration phase (especially the

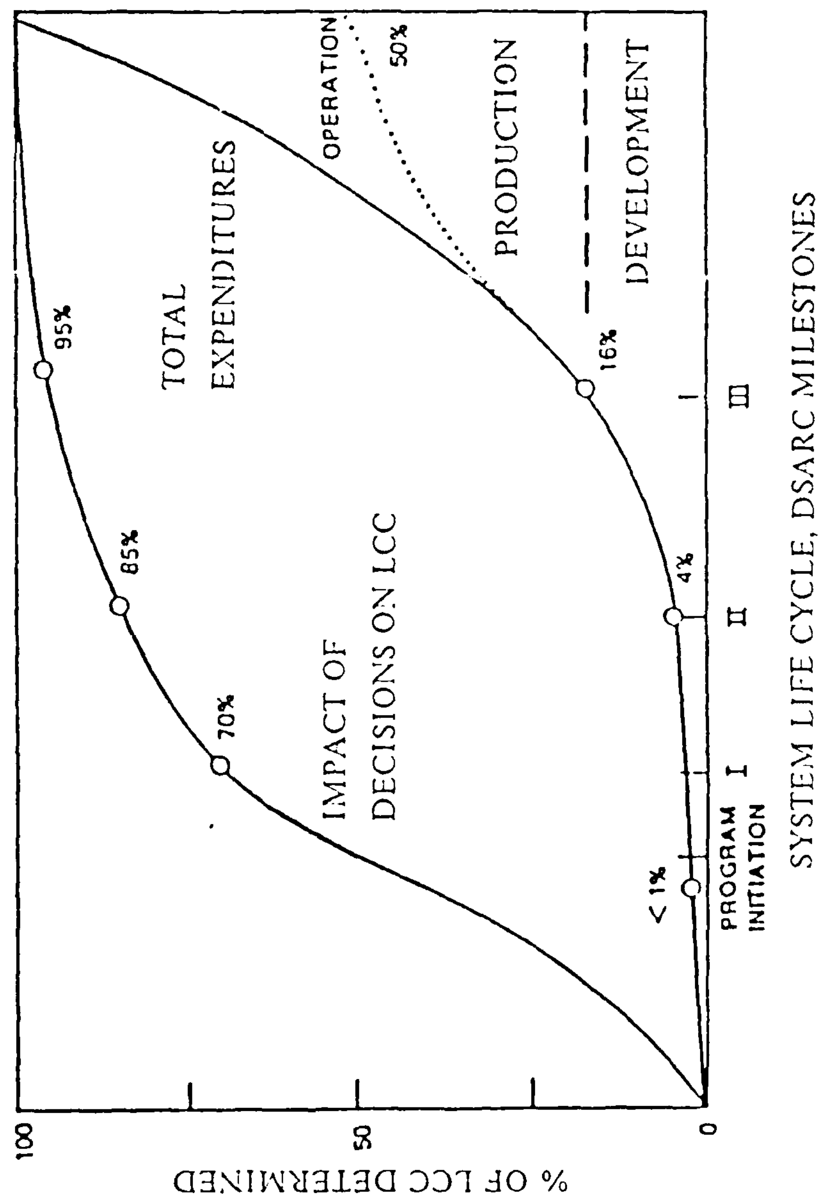

Figure 5
Life-Cycle-Cost Decision Impact and Expenditures
(Source: Acquisition Strategy Guide, DSMC, Ft. Belvoir)

decisions as to which concept is selected and what the performance thresholds for reliability, maintainability, etc., are) fix 70% of the life-cycle costs. In addition, roughly 85% of the LCC are frozen before the Full-Scale Development phase begins, when only a small percentage of the total system acquisition cost has been expended. [Ref. 7:p. 1-8] An acquisition strategy helps in structuring the decision process and ensures that the right decision is made at the right time.

1. Discussion

The cornerstone of the MK 16 acquisition strategy was based on the assumption that the MK 16 was a redesign of the MK 15. This decision/assumption affected every strategic consideration and requirement. In addition, the Program Manager made the decision that a formal "LSA" and "system engineering approach", specifically for the MK 16, was not warranted. [Ref. 5:pp. 3-4]

In March 1988, COMNAVSURFGRU MIDPAC reported in a message to COMNAVSURFPAC that significant material problems exist with the MK 16 MOD O UBA (COMNAVSURFGRU MIDPAC Msg R150716Z Mar. 88). This chapter will show that these problems were partly due to an over-reliance on the experience/history of the MK 15 program.

D. ACQUISITION STRATEGY STRUCTURE

Figure 6 is an overview of the conceptual basis for acquisition strategy development. As shown in Figure 6, there are a number of strategic and functional elements that must be considered. In the acquisition strategy development it is necessary to identify those elements which are critical to the program and select alternatives and decision time intervals that meet program objectives and strategy criteria. This set of alternatives and time intervals is the acquisition strategy, which provides the direction for the development of functional plans such as the TEMP and ILSP. These plans provide the direction and control for program execution. [Ref. 1:p. 3-2]

E. ACQUISITION STRATEGY CONCERNS

Ideally, the Program Manager should be the program strategist. However, in many programs, strategy, or aspects of strategy, are dictated by higher authority. Nevertheless, the program manager must be fully aware of the elements of strategic concern and must make every effort to change a dictated strategy that pushes the program beyond the limits of a feasible solution. [Ref. 1:p. 3-5] To meet the responsibility for formulating and executing the overall acquisition strategy the program manager must understand the following strategic elements:

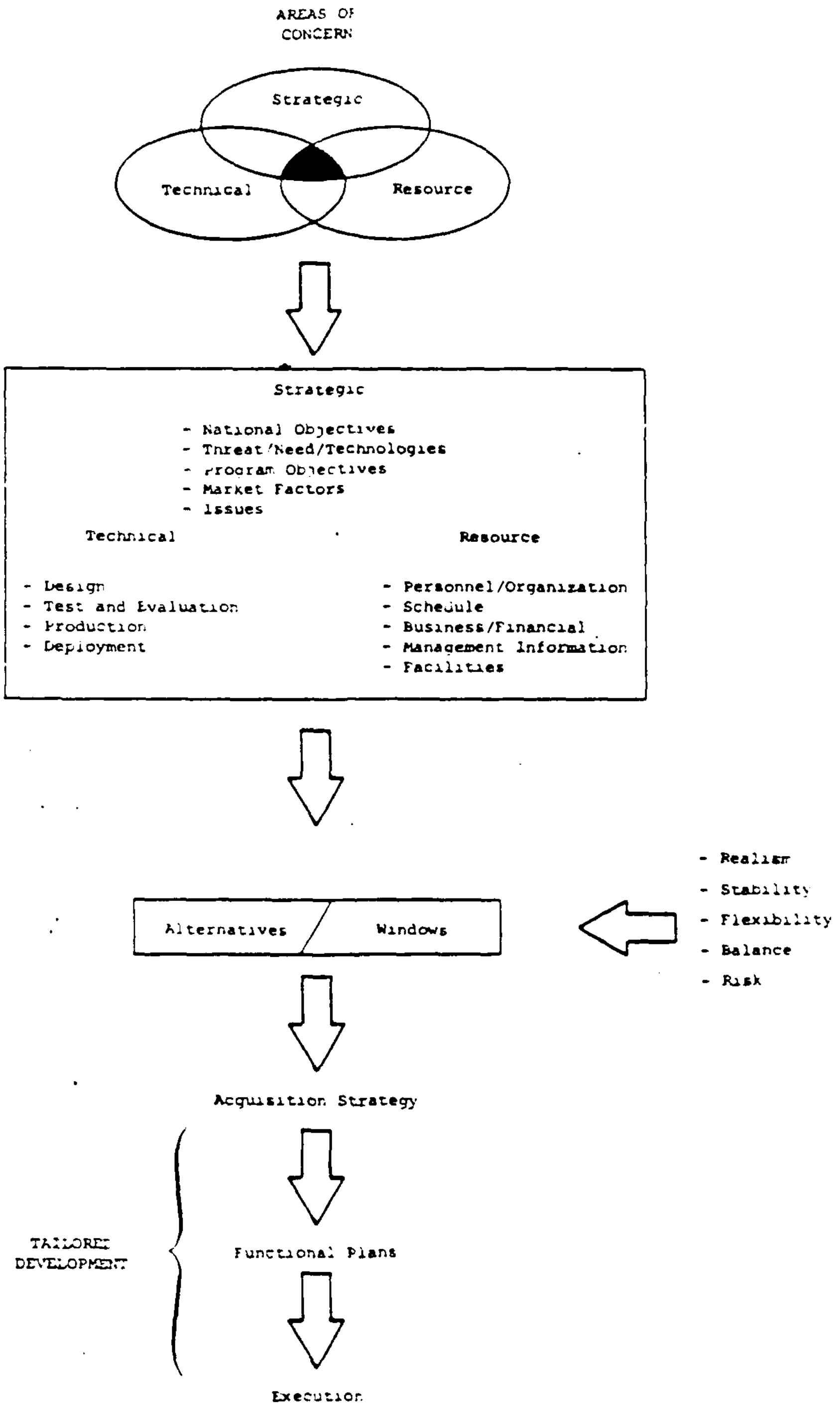

Figure 6
Overview of the Conceptual Basis for
Developing an Acquisition Strategy
(Source: Acquisition Strategy Guide, DSMC, Ft. Belvoir)

1. The national objectives.

2. The nature of the threat, the need, and the technology base.

3. The program objectives, constraints and priorities.

4. The market factors.

5. The critical program issues. [Ref. 1:p. 3-5]

F. ACQUISITION STRATEGY TECHNICAL CONCERNS

Four major elements have been identified as representing the areas of technical concerns, they are:

1. Design.

2. Test and Evaluation.

3. Production.

4. Deployment.

The extent to which mission requirements and program objectives can be met by existing technology will directly determine program risk and resource needs. Each technical element will require the development of nonconflicting strategies that must be integrated into the overall acquisition strategy. [Ref. 1:p. 3-6] The following subsections discuss these four areas of technical concerns.

