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FINAL REPORT

NEW GENERATION STRATEGIC
SUBMARINE STUDY

Contract Number N00140-76-C-6446
Effective Date of Contract: 76 May 01
Contract Expiration Date: 77 Jan 30

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ARPA Order Number 3193
Program Code Number 6E20
Amount of Contract:
$189,563.00 (Estimated)

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FOREWORD

This report is submitted in fulfillment of Contract Data Requirements List Item Number A003, Final Report for the *New Generation Strategic Submarine Study*, Contract No. N00140-76-C-6446.

This research was supported by the Advanced Research Projects Agency of the Department of Defense and was monitored by the Naval Underwater Systems Center, New London Laboratory, under Contract No. N00140-76-C-6446.

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CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

Page

ACRONYMS AND ABBREVIATIONS

AC	Alternating Current
A/D	Analog-to-Digital
AMR	Auxiliary Machinery Room
BCP	Ballast Control Panel
C&D	Control and Display
CNC	Central Navigation Computer
CO_2	Carbon Dioxide
CO	Commanding Officer
COW	Chief of Watch
CPO	Chief Petty Officer
CPU	Computer Processing Unit
CRT	Cathode Ray Tube
C&W	Caution and Warning
CW	Continuous Wave
CWA	Computer Writer Adapter
DC	Direct Current
DCT	Depth Control Tank
D/D	Digital-to-Digital
DOOW	Diving Officer of the Watch
DRAI	Dead Reckoning Analyzer Indicator
EBA	Emergency Air Breathing
ECM	Electronic Countermeasures
EIA	Engineering Industries Association
EM	Electricians Mate
EOOW	Engineering Officer of the Watch
ET	Electronics Technician
EPM	Emergency Propulsion Motor
FN	Fireman
FT	Fire Control Technician
FTB	Fire Control Technician Ballistic
H_2	Hydrogen
HF	High Frequency
HYD	Hydraulic
HM	Hospitalman (Corpsman)
IC	Interior Communications Technician

LiBr	Lithium Bromide
LOS	Launch Operations Station
LSI	Large Scale Integrated (Electronic Circuitry)
MBT	Main Ballast Tank
MCC	Missile Control Center
MF	Medium Frequency
MM	Machinist Mate
MS	Mess Specialist
MSR	Multispeed Repeaters
MT	Missile Technician
MTBF	Mean Tube Before Failure
MTRE	Missile Test and Readiness Equipment
MTTR	Mean Time to Repair
MTU	Magnetic Tape Unit
μP	Microprocessor
NCC	Navigation Control
NOCC	Navigation Operational Checkout Console
NSB	Navigation Switch Boards
NTDS	Naval Tactical Data System
O_2	Oxygen
OBA	Oxygen Breathing Apparatus
OOD	Officer of the Deck
PO	Petty Officer
Press	Pressure
QM	Quartermaster
RCVR	Receiver
RM	Radioman
RPM	Revolutions per Minute
SCC	Ship Control Computer
SID	Standard Information Display
SINS	Ship Inertial Navigation System
SK	Storekeeper
Sonar	Sound Navigation and Ranging
SOP	Ship's Operating Procedures
SN	Seaman
SPM	Secondary Propulsion Motor
SSBN	Submarine Ballistic Nuclear
SSMG	Ship Service Motor Generator
SSTG	Ship Service Turbine Generator
ST	Sonarman

Temp	Temperature
TM	Torpedoman
UHF	Ultrahigh Frequency
VLF	Very Low Frequency
XTMR	Transmitter
YN	Yeoman

1. SUMMARY

The study was undertaken to determine the feasibility and advantages of applying aerospace technology and methods to the design of a new generation of strategic submarine. The study focused on how these methods and techniques could be applied to improve the operational capability, and cost of acquisition and ownership of our strategic submarine deterrent forces. Systems Engineering and Integration and Design to Cost methods used successfully on programs such as Titan launch vehicles, Skylab, and Viking were applied and it was determined that performance and cost could be enhanced over that presently exhibited by a SSBN 640 class submarine. In general the results will also be applicable to strategic submarines presently under construction since they and the SSBN 640 share the same philosophy of independent subsystem mechanization and crew operation and it is in changing these areas that the greatest gains can be achieved. These results relate to the subsystems within the boat excluding weapons and reactor and hull design. The application of these techniques involved the assumption that the new generation of strategic submarine should be an integrated man/machine interactive weapons system with a long-life requirement.

The study resulted in a concept for a new generation strategic submarine manned by a crew complement of 30 that is capable of remaining continuously on station for a year or more, providing a choice in the selection of operating cycles. Economic analyses performed in the study indicate that if the entire fleet of strategic submarines were to be developed with this philosophy, the life cycle cost savings would be $1.9 billion in present value ($3.7 billion in 1976 dollars) over a new fleet designed as extensions of existing SSBN designs.

The study conclusions are based on the results of a detailed functional analysis of an existing strategic submarine and the subsequent upgrading of the subsystems within it by appropriate aerospace techniques of using computers for control when they are suited to the function. Not all systems in the existing submarine were upgraded. Only those systems were upgraded wherein a positive return could be achieved in terms of increased time on station or enhanced survivability, or where a cost benefit would accrue without jeopardizing the improved time on station or survivability. After the subsystems were upgraded, they were integrated together into a ship operated from a set of central control consoles.

The new generation SSBN concept developed in the study has two characteristics which make it significantly different from an existing submarine. First, the functional requirements of existing SSBNs are achieved primarily through the application of the manual actions of a dispersed crew with information transferred verbally from man to man. The new generation SSBN would have man commanding computers from a central console location. The computers would then operate the designated subsystems and report data back to the operator in essentially the same mode of man/machine interaction which has been successfully demonstrated in space programs including Skylab, Space Shuttle, and Viking.

The second characteristic is the way in which reliability is achieved. The Viking program will serve as an example. Clearly, there could be no servicing of equipment for the one-year flight time, nor during time on the planet Mars. Reliability on Viking was achieved by making the elements of the subsystems redundant and having computers (themselves redundant) continuously monitor the health of each element. In this way the computers removed elements about to go bad and replaced them with their redundant counterparts. This concept of redundancy was applied to the restructuring of the subsystems within the strategic submarine. Options of ways to implement redundancy are discussed in Appendix I.

In developing the concept for the new generation SSBN, the systems were first designed to optimally meet the functional requirements followed by determination of the crew requirements to operate the systems, rather than having a given crew size determine the degree of mechanization and automation of submarine systems. To implement the new concept standard Navy hardware, computers, and microprocessors were evaluated and found to be sufficient to meet most of the design goals. Concomitant technology recommendations and advances are delineated in the Conclusions and Recommendations section of this report.

Finally, it was recommended that development of the new concept be implemented in a series of steps beginning with a functional mockup.

II. INTRODUCTION

A. OBJECTIVE

The objective of the study was to evaluate and demonstrate the applicability of advanced aerospace technologies to the development of a conceptual design for the next generation of strategic submarines. The study was undertaken to evaluate not only the applicability of aerospace technologies but also to determine whether or not such application could result in improved performance and improved satisfaction of SSBN functional requirements over and above those which are currently achieved on contemporary strategic submarines.

The emphasis in the study was on how the concept of man/machine interactive systems employed so successfully on Skylab (and to be used on the Space Shuttle) could be applied to strategic submarines. In these space systems, the man commands several computers each of which can: (1) serve as the intelligence element of several servo mechanism loops; (2) gather, process, format and present data; and (3) keep track of the health of hardware. In the space application, relatively few men efficiently controlled all the systems of a vastly complex spacecraft. Another aerospace technology which appeared to have merit for submarine application was the concept of achieving the reliability necessary for long-life (unserviced) operation through computer-controlled subsystem failure detection, isolation and redundancy switching. This concept worked perfectly on Viking (and other spacecraft) enabling every system on board to operate for more than a year.

An additional objective of the study was to evaluate economic impact of implementing these technologies in the development of the new generation of strategic submarines--specifically, to determine if the application would reduce future development and operational costs and to delineate the comparative cost advantages and disadvantages by system and crew impacts.

B. APPROACH

The study approach is illustrated in Figure II-B-1. Five major study tasks were involved. These tasks are briefly discussed below with detailed discussions of the analysis and development approaches presented as applicable in subsequent sections of the report.

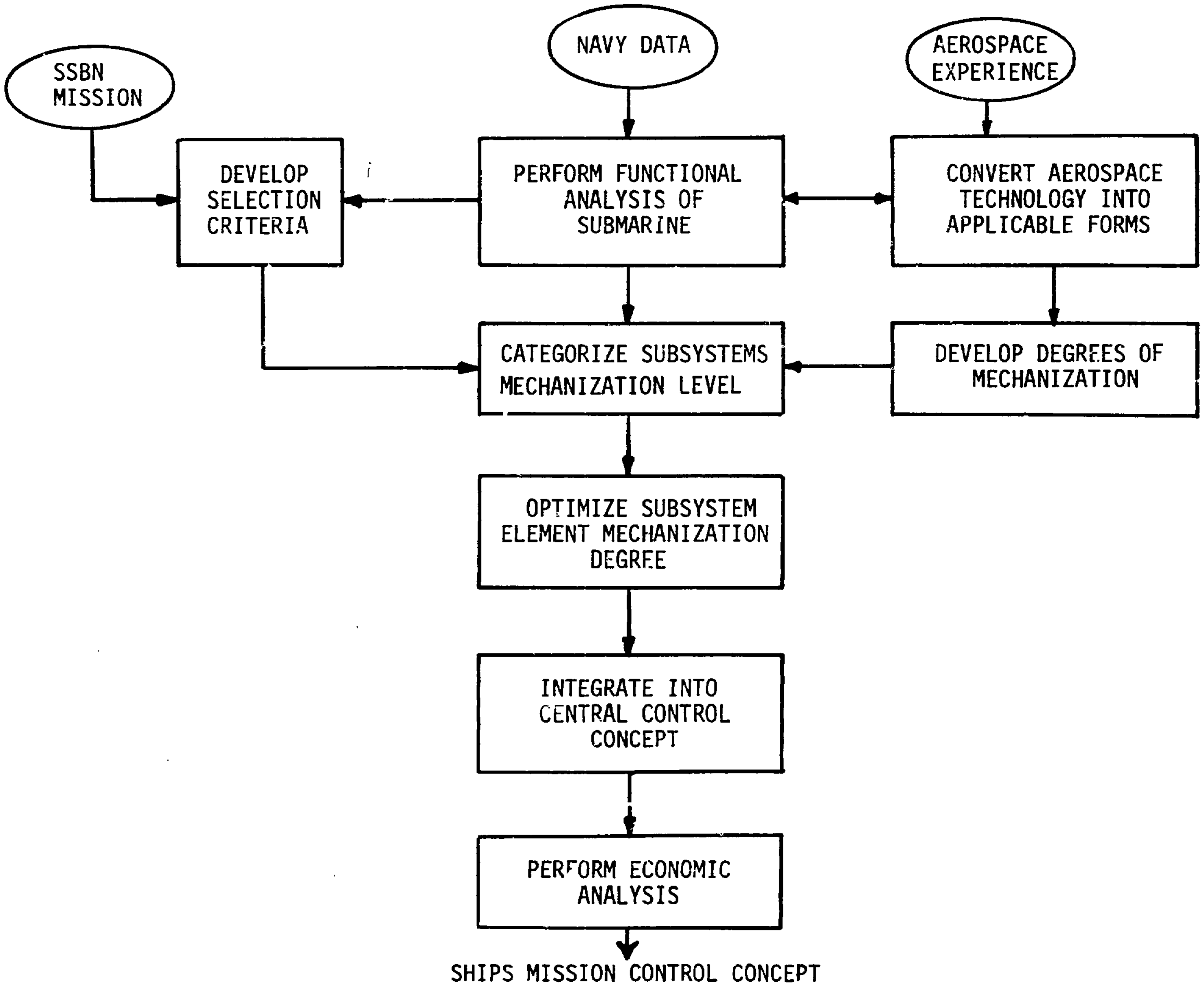


Figure II-B-1 Study Approach

1. Functional Analysis

In order to conduct the study in a meaningful manner, it was necessary to first perform a detailed functional analysis of an existing strategic submarine performing nominal and non-nominal evolutions. The 640 class SSBN was selected as the baseline strategic submarine at the suggestion of ARPA and NUSC. The baseline strategic submarine was evaluated in terms of the subsystems shown in Table II-B-1 and detailed functional analyses of these subsystems and the ships crew were performed. These data served as the baseline point-of-departure for the development of a conceptual design for the next generation SSBN.

2. Degrees of Mechanization and Selection Criteria

Five degrees of mechanization were identified ranging from activities which are totally manual to those which are performed completely by computers acting on their own. Figure II-B-2 provides a general description of the five levels of mechanization (by column) and examples of how various activities are accomplished among the five levels.

The current level of mechanization of the elements comprising the baseline submarine subsystems was approximated. Five selection criteria were developed to determine the value of advancing any subsystem element. The decision to move any subsystem element from where it is now to a higher level of mechanization was based on the selection criteria value and integration into a total ship. The five selection criteria and elements of evaluation are summarized in Table II-B-2.

3. Application of Selection Criteria and Crew Size Determination

The selection criteria were developed by the functional analyses and assessment of the SSBN mission. Each selection criteria was compared to the other to determine its relative value. The increased mechanization of any system or function was determined by the gain, or loss, obtained as a result and the necessary integration of the systems to ensure an operable weapons platform. A crew structure was then constructed to support normal, abnormal, and infrequent situations which may develop.

4. Economic Analysis

A detailed economic analysis which priced the hardware and software to implement the design was estimated as necessary. In order to perform this costing analysis, a strawman hardware and software concept using off-the-shelf Navy equipment configured to embody the necessary redundancy to achieve extended time on station was developed. The

Table II-B-1 Submarine Systems Investigated

• Ship Control
• Engineering Plant
• Auxiliary Services
• Navigation
• External Communications
• Sonar and ECM
• Defensive Weapons
• Strategic Weapons
• Human Habitability and Environmental Control
• Casualty and Damage Control

concept was altered away from optimum in both equipment and crew size and a cost sensitivity analysis was performed.

5. Recommendations for Future Work

The study culminated in a concept that appears to be valid and beneficial. A course of future study and development involving validation of principal elements of the concept by means of a low cost functional mockup is recommended.

DEGREES OF MECHANIZATION

ACTIVITIES	I MANUAL/ORAL	II CENTRAL STATUSING	III MAN-MACHINE CONTROL	IV REMOTE CONTROL	V COMPUTER CONTROL
SENSING	METERS AND INDICATORS VISUALLY READ BY WATCH STANDER	AUTOMATIC SENSORS WITH ELECTRICAL OUTPUT	→	→	→
DATA TRANSMISSION	VOCAL BY WATCH STANDER OVER COMM SYSTEM	TELEMETERED VIA DATA BUS TO CENTRAL DISPLAY PANEL	TELEMETERED VIA DATA BUS TO SHIP MISSION CONTROL COMPUTER	→	→
DISPLAY	LOCAL. OOD RELIES ON VERBAL INFORMATION	METERS AND CRT DISPLAYS HARD COPY	→	→	→
DECISION	OOD MAKES DECISION BASED ON PAST KNOWLEDGE	→	COMPUTER PREPARES DIAGNOSTICS AND MAKES RECOMMENDATIONS	→ OOD IS IN COMMAND LOOP	COMPUTER IN FULL CONTROL. OOD CAN OVERRIDE COMMANDS
COMMAND	VOCAL COMMAND TO WATCH STANDER OVER COMM SYSTEM	→	→	CONTROLS ARE ON THE CENTRAL CONSOLE. COMMANDS TELEMETERED TO ACTUATORS	COMPUTER AUTOMATICALLY SENDS APPROPRIATE COMMANDS VIA DATA BUS TO ACTUATORS
ACTUATION	LOCAL ACTUATION BY WATCH STANDER	→	→	AUTOMATIC LOCAL ACTUATORS REMOTELY CONTROLLED BY OOD.	AUTOMATIC LOCAL ACTUATORS CONTROLLED DIRECTLY BY THE COMPUTER
ACKNOWLEDGEMENT	WATCH STANDER REPEATS COMMAND BACK OVER COMM SYSTEM. OOD VERIFIES. (NOTE: ACTUATION HAS NOT BEEN MADE AS YET.)	→	→	AUTOMATIC ACKNOWLEDGEMENT TO COMPUTER WITH SELF-CORRECTION IN CASE OF DATA TRANSMISSION ERROR	→

Figure II-B-2 Degrees of Mechanization

Table II-B-2 Selection Criteria

CRITERIA	EVALUATED IN TERMS OF:
1. Decrease Cost	• Costs of design, construction, testing and lifetime maintenance.
2. Increased Availability	• Improved strategic weapon and navigation subsystem operation. • Improved communications. • Improved command and control. • Reduced refit time. • Increased reliability. • Improved operating cycles.
3. Reduced Crew Size	• Reduced control stations locations. • Reduced maintenance requirements. • Decreased life cycle costs. • More effective personnel usage. • Improved operational capability. • Reduced in-port support.
4. Increased Survivability	• Reduced own-ship detectability. • Improved covert escape capability. • Improved tactical weapon capability. • Improved contact detection capability. • Automated contact analysis. • Improved reaction time.
5. Improved Operability	• Technology availability. • Improved ship's safety. • Using computers to perform status, record-keeping, and maintenance evaluation. • Reduced human error potential.

III. RESULTS

A. FUNCTIONAL ANALYSES

The results of a systems engineering analysis of an existing fleet ballistic missile submarine are presented in this section of the report. The purpose of the analyses was to provide a detailed understanding of the manner in which various submarine subsystems and the crew interact to accomplish the mission objectives of an operational SSBN. These data served as the reference for establishing a baseline set of functional requirements for the new generation SSBN.

The approach used in performing the analysis was to first categorize the operations performed within the submarine into functional divisions. Each of these functional divisions was then designated a subsystem and the hardware elements within the baseline submarine were sorted into their applicable subsystem. The SSBN 640 class submarine equipment was used because of the availability of previous operational history and characteristics.

Two interrelated types of functional analyses were performed. One type involved an analysis of the basic SSBN operational subsystems; the emphasis in this analysis was on systems and associated equipment elements and their operational characteristics under normal and emergency conditions. The other type of functional analysis was directed to a delineation of crew functions, operations, and activities required to operate the SSBN. Obviously, the two types of functions are interdependent--they have been separated for purposes of discussion only. The system and element functional analyses are presented in Section 1 and the crew functional analyses are presented in Section 2 below.

The data developed in the functional analysis was used in the development of the concept for the new generation of strategic submarine. Within the technical analysis section of the report, each current SSBN 640 system (element) was evaluated in relation to integrated subsystem operation to determine its functional necessity to the "new generation submarine."

1. System and Element Functional Analyses

The operational functions of our baseline submarine's subsystems were analyzed under normal and emergency cruise conditions and when the ship is submerging and surfacing. To support this analysis, data were obtained by reviewing available Naval documentation, through retired and active duty Naval personnel experienced directly with strategic submarines, and Martin Marietta engineering staff personnel.

The subsystems were thoroughly evaluated to establish functional commonalities, interrelationships, and independence. The ten subsystems identified are listed in Table III-A-1. Functional analyses within each of the subsystems listed were performed. The results are presented below.

Table III-A-1 Subsystem Categories

SUBSYSTEMS
a) Ship Control
b) Engineering Plant
c) Auxiliary
d) Navigation
e) External Communications
f) Sonar and Electronic Countermeasures
g) Defensive Weapons
h) Strategic Weapons
i) Habitability
j) Casualty and Damage Control

a. Ship Control - The ship control subsystem consists of system elements required to perform and maintain four submarine operational functions under normal and emergency conditions. The four operational functions are--1) submerging, 2) surfacing, 3) buoyancy control, and 4) steering and diving.

1) Submerging - The capability to submerge the ship from a surface-floating condition requires that the "Rig for Dive" prerequisite checklist is completed and the operation is accomplished by flooding the main ballast tanks (MBT) with sea water through the open flood ports in the bottom of each tank and venting the air at the top of each tank. The major system elements required to accomplish this operation and the related functions of each are presented in Table III-A-2, and functionally illustrated in Figure III-A-1.

2) Surfacing - Surfacing a submerged submarine is normally initiated at periscope depth by using compressed air to blow the sea water out of the main ballast tanks. The surfacing is accomplished by any one of three methods--normal blowing, emergency blowing, low pressure blowing. The system elements and the functions for each of these operations are listed in Table III-A-2, and the functional interrelationships are presented in Figure III-A-2.

3) Buoyancy - The overall buoyancy of the ship is controlled either by pumping water overboard, or by flooding water into a depth control tank and then pumping it to a variable ballast tank to maintain the desired trim. In conjunction with the trim control, the hovering sequence performs accurate depth control by rapidly moving ballast sea water between the sea and the two depth control tanks (DCT).

The major system elements and functions for the trim control and hovering sequence are presented in Table III-A-2 and are represented pictorially in Figure III-A-3.

4) Steering and Diving - The steering and diving system provides the longitudinal stability and control of the ship by the hull, fixed stern stabilizers, and movable control planes. The system provides control of the rudder and diving planes under normal and emergency conditions. An automatic steering and diving system, Conalog, can also be used to control the rudder and diving planes.

The principal system elements and respective functions are listed in Table III-A-2, and the functional flow of these elements is illustrated in Figure III-A-4.

b. Engineering Plant - This subsystem consists of numerous individual propulsion, electrical, steam-flow, and auxiliary support systems and equipment. It is difficult to analyze the subsystem as a single entity; therefore it has been subdivided into the two systems--Ship Propulsion and Steam-Feed Flow.

1) Ship Propulsion - This system provides the forward or reverse propulsive force of the ship, and the generation of electrical power. The primary system elements that comprise the Ship Propulsion System are presented in Table III-A-3, along with the specific functions of each. Figure III-A-5 illustrates the functional flow for this system.

2) Steam-Feed Flow - This system provides the means to distribute the steam to the steam-operated equipment and to return the condensate as a feed water supply to the steam generator. Analyzing this system provided a thorough understanding of the major system elements that comprise this system. Table III-A-3 presents the results of this analysis, and Figure III-A-6 illustrates the functional interacts of each element.

c. Auxiliary Subsystem - The Auxiliary Subsystem, like the Engineering Plant subsystem, is composed of many individual systems and equipment. The subsystem was subdivided into systems in a similar manner as discussed for Ship Control and Engineering Plant. The new systems classification includes--1) air conditioning, 2) compressed air, 3) crew support, and 4) equipment support.

1) Air Conditioning - The capabilities of this system are provided by three air conditioning refrigerant plants, which consist of two vapor compression plants using the refrigerant freon (R-114) and a Lithium Bromide (LiBr) Absorption Plant using water as the refrigerant.

Both plants provide the cooling media by which the various systems and equipment onboard the ship are maintained within their operating environmental conditions. This is accomplished by the circulation of fresh water chilled by the air conditioning plants. The air conditioning load placed on the operating plant(s) is determined by the requirement to maintain a desired chill water supply temperature to the elements.

The results of the functional analysis conducted on this system are presented in Table III-A-4, and the functional flow presented in Figure III-A-7.

2) Compressed Air - The compressed air system consists of two pressure categories--a) high pressure (4500 psig), and b) low pressure systems (i.e., 700, 400, 150, 100, 85, 75, 40, and 20 psig).

(a) High Pressure Air - The main function of the high pressure system is to empty the MBT of water by displacement, which provides a positive buoyancy to surface.

(b) Low Pressure Air - The low pressure air systems supply service air to numerous service air connections through the ship. The functional flow illustration clearly shows how the various air pressure levels are obtained, namely through pressure reducing stations. The flow directions illustrate the following--(1) a 4500/700 psig reducing station supplies the 700 psig air; (2) the 700 psig

reducing stations provide the 150, 100, and 400 psig air; (3) the 100 psig reducing stations provide the 40 and 20 psig air; and (4) an alternate O_2 generator air system also supplies 20 psig service air. Table III-A-4 presents the functions of each of these air supplies, and Figure III-A-8 illustrates the functional flow.

3) Crew Support System - The Crew Support System as we have defined has the capability to support the crew's life aboard the submarine excluding the habitability provision which is discussed under the Habitability subsystem.

The system elements that comprise the Crew Support System are tabulated on Table III-A-4 and are illustrated in functional form in Figure III-A-9.

4) Equipment Support System - This system provides the auxiliary equipment essential for submarine operations. The system elements included under this system are presented on Table III-A-4, and the functional flow of these elements is presented in Figure III-A-10.

d. Navigation Subsystem - The Navigation Subsystem performs and determines the submarine position, attitude and velocity information necessary to support the missile fire control system and conventional navigation. The system elements that comprise this subsystem are listed in Table III-A-5, and their functional flow is illustrated in Figure III-A-11.

e. External Communications Subsystem - This subsystem provides the capability to transmit and receive radio frequency messages over the desired frequency range. It also provides the capability for desired security and typed message copies. Table III-A-6 presents a detailed listing of the system elements and their functions as applied to this study. Figure III-A-12 illustrates the functional flow of the elements.

f. Sonar and Electronic Countermeasures Subsystem - The Sonar and Electronic Countermeasures (ECM) subsystem respectively provides acoustic information, and electromagnetic information necessary to ensure survivability during the ship's mission for any defense condition.

The complexity of this subsystem warranted subdividing the subsystem into the Sonar Group and ECM Group. The system elements of each of these systems are presented on Table III-A-7, and the functional illustrations are presented in Figure III-A-13 for Sonar, and Figure III-A-14 for ECM.

g. Defensive Weapons Subsystem - This subsystem provides all the essential systems and equipment to support the capability to fire torpedos as a defensive or offensive action. This subsystem consists of the principal system elements identified in Table III-A-8, and the functional flow is presented in Figure III-A-15.

h. Strategic Weapons Subsystem - The Strategic Weapons Subsystem is defined as that system and equipment consisting of ballistic missiles and supporting systems required to provide a major deterrent against attack by any agressor, and to provide a rapid retaliatory action in the event of enemy aggression. The system elements involved in this subsystem are depicted in Table III-A-9, and functionally illustrated in Figure III-A-16.

i. Habitability Subsystem - The Habitability Subsystem as evaluated consists of two systems--1) life support, and 2) waste management.

1) Life Support System - This system provides the capability to support human life under normal and casualty situations for prolonged submerged periods. Also, provisions are available for instrumentation essential in analyzing the atmosphere concentrations and the hydrocarbon contaminants.

2) Waste Management System - This system provides the means for disposal of waste products generated onboard the ship while being submerged.

The system elements for the two systems listed above are presented in Table III-A-10, and the functional interacts of each system are illustrated in Figure III-A-17.

j. Casualty and Damage Control Subsystem - The Casualty and Damage Subsystem provides the capability to prevent and limit casualties from occurring, and to enable immediate corrective action to be taken by the crew. Also, the capability to minimize, maintain, repair, and recover from any casualty situation through quick and effective action by the crew is provided.

The system elements comprised in this subsystem are tabulated in Table III-A-11.

Table III-A-2 System (Element) Functional Analysis Results--Ship Control Subsystem

SYSTEM (ELEMENT)	FUNCTION
A. Submerging	
1. Main Ballast Tank (MBT) Vents	• Provide the capability to flood the MBTs for submerging.
2. Electro-Hydraulic Vent Control Valves	• Provide the means to actuate MBT valves to control MBT venting.
3. Vent Valve Position Indicator	• Provide indicator lights to display MBT vent valve position (open or closed).
4. Hull Openings	• Provide the means to access or exit through the hull excluding personnel access. (ie. sea water, missiles, etc.)
5. Electro-Hydraulic Hull Opening Valves	• Provide the remote control capabilities to actuate valves with manual provisions.
6. Hull Opening Valve Position Indicators	• Provides open or shut indications on desired hull openings (maybe electrical or mechanical, local or remote).
7. Hatches	• Provide openings normally used for personnel access to the ship.
8. Hatches Shut Indicators	• Provide electrical open or shut indications on the Ballast Control Panel
9. Ballast Control Panel	• Provides the primary control station for changing the buoyancy of the ship and trimming, for submerging.
B. Surfacing	
1. Main Ballast Tanks	• Provide the reserve buoyancy required for surfacing.

Table III-A-2 (Continued)

SYSTEM (ELEMENT)	FUNCTION
B. <u>Surfacing</u> (Cont'd)	
2. Normal Group Blow Solenoid Valves	• Provide the capability to remotely control the high pressure air (4500 psig) distribution to each main ballast tank group. (Manual override capability).
3. Normal Blow Indicator Lights	• Provide electrical open or shut indicators to display the valve group positions.
4. Group Blow Inhibit Solenoid Valves	• Provide the capability to inhibit blowing of a selected MBT group by solenoid operated list control valves.
5. List Control Indicator Lights	• Provide electrical open or shut indicators to display list control valve positions on the Ballast Control Panel.
6. Emergency Blow Valves	• Provide the capability to pneumatically control the high pressure air (4500 psig) supply to rapidly blow MBTs groups in an emergency situation.
7. Emergency Blow Indicator Lights	• Provide electrical open or shut indications of valve positions displays on Ballast Control Panel.
8. Emergency Blow Remote Actuation Valves	• Provide the capability to remotely control the emergency blow valves.

Table III-A-2 (Continued)

SYSTEM (ELEMENT)	FUNCTION
B. <u>Surfacing</u> (Cont'd)	
9. Low Pressure Blower Controller	• Provides the capability to control the speed, fast or slow, of the Low Pressure Blower motor and an emergency stop.
10. Low Pressure Blower Displays	• Provide lighted indicators to display motor run, slow or fast speed motor operations.
11. Isolation and Low Pressure Blow Header Valves	• Provide the capability to control the Low Pressure air supply to blow MBTs.
12. Low Pressure Blower	• Provides the capability to exhaust stale air from the ship when the ship is surfaced or at periscope depth.
C. <u>Buoyancy (Trim Control & Hovering)</u>	
1. Sea Valve	• Provides the means to isolate sea pressure from the trim main piping.
2. Trim Pump	• Provides the capability to transfer water from one tank to the trim discharge main for discharge into another tank, for auxiliary use throughout the ship or to sea.
3. Trim Pump Controller	• Provides the capability to control the pump speed in order to vary its pumping rate.
4. Trim Pump Discharge and Sea Connection Control Valves	• Provides the selection of directing the trim pump discharge "to sea" or to the trim discharge main (another variable ballast tank).
5. Variable Ballast Tanks	• Provide a means to ballast water in order to control the trim and buoyancy of the ship.

Table III-A-2 (Continued)

SYSTEM (ELEMENT)	FUNCTION
C. Buoyancy (Cont'd)	
6. Trim Priming Pump	• Provides the capability to remove air from the trim system piping, in order to insure a positive s tion to the trim pump.
7. Trim Priming Pump Controller	• The controller starts or stops the pump motor and can be operated locally or at the Ballast Control Panel.
8. Flood and Drain Valve	• Provide the means of isolating or pumping water to/from its associated tank.
9. Depth Control Tanks (DCT)	• Provide the weight variation during the hovering sequence and trim evolutions.
10. Blow and Vent Valves	• Provide the means to control the blowing and venting of the associated DCT.
11. Air Supply Valve	• Provides the means to pressurize depth control tank and automatically regulate air pressure 50 psig above sea pressure.
12. Hovering and Depth Throttle Valve	• Provides the capability to throttle the flow of sea water for hovering control; manually or automatically.
13. Hovering Sea Valve	• Provides positive isolation from sea pressure.

Table III-A-2 (Continued)

SYSTEM (ELEMENT)	FUNCTION
D. <u>Steering and Diving</u>	
1. Conalog	• Provides an automatic steering and diving system to control the rudder and diving planes (cannot control buoyancy).
2. Ram (Rudder)	• Provides the means to position the rudder by a hydraulically actuated ram.
3. Power Transfer Valve	• Provides the means to select either main hydraulic oil (normal control) or vital hydraulic oil pressure (emergency control) to move the ram.
4. Normal Control	• Provides a supply of main hydraulic oil pressure to move the associated control surface plane in the desired direction under proportional control. Transfer to emergency control is manually or automatically initiated.
5. Hand Pump	• Provides the means to generate hydraulic oil pressure to move the rudder when the normal supply of hydraulic oil pressure is not available.
6. Emergency Control	• Provides a supply of vital hydraulic oil pressure to move the associated control surface plane in the desired directions under rate control transfer to normal control is manually initiated.
7. Ram (Fairwater Planes)	• Provides the means to position the fairwater planes by a hydraulically actuated ram.

Table III-A-2 (Concluded)

SYSTEM (ELEMENT)	FUNCTION
D. <u>Steering and Diving</u> (cont'd)	
8. Ram (Stern Planes)	• Provides means to position the stern planes by a hydraulically actuated ram.
9. Hand Pumps (individual units for Fairwater and stern planes)	• Provides the means to generate hydraulic oil pressure to move either the stern or fairwater planes when the normal supply of hydraulic oil pressure is not available.

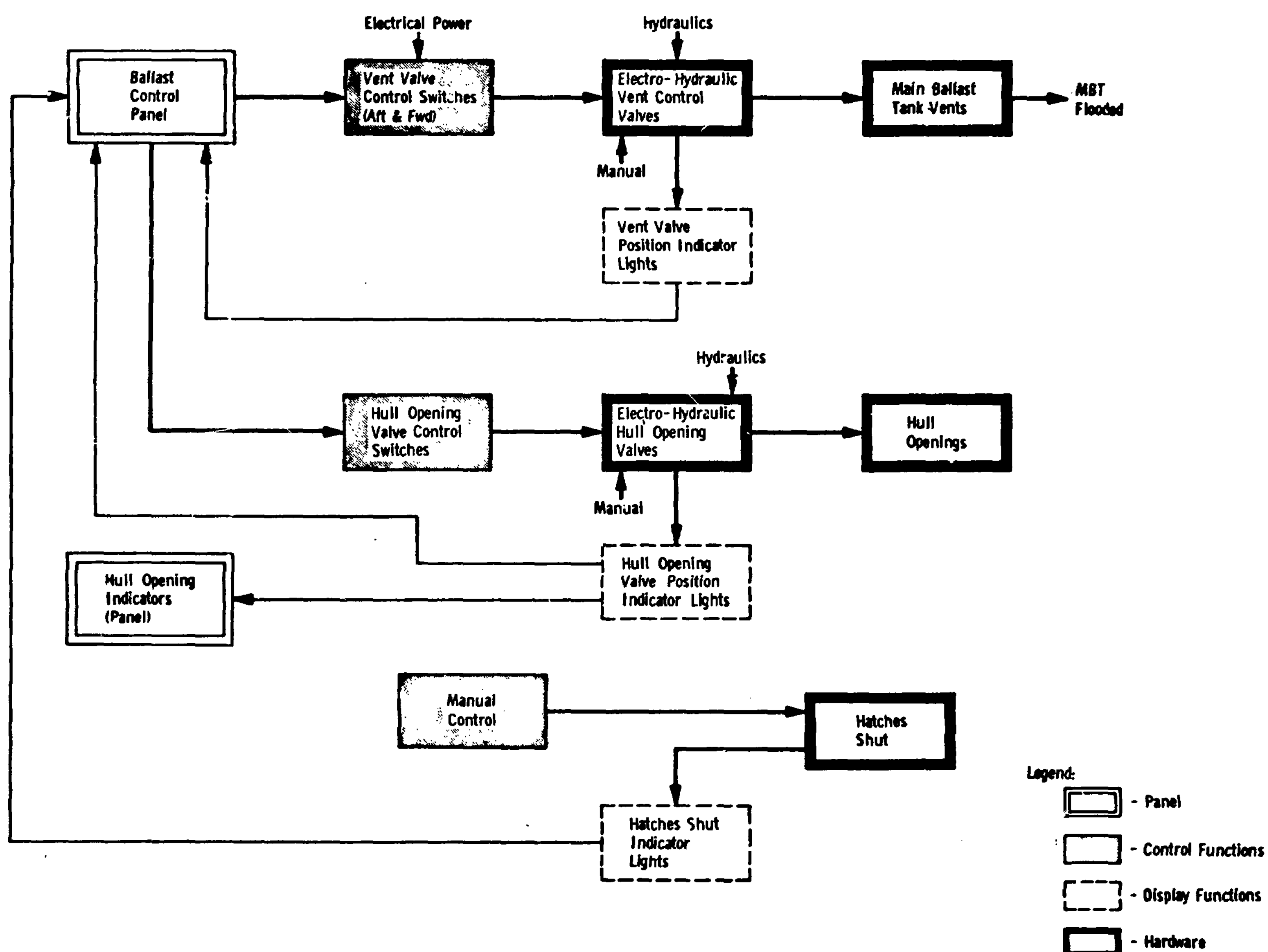
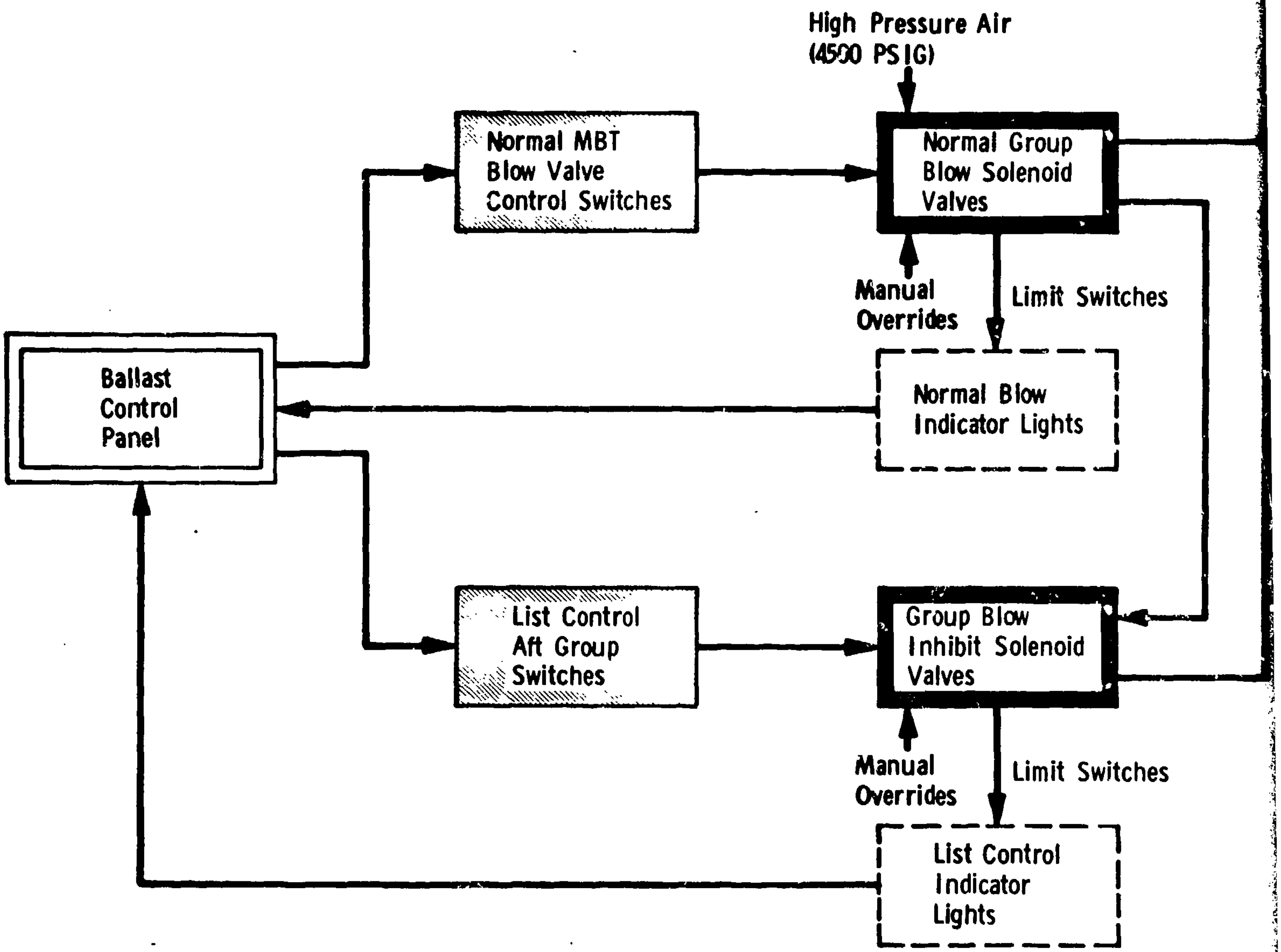
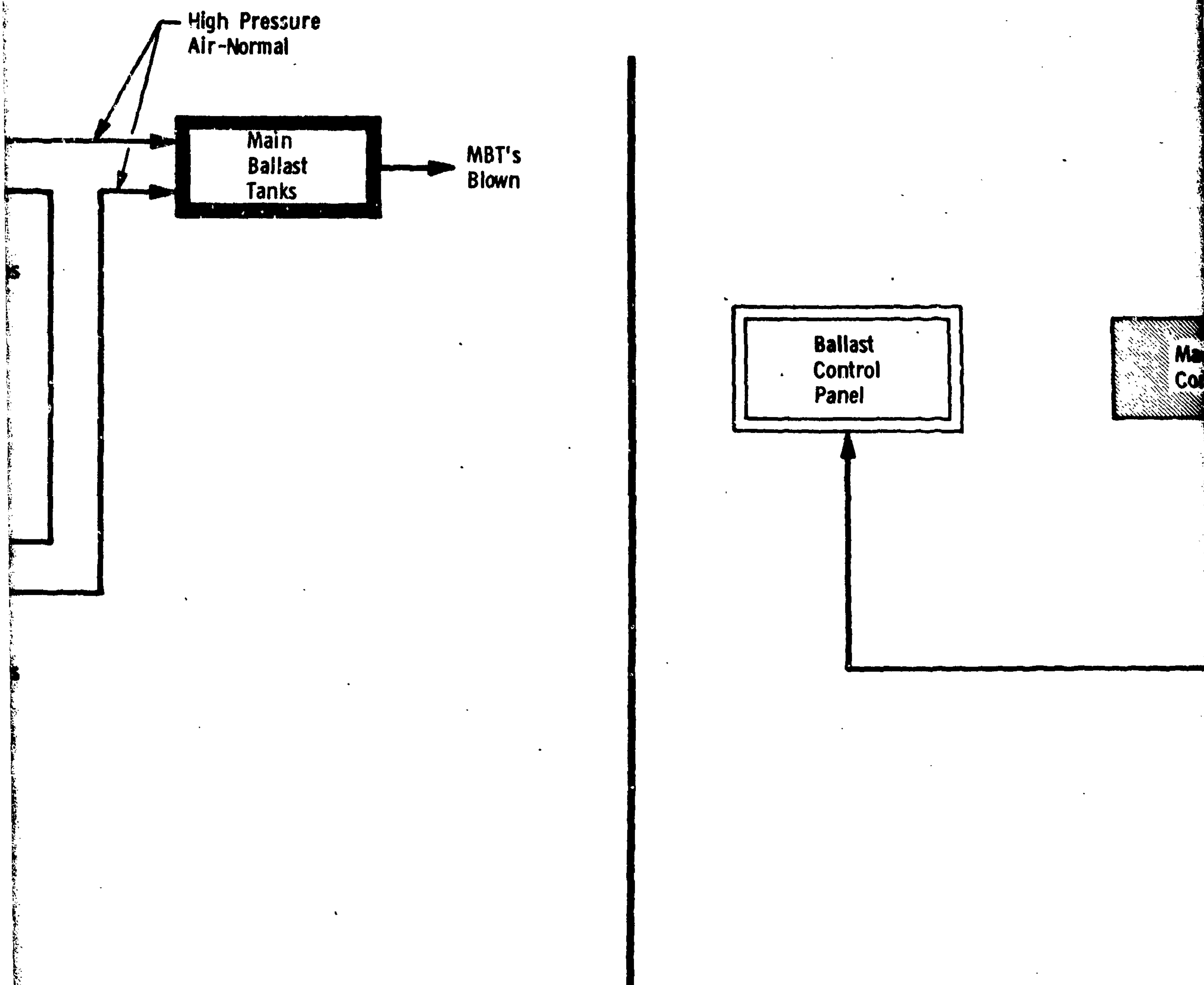


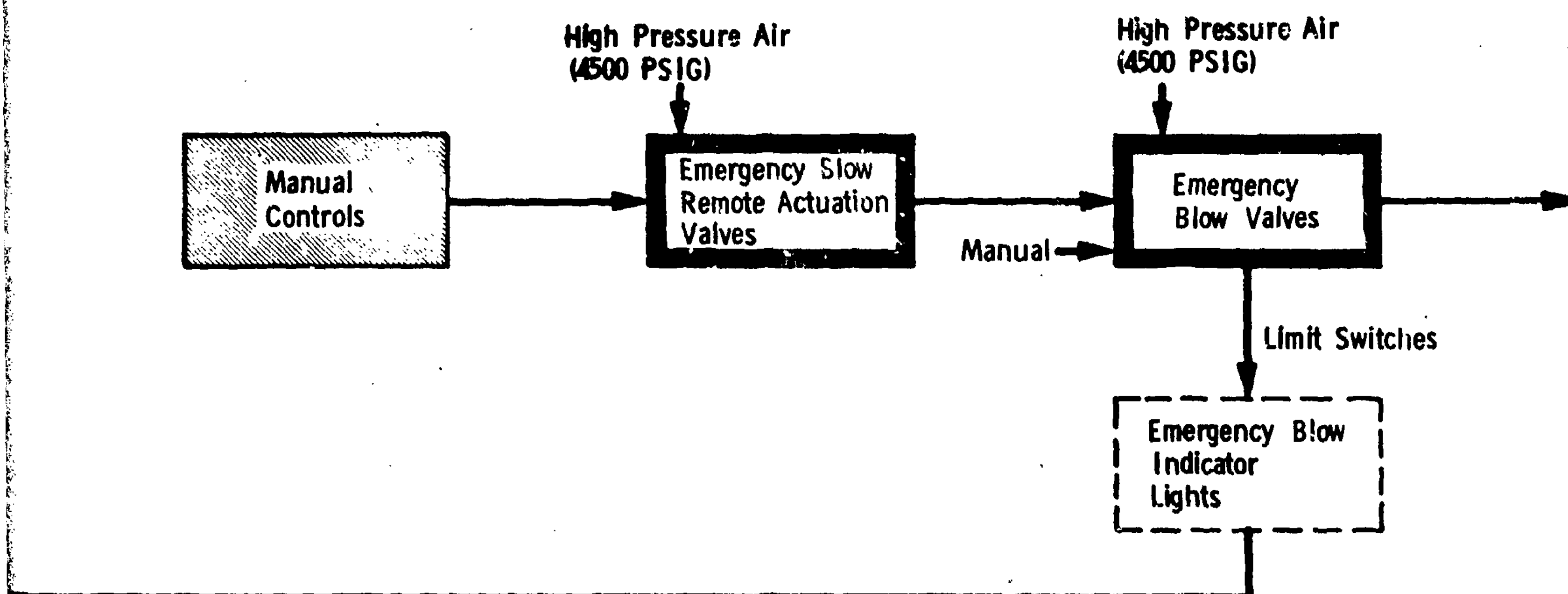
Figure III-A-1 Simplified Functional Diagram - Submerging