1. Design

In the design strategy the mission requirements stemming from the program objectives, mission profile, and operational environment must be translated into system and then item specifications through system engineering studies. In addition to performance requirements, the strategy must address how the design will satisfy operational suitability requirements - e.g., readiness, safety, reliability, and maintainability. Strategy alternatives include pre-planned product improvement (P^3I), Technical Data Package (TDP), and Warranties/Guarantees. [Ref. 1:p. 3-6]

a. **Discussion**

The following is a discussion of the system engineering process. It is a process by which an operational need is transformed into a preferred system configuration. This transformation is achieved by the iterative application of functional analysis, synthesis, optimization, definition, design, test and evaluation. Technical parameters for the entire system are integrated to assure compatibility of all physical, functional, and program interfaces. The goal is system definition and design optimization. This process of integration also combines reliability, maintainability, logistic support, human factors and other related specialties into the total engineering effort. [Ref. 7:p. 9]

In an acquisition program, the system engineering approach includes performing the following tasks:

1. Identifying high-risk areas and continually assessing their impact on the program.
2. Determining program technical requirements and integrating the specialty efforts and such disciplines as configuration management and data management.

3. Providing the rationale and the definitive specifications for all hardware/software, facilities, and personnel required to carry out and support contractual requirements.

4. Establishing appropriate baseline and management reviews to permit effective engineering change control and monitoring.

5. Establishing the rationale for ensuring that engineering decisions leading to the selection of design alternatives are based upon system/end-product cost effectiveness considerations.

6. Planning system T&E programs to ensure meeting development and mission requirements, evaluating achievement, and reporting technical performance against program objectives both for early identification of problems and for visibility by management so that timely corrective action can be taken.

7. Providing appropriate and timely redefinition of program technical requirements in response to changes directed by the customer or the problems identified through evaluation of performance. [Ref. 8:p. 4-48]

In discussing the system engineering of the MK 16 with Mr. John Pennella (Project Engineer MK 16, NAVEODTECHCEN), he said that <u>no formal system engineering was done.</u> Historical data from the MK 15 and its civilian counterpart (CCR-1000) was used to lock-in operational requirements for readiness, reliability and maintainability. In addition, he indicated that suboptimization rather than system optimization was incorporated into the system engineering process used for the MK 16.

Its obvious that deleting a requirement like system engineering from an acquisition strategy, can save time and money up front in a program. However, like a popular TV commercial for an oil filter says, you can either pay a little now or a lot later. If the later payment is elected, it usually ends up costing more in the long run. The end result of system engineering is supposed to prevent this situation from developing.

2. Test and Evaluation

The test and evaluation strategy is concerned with the type, amount, and timing of testing. Testing could include components, subsystems, and systems. Typical questions include:

1. How much testing is necessary?
2. How much test, analyze, and fix (TAAF) will be required, and at what levels?
3. What test feedback and failure analysis procedures will be used? [Ref. 1:p. 3-6]a.

a. Discussion

<u>Where</u> we do our TECHEVAL and OPEVAL is just important as <u>how we conduct it</u>. A case in point is how the dry suit was tested.

On 10 June 1985, an OPEVAL was conducted on the dry suit that is now in use. This dry suit was designed to provide thermal protection for a diver in cold water. The dry suit is an essential piece of support equipment. Without thermal protection the mission profile of the MK 16 would be severely restricted.

The NAVEODTECHCEN pier on the Potomac River was chosen as the T&E site due to its proximity to the dive locker and relatively cool water. However, unusually warm weather caused air temperatures as high as 90^0F on the surface and water temperatures which varied from approximately 80^0F on the surface to 64^0F on the bottom. The warm air temperatures in particular caused problems with the fully suited divers during both the pre-dive and post-dive periods.

The original plan had called for 38^0F to 45^0F water temperature in the NAVEODTECHCEN hyperbaric chamber complex. However, due to problems with the wet pot refrigeration equipment, the temperature could not be reduced and the dives were performed in 80^0F water. The divers were compressed to 100 FSW equivalent pressure at average rates of 40 to 50 feet per minute.

The results of this evaluation were as follows:

1. The dry suit that was selected established the specifications for the first article that was tested by the Experimental Diving Unit in 1987.

2. Positive points cited: easier to work/swim, easy to don/doff, better mobility, "best suit ever worn", use in all situations, durable, and "far superior to any other suit ever worn."

3. Divers recommended that dry glove system be replaced because they didn't provide enough dexterity. They recommended that a wet glove arrangement be used as opposed to a dry glove arrangement. [Ref. 9:pp. 1-10]

In response to a tasking by NAVSEA, the Experimental Diving Unit conducted first article testing on the EOD

Dry Suit MK 1 MOD O, in November 1987. The objective of this study was to evaluate the MK 16 MOD O UBA along with the equipment necessary to support a diver for the longest HEO_2 Decompression Table in 4.4°C (40°F) water. The results were that, "all dives were aborted for thermal considerations, the first article EOD Dry Suit MK 1 MOD O was inadequate to support a diver in a long duration cold water dive." [Ref. 9:p. 1]

The wet suit gloves that the original evaluators liked because of their mobility and dexterity, offered little thermal protection in cold water. All dives were terminated because the divers were cold. The most common complaint was painful hands or feet which were numb and nonfunctional after 90 minutes. In addition, none of the suits had a sufficient air supply to prevent a suit squeeze to depths of 270 FSW. During this evaluation many dives had their dive profiles changed as a result of suit squeeze. For thermal protection it is necessary to have a layer of air in and around the insulating material. If water pressure exceeds the pressure within the dry suit, the result will be a suit squeeze (extremely painful). [Ref. 10:pp. 1-7]

3. Production

The production strategy is concerned with the capability to produce hardware (and associated software) within stated goals. The transition from development to production is perhaps one of the most difficult problems facing the Program Manager. It is necessary to ensure that the design is mature and stable. [Ref. 1:p. 3-7]

a. Discussion

Following delivery of the first three UBA production units on 8 November 1984, several problems were brought to light that subsequently delayed production and IOC. Design problems were discovered in the following three components:

1. Secondary Display.
2. Pressure Gauge and Hose Assembly.
3. Lee Valve (oxygen addition valve)

The Lee valve was the major component that delayed production until a new manufacturer could be found for it. The Lee valve was found to fail in the open position while adding oxygen to the system. Instead of fixing this problem, the Lee Manufacturing company decided to stop manufacturing this type of valve. A new manufacturer was subsequently found and the problem was resolved successfully. However, production of the UBA was delayed approximately six months. As a result of this delay a new delivery schedule had to be established by the Program Manager.

4. Deployment

The deployment strategy encompasses the field installation, operation, and support of the product. Some of the critical requirements include operation and support costs, manning levels, readiness and capability rates, and training. One of the first technical elements to be addressed in examining supportability is the maintenance concept, which influences the number and types of personnel, training, facility, and support system requirements. Strategic approaches must be developed for acquiring the total System Support Package (SSP), which includes spares, inventory, test equipment, training, publications, and data. Other questions to be addressed concern facility requirements and contractor support. [Ref. 1:p. 3-7]

a. Discussion

As the design and technical problems were being corrected, attention was then diverted to the often overlooked area of logistics support. Logistic support will be discussed in the ILS section. However, the ILS portion of the MK 16 program was the weak link within the MK 16 program for various reasons. One reason for this deficiency was the Integrated Logistics Support Management Team (ILSMT) organization and how it functioned. Principal members of ILSMT told the author that no regular meetings were scheduled and only on rare occasions did the key members of the ILSMT ever meet. One individual stated that he thought ILS was secondary to the goal of getting an end item out to the fleet.

G. ACQUISITION RESOURCE CONCERNS

The five major resource concerns that shaped the development of the MK 16 acquisition strategy and determined its effectiveness, are listed below.

1. Personnel/Organization.
2. Schedule.
3. Business/Financial.
4. Management Information.
5. Facilities. [Ref. 1:p. 3-7]

These five major elements are discussed in the following subsections.

1. Personnel and Organization

The elements that should be considered in developing a program management organization are listed as follows:

1. The skills needed in the program office.
2. The organizational structure of the program office and its relationship to other service commands and DoD.
3. Availability and capability of Government personnel. [Ref. 1:p. 3-8]

a. Discussion

During the research for this thesis the author evaluated the manning structure within the Program Management Office, and found it deficient. The following paragraphs give a detailed account, in chronological order, of the Program Management Office manning problem.