(a) Normal Blow Operation

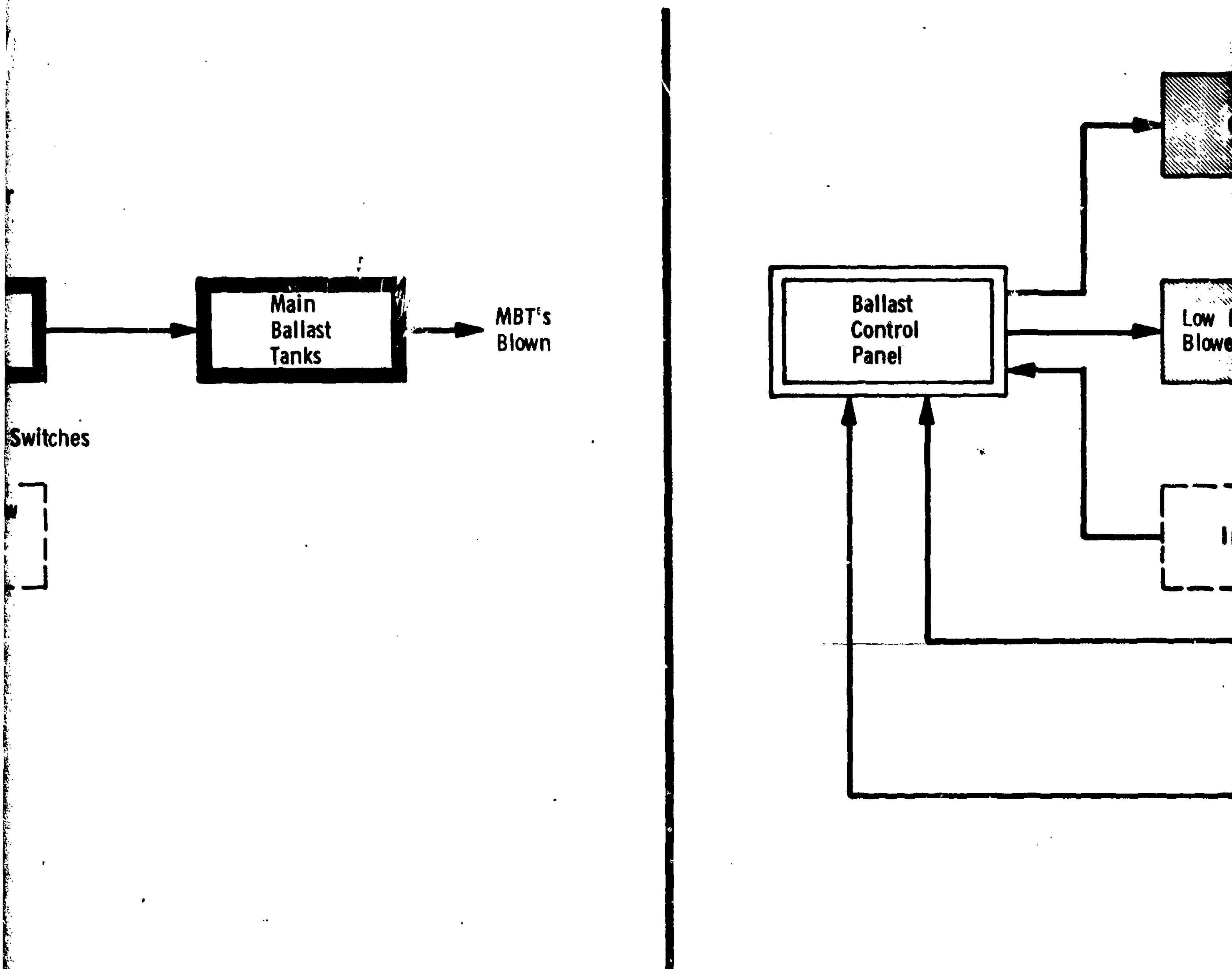

High Pressure Air-Normal
Main Ballast Tanks
MBT's Blown
Ballast Control Panel

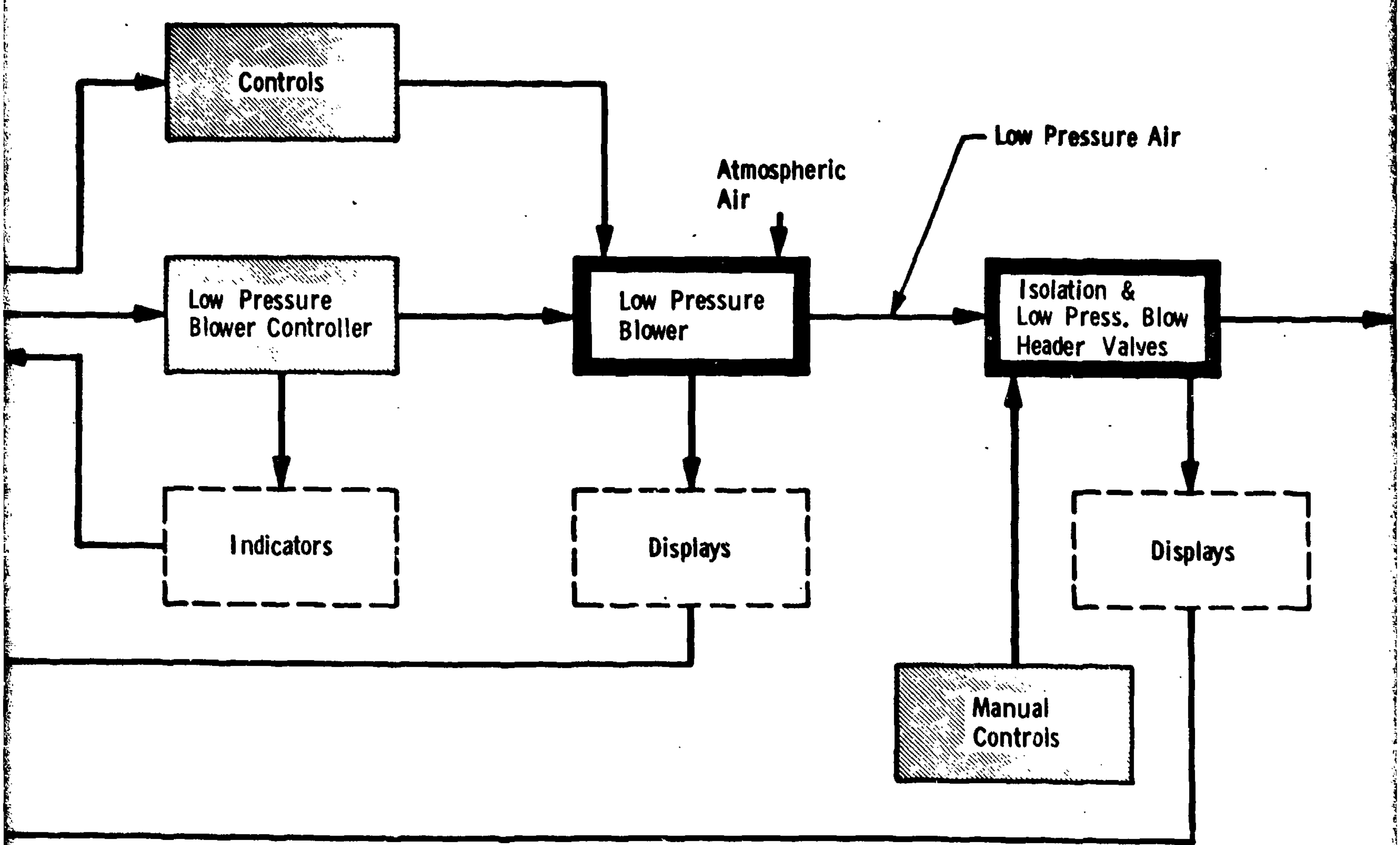
2



(b) Emergency Blow Operation

3


Main Ballast Tanks
MBT's Blown
Switches
Ballast Control Panel



(c) Low Pressure Air Blowing

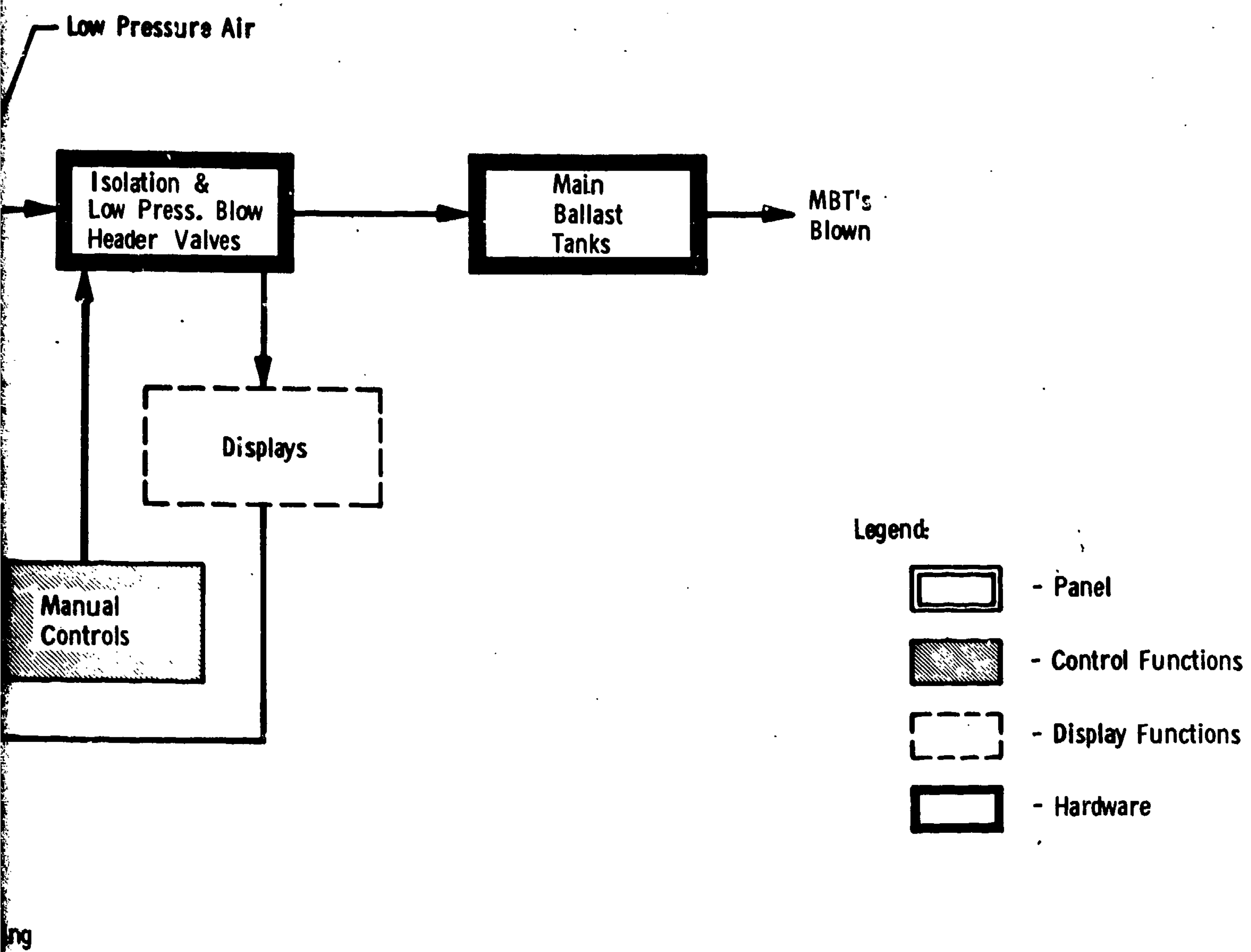
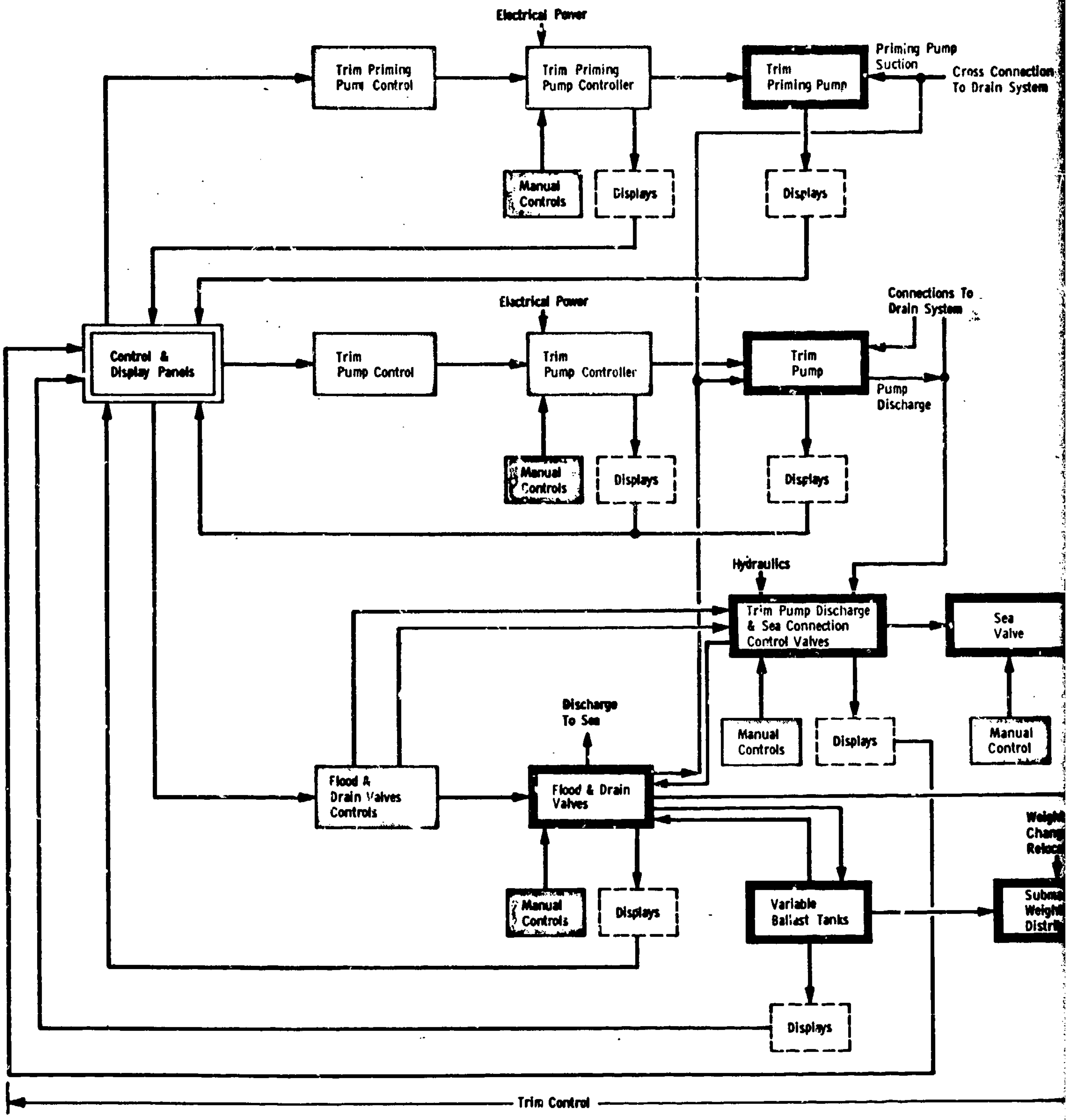
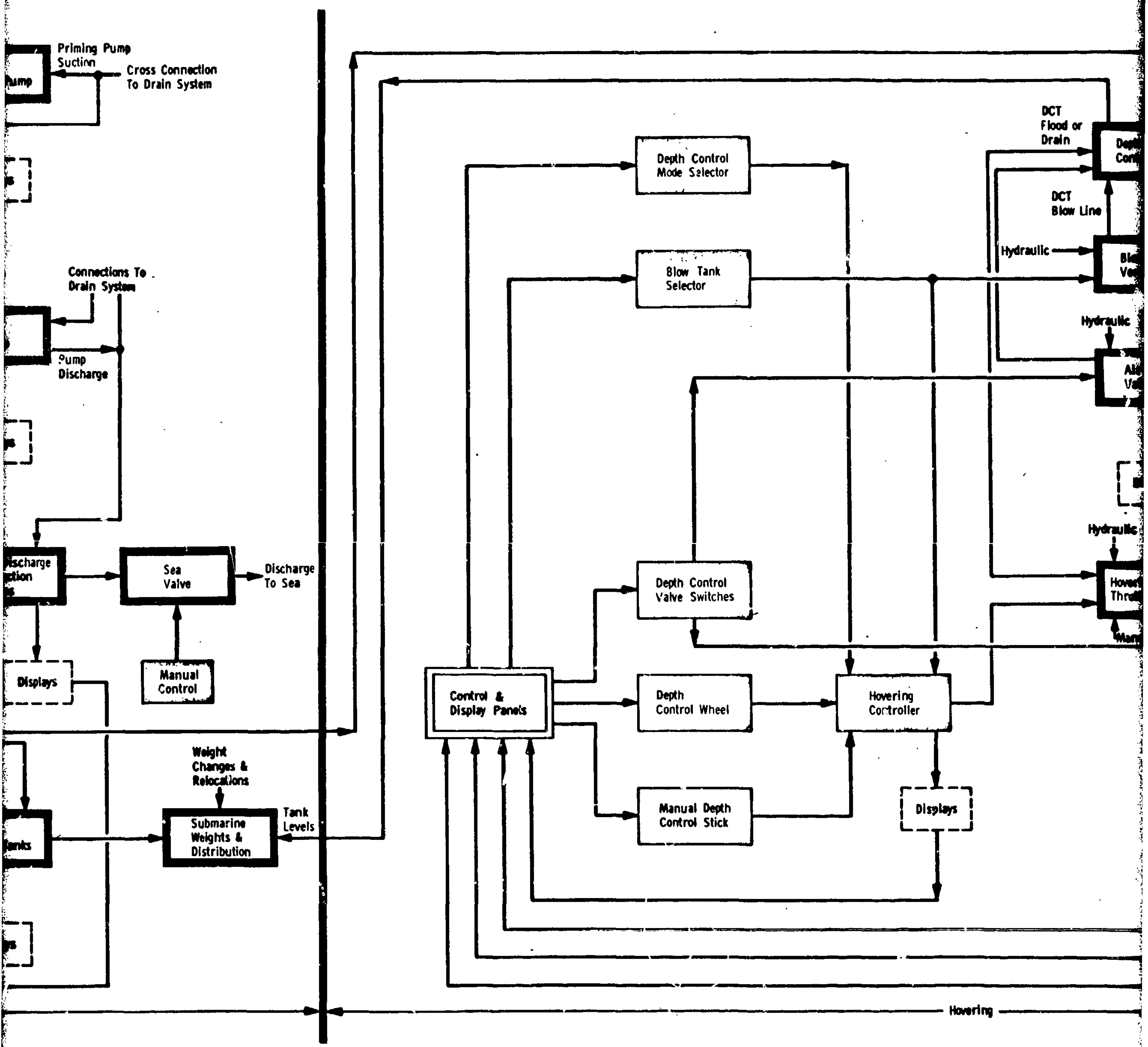


Figure III-A-2 Simplified Functional Diagram - Surfacing

6



Electrical Power
Trim Priming Pump Control
Trim Priming Pump Controller
Trim Priming Pump
Priming Pump Suction
Cross Connection To Drain System
Manual Controls
Displays
Displays
Electrical Power
Connections To Drain System
Control & Display Panels
Trim Pump Control
Trim Pump Controller
Trim Pump
Pump Discharge
Manual Controls
Displays
Displays
Hydraulics
Trim Pump Discharge & Sea Connection Control Valves
Sea Valve
Discharge To Sea
Manual Controls
Displays
Manual Control
Flood & Drain Valves Controls
Flood & Drain Valves
Manual Controls
Displays
Variable Ballast Tanks
Displays
Trim Control



Priming Pump Suction
Cross Connection To Drain System
Connections To Drain System
Pump Discharge
Sea Valve
Discharge To Sea
Displays
Manual Control
Weight Changes & Relocations
Submarine Weights & Distribution
Tank Levels
Depth Control Mode Selector
Blow Tank Selector
DCT Flood or Drain
DCT Blow Line
Hydraulic
Depth Control Valve Switches
Control & Display Panels
Depth Control Wheel
Hovering Controller
Manual Depth Control Stick
Displays
Hovering

2

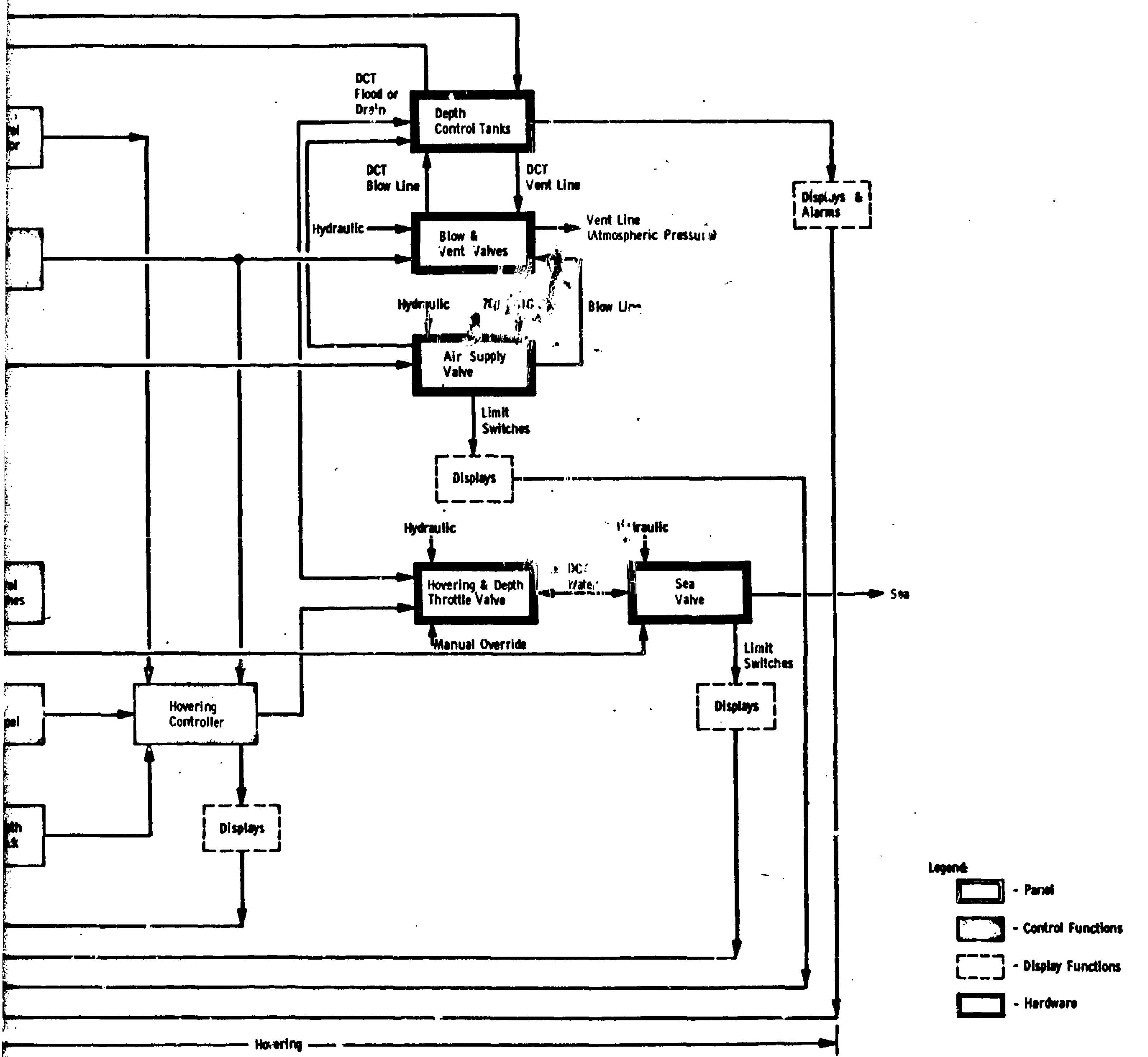
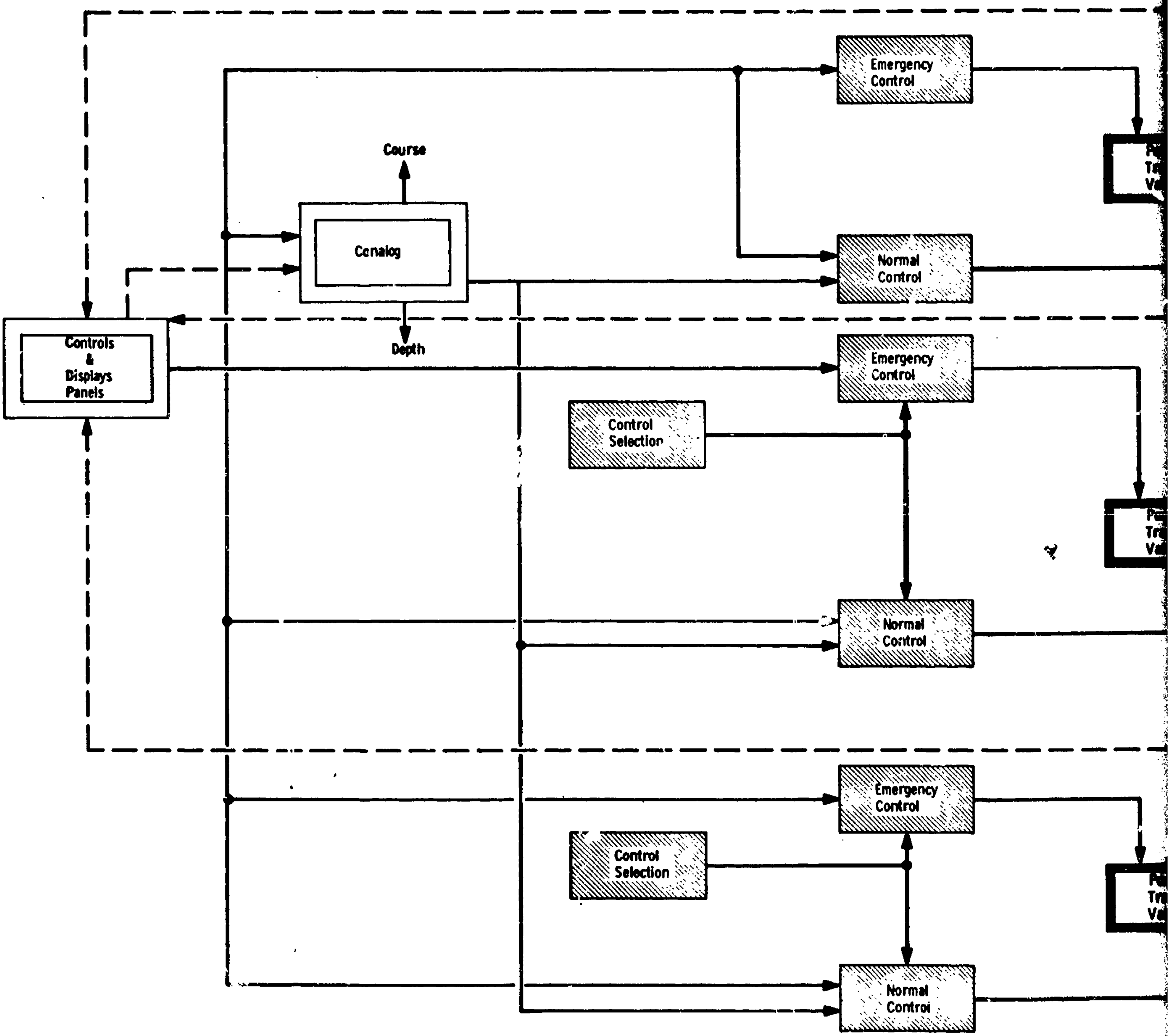


Figure III-A-3 Simplified Functional Diagram - Buoyancy

3


Course
Conalog
Depth
Controls & Displays Panels
Emergency Control
Normal Control
Emergency Control
Control Selection
Normal Control
Emergency Control
Control Selection
Normal Control

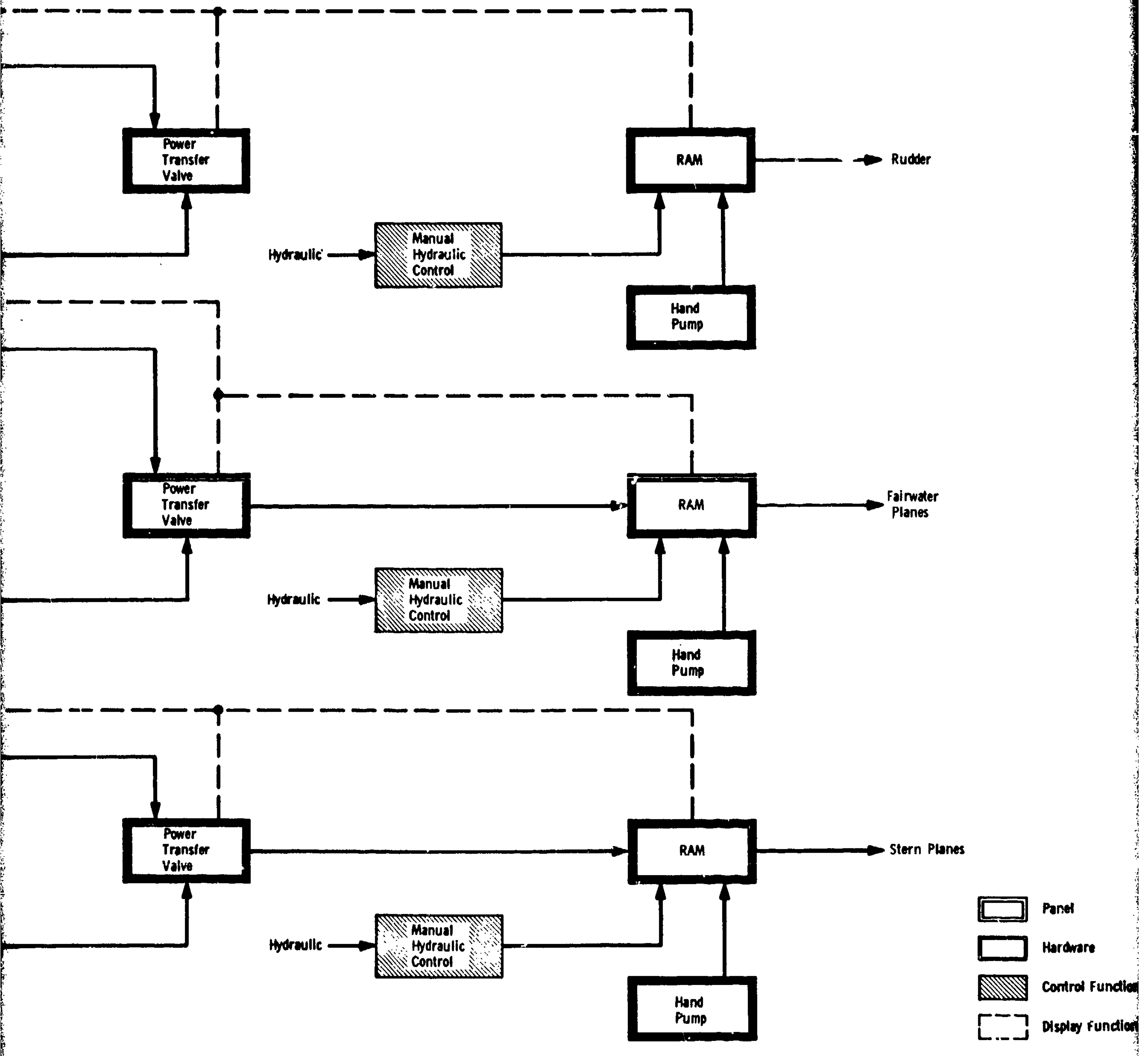


Figure III-A-4 Simplified Functional Diagram - Steering and Diving

Table III-A-3 System (Element) Functional Analysis Results--Engineering Plant Subsystem

SYSTEM (ELEMENT)	FUNCTION
A. <u>Ship Propulsion</u>	
1. Propulsion Turbines	• Develop the ship's primary propulsive power through the interconnected drive train.
2. Reduction Gear	• Permits the propulsion turbines to operate at their most efficient higher speeds while the propeller may operate at its most efficient lower speed. Also provides the connection of two main propulsion turbines to one main shaft and propeller.
3. Propulsion Clutch	• Provides the capability to either connect or disconnect reduction gear from the propeller shaft.
4. Shaft Seal	• Provides a seal around main shaft to prevent inward seepage of sea water.
5. Shaft Lube Oil	• Provides the capability to supply oil to the clutch control oil system and to lubricate main shaft components and bearings.
6. Main Lube Oil	• Provides pressurized control oil supply for the main propulsion turbines and a source of lubrication oil for the turbines and the reduction gear.
7. Lube Oil Transfer	• Provides the capability to transfer and centrifugally purify lubricating oil between storage tanks and lube oil sumps.
8. Ship Service Turbine Generators (SSTG)	• Supply the ship's AC power for distribution (two for redundancy).

Table III-A-3 (Continued)

SYSTEM (ELEMENT)	FUNCTION
A. <u>Ship Propulsion</u> (cont'd)	
9. SSTG Throttle Valves	• Provide frequency control of the ship's service turbine generators, startup and shutdown of the turbines.
10. SSTG Lube Oil	• Provides the capability to supply control oil to the turbine throttle and govenor valves and to lubricate the turbine and generator bearings.
11. Emergency Propulsion Motor	• Provides a means for secondary (emergency) propulsive power when the propulsion turbines are not used or operating.
12. RPM Transmitter	• Provides indication of propeller shaft speed and total revolution count locally and at the steam control panel.
13. Diesel Generator	• Provides an auxiliary supply of electrical power and an alternate means of exhausting contaminated or stale air from the submarine.
14. Ship Service Motor	• Provide a normal source of DC power (battery is alternate) or an alternate source of AC power (SSTG is normal).
15. SSMG Excitation Control	• Provides a means to control the SSMG to select operation as either an AC or DC generator.
16. Battery	• Provides an emergency source of DC power to the vital equipment necessary to support minimal ship operation (ie. EPM, lube oil, trim and drain, SSMG to produce limited AC power).

Table III-A-3 (Continued)

SYSTEM (ELEMENT)	FUNCTION
A. Ship Propulsion (cont'd)	
17. Secondary Propulsion Motor (SPM)	• Provides a propulsion source to assist in restricted ship maneuvers and may also provide a very limited backup propulsion source.
18. Temperature Monitoring	• Provide remote indication, continuous monitoring and alarm of equipment temperatures at critical points.
19. Main Electrical Distribution Bus	• Provides the manual and automatic switch gear for control, redundancy, protection and distribution of electrical power.
B. Steam-Feed Flow	
1. Main Steam	• Provides the means to distribute steam from the source (steam generators) to those elements using high pressure steam (ie. SSTG, auxiliary steam reducer stations, main propulsion turbines).
2. Auxiliary Steam	• Provide the means to reduce and distribute steam for auxiliary use (ie. air ejectors, evaporator, lithium bromide air conditioner, lube oil stowage heaters).
3. Condenser	• Provides a means to condense exhausted steam and to collect it in a hotwell at the bottom of the condenser.
4. Air Ejectors	• Provide the capability to remove noncondensable gases from the main condenser.

Table III-A-3 (Continued)

SYSTEM (ELEMENT)	FUNCTION
B. <u>Steam-Feed Flow</u>	
5. Condensate Pumps	• Provide the capability to provide a positive suction pressure head to the feed pump suction.
6. Feed Pumps	• Provide a means to transfer water from the condensate header to the feed main at sufficient pressure to feed the steam generators.
7. Feed Regulator Valve	• Provides the capability to control automatically the steam generator feed rate.
8. Steam Generabor Water Level Control	• Provides an automatic or manual control of the feed regulator valve in order to permit a constant water mass or level within the steam generator.
9. Water Chemistry	• Provides steam generator water treatment chemical concentration determination and addition to prevent corrosion or reduced oxygen content.
10. Surge Tank	• Provides the capability to absorb surges of condensate when feed water demands change and to determine the requirement for make-up feed water addition.
11. High Pressure Drains	• Provide the capability to remove condensation from steam piping in order to prevent piping errosion or possible downstream element damage.
12. Drain Valves	• Provide the capability to manually or automatically drain condensation without passing steam.

Table III-A-3 (Concluded)

SYSTEM (ELEMENT)	FUNCTION
B. Steam-Feed Flow (Cont'd)	
13. Low Pressure Drains	• Provides the capability to automatically drain the condensation from the lower pressure steam lines.
14. Hotwell Level Control	• Provides an automatic control of the variable speed condensate pumps. The pump speed is varied in order to attempt to maintain a desired hotwell level range. This ensures a minimum pump suction pressure and prevention of condenser flooding.
15. Sea Water Cooling	• Provides control of the transport media (sea water cooling) to form condensate from turbine exhaust steam and remove heat from various Engineering Plant Elements.
16. Auxiliary Fresh Water Cooling	• Provides the capability to supply a cooling media (fresh water) to main, shaft, and ship service turbine generator lube oil coolers, air coolers (SSTG, EPM, SSMG), high pressure air compressors, and hydraulic oil coolers (main and vital).

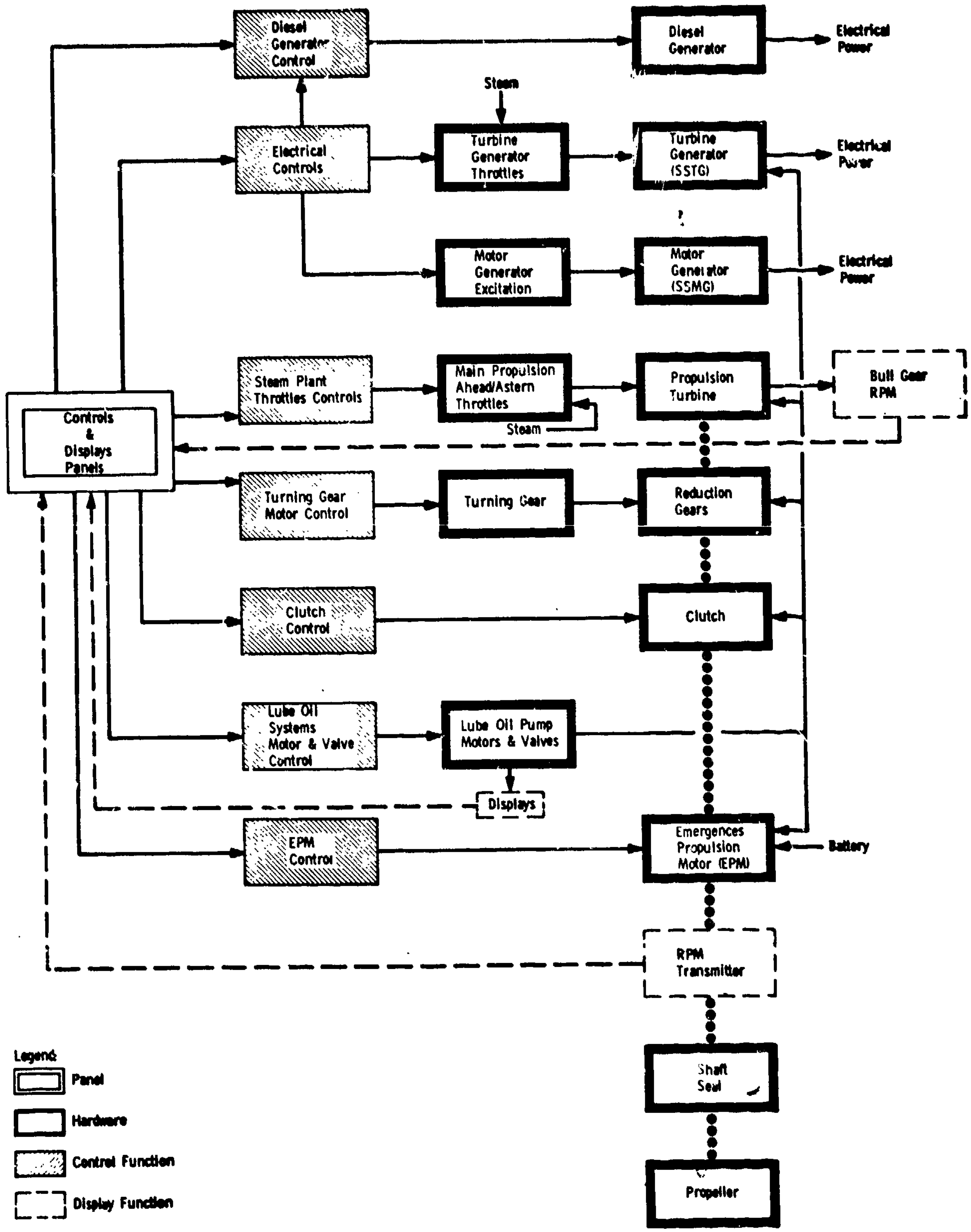


Figure III-A-5 Simplified Functional Diagram - Ship Propulsion System

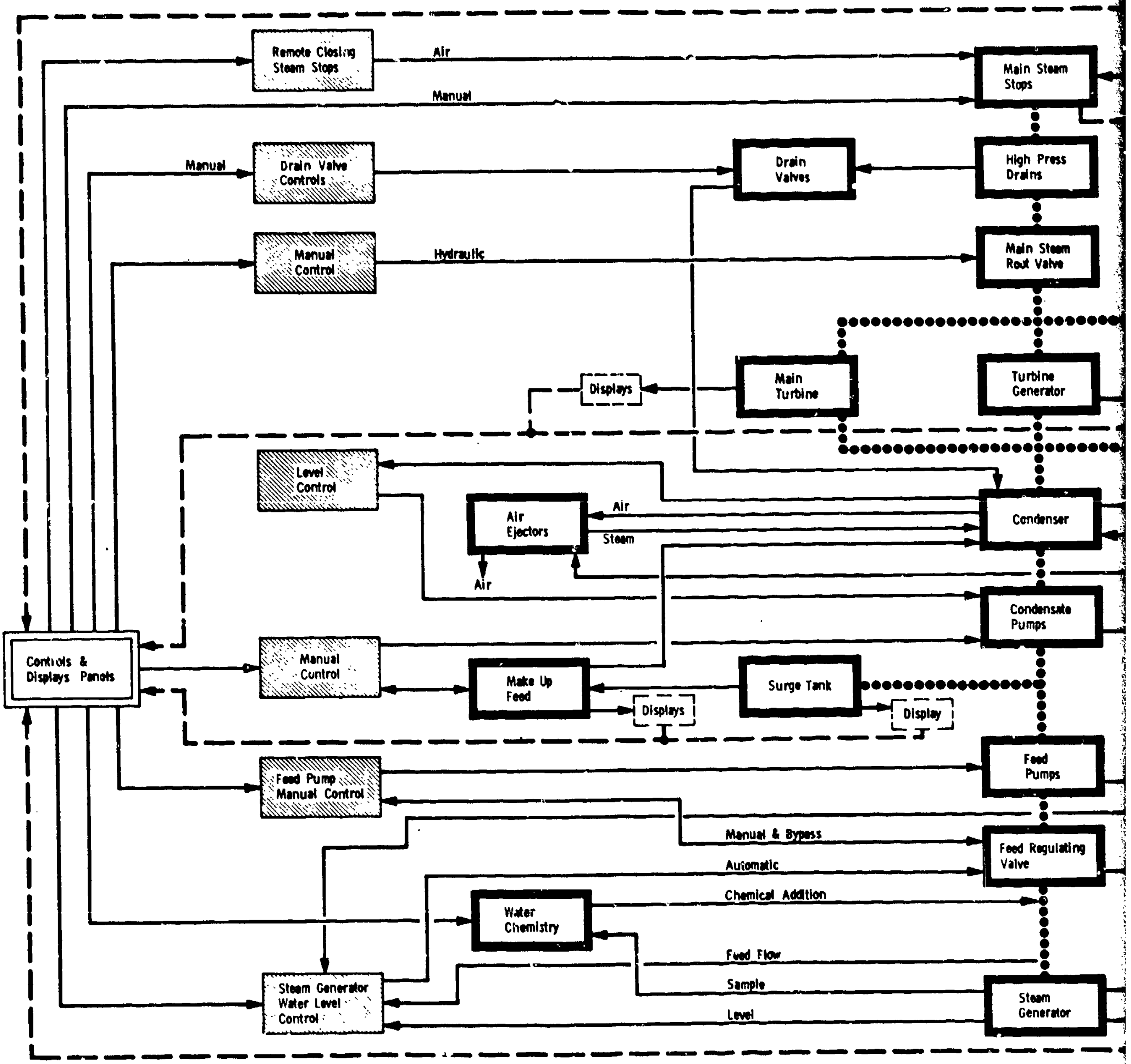


Figure III-A-6 Simplif

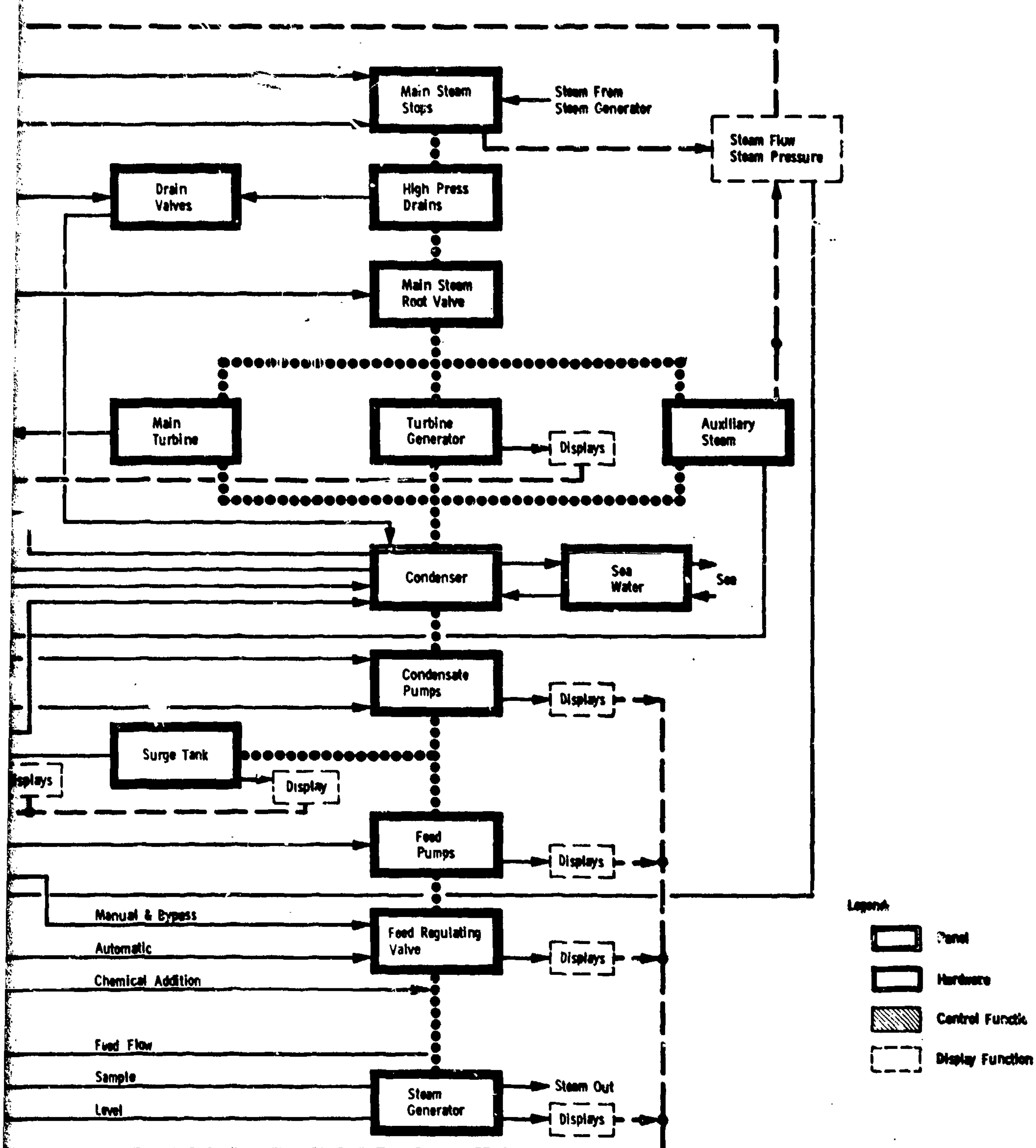


Figure III-A-6 Simplified Functional Diagram - Steam-Feed Flow System

2

Table III-A-4 System (Element) Functional Analysis Results - Auxiliary Subsystem

SYSTEM (ELEMENT)	FUNCTION
A. Air Conditioning	
1. Refrigerant Vapor Compression Plants (R-114)	• Provide refrigeration to reduce chilled water temperature as required to control equipment or atmosphere temperatures.
2. Lithium Bromide Absorption Units	• Provides alternate refrigeration capability.
3. Air Conditioning Chilled Water	• Provides the cooling media (water) which is circulated to maintain a suitable atmosphere for equipment and the comfort of the crew.
4. Pumps (Chilled Water)	• Provide the pressure to circulate chilled water.
5. Air Conditioning Sea Water	• Provides the cooling media (sea water) which removes the heat from the air conditioning plants.
6. Pumps (Sea Water)	• Provide the pressure to circulate sea water.
B. Compressed Air	
1. High Pressure Air Banks	• Provide the capability to store and supply high pressure air (4500 psig).
2. Air Bank Stop Valve	• Provides individual air bank isolation capability.
3. High Pressure Air Compressors	• Provides the means to compress air to high pressure.
4. Low Pressure Air (700 psig)	• Provides the capability to supply service air (700 psig) to the header for distribution to ship's equipment (i.e., hovering, sanitary tanks, escape trunks, etc).
5. Low Pressure Air (150 psig)	• Provides the capability to supply service air (150 psig) to torpedo room and to several ship's applications (i.e., fuel oil tanks, ventilation head valve operation, etc)

Table III-A-4 (Continued)

SYSTEM (ELEMENT)	FUNCTION
B. Compressed Air (Cont'd)	
6. Low Pressure Air (100 psig)	• Provides the capability to supply service air (100 psig) to the header for distribution to ships equipment (i.e., emergency air breathing, emergency SSTG lube oil drive, service air, etc).
7. Low Pressure Air (400 psig)	• Provide the capability to supply air to the torpedo tube firing system.
8. Low Pressure Air (40 psig)	• Provides the capability to supply air to the potable water system.
9. Low Pressure Air (20 psig)	• Provides the air supply for operating control and sensor devices, primarily ventilation and air conditioning.
10. Low Pressure Air (75 psig)	• Provides an alternate air source for O_2 generator control.
11. Control Air Compressors	• Provide the means to pressurize air for a normal source for O_2 generator control.
C. Crew Support	
1. Refrigerant Plants	• Provides the capability to supply refrigeration to each of the ship's chilled stores, frozen food storage, and miscellaneous refrigeration units.
2. Thermostat Controls	• Provide the capability to convert temperature measurements into air pressure signals to control overall refrigeration plant operation.
3. Refrigerant Compressor	• Provides the means to pressurize the refrigerant (Freon 12).
4. Electrical Distilling Unit	• Provides an alternate means to convert sea water to fresh water to support ship and crew operation.

Table III-A-4 (Concluded)

SYSTEM (ELEMENT)	FUNCTION
C. Crew Support (Cont'd)	
5. Steam Evaporator	• Provides the primary means to convert sea water to fresh water.
6. Salinity Cell	• Provides the capability to monitor fresh water for salinity purity (continuity).
D. Equipment Support	
1. Main Hydraulic System	• Provides the capability to supply hydraulic oil pressure to the majority of the hydraulically operated equipment throughout the ship.
2. Vital Hydraulic System	• Provides hydraulic oil pressure to "vital" hydraulically-operated equipment throughout the ship.
3. External Hydraulic System	• Provides the capability to supply hydraulic oil pressure to equipment actuators exposed to sea water pressure (antennas, periscopes, masts, and snorkel masts).
4. Electronic Cooling System	• Provides the capability to distribute fresh water to cool electronic components.
5. Fuel Oil and Compensating Water	• Provides the capability to replace used fuel oil with sea water and maintain a system pressure by either water or air.
6. Anchor Control	• Provides the means to secure, release, and raise the anchor.
7. Capstan	• Provides the capability to utilize mooring lines to move the ship as desired while next to the pier or wharf.

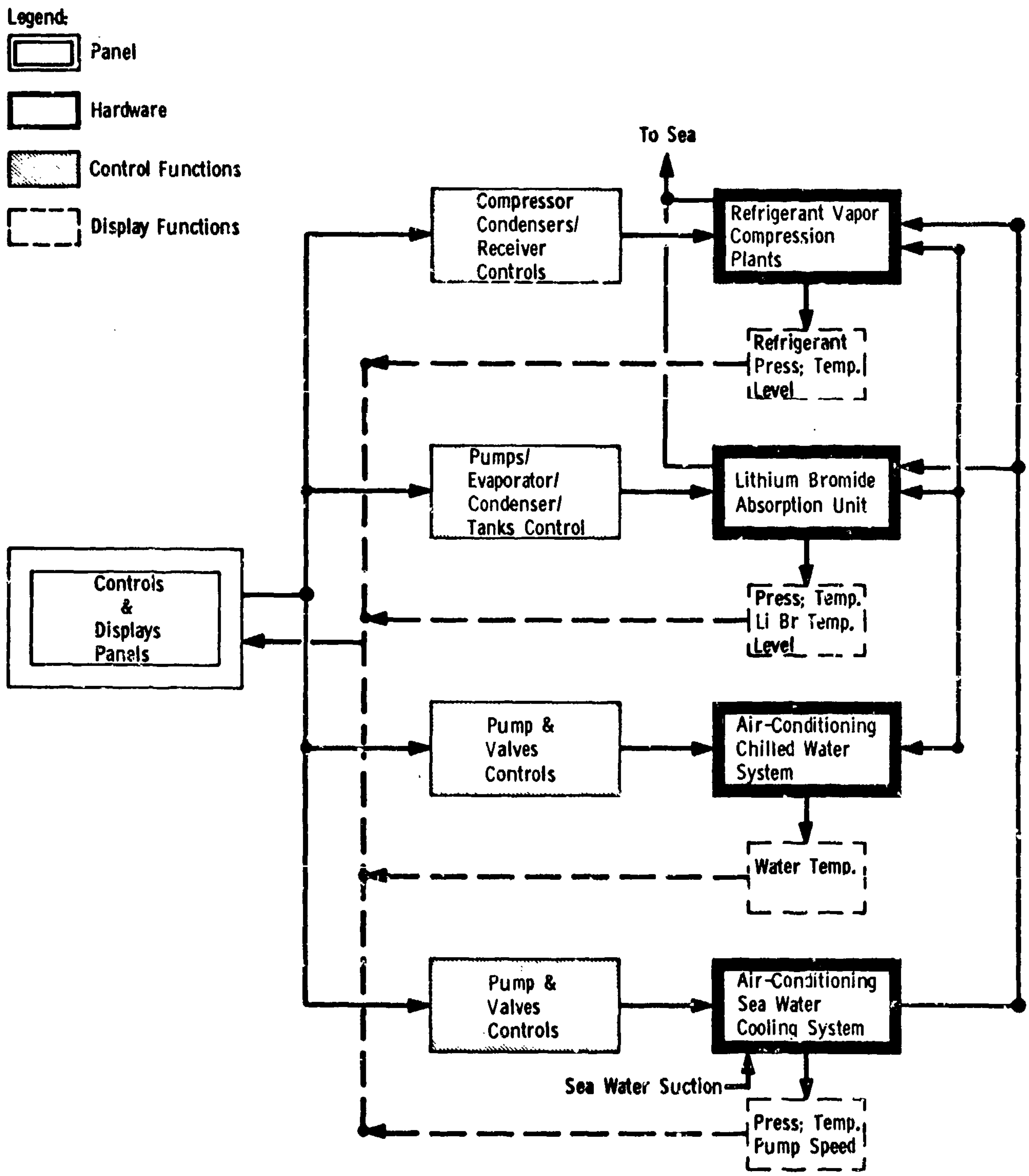


Figure III-A-7 Simplified Functional Diagram - Air Conditioning System

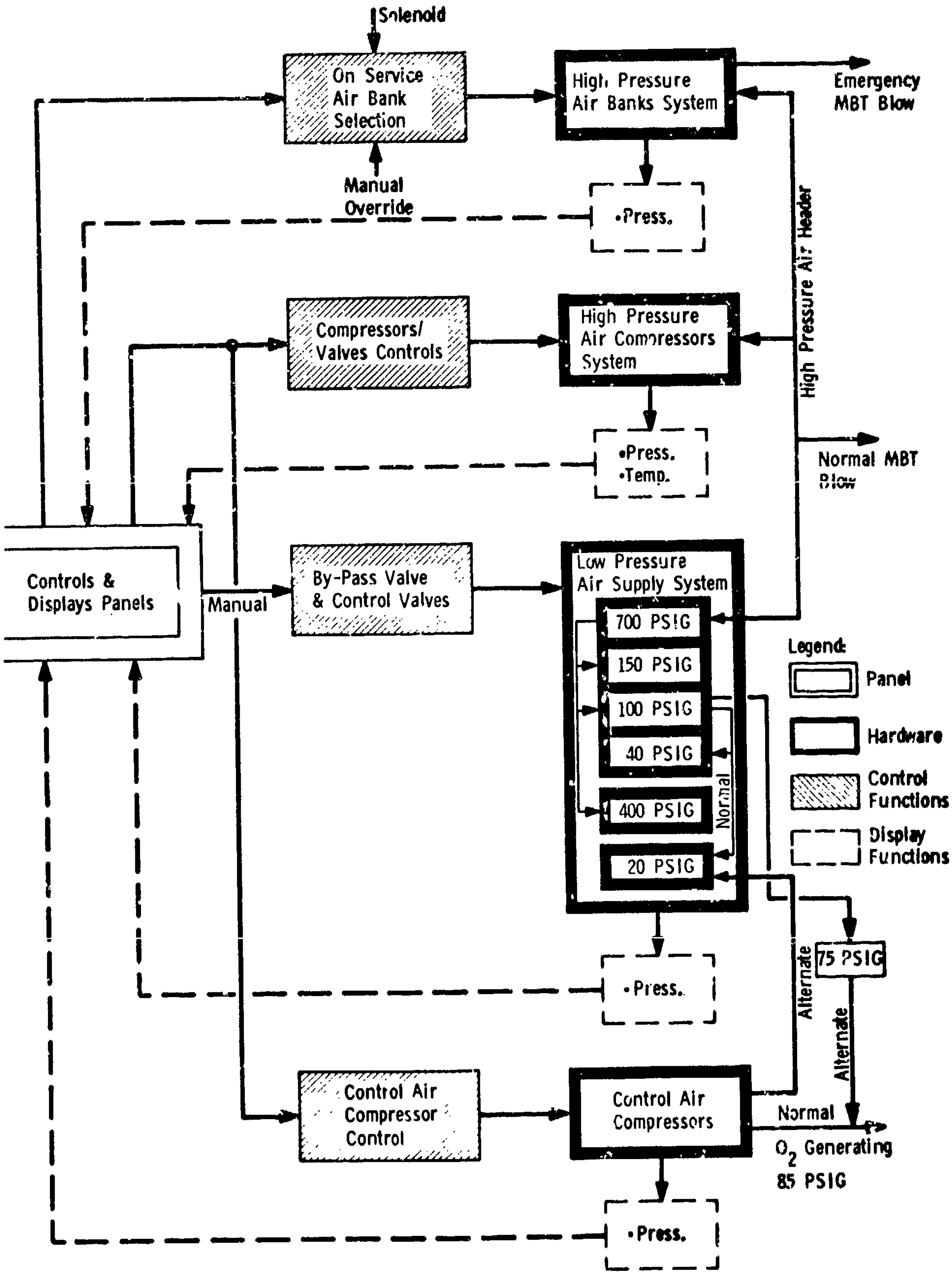


Figure III-A-8 Simplified Functional Diagram - Compressed Air System

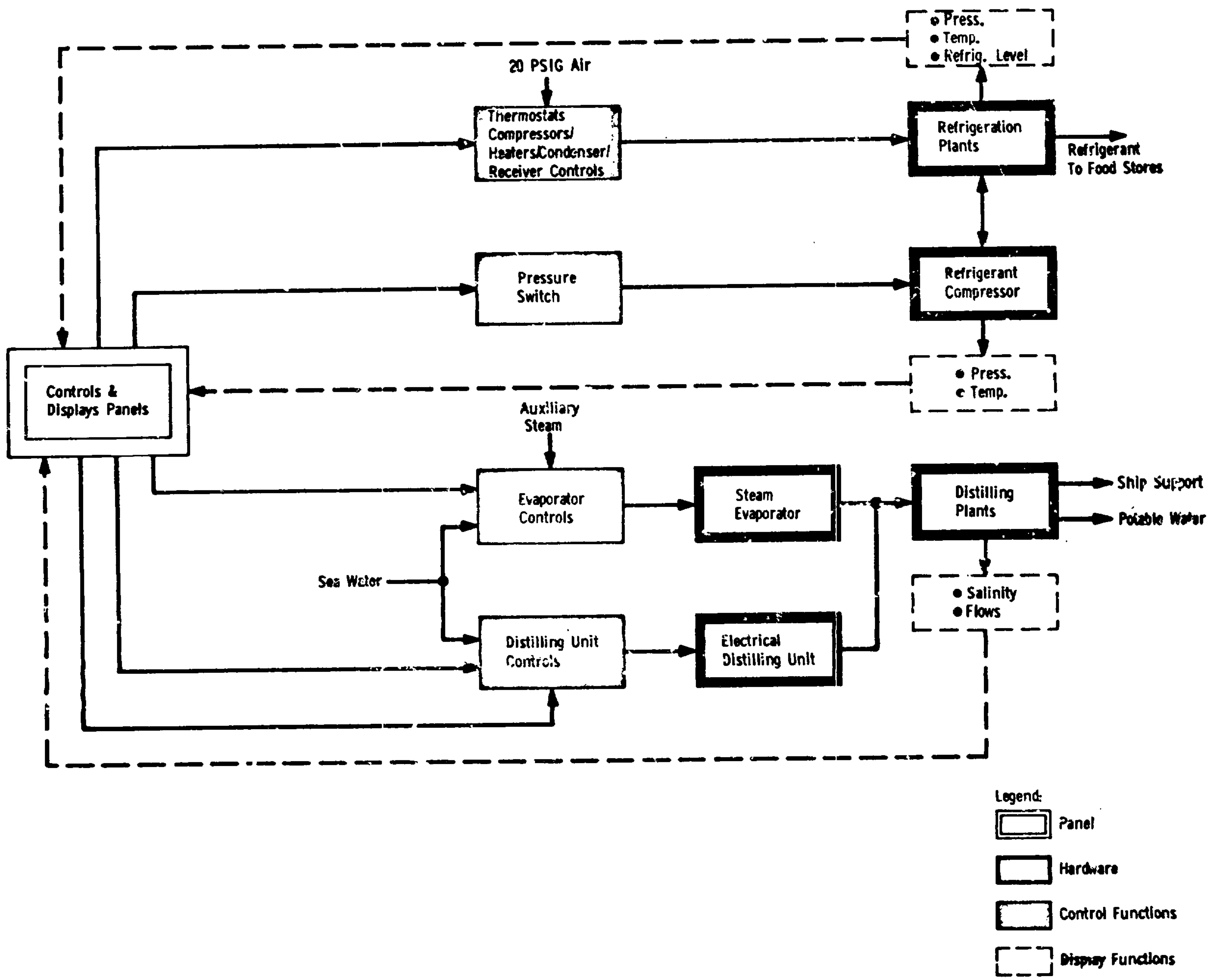


Figure III-A-9 Simplified Functional Diagram - Crew Support System

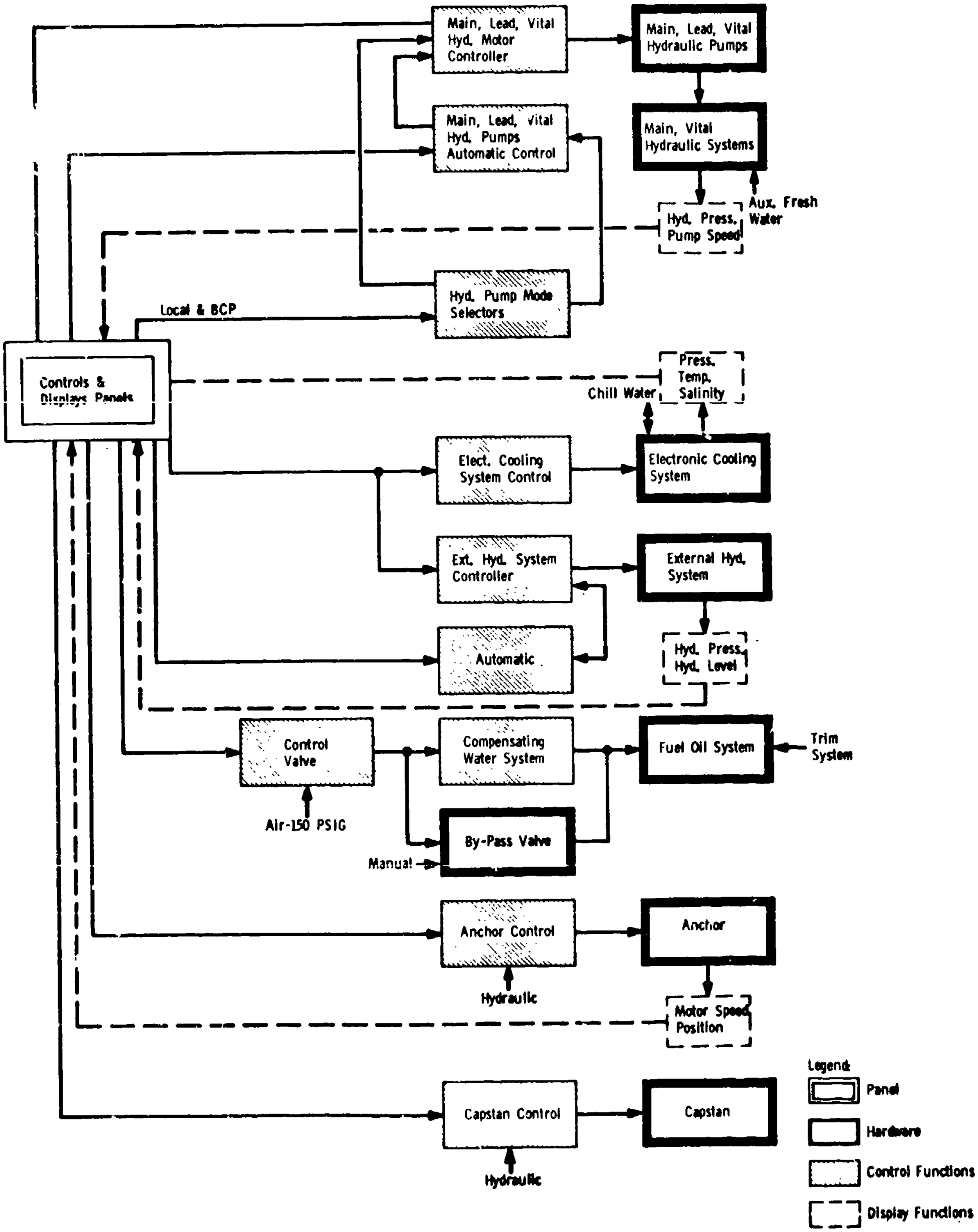


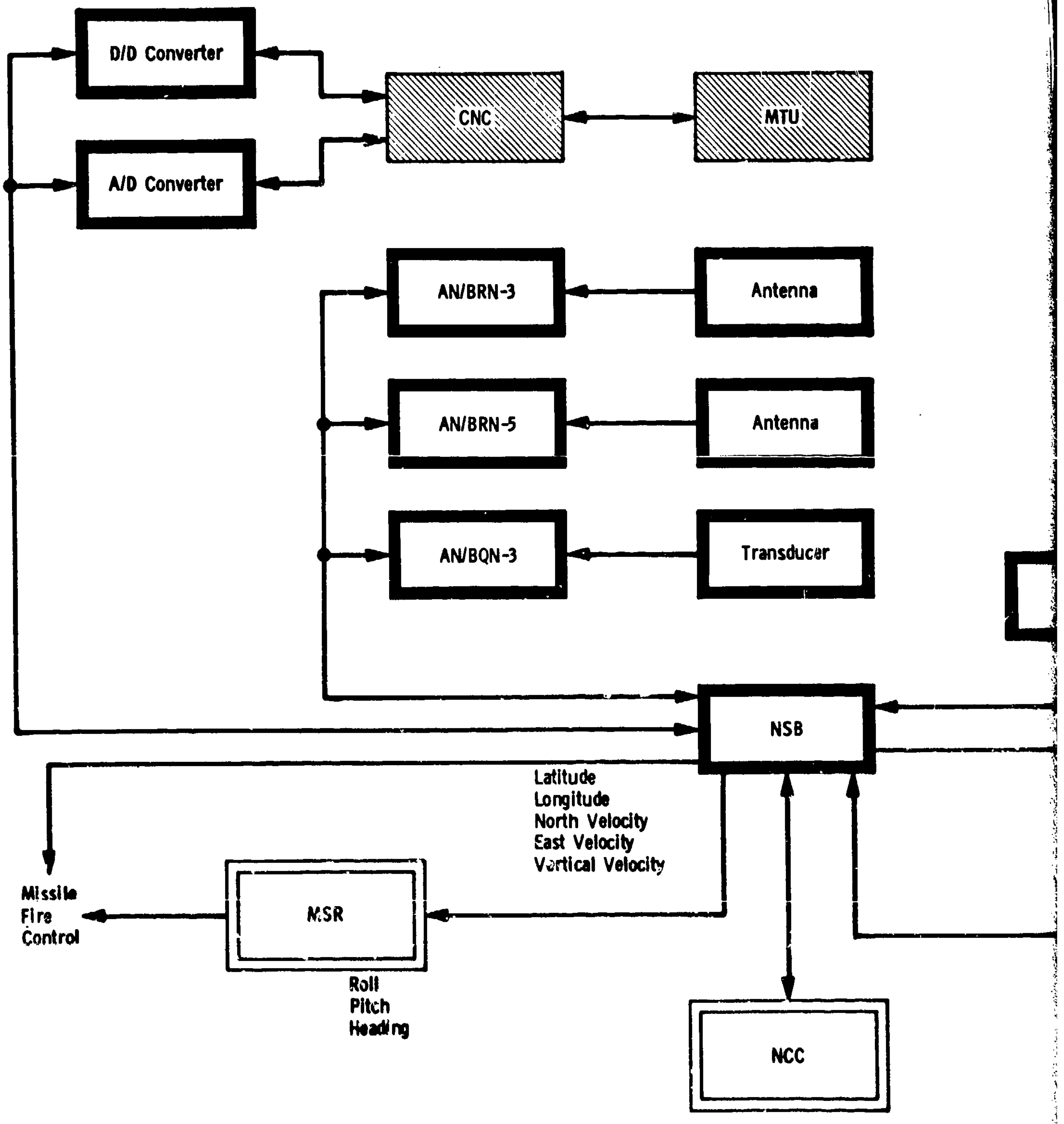
Figure III-A-10 Simplified Functional Diagram - Equipment Support System

Table III-A-5 System (Element) Functional Analysis Results - Navigation Subsystem

SYSTEM (ELEMENT)	FUNCTION
1. Gyro Compass (MK-19)	• Provides a heading indication to steer the ship (in addition to the inertial navigation system).
2. Dead Reckoning Analyzer Indicator (DRAI)	• Provides a summation of ship movement in both east-west and north-south directions.
3. Electromagnetic Log	• Provides a ship velocity indication.
4. Dummy Log	• Provides the capability to simulate desired ship velocity indications.
5. Central Navigation Computer (CNC)	• Receive, analyze, and make recommendations based on navigational information inputs.
6. D/D Converter	• Transmits digital-to-digital information to and from the CNC.
7. A/D Converter	• Transmits analog-to-digital information to and from the CNC.
8. Magnetic Tape Unit (MTU)	• Provides data input to the CNC and provides recording capability through the CNC.
9. Multispeed Repeaters (MSR)	• Transmits analog data for the missiles (roll, pitch, and heading).
10. Navigation Switchboards (NSB)	• Provides automatic or remote switching capability for desired navigational information.
11. Computer Writer Adapter (CWA)	• Provides the capability to adapt signals from the CNC in order to provide an alternate method of recording data.
12. Navigation Control Console (NCC)	• Provide a central control console for input to and output of the CNC.
13. Navigation Operational Checkout Console (NOCC)	• Provides a central console to simulate test signals for checking various navigation subsystem equipment.