On 16 May 1985, Mr. W. A. Tarbell (Deputy Commander for Acquisition and Logistics) wrote a memorandum to SEA 06. In the memorandum he stated, "I reviewed logistics support for the MK 18 MOD O Mine Detection and Neutralization System this week and your Program Management Office (SEA 06X) folks have done a good job." Continuing on he said, "However, I noted that they are responsible for about 20 ACAT III and IV PROGRAMS and I noted very few people assigned to manage these programs." He ended his memorandum with, "I wonder if all the programs assigned to SEA 06X are getting adequate management attention?" [Ref. 11]

On 30 August 1985, the EOD program manager sent a memorandum to SEA 06. In that memorandum he stated, "Admiral, I urgently need your help in obtaining additional people for the EOD Program Office." [Ref. 12] The Program Manager's memorandum explained that within the last year and a half preceding his request, the EOD Program Office experienced significant growth in acquisition and life-cycle management responsibilities without an accompanying growth in people. In regards to being undermanned the Program Manager ended his memorandum with the following statement:

> CNO and SECNAV involvement in the acquisition management process at all levels since the disestablishment of NAVMAT has greatly reduced our ability to tailor program requirements at the sub-project level . . . we are playing a game of catch-up, we need more people to maintain control under more direct oversight. [Ref. 12]

This was the first time the EOD Program Manager went on record to document this manning problem. On 19 May 1987, SEA 06 established a policy for consistent and equitable manning within SEA 06 Program Management Offices. SEA 06 gave the following reason for creating this new manning policy, "Since becoming SEA 06, I have been increasingly concerned about the lack of consistency in our structure, staffing and utilization of our Program Management Office." He went on to say, "I directed a study to be conducted which reevaluated the implementation of project management in SEA 06 and developed a methodology for estimating Program Management Office staffing requirements." [Ref. 13]

In 1987 the Program Manager submitted a new staffing plan for the Program Management Office to SEA 06. Figure 7, is the present staffing structure of the Program Management Office. Figure 8, is the new staffing plan which reflects the addition of 10 personnel needed to bring the EOD Program Management Office into compliance with SEA 06's memorandum. The manning level within the Program Management Office is still not in compliance with SEA 06's memorandum.

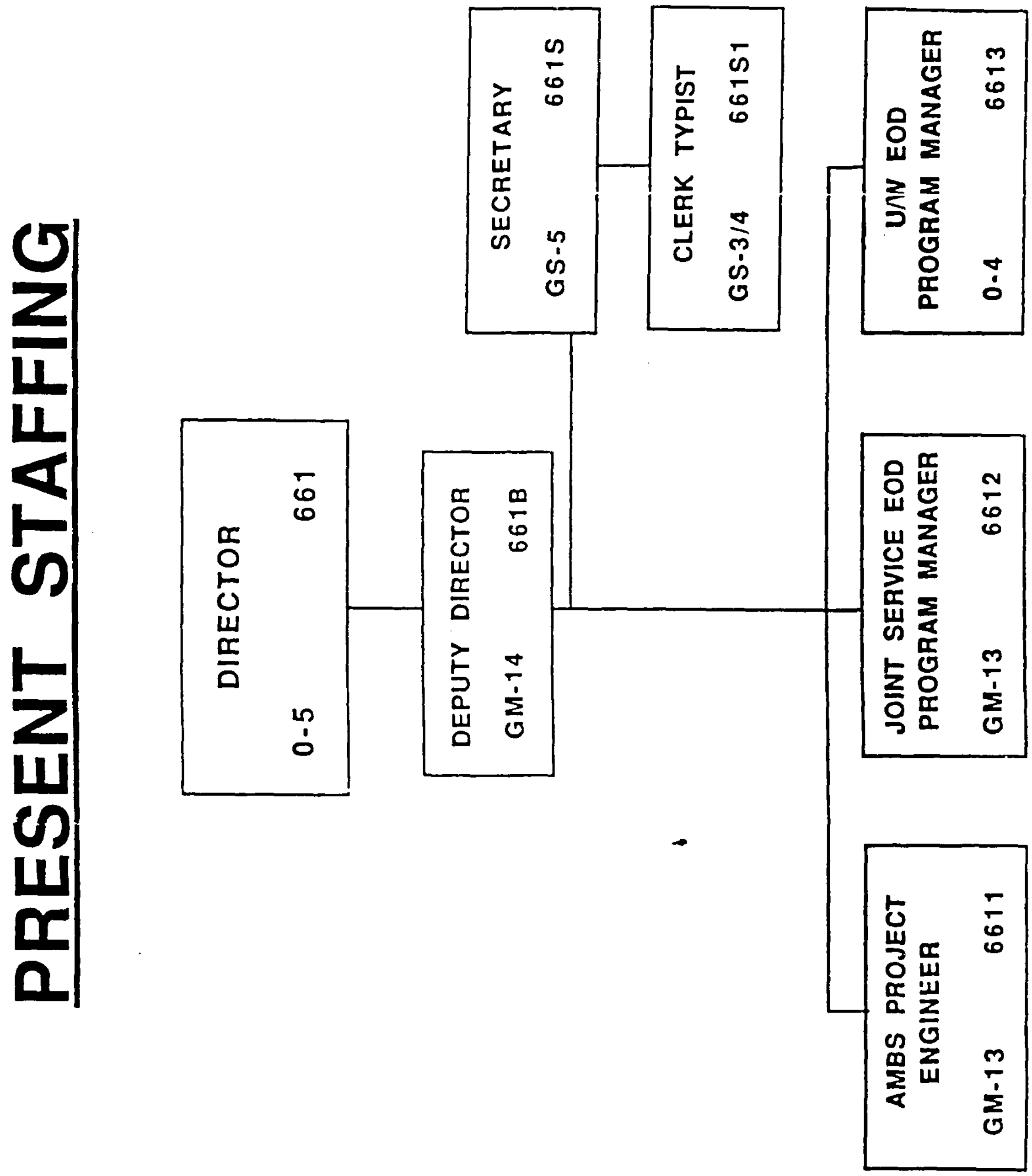

Figure 7
Present Manning Level of EOD Program Management Office
(Courtesy of the EOD Program Office)

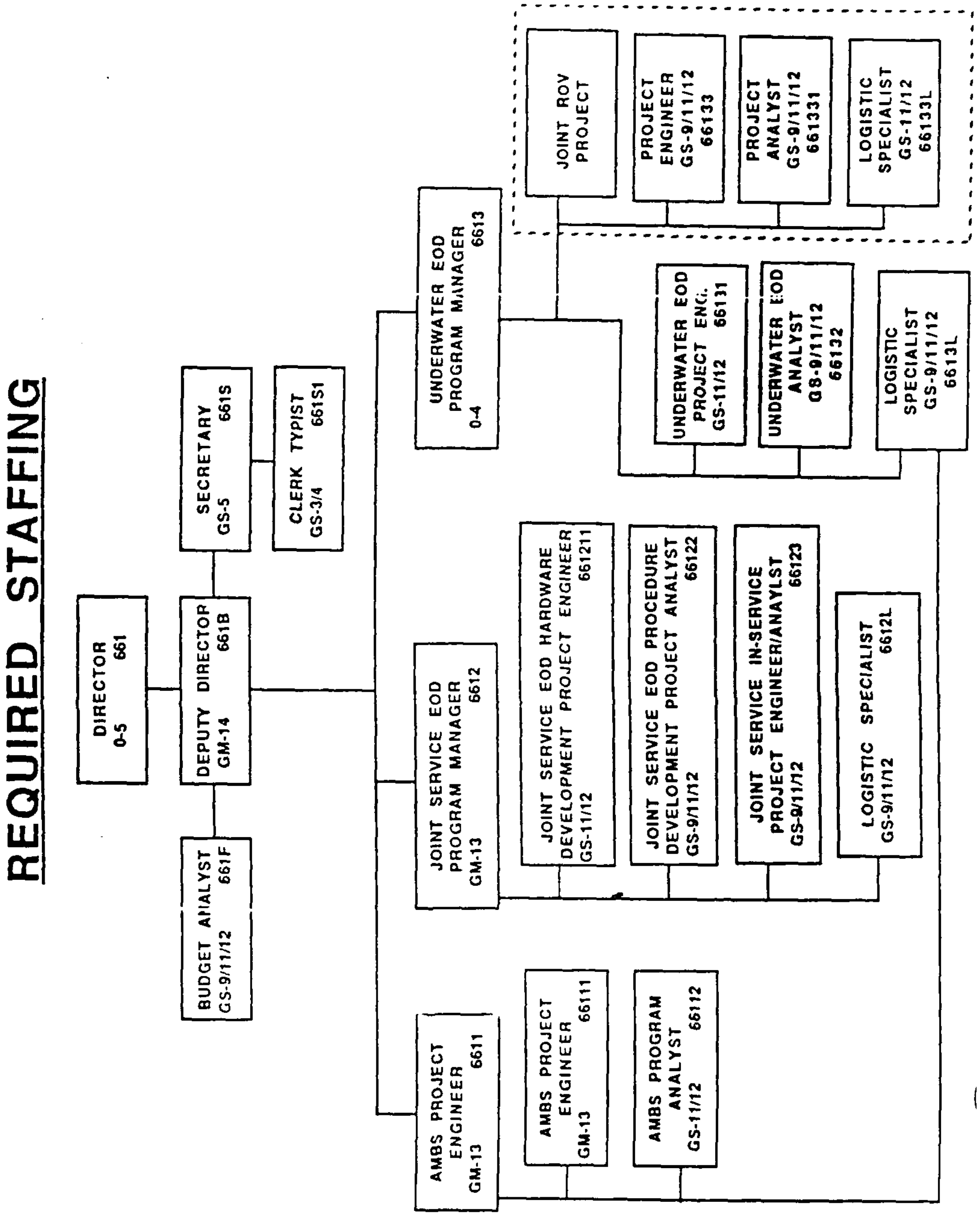

Figure 8
Required Manning Level of EOD Program Management Office
(Courtesy of EOD Program Office)

2. Schedule

"In many programs there is a pacing item or activity, one that dictates or defines expected completion dates." [Ref. 1:p. 3-8] In the MK 16 program an example of this was the oxygen addition valve. If risk analysis had been performed on the oxygen addition valve, it would have revealed an item that had the potential to delay production of the UBA. An applicable strategy such as phase concurrency, combined testing or parallel technology development, could then have been developed to counter this problem. However, in regards to the MK 16 program, when a material problem such as the oxygen addition valve arose, the acquisition process stopped until the problem was resolved.