Table III-A-5 (Concluded)

SYSTEM (ELEMENT)	FUNCTION
14. Satellite Fix Equipment (AN/BRN-3)	• Provides the capability to obtain navigational fix information transmitted by satellite.
15. Radio Navigation Fix Equipment (AN/BRN-5)	• Provides the capability to obtain navigational fix information transmitted by ground based stations.
16. Ocean Bottom Navigational Fix Equipment (AN/BQN-3)	• Provides the capability to obtain navigational fix information by ocean bottom comparison.
17. Inertial Navigation Equipment (SINS)	• Provides computer controlled inertial navigation platforms.


D/D Converter
A/D Converter
CNC
MTU
AN/BRN-3
Antenna
AN/BRN-5
Antenna
AN/BQN-3
Transducer
NSB
Latitude
Longitude
North Velocity
East Velocity
Vertical Velocity
Missile
Fire
Control
MSR
Roll
Pitch
Heading
NCC

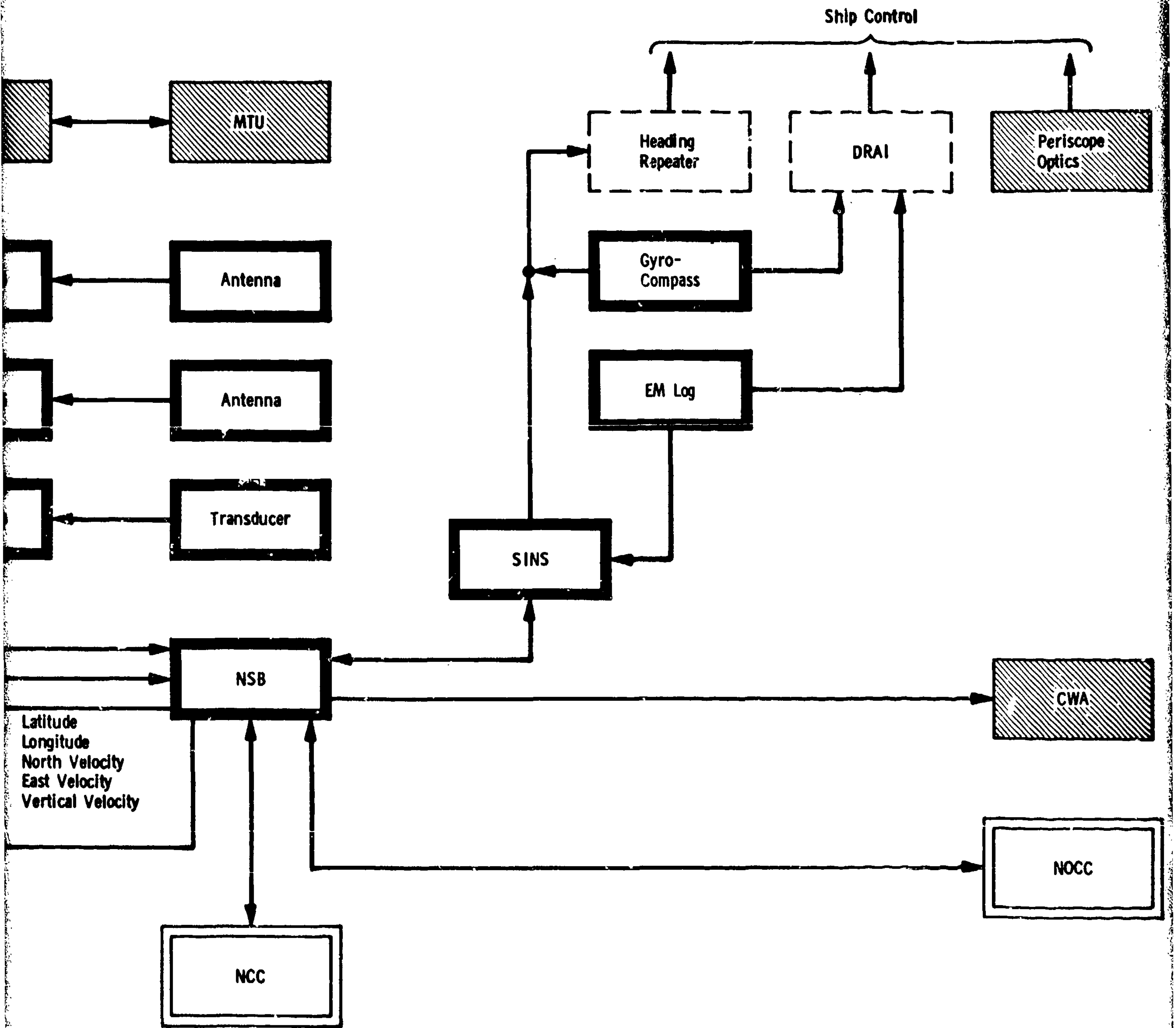


Figure III-A-11 Simplified Functi

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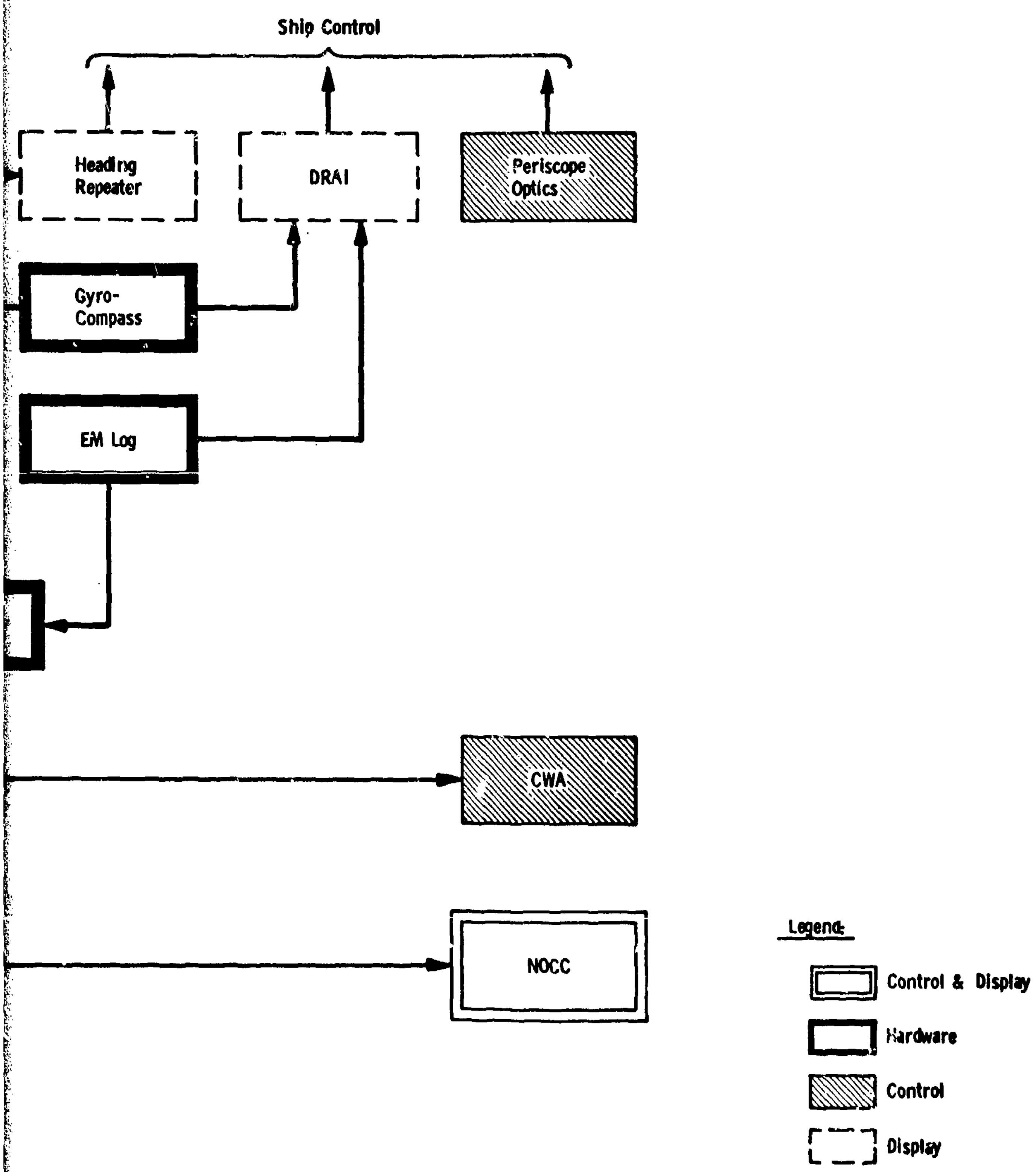
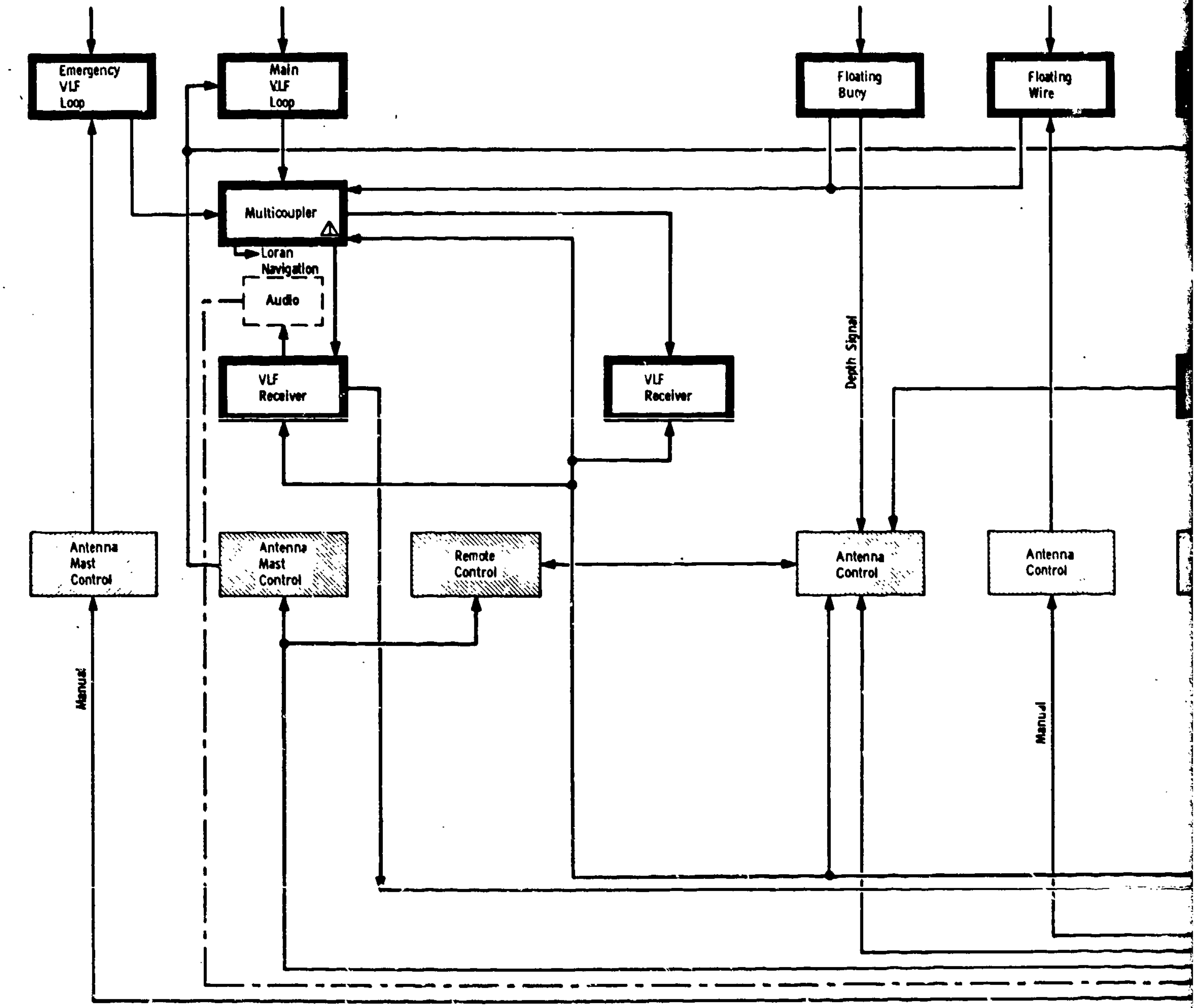


Figure III-A-11 Simplified Functional Diagram - Navigation Subsystem

3

Table III-A-6 System (Element) Functional Analysis Results - External Communications Subsystem

SYSTEM (ELEMENT)	FUNCTION
1. Transmitter (AN/WTR-4)	• Provides high power transmission capability within the MF and HF ranges.
2. Transceiver (AN/SRC-20)	• Provides transmitter and receiver capabilities within the UHF range. Used for harbor control.
3. Transceiver (AN/URC-32)	• Provides medium power transmitter and receiver capabilities within the MF and HF ranges.
4. Receivers (AN/WRR-3 and AN/BRR-3)	• Provides redundant receiver capabilities within the VLF range.
5. Receivers (R-1051)	• Provides redundant receiver capabilities within the MF and HF ranges.
6. Security Equipment	• Provides message security through automatic or manual encryption and decryption.
7. Radio Telephone	• Provides the capability to use hand phones and/or speakers for voice communications from local or remote control stations.
8. Teletype	• Provides the capability to obtain a typewritten copy of desired messages.
9. Multicoupler (AN/BRA-16)	• Provides controlled switching of communications input/output devices.
10. Receiver (AN/URR-44)	• Provides radio reception for ships crew entertainment.
11. Test Set (AN/URM-114)	• Provides signal generation for testing capability.
12. Tape Recorder (RD-219)	• Provides the capability to record received voice and CW messages.
13. Antennas	• Provides a normal alternate, or emergency antenna, which can be used throughout the frequency range of each piece of communications equipment and the means for control of those antennas.



Emergency VLF Loop
Main VLF Loop
Floating Buoy
Floating Wire
Multicoupler
Loran Navigation
Audio
VLF Receiver
VLF Receiver
Depth Signal
Antenna Mast Control
Antenna Mast Control
Remote Control
Antenna Control
Antenna Control
Manual
Manual

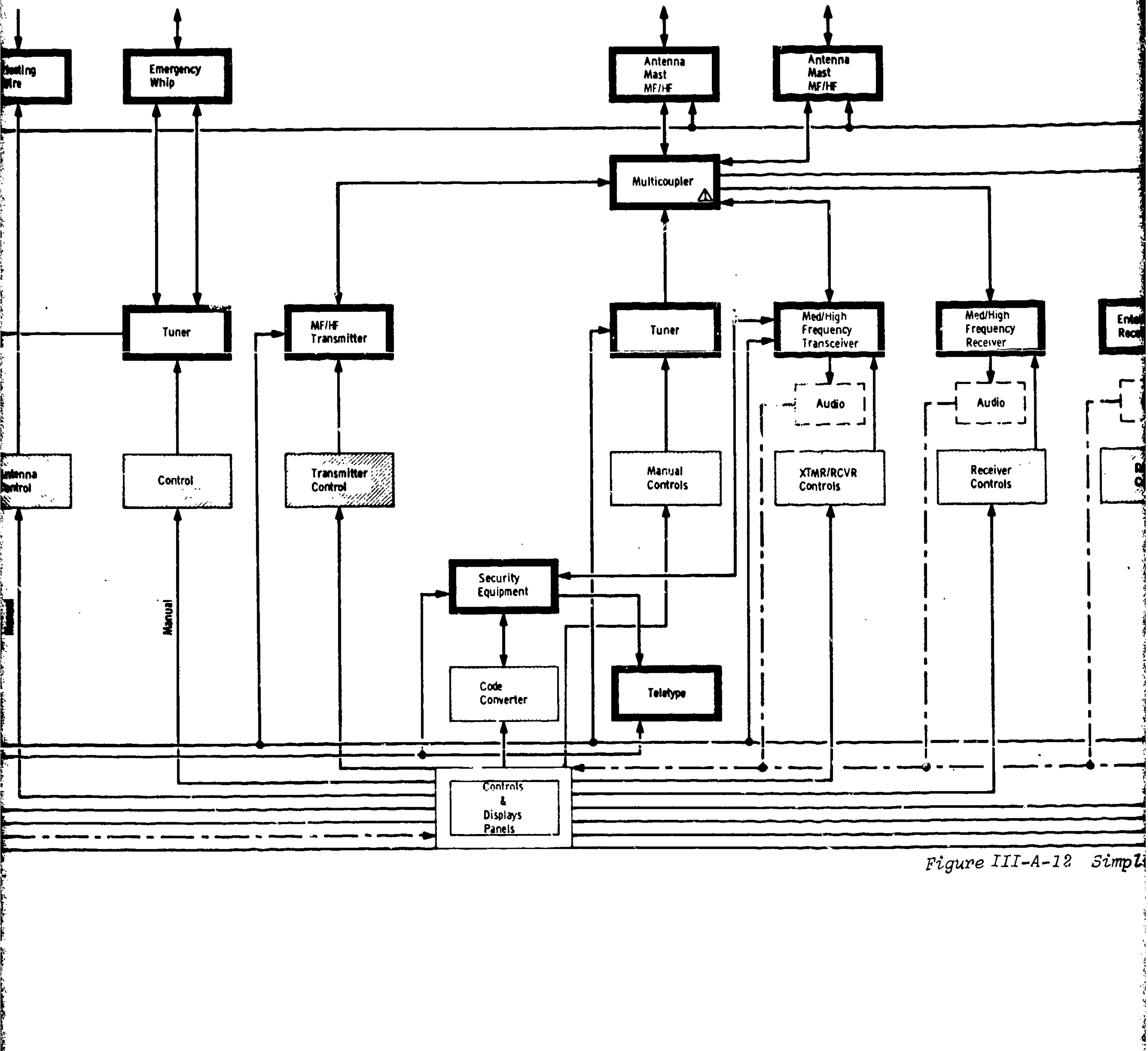


Figure III-A-12 Simpli

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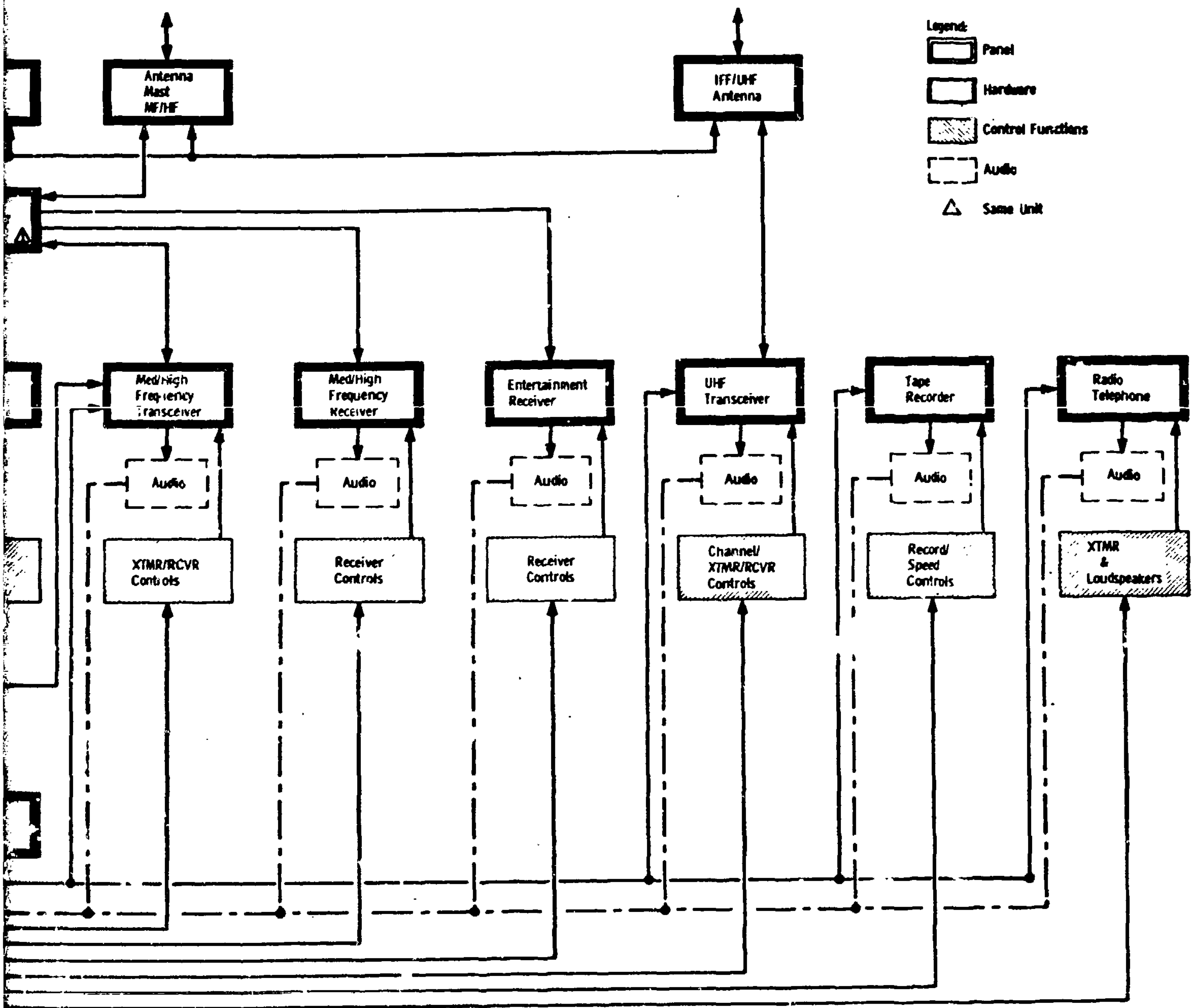


Figure III-A-12 Simplified Functional Diagram - External Communications Subsystem

3

Table III-A-7 System (Element) Functional Analysis Results - Sonar/ECM Subsystem

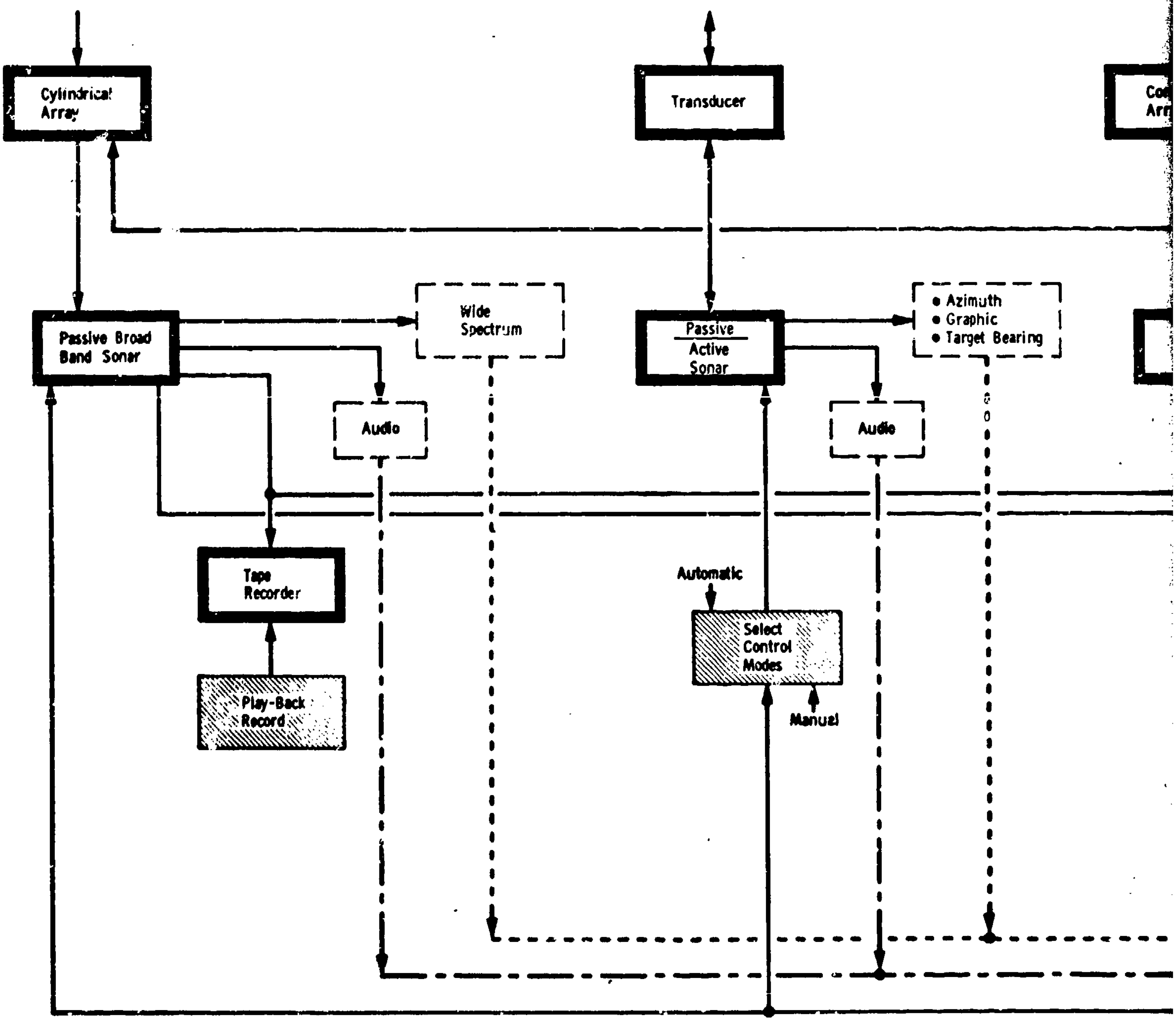
SYSTEM (ELEMENT)	FUNCTION
A. <u>Sonar</u>	
1. Passive Snnar (AN/BQR -2) Cylindrical Array	• Provides wide frequency band passive reception of any characteristic sound change in the surrounding water.
2. Active Sonar (AN/BQS-4)	• Provides the capability for detection of a reflected sound pulse (echo ranging).
3. Passive Sonar (AN/BQS-7)	• Provides an alternate wide frequency band passive reception of any characteristic sound change in the surrounding water.
4. Passive Sonar (AN/BQR -15) Trailing Array	• Provides wide requency band passive reception of any characteristic sound change in the surrounding water. Array location provides contact detection behind the submarine and additional target motion analysis technique availability.
5. Passive Sonar (AN/BQR-20)	• Provides the capability to monitor selected narrow frequency bands which aid in contact classification. Other passive sonar arrays are used to obtain this signal.
6. Passive Sonar (AN/BQR -19) Overhead Array	• Provides a sonar search above a thermal level within the water. Increases ship safety when changing to periscope depth.
7. Sonar Performance Computer (AN/BQA-8)	• Provides physical information which indicates the sonar capabilities within local waters.
8. Sonar/ECM (AN/WLR-9)	• Provides a dedicated sonar to detect and alarm on reception of a characteristic "threat" sonar.
9. Fathometer (AN/UQN-1)	• Provides the capability to determine water depth under the ship.

Table III-A-7 (Continued)

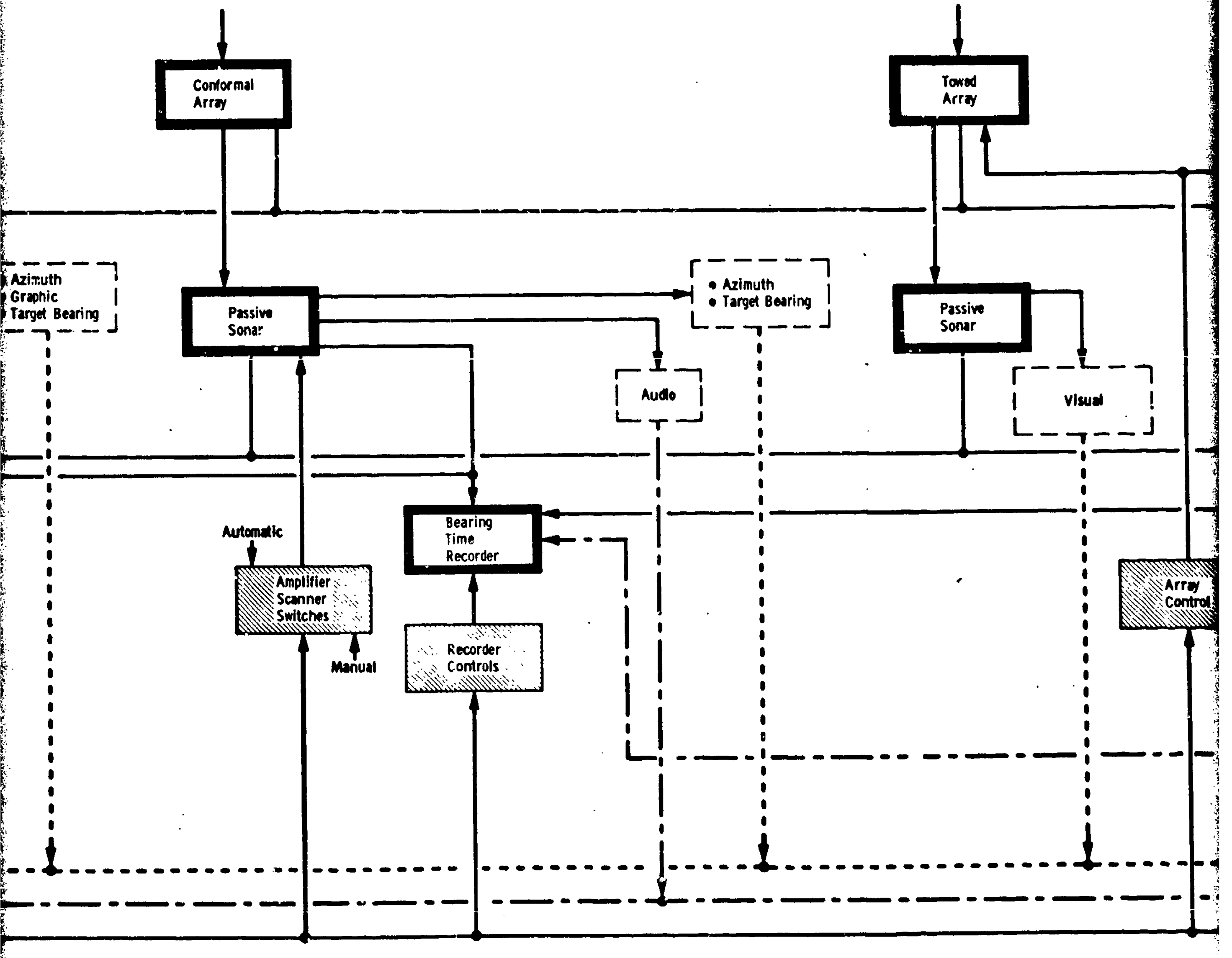
SYSTEM (ELEMENT)	FUNCTION
A. Sonar (Cont'd)	
10. Underwater Telephone (AN/WQC-1)	• Provides the capability to communicate (voice or CW) outside of the ship using water as the transfer medium.
11. Sonar Contact Parameter Identification (AN/BQQ-3)	• Provides the capability to modulate the wide frequency band to determine sonar contact parameters such as the number of propeller blades or the number of propellers.
12. Sound Velocity Profile (AN/BQH-1)	• Provides the capability to determine water density changes in relation to water depth.
13. Bearing Time Recorders	• Provides an automatic hard copy display of continuous contact bearings in relation to time.
14. Tape Recorder (AN/UNC-7)	• Provides a continuous record of oral sonar receptions, communications, and operator evaluations of contacts.
15. Emergency Underwater Telephone	• Provides an emergency method of underwater communications exterior to the ship. Transmitter/receiver sets are at both ends of the ship.
B. ECM	
1. Radar	• Provides a limited surface search and navigational radar capability.
2. ECM Equipment (AN/WLR-1)	• Provides the capability to search required frequency bands for electromagnetic transmissions and identify the electronic characteristics of any received signal to allow possible source identification.
3. ECM Equipment (AN/BLR-10)	• Provides a fast automatic search of the higher frequency bands for electromagnetic transmissions which are of the greatest threat toward detection.