3. Business and Financial

A business strategy defines the competitive and contracting policy the program manager wants to follow in the execution of a acquisition program. The request for proposal (RFP) defines the contractual issues. The structure of the RFP, the solicitation approach, use of data-rights clause, and the source selection strategy make up the business strategy. [Ref. 1:p. 3-8]

a. Discussion

The concept of competition for Navy systems must be viewed with respect to the leverage we enjoy as a single buyer. Competition, in an economic sense, forces firms to adopt the most efficient production techniques and to undertake long term planning and investments to reduce costs and increase quality. In addition, it encourages contractors to recommend design changes and performmance enhancements that improve market position by lowering price, in lieu of cost increasing engineering changes so typical of sole-source contracts. [Ref. 14:pp. 1-24]

Research for this thesis revealed that the acquisition strategy for the MK 16 did not have an effective nor well thought out plan for competition. The failure to develop a technical data package underscores the fact that competition was not an integral part of the original acquisition strategy. All MK 16 acquisition contracts have been on a sole source basis.

4. Management Information

A management information strategy helps the Program Manager establish a plan for monitoring the progress of the program. "Accurate, timely, and complete information is an important ingredient in the successful execution of any management approach used by the Program Manager." [Ref. 1:p. 3-8]

5. Facilities

"A facilities strategy considers the facility requirements for establishing, modernizing, and certifying production and operational capabilities." [Ref. 1:p. 3-9]

Productivity, cost reduction, surge capacity, and factory capability are typical concerns. [Ref. 1:p. 3-10]

H. ACQUISITION STRATEGY CRITERIA

For an acquisition strategy to provide the basis for meeting program objectives and to aid in gaining program acceptance and support, it must meet certain criteria:

1. Realism.
2. Stability.
3. Flexibility.
4. Resource balance.
5. Controlled Risk.

The following five subsections discuss the above program criteria requirements. Each one applies to the acquisition strategy used for the MK 16, either directly or indirectly.

1. Realism

An acquisition strategy is realistic if the program objectives are attainable and the strategic approach used can be successfully implemented with reasonable assurance. It is impossible to develop a realistic strategy with unrealistic goals and objectives. One of the best ways of achieving program reality is through the development of an acquisition strategy that is neither overly optimistic nor conservative. [Ref. 1:p. 3-13]

a. Discussion

There were many pressures working against "realism" within the MK 16 acquisition strategy. The first requirement for a successful strategy is an accurate assessment of the state of the art in all technology areas. Technological risk was assessed as low in the MK 16 program, when in reality it was high. As a result of this mistake the acquisition strategy was flawed from the very beginning. A review of Figure 4, will confirm this statement.

2. Stability

Acquisition stability is the characteristic that keeps negative external or internal changes from seriously influencing or delaying program progress. A good example of an external change is a change in program funding. A decrease in program funding might result in the reallocation of resources and priorities within a Program Management Office or in the cancelling of a program.

An example of a negative internal change is a constant turnover of personnel within a Program Management Office. This could lead to lack of continuity and accountability within a Program Management Office.

These negative changes often result in cost, schedule, or performance requirements that can potentially delay the attainment of program objectives. "Frequently, when a major change is made, such as in funding change, a downstream parameter such as logistics support bears the brunt of the change." [Ref. 1:p. 3-14]

a. Discussion

Integrated logistic support bore the brunt of changes within the MK 16 program. ILS will be discussed in more detail in the section on ILSP.

3. **Flexibility**

"Flexibility is a characteristic of the acquisition strategy related to the ease with which changes and failures can be accommodated without significant changes in resource requirements." [Ref. 1:p. 3-17] If a program doesn't have flexibility, any disruption can result in major problems for the program, such as, instability, insufficient allocation of resources and unrealistic approaches being taken to resolve the problem.

a. Discussion

The acquisition strategy used for the MK 16 was reactive rather than pro-active. When problems arose within the program, progress frequently stopped until a solution was found. A good example was the oxygen addition valve that delayed production by approximately six months.

4. **Resource Balance**

The following definition of resource balance will help the reader understand the importance of this concept in an acquisition strategy:

1. Resource balance is a condition of equilibrium between and within major program objectives that are competing for resources.

2. The achievement of cost, schedule, and technical requirements uses resources of time, people, facilities, and money, all of which are limited.

3. The degree of balance is not usually measured directly, but it can be measured in terms of risk in meeting objectives. In this sense, a balanced program is one for which all the risks are approximately equal. [Ref. 1:p. 3-16]

The Program Manager must understand the priorities, relationships, risks, and required resources for each objective, if he does, then a balanced strategy can be developed. [Ref. 1:p. 3-16]

a. **Discussion**

The MK 16 program was not resource balanced. As previously discussed, the manning level was a major problem within the Program Management Office. In a balanced program, resources can be allocated to achieve desired goals and objectives in a uniform manner. Because of the manning level within the EOD Program Management Office, the Program Manager couldn't allocate personnel in a balanced manner to meet the requirements of the MK 16 program. The result was that predetermined objectives and goals weren't achieved. Figure 4, supports this statement.

5. **Controlled Risk**

Risk, as applied to an acquisition strategy, is the probability that a program objective or goal, won't be achieved. The following list discusses the concept of risk in an acquisition strategy:

1. Risk as applied to acquisition strategy, is a measure of the probability and consequence of not achieving a milestone or predetermined program goal.

2. In general, as either the uncertainty or consequences from not achieving a goal increases, so does the risk. Both the uncertainty and the damage must be considered in a risk analysis.

3. An acquisition strategy should be structured to identify hazards and to allow safeguards to be developed to overcome them. If enough analysis is done risk can be reduced to an acceptable level. [Ref. 1:p. 3-20]

a. Discussion

Risk analysis was not conducted nor was it part of the acquisition strategy. The Mk 16 UBA was considered a low risk program because of the assumption that the MK 16 was a redesign of the MK 15. As a result of this assumption the Program Manager saw no need to structure the acquisition strategy to deal with risk when it didn't exist. In reality, however, the MK 16 program was a high risk program. The section entitled, "MK 16 Acquisition Strategy" in chapter four, will discuss why the MK 16 program was a high risk program.

I. ACQUISITION STRATEGY CONSTRAINTS AND LIMIATATIONS

The following are a few of the primary constraints and limitations imposed on the formulation and execution of the MK 16 acquisition strategy:

1. Economic Constraints.

2. Political Constraints.

3. Technical Constraints.

4. Schedule Constraints.

5. Resource Constraints.

The constraints and limitations listed above are discussed in the next five subsections. Each of these constraints, either directly or indirectly, affected the development and execution of the MK 16 acquisition strategy.

1. Economic Constraints

The following is a definition of economic constraints:

> Pressures exist to hold down program costs. Over the last several years, cost has grown to be equal to, if not more important than schedule, performance and supportability as the major element of a system acquisition. The push for competition, dual or second sourcing, component breakout, affordability and other similar concepts/methods involved in the production of systems have forced the Program Manager to ensure incorporation of cost efficient methods into the acquisition strategy. [Ref. 6:p. 93]

a. Discussion

To date, all contracts have been awarded to Rexnord on a sole-source basis. The first buy was sole-source to Rexnord because no other manufacturer wanted to bid on the solicitation. After the contract was awarded to Rexnord, the Program Manager decided to have Rexnord convert their drawings to NAVSEA level III drawings. This was done, through a modification to the original contract, after the original contract was awarded to Rexnord. The original contract only called for level II drawings.

In 1984, the technical data package (TDP) was found to be deficient because Rexnord was unable to meet the requirements of DOD-STD-100 for level III drawings. The drawings were then returned to the Government. Subsequently, a contract was awarded to WESTINGHOUSE for $348,914.00 to convert the Rexnord drawings to level III.

In 1986, the contract with WESTINGHOUSE expired and the drawings were again returned to the Government, still unfinished.

On 10 April 1986, the Program Manager requested authorization to award another contract to Rexnord (using other than full and open competition). The request was approved and the second contract was awarded to Rexnord on a sole-source basis.

The drawings that were mentioned previously are still deficient and don't reflect the configuration of the MK 16. Numerous engineering changes have not been incorporated into these drawings. This fact was discussed on 12 April 1989 at the quarterly logistic support meeting at NAVEODTECHCEN Code 45. Mr. Jesse M. Urquidez (Code 454) stated that the current plan called for a competitive package to be put together, with the engineering changes attached to the appropriate drawing, for a competitive buy sometime in FY 91. If this competitive package is not handled correctly, it could become a "contractor's dream come true!"

2. Political Constraints

The following guidance is provided in regards to political constraints on an acquisition strategy:

1. The development and execution of an acquisition strategy, can be significantly influenced by political concerns. This influence can result from hearings held by congress, or requirements imposed in the Defense Authorization or Appropriation Bills.

2. Some of the many political concerns can include such issues as the size, scope or cost of a program; the overall level of defense expenditures; the state of the economy; the condition and location of potential prime and subcontractors; special interest group concerns and; proposed basing schemes.