Table III-A-7 (Concluded)

SYSTEM (ELEMENT)	FUNCTION
B. ECM (Cont'd)	
4. Microwave Intercept Receiver	• Provides early warning of possible "threat" radars by use of the periscope as the antenna mast. This provides less antenna exposure than the ECM antenna but less characteristic information on a received signal.
5. Electronic Identification (AN/UPX-17)	• Provides the capability to electronically identify the ship on request. A coded electronic reply is initiated in response to a coded electronic request.

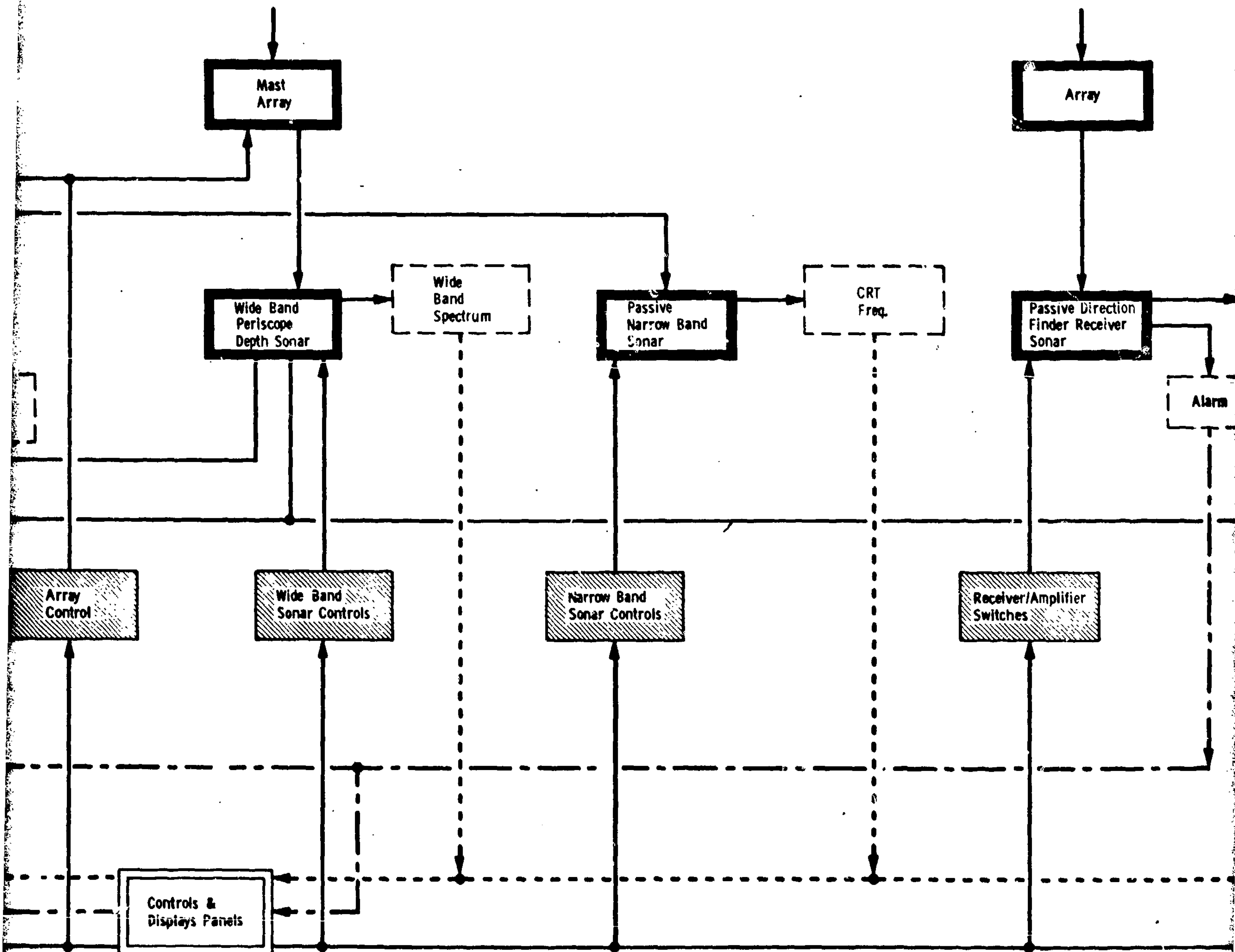


Cylindrical Array
Transducer
Passive Broad Band Sonar
Wide Spectrum
Passive
Active
Sonar
• Azimuth
• Graphic
• Target Bearing
Audio
Audio
Tape Recorder
Play-Back Record
Automatic
Select Control Modes
Manual



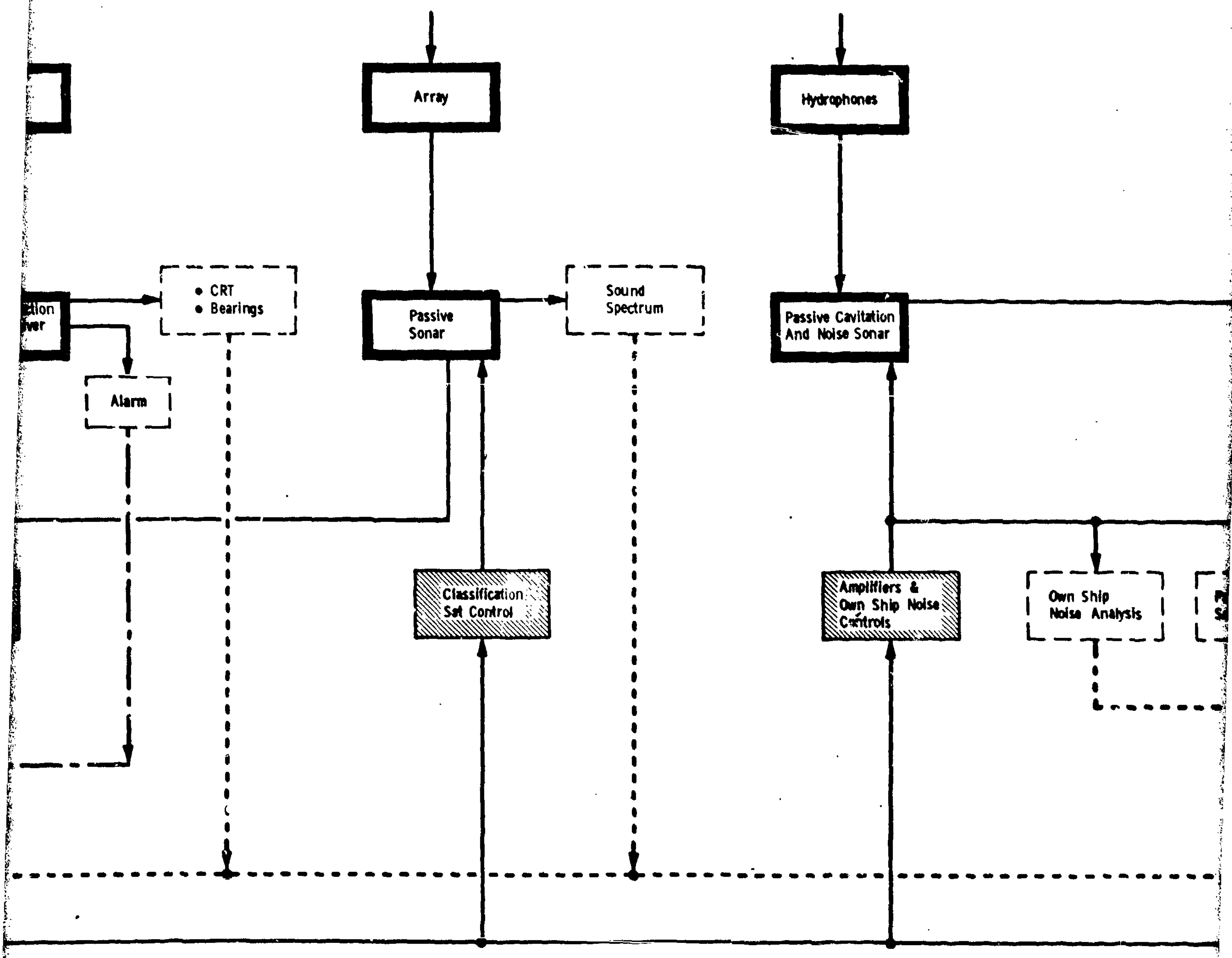
Conformal Array
Towed Array
Azimuth
Graphic
Target Bearing
Passive Sonar
Azimuth
Target Bearing
Passive Sonar
Audio
Visual
Automatic
Amplifier Scanner Switches
Manual
Bearing Time Recorder
Recorder Controls
Array Control

2

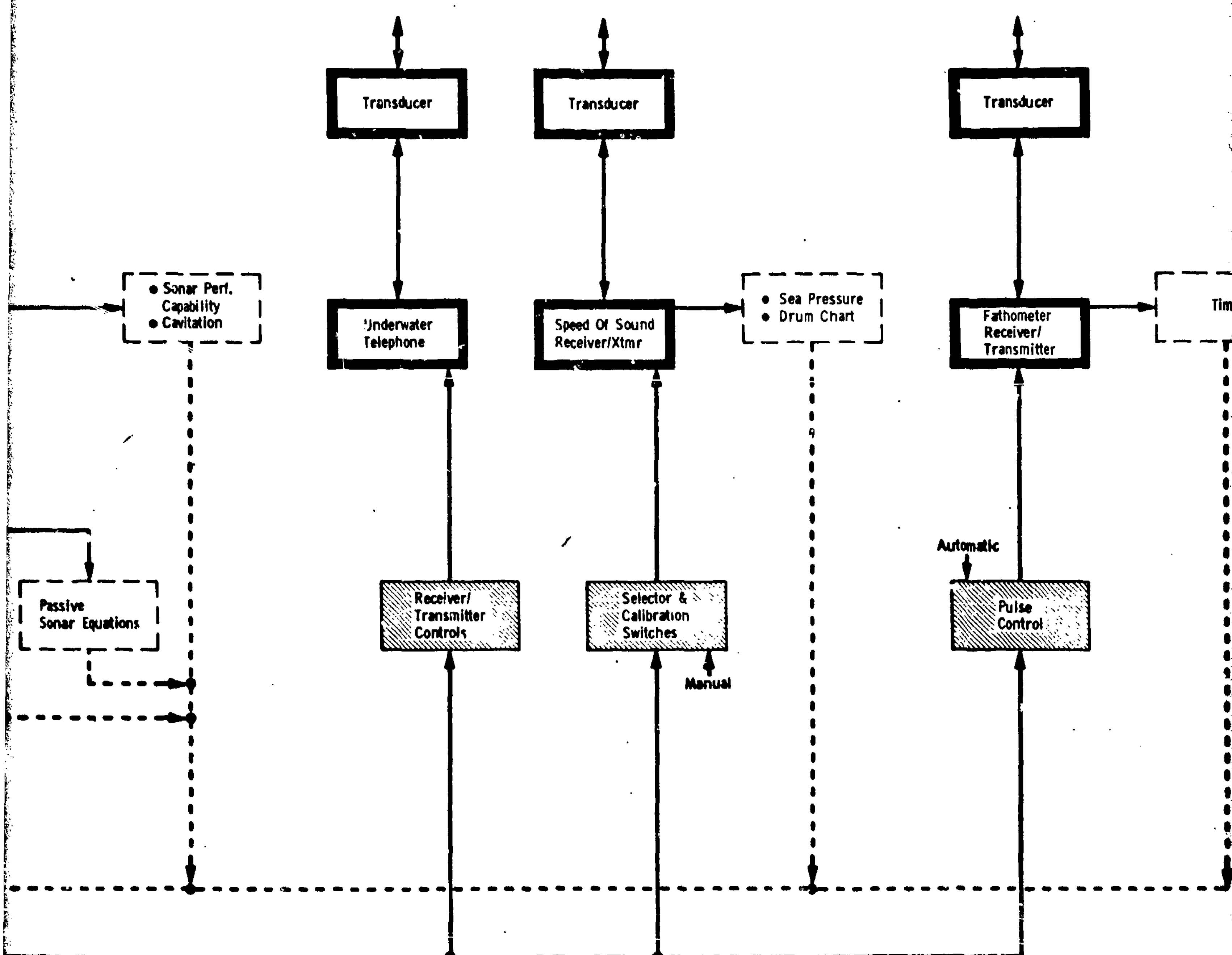


Mast Array
Array
Wide Band Periscope Depth Sonar
Wide Band Spectrum
Passive Narrow Band Sonar
CRT Freq.
Passive Direction Finder Receiver Sonar
Alarm
Array Control
Wide Band Sonar Controls
Narrow Band Sonar Controls
Receiver/Amplifier Switches
Controls & Displays Panels

3


Array
Hydrophones
• CRT
• Bearings
Passive
Sonar
Sound
Spectrum
Passive Cavitation
And Noise Sonar
Alarm
Classification
Set Control
Amplifiers &
Own Ship Noise
Controls
Own Ship
Noise Analysis

4



Transducer
Transducer
Transducer
• Sonar Perf. Capability
• Cavitation
Underwater Telephone
Speed Of Sound Receiver/Xtmr
• Sea Pressure
• Drum Chart
Fathometer Receiver/ Transmitter
Tim
Automatic
Passive Sonar Equations
Receiver/ Transmitter Controls
Selector & Calibration Switches
Pulse Control
Manual

Figure III

5

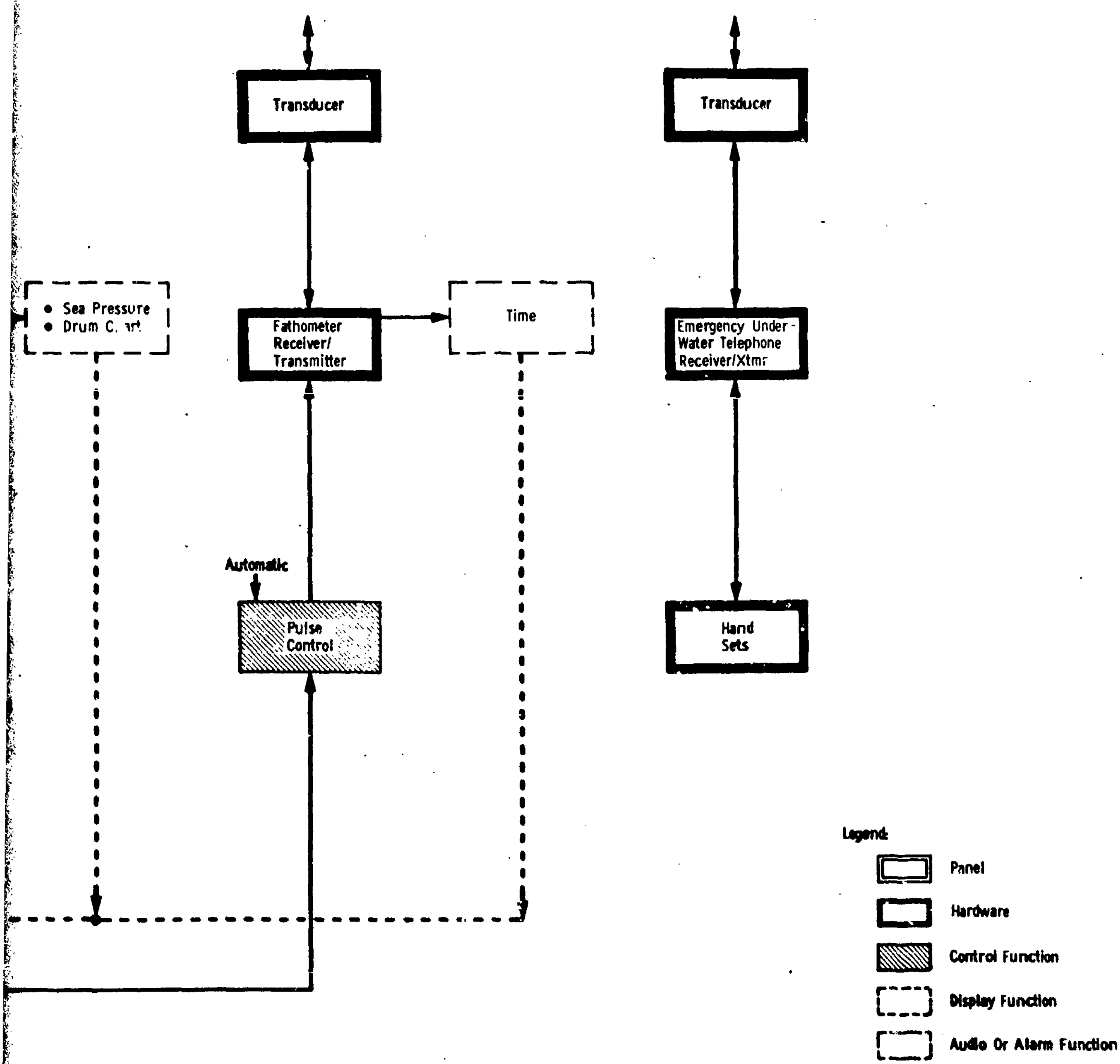


Figure III-A-13 Simplified Functional Diagram - Sonar System

6

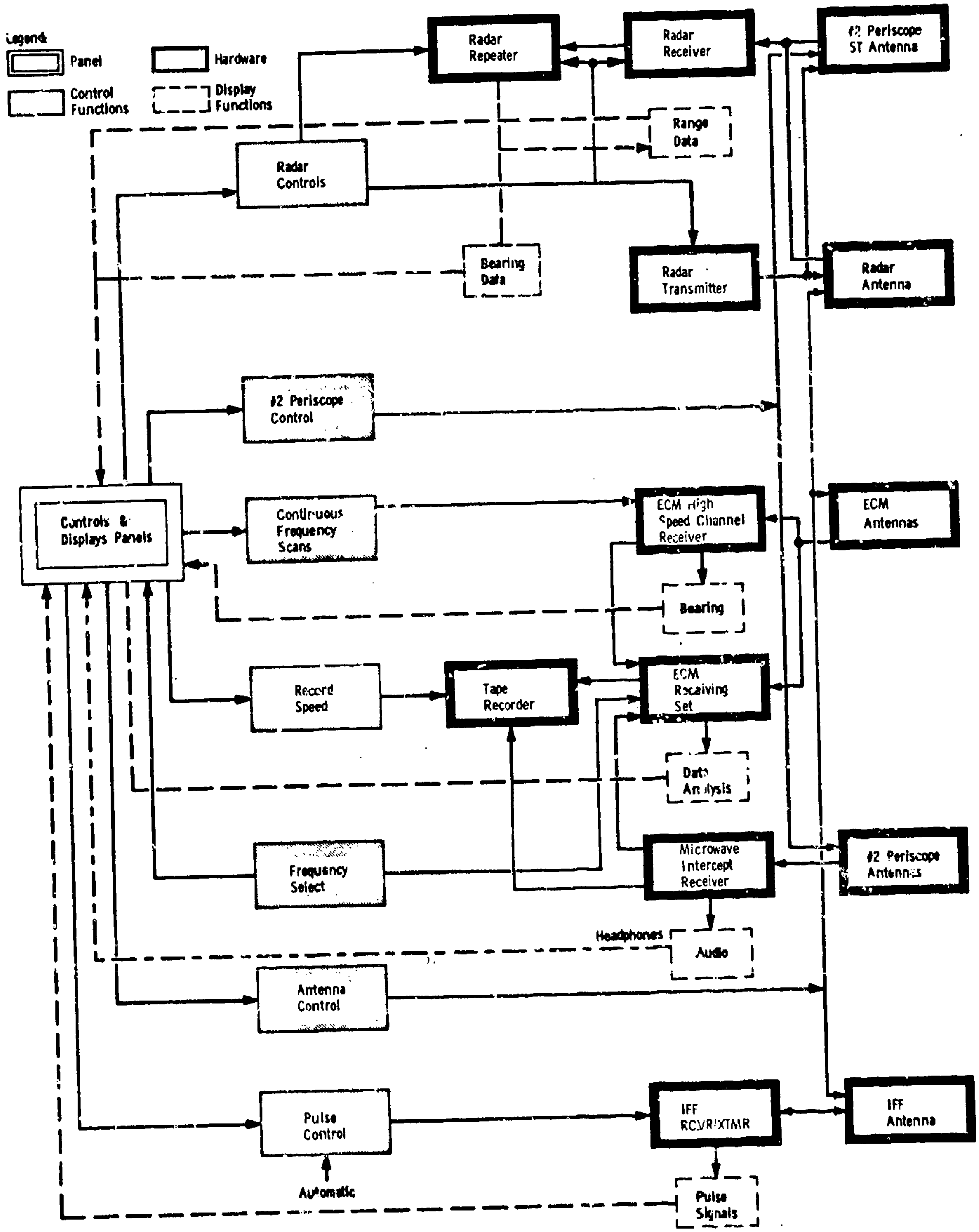


Figure III-A-14 Simplified Functional Diagram - Electronic Countermeasure Subsystem

Table III-A-8 System (Element) Functional Analysis Results - Defensive Weapons Subsystem

SYSTEM (ELEMENT)	FUNCTION
1. Torpedo Tubes	• Provide the capability to eject the torpedo from the ship, either by water impulse or swimming out. Also provides the control to flood or drain sea water from a tube.
2. Torpedo	• The mechanism to transport the explosive to the desired target.
3. Signal Ejectors	• Provide the capability to launch indication or decoy devices from the ship.
4. Fire Control System	• Provides the capability to remotely input desired torpedo control signals, directly or indirectly as computed by the equipment, and to initiate torpedo firing.
5. Bearing-Range Indicators (MK-8)	• Provide the capability to display continuous target bearing or range information from a selected source.
6. Manual Target Motion Analysis Plots	• Provide information which can be used to aid in the determination of the best target motion solution.

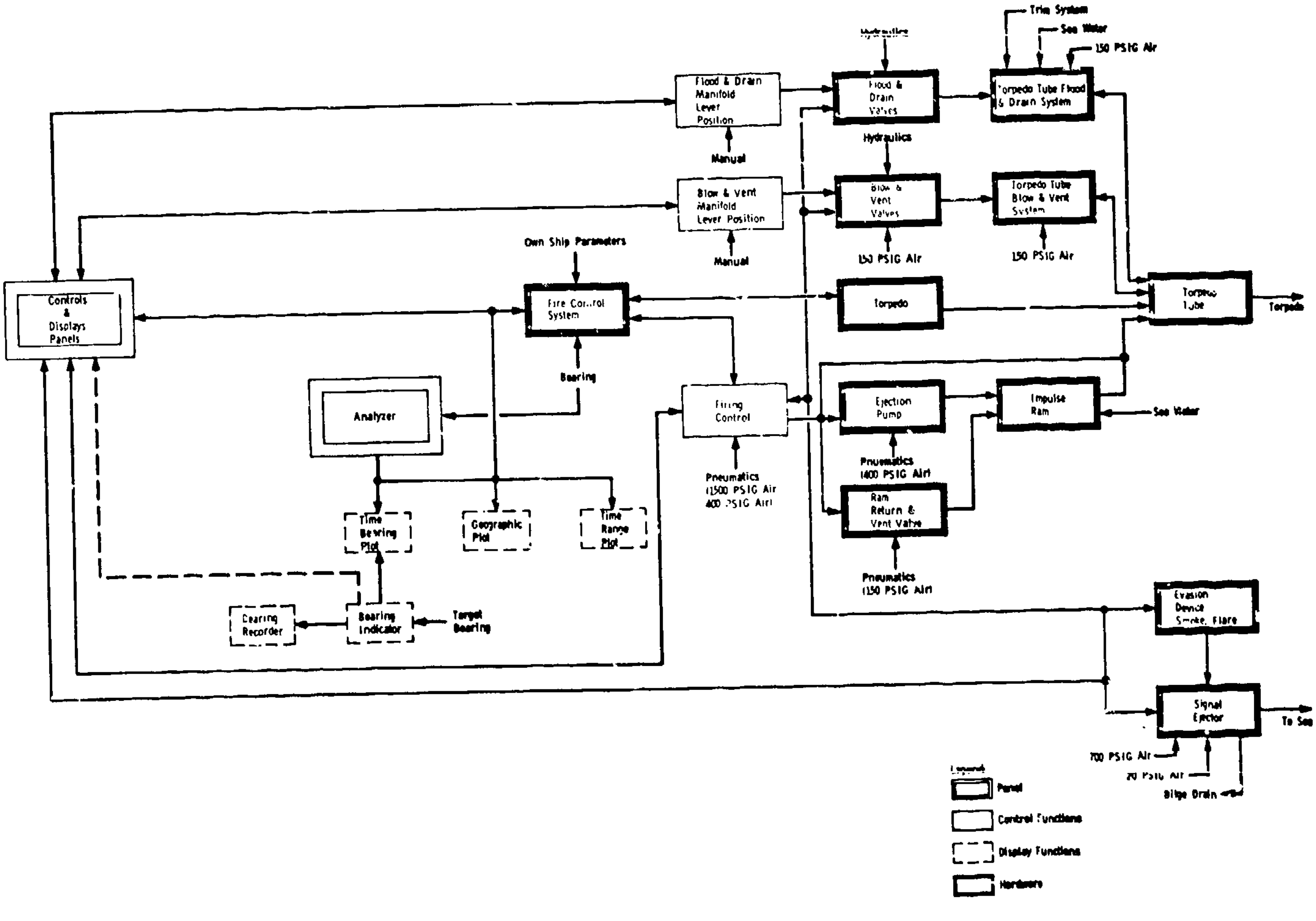


Figure III-A-15 Simplified Functional Diagram - Defensive Weapons Subsystem

Table III-A-9 System (Element) Functional Analysis Results - Strategic Weapons Subsystem

SYSTEM (ELEMENT)	FUNCTION
1. Missile Tubes	• Provide the storage and ejection cylinder for the missiles.
2. Gas Generators	• Provide the gas pressure necessary to impulse the missile out of the tube and to the water surface.
3. Missile Tube Pressurization	• Provides the capability of equalizing missile tube pressure with the associated sea pressure to permit opening the missile tube hatch.
4. Missile Gas System	• Provides a source of stored nitrogen and the capability to inert the missile tubes if desired.
5. Missile Compensation	• Provides the capability to automatically compensate for the large weight changes (maintain buoyancy) associated with launching a missile.
6. Missile Hydraulics	• Provide a hydraulic source and control valves for hydraulically operated equipment associated with the missile tubes.
7. Attach Center Indicating Panel	• Provides remote status indication within the ships control room of each missile and provide the capability to grant or withdraw the capability to launch missiles.
8. Missile Tube Temperature Control	• Provides the capability to measure and control the missile tube temperature.
9. Missile Tube Dehumidification	• Provides the capability to measure the humidity, alarm, and dehumidify each missile tube's atmosphere.
10. Optical Reference	• Provides the capability to transfer position of the reference inertial platform (navigation) to each missile.

Table III-A-9 (Concluded)

SYSTEM (ELEMENT)	FUNCTION
11. Integrated ata Acquisition Subsystem (IDAS)	• Provides the capability to record pertinent subsystem data.
12. Fire Control System (MK-88)	• Provides the capability to determine fire control parameters, transmit data to each missile, and control the fire control sequence.
13. Missile Test and Readiness Equipment (MTRE)	• Prepares and checks out missile readiness conditions. Sequentially performs and monitors each missile under control of the fire control system.