3. In order to develop a successful acquisition strategy, the Program Manager must be able to anticipate the impact that political pressures can have on the program. The Program Manager must be able to calculate the political ramifications of each strategy option considered as well as the likelihood of its acceptance. [Ref. 6:p. 93]

3. Technical Constraints

The following discussion provides guidance on creating a balanced acquisition strategy in regards to technical constraints:

1. Technical considerations frequently become the overriding concern of personnel responsible for managing and reviewing program progress.

2. The Program Manager's objective should be to strike a balance between technical performance, program costs/funding, schedule requirements and supportability issues.

3. The identification and categorization of all of the technical issues which must be resolved during a program's life cannot possibly be addressed in the early

stages of the program. The objective at program initiation should be to identify the types of issues which need to be addressed, the methodology to be used to address them and the phase of the acquisition process when they must be considered. [Ref. 6:p. 93]

4. Schedule Constraints

Schedule constraints and the impact they have on the development of an acquisition strategy are discussed below:

1. There is constant pressure to reduce the time it takes to acquire and field new systems. If an IOC date has been established, the strategy options available to the Program Manager become restricted.

2. Scheduling requirements impact the development of an acquisition strategy such as the scheduling of test and evaluation activities, the programming of events involving different fiscal years or types of funds (e.g., research and development versus production funds), and establishing formal program reviews.

3. If a programs's acquisition strategy is dominated by schedule constraints, many strategy options will be eliminated. As an example, an inflexible IOC date would require the Program Manager to force fit design/development, and production activities into perhaps an extremely tight schedule. [Ref. 6:pp. 93-94]

a. Discussion

As was previously mentioned, the acquisition strategy for the MK 16 was found to be reactive instead of pro-active. The reason for this can be directly attributed to the deficient manning level within the Program Management Office. In a management environment like this, acquisition strategy options and alternatives that could have improved the program are viewed as a luxury, and were traded off to save time and money in the achievement of a milestone or schedule. It is noteworthy to add that CINCPACFLT wanted the MK 16 delivered no later than 1 June 1986 (CINCPACFLT MSG R140219Z Aug. 84). The first operational units were delivered to fleet in November 1985.

5. Resource Constraints

What type and amount of resources a program has is critical to the success or failure of an acquisition strategy. The most important resources are money and knowledgeable personnel. In his article, "Acquisition Strategy," Dr. Lamm made the following statement:

> The lack of other critical resources, however, such as access to Government laboratories and test facilities, engineering support, higher level organizational support, legal counsel, business strategy support and technical/production skills, can place severe limitations upon the execution of even the most carefully structured acquisition strategy. [Ref. 6:p. 94]

a. Discussion

The great majority of DoD acquisition programs are constrained by money. However, the major constraint in the Mk 16 program was insufficient personnel within the Program Management Office and NAVEODTECHCEN Code 45 organization. As previously stated, the EOD Program Management Office needs an additional 10 personnel and Code 45 needs approximately 17 more personnel. Tasks that normally would be handled by a GS-8, are being done by GS-4 personnel in the Code 45 organization. It is commendable that these personnel are willing to perform tasks they weren't properly trained to do, nor monetarily rewarded for. However, in the long run this will become a management problem. The Department Head who is in charge of Code 45 (Major Kertis Peterson) has performed excellently, however, no one man can solve the problem of being undermanned by 17 people. Code 45 is currently documenting this manning problem within NAVEODTECHCEN.

J. ACQUISITION STRATEGY BENEFITS

> Successful program management requires the continuing actions of planning, organizing, directing, coordinating, controlling, and evaluating the use of money, material, staff, contractors, and facilities to achieve program objectives within the constraints placed on the program. [Ref. 1:p. 3-1]

1. Discussion

If a Program Manager is unable to create an acquisition strategy that takes into consideration the concepts previously mentioned in this chapter, the result will be, "diversions from program objectives, additional cost, schedule, and technical problems during subsequent cycle phases." [Ref. 1:p. 3-2]

K. INTEGRATED LOGISTICS SUPPORT

> Logistics in the context of the system life-cycle involves planning, analysis and design, testing, production, distribution, and sustaining the support of a system throughout the consumer use period. [Ref. 7:p. 5]

The different areas of logistic support and how they are interrelated throughout the life-cycle of the system are shown in Figure 9. This section provides an overview of the logistic

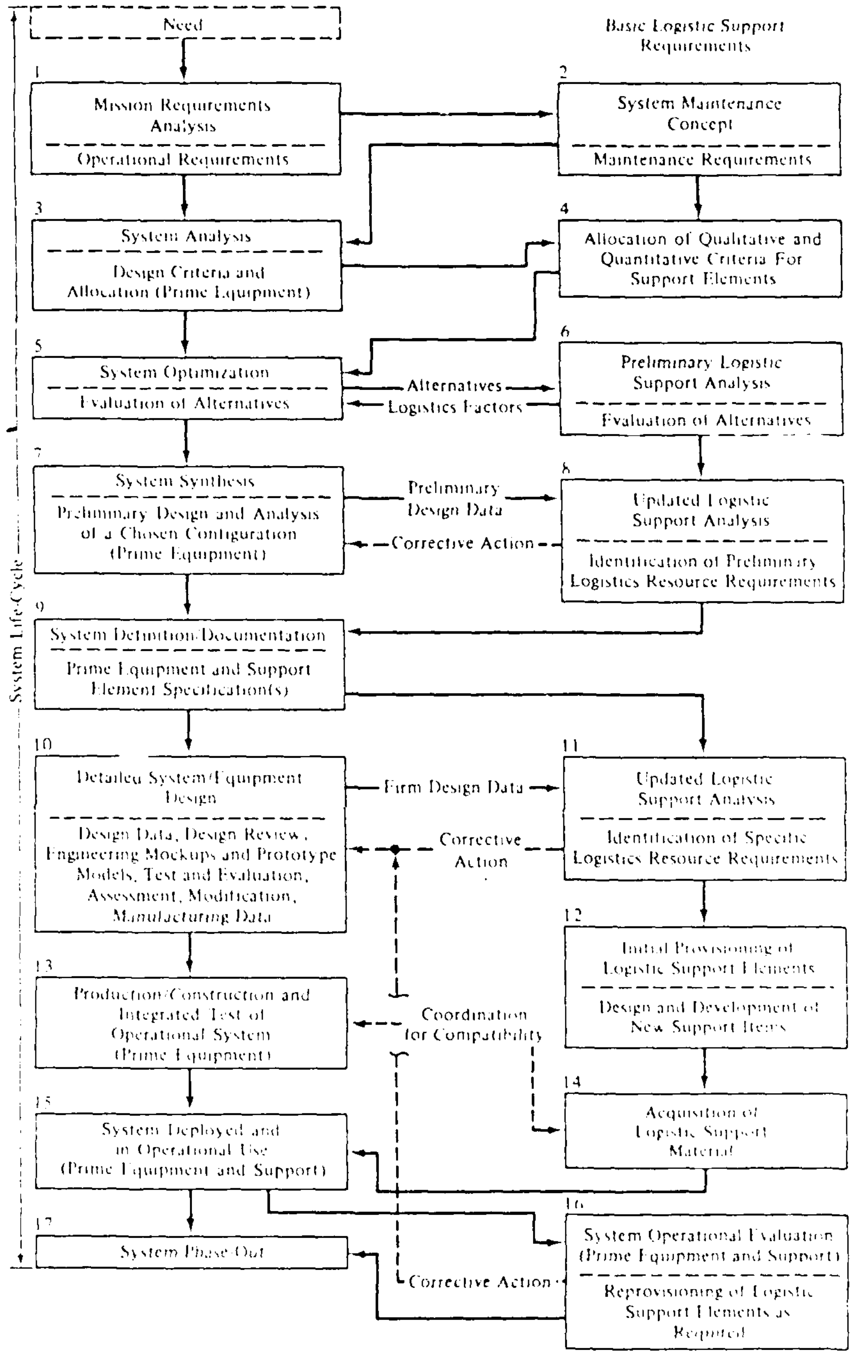

Figure 9
Logistics in the System Life Cycle (p. 7)
Source: Logistics Engineering and Management by Benjamin S. Blanchard

activities highlighted in Figure 9. A detailed explanation of this integrated logistics support model is provided in Appendix B. An analysis of the logistic development process depicted in Figure 9 will give the reader an understanding of the importance of logistics in the life-cycle of a system. In addition, the reader will gain an understanding of why logistic requirements <u>must be planned and integrated into the system design concept from the very beginning of a program</u>. [Ref. 7:p. 4-6]

> Integrated logistic support is basically a management function that provides the initial planning, funding and controls which help to assure that the ultimate consumer (or user) will receive a system that will not only meet performance requirements, but one that can be expeditiously and economically supported throughout its programmed life-cycle. [Ref. 7:p. 11]

The steps highlighted in Figure 9, are critical to the formulation, development, and execution of any acquisition program. Each block ⌣ be "tailored" to satisfy the planning requirements of any type of program. Figure 9 depicts a thought process that integrates systems engineering and ILSP. The result, when this model is correctly tailored and executed, is system optimization. [Ref. 7:pp. 8-9]

1. Discussion

MK 16 logistic support problems first came to light in late 1985. These problems were precipitated by the Program Manager's decision not to conduct a LSA, ILS/system engineering based strategy. The ILSP and the acquisition plan stated that a formal LSA for the MK 16 was not warranted because the MK 16 was merely a redesign of the MK 15. The Program Manager reasoned in the ILSP that the support requirements of the MK 15 which had been validated through successful completion of DT-111 TECHEVAL and OT-111 OPEVAL could also be applied to the MK 16. The LSA section of the ILSP concluded with the statement that, "the utilization of MK 15 experience and data . . . would achieve the end objective of an LSA without the additional expense and time of a formal LSA program." The decision not to conduct a LSA was probably made because of funding, schedule and Program Management Office manning constraints. The repercussions of that decision began to be felt in late 1986 when the Provisioning Parts List was deemed to be unusable as a result of errors and the omission of critical data such as: replacement factors; estimated prices; shelf life codes; and maintenance factors.

Problems with logistic support began to affect the fleet in early 1988. COMNAVSURFPAC indicated that significant logistic support deficiencies existed within the MK 16 acquisition program. In addition, COMNAVSURFPAC also pointed out that inadequacies in the MK 16 Logistics Support Program had directly affected the readiness of operational units in a negative manner.

To address the fleet problems, the first MK 16 logistics material support meeting was held by COMNAVSEASYSCOM at the NAVEODTECHCEN on 30 March 1988. The purpose of the meeting was to identify and discuss logistic and material support problems. Major milestones from the last ILSP, dated 1981, were presented to show program status. Attendees were told by the Program Manager that, "the current MK 16 material and logistic problems were the result of critical logistic support milestones not being met."

Among the mary issues addressed at that meeting, the following are particularly noteworthy. The first issue was whether or not to update the ILSP, since production had already begun. In lieu of updating the ILSP, the meeting attendees concluded that an Operational Logistics Support Summary should be developed to define the operational support requirements.

The second issue was the material support date (MSD) for the MK 16. As a result of continuing provisioning problems, SPCC stated that it would not logistically support the MK 16 until 1991. NAVEODTECHCEN Code 45 is now correcting these provisioning problems.

The third issue was parts availability. The operational units were not receiving ordered parts. The Program Manager reported that, "poor parts planning during the development phases caused the present lack of spare parts." Many users felt that an operational support kit consisting of spare parts should always be provided with the MK 16 UBA. The present plan calls for one operational support kit for every four UBAs. The users felt that this was the most efficient way of maintaining system availability.

The present logistic support plan calls for the elimination of the operational support kit when MSD is achieved. The inventory control point will then provide centralized control for all spare part support. However, no analysis has been done to determine the impact this action will have on logistic support. The majority of users stated that they were concerned with how long it took to receive spare parts.

An analysis might reveal that its more effective to stock spares at the EODGROUP level rather than the EODTECHCEN or retain the operational support kit concept. However, before a final decision is made on eliminating the kits or stocking spares in a centralized rather than a decentralized location, a study needs to be conducted.

During discussions with various personnel from NAVEODTECHCEN Code 45, the following question was asked by the author, "how were the number of spares needed to support this system determined?" The answer given was that estimates were made. No analytical models were used in the development of spare part requirements. The result was that some stockage levels have exceeded demand while others failed to meet demand. The goal is to have the correct amount and type of spares in inventory at the lowest cost. The quantitative methods needed to perform this task are not difficult and any good logistician should be able to use them in achieving an optimum economic order quantity.

The fourth issue was O_2 sensors. 293 failure analysis reports (FARS) were submitted on sensors that were either not within the specified operating parameters, leaking or had broken wires. Rexnord stated that it came out with a gel-type sensor which eliminated the problem of leaking, but the users reported that the sensors were still leaking. The oxygen sensor has caused more controversy than any other component of the MK 16. This problem is presently under investigation by Code 45.

In summation, the primary goal of these quarterly logistic support meetings was to discuss MK 16 logistic support problems and provide solutions in a "plan of action and milestones" (POA&M) format. The secondary goal was the improvement of communication between the Program Manager, the inventory control point (NAVEODTECHCEN), and the fleet. NAVEODTECHCEN Code 45 was tasked by NAVSEA with providing quarterly reports on logistic and material support issues. These quarterly reports have been very beneficial and have resulted in the resolution of many MK 16 ILS problems. The quarterly reports are the result of meetings between fleet personnel, NAVEODTECHCEN Code 45 personnel and the Program Manager.

L. ECONOMIC FACTORS

"In dealing with the aspect of cost, one must address total life-cycle cost." [Ref. 7:p. 66] Historically, the life-cycle cost for a system has been portrayed in the following manner:

1. In the past, total system cost has not been too visible, particularly those costs associated with system operation and support.

2. The cost visibility problem can be related to the "iceberg effect" illustrated in Figure 10. One must consider not only system acquisition cost, but other costs as well. [Ref. 7:p. 66]

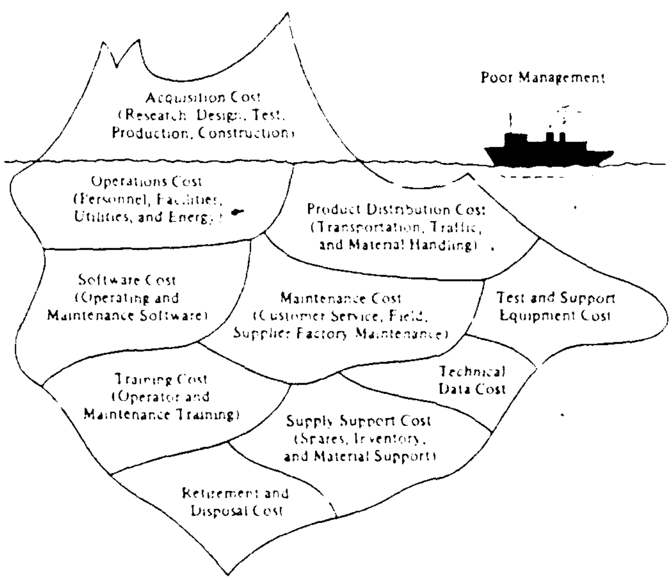

Figure 10
Total Life-Cycle Cost Visibility
Source: Logistics Engineering and Management by
Benjamin S. Blanchard

Historically, when addressing total cost, experience has shown that a major portion of the projected life-cycle cost for a system is the result of decisions made during the early phases of program planning and system design. These decisions pertain to the evaluation of alternative use profiles, maintenance and support policies, and level of repair concepts. Thus, in dealing with economic factors, a life-cycle approach is required. [Ref. 7:p. 66]

1. **Discussion**

The LCC data presented here was provided by NAVEODTECHCEN Code 45. The following is a list of estimated "sunk" costs for the MK 16. This list includes all known costs for fielding 441 MK 16's. The list does not include the Gas Transfer System or the Diver Thermal Protection Suit. Cost data on these latter components was unavailable for inclusion in this list. [Ref. 15]

	ITEM/TASK	COST
a.	441 MK 16 UBA's @ $41,550 each.	$18,323,550
b.	111 Operational Support Kits @ $46,280 each.	$ 5,137,080
c.	Westinghouse Engineering drawing contract ("K").	$ 385,000
d.	Oxygen Cleaning/Depot Repair Facility. (Note: includes initial stock of DLR parts).	$ 3,101,075
e.	"K" item acceptance, Production Engineering and Certification.	$ 455,000
f.	O&M manual revision "K".	$ 89,000
g.	Physical Configuration Audit and Eng. Drawing Package correction.	$ 128,000

h.	Spares "K" through NRCC (Note: to replace spares issued to fleet).	$ 293,000
i.	Oxygen Sensors (Note: only through FY 90).	$ 200,000
j.	Provisioning Parts buy by SPCC (Note: this is an estimate based on current prices).	$ 6,481,000
k.	5 Year overhaul of first 96 MK 16 UBAs @ $12,700 each (Note: $6,000 for parts and $6,700 for labor).	$ 1,221,120
l.	Depot Level Repair costs until MSD, approximately $350,000 per year, estimate 2 years till MSD.	$ 700,000
m.	Product Improvement Program (PIP).	$ 900,000
n.	RD&T (Note: this is an approximate cost from data gathered).	$ 2,700,000
TOTAL		$40,113,825

During phone conversations between the Program Manager, Code 45 and the author, the following information was provided. If 15 years was assumed as the estimated useful life for the MK 16, an additional cost of approximately seven to ten million dollars could be added to the previous total of $40,113,825. [Ref. 15] The new LCC total would then be somewhere between $47,113,825 and $50,113,825. If we use $50,113,825 for the LCC for the MK 16, simple computations quickly reveal that acquisition of 441 MK 16 UBA's make up only 36.57% of the LCC and ILS makes up 63.43% of the LCC of the system. This confirms the concept contained in Figure 10, that ILS is the lower part of the iceberg, unseen until the bill comes in.

In summation, the recent combination of economic trends, cost growth experienced for many systems, and budget reductions within DoD, has created an awareness of total system cost. In addition, the acquisition costs of operating and maintaining systems in existence are increasing at an alarming rate. The end result is that fewer dollars are available to meet new requirements, as well as maintaining existing systems. [Ref. 7:p. 65-66]

IV. LESSONS LEARNED

A. INTRODUCTION

The purpose of this thesis was to analyze the strategic planning and management control processes used by different DoD agencies in taking this program from concept to full operational capability. From this analysis, principal "lessons learned" in fielding this ACAT III system were developed and discussed, in the hope that subsequent systems could be fielded more effectively.