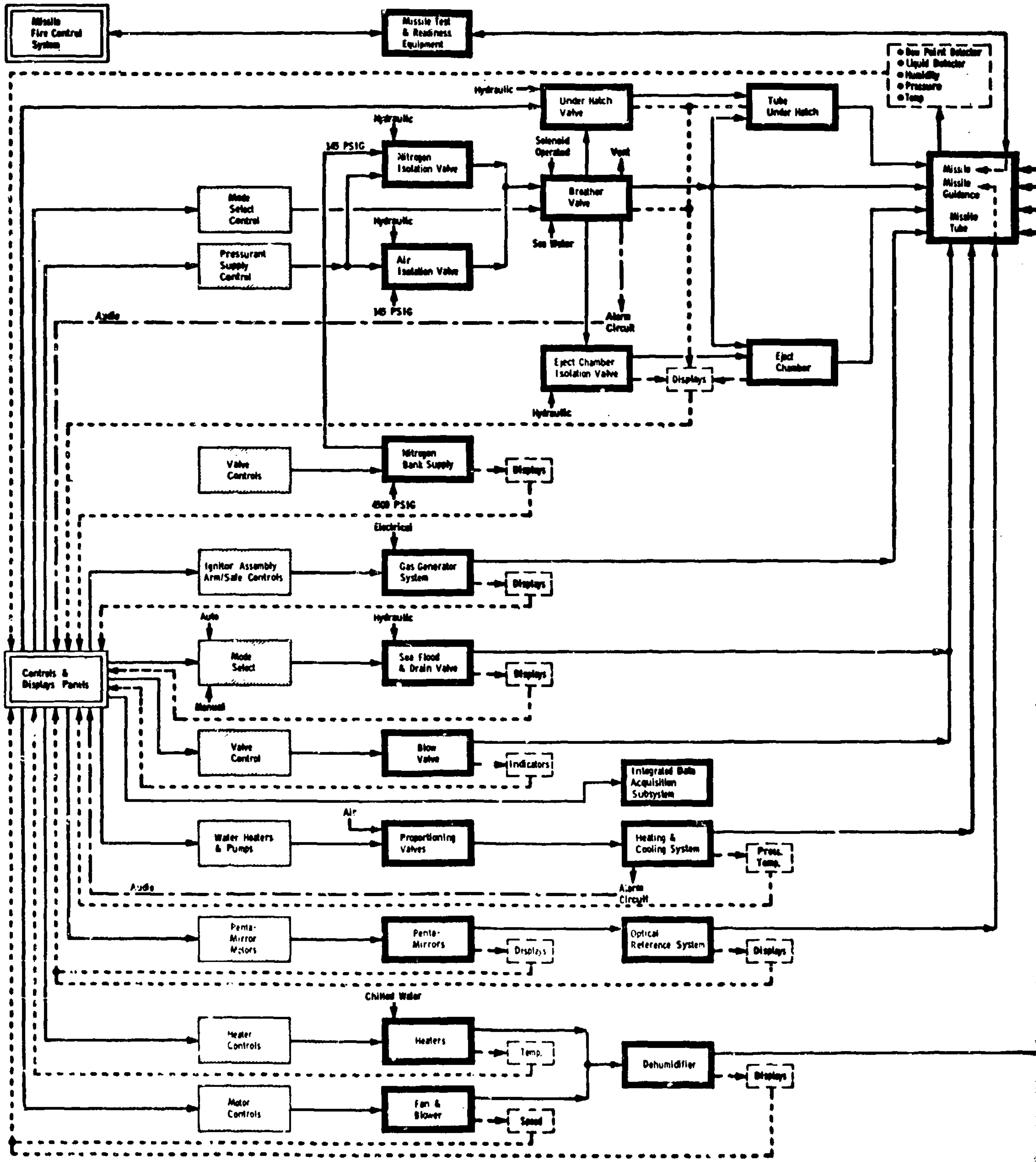


Figure III-A-16 Simplified F

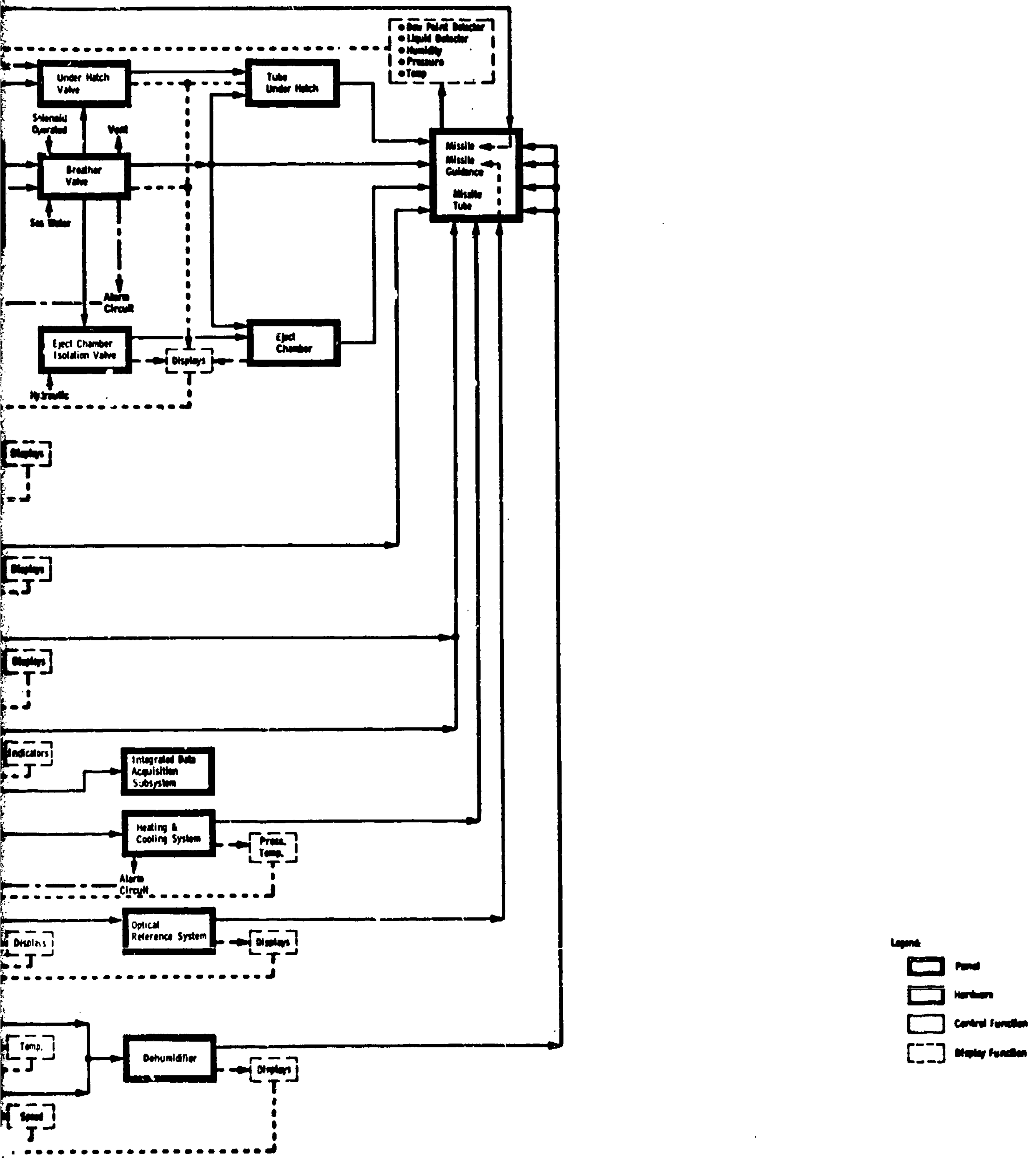


Figure III-A-16 Simplified Functional Diagram - Strategic Weapons Subsystem

2

Table III-A-10 System (Element) Functional Analysis Results - Habitability Subsystem

SYSTEM (ELEMENT)	FUNCTION
A. <u>Life Support</u>	
1. Ventilation	• Provides for the recirculation of air throughout the ship, emergency ventilation of any portion of the ship, introduction of exterior air into the confined ship's atmospnere, and an air supply to the diesel engine.
2. CO_2 Scrubbers	• Provide for removal and concentration control of carbon dioxide within the atmosphere.
3. O_2 Generators	• Provide for the production of oxygen to replenish that used while submerged.
4. CO/H_2 Burners	• Provide for removal and concentration control of carbon monoxide, hydrogen, and some hydrocarbons within the atmosphere.
5. O_2 System	• Provides storage banks and variable regulated distribution to the atmosphere.
6. Potable Water	• Provides the capability to store and distribute potable water.
7. Galley	• Provides the capability to prepare food and maintain the necessary dining utensils.
8. Laundry	• Provides the capability to wash and dry laundry on board ship.
9. Atmosphere Analyzer	• Provides the capability to sample the atmosphere of each compartment through a central console. Provision is provided to determine the concentration of those gases necessary for life support and those detrimental to life support that may be generated on board ship.

Table III-A-10 (Continued)

SYSTEM (ELEMENT)	FUNCTION
A. Life Support (Cont'd)	
10. Total Hydrocarbon Analyzer	• Provides a time-related total concentration of hydrocarbons as well as the concentration of some specific hydrocarbons. Results and concentrations can be compared in a time-related manner.
B. Waste Management	
1. Trash Disposal Unit	• Provides the capability to dispose of trash in a covert manner.
2. Plumbing - Sanitary Tanks	• Provide the capability to collect and dispose of liquid and semi-liquid waste.

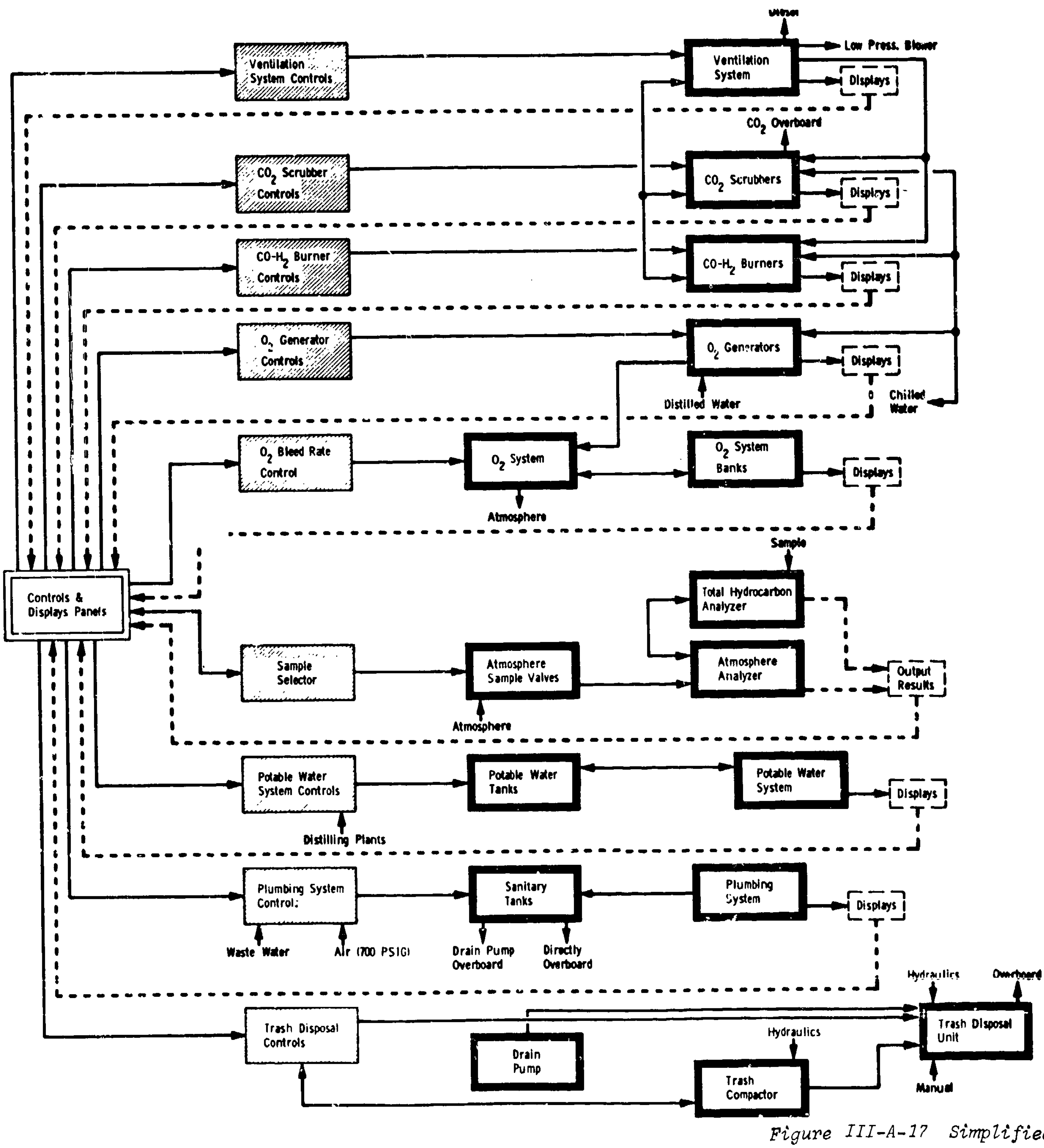


Figure III-A-17 Simplified

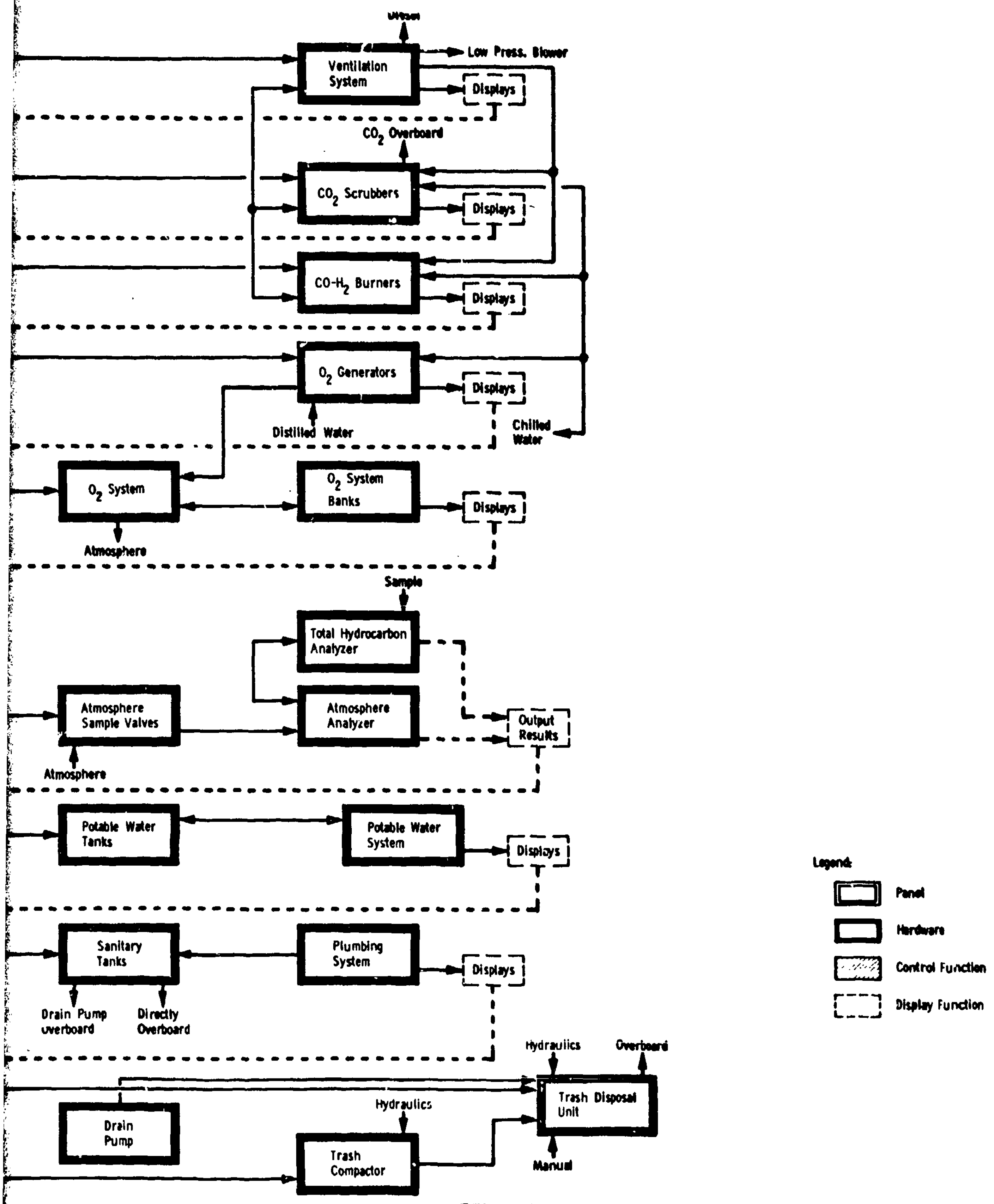


Figure III-A-17 Simplified Functional Diagram - Habitability Subsystem

2

Table III-A-11 System (Element) Functional Analysis Results – Casualty and Damage Control Subsystem

SYSTEM (ELEMENT)	FUNCTION
1. Water-tight Doors and Hatches	• Provide the means to isolate the ship's compartments with water-tight seal doors.
2. Escape Trunks	• Provide escape exits for emergency exit from the ship. Most of the escape trunks are also used for normal entrance and exit of equipment and crew.
3. Submersible Pumps	• Provide portable submersible pumps to supply a backup method of removing water from bilges.
4. Damage Control Tools	• Provide a set of hand tools (wrenches, screw drivers, cutters, etc), sealing devices (patching materials, metallic straps, etc) for emergency or casualty repairs.
5. Emergency Lighting	• Provides emergency lighting capabilities for permanently mounted and portable units.
6. Fire Extinguishers	• Provide portable fire fighting capability with CO_2 and chemical extinguishers to control fires within the capability of the extinguishers.
7. Fire Hoses	• Provide the capability to control large fires with sea water.
8. Steam Suits	• Provide heat retardant suits with the capability for connection to an external air supply for application with a steam leak casualty.
9. Salvage Air	• Provides the capabilities to pressurize the ship's compartments from internal air systems, and from outside sources.
10. Internal Communications	• Provide the capability for sound powered and amplified internal voice communications circuits.

Table III-A-11 (Concluded)

SYSTEM (ELEMENT)	FUNCTION
11. Emergency Air Breathing (EBA)	• Provides the manifold outlets to connect air breathing masks within the ship's compartments for emergency atmosphere control.
12. Oxygen Breathing Apparatus (OBA)	• Provides a portable breathing lung which utilizes a self-contained oxygen source (time-limited) for use within a contaminated atmosphere.
13. Lithium Hydroxide Canisters	• Provide a backup method to remove CO_2 from the ship's atmosphere.
14. Radiation Detection	• Provides the capability to measure air, surface, and water radiation levels.
15. Messenger Buoy	• Provides the capability to release a buoy if disabled in order to identify the ship location and aid in rescue activities.
16. Security Buoy	• Provides the capability to release (manual or automatic) a casualty buoy which will transmit a casualty message.

2. Crew Functions

The crew functions, operations, and activities required to operate the current baseline SSBN for nominal, non-nominal, and casualty evolutions are presented in this section. The data represent the results of an in-depth analysis of crew functions on current, operational SSBNs. The data were obtained from reviews of existing Naval manuals and regulations and interviews with active-duty and retired Navy submarine command personnel.

Specific emphasis in these analyses was directed to evaluations of: (1) specific crew member duties and responsibilities; (2) specific crew operations required to accomplish the SSBN mission functions and evolutions; and (3) the command structure on SSBNs including the underway and in-port watch structure and the administration structure. These data served as the basis for determining the impact of mechanization concepts on crew functions and procedures and on crew size discussed in Section III-B.6 of the report.

The data are presented in three categories:

a. SSBN Watch Organization - A discussion of watch stander requirements and responsibilities, specification of underway and in-port watch structures, and identification of personnel responsibilities and organizational relationships.

b. Administrative Structure - Identification of typical SSBN administrative structure.

c. Operational Analyses - Identification of nominal SSBN mission segments and relevant Bills, and specification of crew member command responsibilities, actions, and communication responsibilities for eight major ship control Bills.

a. The SSBN Watch Organization - The basic purposes and requirements for watches on naval vessels are set forth in U. S. Navy Regulations which state that watches are established for the *safety* and *proper operation of the command.*

The following instructions, paraphrased from General Duties of Watch Officer, U. S. Navy Regulations, set forth the general guides for standards to be met by all watchstanders. Specifically each person on watch:

- is responsible for the proper performance of all duties prescribed for his watch and all persons under him will be subject to his orders;

- remains responsible for his watch and at his station until properly relieved. He is required to instruct all persons on watch under him in the performance of their duties, and to ensure that they are at their stations, attentive, alert, and ready for duty. He will train himself and his subordinates to foresee situations which may arise and to take such timely and remedial action as may be required;

- is responsible for informing the appropriate persons of matters pertaining to his watch which they should know for the proper performance of their duties;

- makes all required inspections and any such additional ones as permitted and considered necessary to ensure that the duties of the watch are properly performed.

There are two primary areas of responsibility assigned to watchstanders--casualty action, and log-keeping and instrumentation.

In terms of casualty action, each watchstander is required to read and understand all casualty procedures pertinent to his watch station and to review these casualty procedures periodically as necessary to ensure complete familiarity. In the event of a casualty at his watch station, he takes active charge of casualty control until relieved by a senior, and all casualties and abnormal conditions are reported, through the watch organization, to the Officer of the Deck or the Duty Officer.

The importance of log keeping and instrumentation monitoring responsibilities has been emphasized from extensive experience with naval machinery/equipment. Therefore, watchstanders are required to carefully note the significance of log readings and trends. A review for trends at the time of recording hourly readings may indicate a system change which can be diagnosed and rectified before the situation deteriorates into a casualty. All such trends are reported immediately and investigated promptly.

Underway watches are never longer than six hours in length except for abnormal evolutions or casualty actions. The standard watch is four hours in length. In-port watches will normally be four hours in length but may be extended as necessary to meet special requirements (e.g., during overhaul or new construction).

Watch rotation requires the relieving watchstander to make a thorough and complete inspection of all spaces and equipments under his cognizance *before* relieving the on-duty watchstander. It is usual practice for the relief to examine all applicable equipment log readings on his watch station since he last had the watch, noting any variations from normal such as voltages, pressures, temperatures, etc. [He is specifically required to read the commentary sections (remarks) of applicable logs back to the last time he was on watch (or to the time of getting underway, plant startup, equipment lightoff, or for the preceding three watches if continuity of watches has been interruped) carefully noting and discussing unusual conditions, deviations from normal or other matters of importance.] Such variations should be discussed and any questions resolved prior to watch relief. Watch relief must also insure that the preceding watch has completed and signed the log sheets as required.

1) *Normal Underway Watch Requirements* - The SSBN crew is organized into three watch sections for underway cruising. Each section is capable of operating the ship both surfaced and submerged on all types of propulsion. The watch structure is shown in Table III-A-12.

Note: Only personnel currently qualified in accordance with the provisions of BUPERSINST 1540.40 are assigned to watch stations marked with an asterisk. Specific instructions regarding stationing these watches are presented in Engineering Department Organization Manual for Naval Nuclear Propulsion Plants.

Table III-A-12 Normal Underway Watches

WATCH	SUBMERGED	SURFACED	NORMALLY MANNED BY
Officer of the Deck	Periscope Station	Bridge	Officer
Diving Officer of the Watch	Control Center	---	Officer/CPO
Chief of the Watch	BCP	BCP	CPO/Senior PO
Quartermaster	Attack Center	Attack Center	QM
Navigation Center Supervisor	Navigation Center	Navigation Center	ET/QM
Navigation Watch	Navigation Center	Navigation Center	ET/QM
Navigation Equipment Technician	Navigation Center	Navigation Center	ET
Sonar Supervisor	Sonar Control Room	Sonar Control Room	ST
Radar/ECM	Attack Center	Attack Center	ET
Sonar Operator	Sonar Control Room	Sonar Control Room	ST
Radio Supervisor	Radio Room	Radio Room	RM
Radio Operator	Radio Room	Radio Room	RM
Helmsman	Helm/Fairwater Planes	Helm	SN/FN
Planesman	Stern Planes	Bridge Lookout	SN/FN
Lee Helmsman/Messenger	Control Center	Control Center	SN/FN
Torpedo Room Watch	Torpedo Room	Torpedo Room	TM
Missile Control Supervisor	Missile Control Center	Missile Control Center	FT/MT
MCC Assistant (when assigned)	Missile Control Center	Missile Control Center	MT/FT
LOS Watch	Missile Compartment	Missile Compartment	TM/MT
Assistant LOS Watch	Missile Compartment	Missile Compartment	MT/TM
Missile Compartment Roving Patrol	Missile Compartment	Missile Compartment	TM/MT/FTB
EOOW*	Maneuvering Room	Maneuvering Room	Officer
Engineering Watch Supervisor*	Engineering Spaces	Engineering Spaces	CPO/Senior PO
Throttleman*	Maneuvering Room	Maneuvering Room	EM/IC
Electrical Operator*	Maneuvering Room	Maneuvering Room	EM/IC

*Only personnel who have successfully completed nuclear power training shall be assigned to these watches.

Table III-A-12 (Concluded)

WATCH	SUBMERGED	SURFACED	NORMALLY MANNED BY
Reactor Operator*	Maneuvering Room	Maneuvering Room	ET
Auxiliary Electrician Forward	Control Room	Control Room	IC/EM
AMR #2 Upper Level*	AMR #2 UL/Tunnel	AMR #2 UL/Tunnel	ET/IC
Auxiliary Watch Forward	Control Room	Control Room	MM
Engine Room Supervisor*	Engine Room	Engine Room	MM
Engine Room Upper Level*	Engine Room UL	Engine Room UL	MM
Engine Room Lower Level*	Engine Room LL	Engine Room LL	MM
AMR #2 Lower Level Watch*	AMR #2 LL	AMR #2 LL	MM
Auxiliaryman Aft	Engineering Spaces	Engineering Spaces	MM
AMR #1	AMR #1	AMR #1	MM/EM/IC
Engineering Laboratory Technician*	Nucleonics Laboratory	Nucleonics Laboratory	MM
Auxiliary Electrician Aft*	Engineering Spaces	Engineering Spaces	EM/IC

*Only personnel who have successfully completed nuclear power training shall be assigned to these watches.

The underway watches identified below are normally stood on a part-time basis as assigned by the appropriate Department Head.

SPECIAL WATCHES (may have one or more men per watch)	STATION	NORMALLY MANNED BY
Ship's Cooks	Galley	MS
Messmen	Galley	SN/FN
Yeoman	Ship's Office	YN
Stewards	Pantry	MS
Hospital Corpsman	Sick Bay	HM
Storekeepers	Supply Office	SK

The specific responsibilities and organizational relationships of personnel assigned major responsibility for ship control functions are presented in Table III-A-13.

2) *Watch Organization In-port* - The in-port duty section is responsible for the security of the ship at anchor or moored. It shall be directed and supervised by a Duty Officer assisted by an Engineering Duty Officer and shall consist of sufficient personnel having the necessary qualifications to get the ship underway and perform all routine submarine evolutions. As a minimum, the in-port duty section shall be composed of the following:

- Duty Officer;
- Weapons Duty Officer (if tactical missiles are on board);
- Duty Chief Petty Officer;
- Engineering Duty Petty Officer qualified as Engineering Watch Supervisor;*
- Continuous Petty Officer of the Deck;
- Continuous Topside Sentry;
- Continuous Below Decks Watch;
- Continuous Shutdown Maneuvering Area Watch;*
- Continuous Propulsion Plant Shutdown Roving Watch;*
- Shutdown Electrical Operator (when assigned);*
- Continuous Weapons Watch (if missiles or ASTOR are on board);
- Other departmental watches as required.

The specific responsibilities and organizational relationships of in-port watch personnel are identified in Table III-A-14.

*Only personnel who have successfully completed nuclear power training shall be assigned to these watches.