1. Discussion

From the research conducted the following "lessons learned" are presented:

1. Risk analysis is critical to the development of an acquisition strategy.

2. The system acquisition process of integrating LSA/ILS into a system engineering approach should never be traded-off.

3. To be effective and in control of the management process, organizations must be properly staffed.

The following sections discuss these three interrelated "lessons learned" in more detail:

a. MK 16 Acquisition Strategy

It is noteworthy to add that when the R&D effort first started, the task of making the MK 16 nonmagnetic and acoustically quiet seemed an easy goal. In practice, nonmagnetic and acoustic design requirements fathered a host of engineering challenges, such as meeting military standards for low measure magnetic signature and changing the oxygen add valve from a solenoid (which makes a clicking sound) to the acoustically quiet piezoelectric valve. [Ref. 4:p. 9]

The acquisition strategy for the MK 16 evolved from the assumption that the MK 16 was merely a redesign of the MK 15. Subsequently, technical risk was determined to be low when, in reality, it was high. As a direct result of this assumption, the acquisition strategy and plans were structured for a low risk program. The MK 16 had no alternate plans to deal with technical problems in an effective manner. When a technical problem arose the program simply stopped until the problem was corrected. For example, finding a replacement for the Grindley oxygen addition valve resulted in a six month delay in the IOC date.

The product improvement program (PIP), which was initiated by Code 45 in 1988, had the goal of increasing reliability and decreasing maintenance costs. Since this function wasn't performed up front by the Program Manager, Code 45 is now doing it after the fact and at a higher cost.

Increased cost in acquisition programs has received a lot of special attention, particularly in light of recent reductions in DoD's budget. If the acquisition strategy for the MK 16 included pre-planned product improvement (P^3I), a cost savings could have been realized. Pre-planned product improvement could have performed the same function as PIP but at a lower cost.

In addition, an innovative approach to competition could have been planned into the acquisition strategy from the beginning. The failure to develop a technical data package underscores the fact that competition was not an integral part of the original acquisition strategy.

Current DoD system acquisition policies don't account for the fact that system acquisition is concerned basically with an industrial process. The acquisition process for the MK 16 was a technical process focused on the design, test, and production of a system. It will either fail or develop problems if these processes are not done in a controlled and disciplined manner. The acquisition strategy is the mechanism that performs this function of control and discipline. The Program Manager has to realize that the acquisition process is a continuum of interrelated and interdependent disciplines. Incorrect assessments of program risk will result in a failure to do well in other areas of the acquisition process. When this happens, as it did with the MK 16 program, a high risk program results, whose equipment is deployed later than originally planned and at a higher cost. [Ref. 16:pp. 68-69]

b. **MK 16 Integrated Logistics Support**

The integration of LSA and system engineering, as previously mentioned, is an acquisition system process that can be tailored to the needs of a program. It is a thought process towards system optimization. When this process was deleted from the acquisition strategy, money and time were saved, but what was saved up front was lost as the program progressed through the phases of the acquisition cycle. The following list describes some of the present problems with material and logistic support for the MK 16:

1. Since the ILSP of 1981 was never updated, the Program Manager decided that a Operational Logistics Support Summary (OLSS) should be done to define the MK 16 operational support requirements. The OLLS will be delivered in 1989.

2. The material support date (MSD), which was originally scheduled for 1983, will not be achieved until 1991.

3. Both EODGROUP ONE and TWO are concerned about material and logistic support problems since only 60% of the MK 16 inventory is currently operational.

4. The depot and organizational stockage levels were made using "estimates" rather than quantitative methods.

5. $348,000 was spent for a technical data package (TDP) that still does not meet military standards for level III drawings.

6. A study needs to be conducted to determine location and stockage levels for of spares required to support the MK 16 UBA. In addition, a study needs to be done to determine if spare parts should be centrally or decentrally located once MSD is achieved and if operational support kits should still be supplied once MSD is achieved.

The fleet now has a system that satisfies an operational requirement. However, the bill for maintaining and supporting this system could have been lower if an integrated LSA and system engineering approach was used in the development of the MK 16. When it arrives, the end-user will have to pay the price for what was saved up front.

Reliability and maintainability are inherent design attributes, however, no trade-off analysis was done to achieve an optimum system. The reason for this was that these factors were locked-in as a result of early program decisions. The factors of reliability and maintainability determine the amount and frequency of maintenance for the MK 16. There is an inverse relationship between reliability and maintenance. If reliability was increased for the MK 16, maintenance requirements at the depot and organizational levels would have decreased. The bottom line is that time and money would have been saved because of a concurrent reduction in preventive and corrective maintenance for the MK 16. In addition, not as many spares would have been needed to support the MK 16. Less inventory would have been needed to support the MK 16 and, as a result, costs would have been reduced over the life-cycle of the system. However, there is one problem that has to be dealt with when specific program characteristics like reliability are increased. The Program Manager has to be able to show that the extra cost involved with an increase in reliability will save enough in the cost of maintaining and supporting the system so that the MK 16 will cost less over its life-cycle. This is not a difficult task but it does require a properly manned Program Management Office with qualified personnel.

c. Manning within the PMO and Code 45

The majority of problems discussed here and in chapter three can be attributed directly or indirectly to the fact that the Program Manager was undermanned by 10 personnel and NAVEODTECHCEN Code 45 by 17 personnel. That these two organizations have accomplished as much as they have is a credit to the personnel within them.

In conversations with many Program Managers, the one piece of advice given over and over was, "surround yourself with good people and give them the freedom to do the job." However, in an environment where the program is undermanned, it's unrealistic to expect that the "few" can do the job of "many".

Manning within the Program Management Office: If a Program Manager is placed in an environment that is constrained by manning, cost, and schedule considerations, the result will be the development of an acquisition strategy that reflects these constraints. The stability and effectiveness of a Program Management Office will also be affected by the number of Program Managers assigned to a program over time. The MK 16 program has had six Program Managers over a 13-year period. The average tour length for each Program Manager was 2.17 years. The policy for tour lengths has recently been changed to three years. This change should have a positive effect on the acquisition process within the Explosive Ordnance Disposal Program Management Office.

Manning within NAVEODTECHCEN Code 45: The integration of support into the design process is a complex endeavor. Successful integration requires that the ILS manager take a strong leadership role in both system engineering and ILS processes. This was a major weakness within the MK 16 program and can't be completely attributed to the fact that Code 45 was undermanned by 17 personnel.

The Integrated Logistics Support Management Team (ILSMT) organization didn't function as designed. Conversations with various members of the Integrated Logistics Support Management Team (ILSMT) revealed that meetings were not held on a regular basis to discuss logistic support matters. In addition, various members of the ILSMT felt that logistic support was of secondary importance to getting the UBA hardware out to the fleet.

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

Program Manager: The manning structure of the Explosive Ordnance Disposal Program Management Office is deficient. The EOD Program Management Office is undermanned. An additional 10 people, are required to bring it into compliance with SEA 06's program management manning document. The required qualifications for these additional people are provided in Figure 8. During the research for this thesis, deficient manning within the Program Management Office was found to be directly or indirectly responsible for the majority of MK 16 material and logistic problems discussed in this paper. This manning problem, which was first documented on 30 August 1985, still has not been resolved.

The acquisition strategy that was developed for the MK 16 wasn't structured as a strategic document. Short-term planning was stressed rather than long-term planning. In defense of the Program Manager, it's difficult to develop a strategic plan when all of the program management resources were being used just to achieve the next program milestone. This management problem was expressed by another Program Manager when he said, "Admiral . . . we are playing a game of catch-up, we need more people to maintain control under more direct oversight." [Ref. 12]

Every Program Manager realizes that he is the one who is responsible and held accountable for the failure or success of a program. However, every successful Program Manager knows, that to succeed, one needs an effective and fully manned professional Program Management Office staff. Being undermanned by approximately 48% results in an management environment where the Program Manager can't plan the work and then work the plan. One of the cardinal rules for a Program Manager is to organize resources to fit the program. However, given the previously documented manning constraint, the result was a program organized to fit the resources. This was the management approach used for the MK 16 program. The first approach results in program optimization while the second often results in suboptimization.

EODTECHCEN Code 45: This organization is undermanned by 17 personnel. This number was derived from an internal manning review conducted by the department head of Code 45. However, a formal manning review should be done since there is no overall manning document similar to the SEA 06 manning directive that can be cited for manning guidance.

As a direct result of this manning problem, individuals are performing tasks they have not been trained to do, nor are monetarily rewarded for. In the long run, this will become a management problem for the organization. The majority of ILS problems that the MK 16 has experienced are directly or indirectly related to the manning level within Code 45.

ILS Management Techniques in System Engineering: LSA was one of the management techniques that was traded-off along with system engineering, to save time and money. As previously mentioned, this was probably the result of, organizing a program to fit the resources. Integrating LSA/ILS into the system engineering process would have resulted in the enhancement of the system development process and ensured the timely influence of support requirements on design. [Ref. 17:p. 4-8] Since, this was never done, the result was less than optimum logistic support for the MK 16. The management techniques mentioned above should never be traded-off.

B. RECOMMENDATIONS

Program Management Office: Take appropriate action to bring the manning structure of the EOD Program Management Office into compliance with SEA 06's Program Management Office Manning Document, as shown in Figure 8.

Add the Material Logistics Support XX32P subspecialty code to the position of Director, SEA 06X (an O5 billet). Appendix A, describes some of the educational skills a graduate of the Material Logistic Support curriculum at the Naval Postgraduate School can bring to the EOD Program Manager billet. The strategic importance of the SEA 06X billet requires that only the "best" personnel from the Special Operations community should be assigned to this billet.

NAVEODTECHCEN Code (45): Take appropriate action to conduct a formal manning review of Code 45, and hire additional personnel as indicated by the manning review.

The Department Head, Code 45, should be a Certified Professional Logistician (CPL) or equivalent. The research for this thesis revealed that an experienced logistician with the appropriate background is needed within the NAVEODTECHCEN organization. Code 45 is the department where this expertise should reside. Code 45 should not be headed by an engineer who has no logistics background for the following reason: engineers are hardware oriented and view logistics as a downstream effort. The bottom line is that LSA/ILS should be a Code 45 function and systems engineering should be a Code 50 function. The result will be an improvement in logistic support and acquisition system development.

ILS Management Techniques in System Engineering: Strongly recommend that the model described in Appendix B be used in the development and execution of all acquisition programs. If the goal of a Program Manager is system optimization, the integration of ILS into the system engineering process will achieve it. <u>This process is essential to the success of a program</u>. To make this happen, a real time iterative relationship between the ILS process and the product definition (design) process is necessary. ILS program success hinges on how the readiness and supportability characteristics are designed into the system during early development. The system engineering process provides a framework for the material system to acquire the desired supportability characteristics. "System engineering, when done properly, integrates the effects of logistic disciplines such as survivability, reliability, and maintainability within the system design." [Ref. 17:p. 4-1]

APPENDIX A

DEPARTMENT OF ADMINISTRATIVE SCIENCES
MASTER OF SCIENCE IN MANAGEMENT
MATERIAL SUPPORT CURRICULUM
EDUCATIONAL SKILL REQUIREMENTS

Upon graduation, the student will have acquired these skills:

1. Thorough understanding of managerial theory and principles.

2. Thorough knowledge of organizational planning, coordinating, and control systems: diagnosis, design, implementation, and operation.

3. Thorough knowledge of the life-cycle of costing, cost-benefit analysis, optimization techniques, and probability models and statistics.

4. Thorough knowledge of the life-cycle of systems: research, development, production, provisioning, operation, maintenance and logistic support.

5. Knowledge of the theories and principles of physical distribution and production.

6. Knowledge of the civil service system, career planning and manpower requirements determination as related to the formulation and execution of logistic policy.

7. Knowledge of management information systems and their efficient and effective use in the Navy.

8. General knowledge of systems design and analysis theory and practice including reliability, maintainability, configuration management, systems interpretation, quality assurance, and systems performance measurement.

9. General familiarity with logistics support for operational and contingency planning.

10. Understand the structure and process of DON/DoD logistics system including integrated logistic support planning.

11. Understanding of concepts of systems acquisition and application of project management with the process.

12. Understanding of all phases of the acquisition process and the relationship of integrated logistics support to acquisition.

APPENDIX B

The following paragraphs describe the integrated logistic support model/process highlighted in figure 9.

Figure 9, blocks 1 and 2. Given a specific need, the system operational parameters, mission profiles, deployment, utilization, effectiveness figures of merit, maintenance constraints, and environmental requirements, will then be defined. Effectiveness figures of merit include: maintenance constraints; availability; dependability; reliability; and maintainability. When this information is used, the end result is the definition of the system maintenance concept and development of a system level specification. It is important to remember that the operational requirements and the maintenance concept are the basic determinants of logistic support resources. [Ref. 7:p. 7]

Figure 9, blocks 3 and 4. Major operational, test, production, and support functions are identified, and qualitative requirements for the system are then allocated as design criteria. The design criteria or constraints are allocated to the significant levels of prime equipment as well as the applicable elements of support (i.e., test and support equipments, facilities, etc.). Those requirements that include logistic factors also form boundaries. [Ref. 7:p. 7]

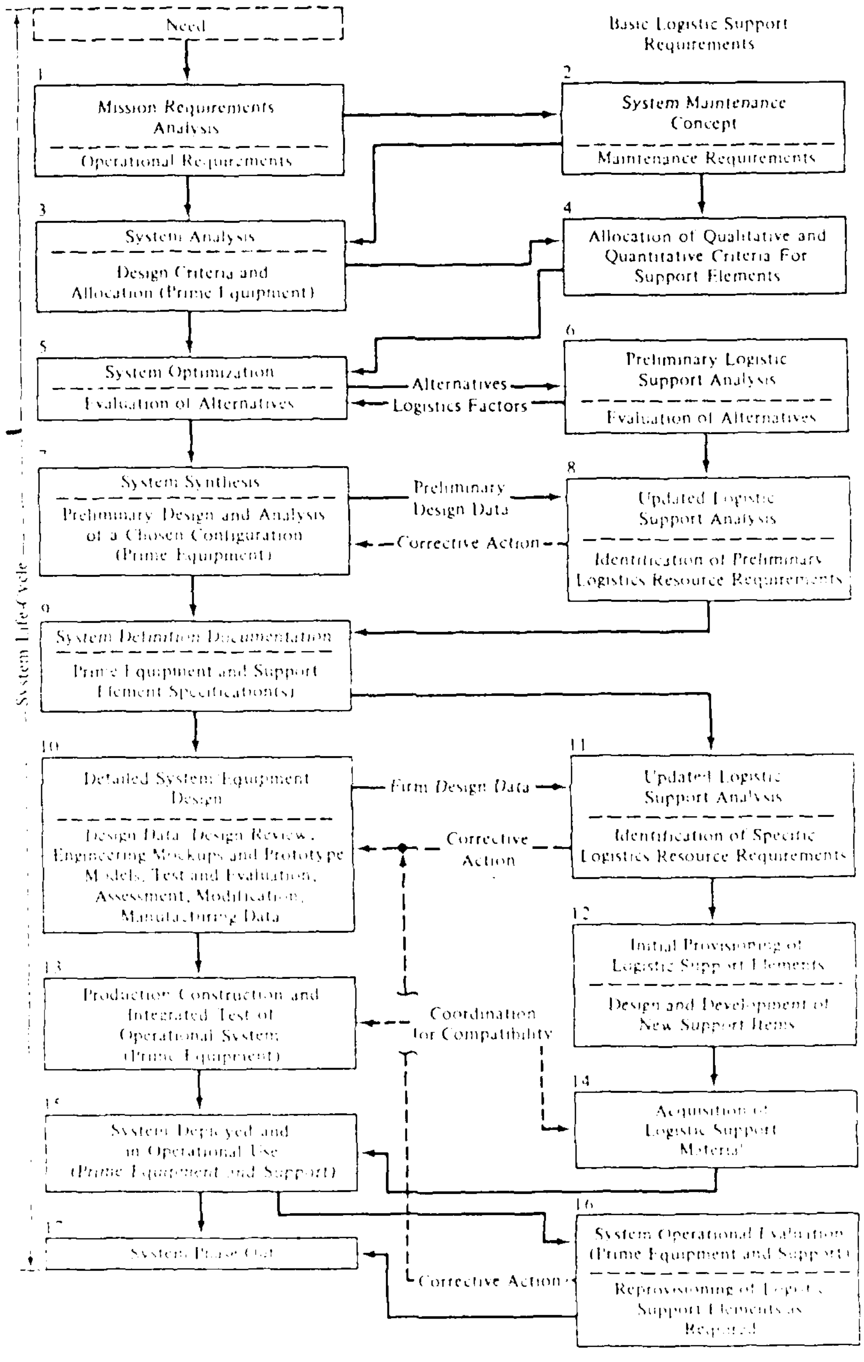

Figure 9
Logistics in the System Life Cycle (p. 7)
Source: Logistics Engineering and Management by Benjamin S. Blanchard

Figure 9, blocks 5 and 6. The boundaries that were established by the design criteria, alternative prime mission equipment and support configurations are evaluated through trade-off studies, and a preferred approach is selected. For each alternative, a logistic support analysis is accomplished to determine the required resources for that alternative. As a result of some trade-off study iterations, a prime mission equipment configuration and support policy are chosen. [Ref. 7:p. 8]

Figure 9, blocks 7, 8, and 9. The prime mission equipment configuration is then evaluated by a LSA effort which identifies the logistic resources needed to support it. The system configuration is then reviewed in terms of its expected overall effectiveness and capability to cost-effectively satisfy the statement of need. The ultimate output leads to the development of sub-system specifications and lower-level specifications which form the basis for the detail design. [Ref. 7:p. 8]

Figure 9, blocks 10, 11 and 12. During the design process, direct assistance is provided to design engineering personnel in areas such as reliability, maintainability, supportability, and human factors. These tasks include the interpretation of criteria; accomplishment of special studies; participation in the selection of equipment and suppliers; accomplishment of predictions (reliability and maintainability); participation in formal and informal design reviews; and participation in the test and evaluation of engineering models and prototypes. An in-depth logistic support analysis, based on released design data, results in the identification of specific support requirements in terms of tools,test and support equipment, spare/repair parts, personnel quantities and skills, training requirements, technical data, facilities, transportation, packaging, and handling requirements. The logistic support analysis at this stage provides the following program data:

1. An assessment of the prime equipment design for supportability and potential cost/system effectiveness.
2. A basis for the provisioning and acquisition of specific support items. [Ref. 7:p. 8]

Figure 9, blocks 13,14,15, and 16. Prime mission equipment items are then produced and/or constructed, tested, and deployed or phased into full-scale operational use. Logistic support elements are acquired, tested, and phased into operation on an as needed basis. Throughout the operational life-cycle of the system, logistics data are collected to provide an assessment of system cost effectiveness and an early identification of operating or maintenance problems. In addition, this data becomes the baseline for the reprovisioning of support items at selected times during the life cycle. [Ref. 7:pp. 8]

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