Table III-A-13 SSBN Underway Watch Personnel Responsibilities

PERSONNEL	BASIC FUNCTION	ORGANIZATIONAL RELATIONSHIPS	DUTIES
Officer of the Deck (OOD)	The Officer of the Deck underway is that officer on watch who has been designated by the Commanding Officer to be in charge of the ship. He is primarily responsible, under the Commanding Officer, for the safe and proper operation of the ship, and for the safety and performance of personnel in the ship.	The Officer of the Deck reports directly to the Commanding Officer for the safe navigation and general operation of the ship and to the Executive Officer for carrying out the ship's routine.	Keep himself informed concernin affect the safe navigation of t grounding or collision in accor road, and the orders of the Com
			Keep himself informed concernin and the Commanding Officer, and operations.
			Keep himself aware of the statu ordered condition of readiness Officer and the Weapons Officer
			Keep himself informed of the st
			Keep himself informed of the st control equipment. The Command cal Officer shall be notified w
			Make all reports to the Command and by the Commanding Officer.
			Ensure that the Executive Offic changes in the tactical situati heavy weather, equipment out of a change in the ship's routine
			Keep the Navigator informed of changes in visibility, of sight buoys, discolored waters or der indications of set and drift an
			Ensure that the required report or other routines are made promp
			Issue necessary orders to the h an assigned position or to chan with orders of proper authority.
			Directly supervise all personnel exercise overall control of oth
			Keep and sign the Deck Log, su
			Upon being relieved, complete a report the results of this insp to the Commanding Officer.
			Prior to diving the ship, obtai In case ship must be submerged surface the ship if soundings i
			SPECIAL NOTE: Distinction betw Deck must be thoroughly aware o control of the movements of the the watch as outlined in U. S. Conn is also Officer of the Deck

	DUTIES, RESPONSIBILITIES, AND AUTHORITY
Deck the for and f	Keep himself informed concerning the tactical situation and geographical factors which may affect the safe navigation of the ship, and take appropriate action to avoid the danger of grounding or collision in accordance with tactical doctrine, the rules of the nautical road, and the orders of the Commanding Officer or other proper authority.
or ip's	Keep himself informed concerning current operation plans and orders, intentions of the OTC and the Commanding Officer, and such other matters that may pertain to ship or force operations.
	Keep himself aware of the status of the Torpedo and Missile batteries, ensuring that the ordered condition of readiness is maintained, and promptly reporting to the Commanding Officer and the Weapons Officer any changes in the condition of readiness.
	Keep himself informed of the status and current capabilities of the engineering plant.
	Keep himself informed of the status and condition of the ship's atmosphere and atmosphere control equipment. The Commanding Officer, Executive Officer, Engineer Officer and Medical Officer shall be notified whenever internal atmospheric conditions are abnormal.
	Make all reports to the Commanding Officer that are required by U. S. Navy Regulations, and by the Commanding Officer.
	Ensure that the Executive Officer and Department Heads concerned are kept informed of changes in the tactical situation, changes in operations schedules, the approach of heavy weather, equipment out of commission, or any other circumstances which would require a change in the ship's routine or other action on their part.
	Keep the Navigator informed of changes of course, speed and depth, notify Navigator of changes in visibility, of sighting of all land, shoals, rocks, lighthouses, beacons, buoys, discolored waters or derangements to steering system or navigational equipment, and indications of set and drift and unanticipated changes in fathometer readings.
	Ensure that the required reports to the Officer of the Deck concerning tests, inspections or other routines are made promptly and are properly organized.
	Issue necessary orders to the helm and Maneuvering Room to avoid danger, to take or keep an assigned position or to change the course, depth and speed of the ship in accordance with orders of proper authority.
	Directly supervise all personnel on search and ship control watches when submerged and exercise overall control of other watchstanders at all times.
	Keep and sign the Deck Log, supervising entries made by other personnel of his watch.
	Upon being relieved, complete and sign the Deck Log, inspect the ship forward of Frame 85, report the results of this inspection to the Officer of the Deck, and report his relief to the Commanding Officer.
	Prior to diving the ship, obtain verified sounding to assure adequate depth below the keel. In case ship must be submerged for emergency purposes prior to obtaining such sounding, surface the ship if soundings indicate insufficient depth.
	SPECIAL NOTE: Distinction between the Deck and the Conn. Underway, the Officer of the Deck must be thoroughly aware of the distinction between the conn, which is the actual control of the movements of the ship, and the deck, which is the supervisory authority of the watch as outlined in U. S. Navy Regulations and above. When the Officer who has the Conn is also Officer of the Deck, he has the responsibilities imposed by Navy Regulations

2

Table III-A-13 (Continued)

PERSONNEL	BASIC FUNCTION	ORGANIZATIONAL RELATIONSHIPS	DUTIES, RESPO
Officer of the Deck (OOD) (Continued)			as well as those additional ones impos A definite policy of taking over and r of the conn must be clearly understood by him and, most important, carefully b who manually perform the movement direc measure of responsibility for the ship when he is relieved of the conn by the The Commanding Officer, at his discret conn. In addition, he may direct the O conn; but he will rarely, if ever, rel engine order telegraph will, however, f for direction of the ship's movements- ensure efficient response and eliminate sidered proper for the OOD to announce as appropriate) has the conn", and imme the conn, "Sir, I have relinquished the
Diving Officer of the Watch (DOOW)	The Diving Officer of the Watch is that officer or senior petty officer (PO1 or above) on watch directly responsible to the Officer of the Deck for safe and proper submerged control of the ship. Officers and Senior Petty Officers will be designated by the Commanding Officer as qualified to act as Diving Officer of the Watch.	The Diving Officer of the Watch reports directly to the Officer of the Deck.	Keep informed of the navigational facto the ship. Keep informed of the status of all equi Adjust trim and compensation of the shi Direct the activities of the Chief of t and ship attitude during submerged mane the ship. Control routine pumping of all bilges w Make all required reports to the Office Inform the Ship's Diving Officer of tec his attention.
Chief of the Watch (COW)	The Chief of the Watch is the assistant to the Officer of the Deck (when surfaced) and to the Diving Officer of the Watch (when submerged).	The Chief of the Watch reports directly to the Officer of the Deck (when surfaced) and to the Diving Officer of the Watch (when submerged).	Stand his watch at the Ballast Control Initiate the execution of ordered dive Diving Officer of the Watch. Carry out the routine of the ship as sp Day, and orders of the Officer of the D In the absence of an officer on watch f of an emergency, ensuring that word is the Officer of the Deck fully informed emergency until an officer relieves him Ensure that fathometer readings are tak any dangerous situation is deemed to ex

as well as those additional ones imposed by directives of the Commanding Officer.

A definite policy of taking over and relinquishing the conn must be followed. The status of the conn must be clearly understood by the Officer of the Deck, verbally acknowledged by him and, most important, carefully brought to the attention of all personnel on watch who manually perform the movement directed by the Officer who has the Conn. A considerable measure of responsibility for the ship's safety remains with the Officer of the Deck even when he is relieved of the conn by the Commanding Officer or other duly qualified officer.

The Commanding Officer, at his discretion, will relieve the Officer of the Deck of the conn. In addition, he may direct the OOD how to proceed at any time without assuming the conn; but he will rarely, if ever, relieve the deck. Any direct order to the wheel or engine order telegraph will, however, itself constitute assumption of the responsibility for direction of the ship's movements--the conn. Under these conditions, in order to ensure efficient response and eliminate the possibility of conflicting orders, it is considered proper for the OOD to announce to the bridge watch, "The Captain (or other officer as appropriate) has the conn", and immediately thereafter report to the Officer who has the conn, "Sir, I have relinquished the conn."

Keep informed of the navigational factors involving safe and proper submerged control of the ship.

Keep informed of the status of all equipment which may affect submerged ship control.

Adjust trim and compensation of the ship for best submerged control.

Direct the activities of the Chief of the Watch and planesman in maintaining ordered depth and ship attitude during submerged maneuvering, and in conducting diving and surfacing of the ship.

Control routine pumping of all bilges with the drain system.

Make all required reports to the Officer of the Deck.

Inform the Ship's Diving Officer of technical, material and training matters which come to his attention.

Stand his watch at the Ballast Control Panel.

Initiate the execution of ordered dive and take charge of the dive until relieved by the Diving Officer of the Watch.

Carry out the routine of the ship as specified by Ship's Instructions, the Plan of the Day, and orders of the Officer of the Deck or the Diving Officer of the Watch.

In the absence of an officer on watch in the Control Center, initiate action in the event of an emergency, ensuring that word is passed and alarm sounded when appropriate. Keep the Officer of the Deck fully informed and supervise the execution of orders to combat the emergency until an officer relieves him of these duties.

Ensure that fathometer readings are taken, recorded, and reported when directed or when any dangerous situation is deemed to exist.

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Table III-A-13 (Concluded)

PERSONNEL	BASIC FUNCTION	ORGANIZATIONAL RELATIONSHIPS	DUTIES,
Engineering Officer of the Watch (EOOW)	The Engineering Officer of the Watch is that officer on watch certified by the Engineer Officer and Commanding Officer as qualified to be in charge of the propulsion plant, its associated auxiliaries and the atmosphere control equipment. He is primarily responsible for the safe and proper operation of such units and is responsible under the Officer of the Deck, for the safety and performance of all personnel assigned engineering watches and in engineering spaces.	The Engineering Officer of the Watch reports directly to the Officer of the Deck. The Engineer Officer may direct the Engineering Officer of the Watch concerning his duties and may assume the duties of the watch when in his judgment such action is necessary.	Ensure that all orders received f executed. He shall not permit th
			Report promptly to the Officer of probable derangement of machinery
			Ensure that alert watches are bei operated in accordance with instr ified personnel in accordance wit inspections and safety precaution
			Prior to relieving as Engineering situations, and make an inspectio
			Exercise the strictest control ov ance with current directives.
			Ensure that the Engineering Log, properly kept and that the Bell B viduals who have knowledge of the Engineering Officer of the Watch watch. He shall inspect the Engi thereof to the Officer of the Dec
			Control routine pumping of bilges 85 with the permission of the Div
Helmsman		The Helmsman is responsible to the Officer of the Deck in matters of ship control.	Steer the ship and operate the En Deck.
			Be particularly alert to detect a the equipments or indications and Chief of the Watch and Quartermas
			Take immediate action in accordan casualty.
Planesman		The Planesman reports directly to the Diving Officer of the Watch.	Operate his planes as directed by depth and/or angle ordered by the
			Be particularly alert to detect a of his equipments or indicators a Watch.
			Take immediate action in accordan
Lookout		The Lookout reports directly to the Officer of the Deck.	Maintain a continuous 360° sharp sounds and conditions to the Offi
			Report the status of the ship's r played.

	DUTIES, RESPONSIBILITIES, AND AUTHORITY
cer	Ensure that all orders received from the Officer of the Deck are promptly and properly executed. He shall not permit the shaft to be turned except as ordered.
cer i-	Report promptly to the Officer of the Deck and to the Engineer Officer any actual or probable derangement of machinery or auxiliaries.
s ut-	Ensure that alert watches are being maintained. He shall ensure that machinery is being operated in accordance with instructions, that machinery and controls are manned by qualified personnel in accordance with approved section watch bill, and that all applicable inspections and safety precautions are being carried out.
n	Prior to relieving as Engineering Officer of the Watch, inform himself to the tactical situations, and make an inspection of the engineering spaces.
	Exercise the strictest control over water chemistry and radiological controls, in accordance with current directives.
	Ensure that the Engineering Log, Engineer's Bell Book and prescribed operating records are properly kept and that the Bell Book and other operating records are signed by the individuals who have knowledge of the orders given and executed. On being relieved, the Engineering Officer of the Watch shall sign the Engineering Log and Bell Book for this watch. He shall inspect the Engineering Spaces aft of Frame 85 and report the results thereof to the Officer of the Deck.
	Control routine pumping of bilges with the auxiliary drain system for spaces aft of Frame 85 with the permission of the Diving Officer of the Watch.
on- of of	Steer the ship and operate the Engine Order Telegraph as ordered by the Officer of the Deck.
	Be particularly alert to detect any irregularities in the operation or function of any of the equipments or indications and immediately report such to the Officer of the Deck, Chief of the Watch and Quartermaster of the Watch.
	Take immediate action in accordance with casulty procedures in the event of steering casualty.
s ng .	Operate his planes as directed by the Diving Officer in order to attain and maintain the depth and/or angle ordered by the Diving Officer.
	Be particularly alert to detect any irregularities in the operation or function of any of his equipments or indicators and immediately report such to the Diving Officer of the Watch.
	Take immediate action in accordance with casualty procedures in the event of casualty.
cer	Maintain a continuous 360^0 sharp lookout, reporting all contacts, lights, unusual objects, sounds and conditions to the Officer of the Deck.
	Report the status of the ship's running lights each half hour when the lights are displayed.

Table III-A-14 SSBN In-Port Watch Personnel Responsibilities

PERSONNEL	BASIC FUNCTION	ORGANIZATIONAL RELATIONSHIPS	DUTIES, RES
Duty Officer	The Duty Officer is responsible for the security of the ship, for the conduct of the ship's routine and in the absence of the regularly responsible officer, for the supervision of all ship's activities.	The Duty Officer reports to the Commanding Officer in matters relating to the security, operation, and readiness of the ship and to the Executive Officer in administrative matters.	Conduct a complete inspection of the Ensure that the Engineering Duty Off receive reports from the Engineering Supervise preparations for getting u on getting underway. Ensure that the ship is safely moore or proceed to sea, safely navigated. Keep himself informed of the status ing the emergency procedures outline Coordinate ship's routine with major fueling. Personally supervise major evolution ous work unless specifically relieve
Engineering Duty Officer	The in-port Engineering Duty Officer is a commissioned officer qualified in nuclear power (graduate of the Naval Nuclear Propulsion Training Program).	The Engineering Duty Officer reports to the Duty Officer. He shall also report directly to the Commanding Officer whenever he believes such action to be desirable or necessary.	Direct and supervise engineering dep internal security of the ship and th frame 85. Approve the day's list of Engineering Officer. Exercise close supervision over all When propulsion plant conditions rec Supervisor remain continuously in th Maneuvering Room.) He shall dischar Watch delineated in this manual and Exercise the strictest control over istry in accordance with current di Conduct a complete inspection of the to the Duty Officer, at least once Ensure all tours are logged in the Ensure that Battery Charging Proced are adhered to. Verify charging "l battery charge. Keep the ship's Duty Officer inform his relief to the ship's Duty Offic
Weapons Duty Officer	Weapons Duty Officer shall be on board at all times whenever nuclear weapons and/or tactical Poseidon missiles are on board. The Weapons Duty Officer shall assist and be subordinate to the Ship's Duty Officer and	The Weapons Duty Officer reports to the Duty Officer. He shall also report directly to the Commanding Officer whenever he believes such action to be desirable or necessary.	Instructions herein amplify the pro The Weapon's Duty Officer shall: Assist the Duty Officer and direct section in ensuring the security of Exercise close supervision over all the missiles and launching subsyste Remain cognizant of all deviations ity to respond to casualties to the

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	DUTIES, RESPONSIBILITIES, AND AUTHORITY
e-	Conduct a complete inspection of the ship topside and below decks, forward of frame 85.
nding re- rity,	Ensure that the Engineering Duty Officer conducts similar inspections aft of frame 85 and receive reports from the Engineering Duty Officer upon completion of each inspection.
di- nd to	Supervise preparations for getting underway, and be prepared to assume the duties of OOD on getting underway.
c r mat-	Ensure that the ship is safely moored and, if necessary, to get underway to shift berths or proceed to sea, safely navigated. Know currently assigned dispersal area.
	Keep himself informed of the status of any nuclear weapons which may be on board, including the emergency procedures outlined in the Nuclear Accident Folder.
	Coordinate ship's routine with major engineering activities such as oxygen charging or fueling.
	Personally supervise major evolutions such as torpedo loading, diving operations or hazardous work unless specifically relieved by another officer.
ty the shall ly Of-	Direct and supervise engineering department members of the duty section in ensuring the internal security of the ship and the operation of Engineering Department equipment aft of frame 85. Approve the day's list of propulsion plant watchstanders in the absence of the Engineering Officer.
be-	Exercise close supervision over all operations which may affect the reactor plant.
to ces-	When propulsion plant conditions require, ensure that both he and the Engineering Watch Supervisor remain continuously in the Engineering spaces. (His normal station shall be the Maneuvering Room.) He shall discharge the responsibilities of Engineering Officer of the Watch delineated in this manual and in Engineering Department directives.
	Exercise the strictest control over radiological controls, water chemistry, and radiochemistry in accordance with current directives.
	Conduct a complete inspection of the Engineering spaces, reporting completion and results to the Duty Officer, at least once during each 4-hour watch period during his tour of duty. Ensure all tours are logged in the Engineering Log.
	Ensure that Battery Charging Procedures set forth in Engineering Department Instructions are adhered to. Verify charging "line-up" prior to requesting permission to start a battery charge.
	Keep the ship's Duty Officer informed on the status of the engineering plant and report his relief to the ship's Duty Officer.
ffi-	Instructions herein amplify the provisions of U. S. Navy Regulations and Force Regulations. The Weapon's Duty Officer shall:
shall ly to icer	Assist the Duty Officer and direct and supervise Weapons Department members of the duty section in ensuring the security of the ship.
es des-	Exercise close supervision over all operations which involve the security and safety of the missiles and launching subsystem and which involve the readiness of the Weapons System.
y.	Remain cognizant of all deviations from equipment/system lineups which involve the capability to respond to casualties to the missile subsystem or launch subsystem.

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Table III-A-14 (Continued)

PERSONNEL	BASIC FUNCTION	ORGANIZATIONAL RELATIONSHIPS	DUTIES
Weapons Duty Officer (Continued)	will be responsible to him for nuclear weapons safety, security and casualty control. If so qualified, the Ship's Duty Officer may also act as Weapons Duty Officer.		Remain cognizant of the status o on Weapons Systems equipment whe Keep the Ship's Duty Officer inf relief to the Ship's Duty Office
Duty Chief Petty Officer	The Duty Chief Petty Officer is an assistant to the Duty Officer and must be qualified to act as Chief of the Watch. He is responsible for directing and supervising the duty section to ensure: the safety and security of the ship; the efficient execution of the ship's routine and the Plan of the Day; the continuing readiness of ship for sea; the discipline of the crew; and the smart appearance of the ship and crew.	The Duty Chief Petty Officer reports to the Duty Officer.	Keep the watch alert, checking p
Engineering Duty Petty Officer	The in-port Engineering Duty Petty Officer is a senior petty officer qualified in nuclear power (graduate of the Naval Nuclear Power Propulsion Training Program).	The Engineering Duty Petty Officer reports directly to the Engineering Duty Officer. In his military function in the duty section, he is subordinate to and will assist the Duty Chief Petty Officer in the conduct of duties.	The Engineering Duty Petty Offic the petty officer in charge of t Be present in the engineering sp conditions affecting the safety lar times as may be ordered by t Make a complete inspection of th the Engineering Duty Officer at of duty, staggering the time of Officer. Ensure all tours are l
Below Decks Watch	The Below Decks Watch is a responsible petty officer qualified in FBM submarines and fully qualified to detect and correct conditions which may lead to damage to ship or	The Below Decks Watch reports through the Duty Chief Petty Officer to the Duty Officer.	Inspect the ship by continuou low decks checkoff lists. Durin enter all lower deck level space conditions if such entry is not battery well during a battery ch

	DUTIES, RESPONSIBILITIES, AND AUTHORITY
	Remain cognizant of the status of all repairs, maintenance and alterations being performed on Weapons Systems equipment whether by ship's force or by outside activities.
	Keep the Ship's Duty Officer informed of the status of the Weapons System and report his relief to the Ship's Duty Officer.
ty the	Keep the watch alert, checking performance by inspection.
ty rts gin- r. nc- ec-	The Engineering Duty Petty Officer is an assistant to the Engineering Duty Officer. He is the petty officer in charge of the engineering duty section, and as such he shall: Be present in the engineering spaces when the reactor is critical and whenever unusual conditions affecting the safety or operability of the plant exist, and at other particular times as may be ordered by the Engineering Duty Officer.
in- sist ty duct	Make a complete inspection of the engineering spaces, reporting completion and results to the Engineering Duty Officer at least once during each 4-hour watch period during his tour of duty, staggering the time of his inspection with those made by the Engineering Duty Officer. Ensure all tours are logged in the Engineering Log.
tch e ffi-	Inspect the ship by continuous patrol, making hourly notation of conditions in the below decks checkoff lists. During the course of his continuous patrol, the watch will enter all lower deck level spaces (battery well, bilges, storerooms, etc) to ascertain conditions if such entry is not contrary to current evolutions such as entry into the battery well during a battery charge. He shall be particularly alert to detect:

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Table III-A-14 (Concluded)

PERSONNEL	BASIC FUNCTION	ORGANIZATIONAL RELATIONSHIPS	DUTIES,
Below Decks Watch (Continued)	her equipment or jeopardize the safety of personnel. His primary function is to ensure the internal security of the ship forward of the Missile Compartment.		abnormal changes in conditions no water or escaping air, the improp or fuel; any casualties to person abnormal conditions during batter Give alarm in the event of disord Ensure that bilges are pumped whe become half full. Keep himself informed of the oper Inspect bilges from the lower fla Inspect torpedo security bands an ASTOR, visually examine the integ alertness of the torpedo room wat Check all ship's safes locked shu
Petty Officer of the Deck	The Petty Officer of the Deck is a qualified petty officer stationed on the main deck to ensure the external security of the ship. In addition he serves as a communications link between the ship and other activities and as the ship's official representative for all persons coming on board and departing from the ship.	The Petty Officer of the Deck is responsible through the Duty Chief Petty Officer, to the Duty Officer.	
Topside Sentry	The Topside Sentry is a qualified petty officer or nonrated enlisted man who assists the Petty Officer of the Deck in ensuring the external security of the ship.	The Topside Sentry reports to the Petty Officer of the Deck.	
Nuclear Weapons Security Area Armed Guard	To ensure the security of all nuclear weapons when stored below decks or when being loaded or offloaded.		

L S	DUTIES, RESPONSIBILITIES, AND AUTHORITY
	abnormal changes in conditions noted in hourly checkoff list entries; any sound of running water or escaping air, the improper operation of any machinery, or smells of smoke, gas, or fuel; any casualties to personnel or machinery; changes in depth gage and trim readings; abnormal conditions during battery charge.
	Give alarm in the event of disorder, fire or other emergency.
	Ensure that bilges are pumped when necessary and that sanitary tanks are blown when they become half full.
	Keep himself informed of the operating status of all machinery.
	Inspect bilges from the lower flats.
	Inspect torpedo security bands and torpedo tube locking devices on all tubes containing ASTOR, visually examine the integrity of the pneumatic alarm assemblies, and verify the alertness of the torpedo room watch at random intervals not to exceed one-half hour.
	Check all ship's safes locked shut at the commencement of liberty.
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ry re- ty ck.	

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Table III-A-15 SSBN Mission Segments, Crew Operations, and Relevant Bills

MISSION SEGMENT	MAJOR CREW OPERATIONS	
<u>Prepare to Go to Sea</u> (30-day time period)	May include dry docking (nominally every 18 months). Crew change (4 days) includes equipment maintenance during this time. Equipment maintenance, alignment, replacement. Support load out. May include an in-port operation/safety examination (nuclear weapons, administration, engineering, etc). Sea trial period (6 - 7 days) Check equipment operation, Train crew members. Final maintenance and supply load out (3 days).	Snorkel Bi Cold Weath Interior C Repel Boar Security f Ventilation Dry Docking Rescue and General Em Collision B Flooding Bi Toxic Gas B Fire Bill Missile Em Passive Def Reduced El Man Overboa Ship Destru Abandon Shi ASTOR Emerg
<u>Maneuvering Watch - Exit</u> (about a 2 hour time period)	Complete deployment checkoff list. Maneuvers away from tender or pier into channel or open water.	Maneuvering Propulsion Snorkel Bil Battle Bill Ventilation Cold Weathe Reduced Vis Rescue and Interior Co Repel Board Navigation All Emergen
<u>Surface Transit</u> (length of time is determined by time to travel to submergence point)	Normal underway watch except for: Contact Coordinator if sufficient contacts (ships) warrent (officer in Control Room) Radar Operator Navigator or Quartermaster Chief to assist QMOW in piloting problem Rig for dive (checklist) Enter compensation (trim)	Propulsion Snorkel Bil Rig for Div Battle Bill Ventilation Cold Weathe Reduced Vis Rescue and Interior Co Navigation All Emergen

rations, and Relevant Bills

PERATIONS	RELEVANT BILLS (* indicates mandatory)
y every 18 months). uipment maintenance during this replacement. safety examination (nuclear ing, etc). out (3 days).	Snorkel Bill* Cold Weather Bill Interior Communications Bill* Repel Boarders/Sneak Attack Bill Security from Unauthorized Visitors Bill* Ventilation Bill* Dry Docking Bill Rescue and Assistance Bill General Emergency Bill Collision Bill Flooding Bill Toxic Gas Bill Fire Bill Missile Emergency Bill Passive Defense Bill Reduced Electrical Power Bill* Man Overboard Bill Ship Destruction Bill Abandon Ship Bill ASTOR Emergency Bill
. into channel or open water.	Maneuvering Bill* Propulsion Bill* Snorkel Bill Battle Bill Ventilation Bill* Cold Weather Bill Reduced Visibility Bill Rescue and Assistance Bill Interior Communications Bill* Repel Boarders/Sneak Attack Bill Navigation and Piloting Bill* All Emergency Bills
nt contacts (ships) warrent to assist QMOW in piloting	Propulsion Bill* Snorkel Bill Rig for Dive Bill* Battle Bill Ventilation Bill* Cold Weather Bill Reduced Visibility Bill Rescue and Assistance Bill Interior Communications Bill* Navigation and Piloting Bill* All Emergency Bills

Table III-A-15 (Concluded)

MISSION SEGMENT	MAJOR CREW OPERATIONS	
<u>Submerge</u> (10 - 15 minutes)	Secure snorkeling. Secure ventilating. Submerge the ship. Obtain satisfactory trim.	Diving Propuls Ventila Cold We Interio All Eme
<u>Non-alert Transit</u> (1 to 3 days)	Crew training. Transit to patrol area assigned. Rig for patrol quiet. May include a scheduled security check (number of personnel involved would be less than Battle Station Torpedo but more than normal underway watch).	Propuls Snorkel Silent Depth C Battle Ventila Air Rev Cold We Interio
<u>Alert Period</u> (70 days minus transit time)	Maintain continuous communications coverage. Crew training. Required maintenance. Remain undetected, submerged, within assigned area. May include a scheduled security check.	Propuls Snorkel Silent Deep Su Depth C Battle Ventila Air Rev Cold We Interio Repel B Escape Towing Helicop All Eme
<u>Non-alert Return Transit</u> (1 to 3 days)	Crew training (if ORSE-Operation Reactor Safeguards Exam). Transit to port by assigned areas.	Same as
<u>Surface</u> (1 - 5 minutes)	Surface the ship. Shift to ventilating outboard.	Surfaci Propuls Ventila Cold We Interio
<u>Surface Transit Return</u> (time is variable)	Rig for surface. Same special watch requirements as egress transit. May include the at-sea transfer of an examination board, return to an assigned exercise area, and conducting an operational exam (2 days).	Same as
<u>Maneuvering Watch - Return</u> (1 to 2 hours)	Maneuver from channel alongside tender or pier.	Same as

PERATIONS	RELEVANT BILLS (* indicates mandatory)
	Diving Bill* Propulsion Bill* Ventilation Bill* Cold Weather Bill Interior Communications Bill* All Emergency Bills
check (number of personnel le Station Torpedo but more	Propulsion Bill* Snorkel Bill Silent Running Bill* Depth Charge Bill Battle Bill Ventilation Bill* Air Revitalization Bill Cold Weather Bill Interior Communications Bill*
ns coverage. thin assigned area. check.	Propulsion Bill* Snorkel Bill Silent Running Bill* Deep Submergence Bill Depth Charge Bill Battle Bill Ventilation Bill* Air Revitalization Bill* Cold Weather Bill Interior Communications Bill* Repel Boarders/Sneak Attack Bill Escape Bill Towing Bill Helicopter Transfer Bill All Emergency Bills
Reactor Safeguards Exam). .	Same as leaving port except REMOVE: Rig for Dive/Surface Bill
	Surfacing Bill* Propulsion Bill* Ventilation Bill* Cold Weather Bill Interior Communications Bill*
as egress transit. of an examination board, rea, and conducting an opera-	Same as Port Exit except ADD: Towing Bill
tender or pier.	Same as Maneuvering Watch (Exit) except ADD: Towing Bill

2

b. Administrative Structure - The administrative structure on the SSBN is distinct from the watch structure and serves a different purpose. The administrative structure consists of various administrative departments with an officer in charge of each and it serves the basic purposes of controlling personnel matters, preparation and submittal of various equipment and personnel reports, and maintenance of ship's equipment. The watch structure, by way of comparison, serves the basic purpose of operating the submarine as it performs its mission. The Administrative Structure for the baseline SSBN is shown in Figure III-A-18.

c. Operational Analyses - To facilitate an understanding of crew functions and operations, the nominal mission of the baseline SSBN was divided into 10 identifiable segments. These mission segments, their approximate time requirements, and the major crew operations and relevant Bills for each segment are identified in Table III-A-15. Table III-A-15 thus provides an overview of the major crew operations involved in a nominal SSBN mission.

The specific crew responsibilities and activities involved in operating the SSBN in nominal and casualty modes are outlined in the *Ship's Operating Procedures* (SOP). These operations are written in the form of Operational and Emergency Bills and their purpose is to provide guidance for the execution of crew functions. Table III-A-16 through Table III-A-23 were developed from an analysis of various Bills and interviews with submarine personnel to delineate the crew tasks and responsibilities for the major ship control functions of diving, surfacing, snorkeling, propulsion, ventilation, battle, and general emergency. Each table identifies the specific personnel involved in accomplishing a function (Bill), their command responsibilities, actions, and communication responsibilities. The numbers shown in parentheses for each action or communication task identify the relative sequence of tasks for each crew member.

ADMINISTRATIVE ORGANIZATION

COMMANDING OFFICER

EXECUTIVE OFFICER

DIVING OFFICER

COMMAND DEPARTMENTS

NAVIGATION

1. Navigation & Piloting.
2. Operation, Maintenance & Repair of Navigation and assigned Electronic Equipment.
3. Department Training.

OPERATIONS

1. Preparation of OpPlans.
2. Intelligence.
3. Communications.
4. Visual Search.
5. Electronic Search.
6. Electronic Countermeasures.
7. Issue and Control of CMS distributed publications.
8. Operational Evaluation.
9. Operation, Maintenance & Repair of assigned Electronic Equipment.
10. Photography.
11. Department Training.
12. Postal matters.

1. Operation, of Missile Fire Contr and associ Control sy munition, equipment above.
2. Deck Seama
3. Maintenanc hull.
4. Handling a and pyrote
5. Accountabi Nuclear We
6. Departmen

SUPPORT DEPARTMENTS

SUPPLY

1. Procurement, storage and issue of repair parts and consumable supplies.
2. Operation of the General Mess.
3. Admin. of Monetary Funds.
4. Department Training.

1.
2.
3.
4.
5.
6.

Figure III-A-18 SSBN Administrative Structure

ADMINISTRATIVE ORGANIZATION

COMMANDING OFFICER

EXECUTIVE OFFICER

EXECUTIVE STAFF

COMMAND DEPARTMENTS

TIONS

f OpPlans.

ıs.
ı.
ıarch.
ıuntermeasures.
ıtrol of CMS dis-
ications.
:valuation.
ıintenance & Repair
:lectronic Equipment.

'aining.
's.

WEAPONS

1. Operation, Maintenance & Repair of Missile, Launcher & Missile Fire Control systems, Torpedoes and associated launch & Fire Control systems, small arms & ammunition, and of Electronic & test equipment associated with the above.
2. Deck Seamanship.
3. Maintenance of ship's exterior hull.
4. Handling and stowage of explosives and pyrotechnics.
5. Accountability & custody of Nuclear Weapons.
6. Department Training.

ENGINEERING

1. Operation, Maintenance & Repair of propulsion, reactor and electrical installations, Auxiliary and Atmosphere Control Equipment.
2. Damage Control.
3. Repair of Hull.
4. Maintenance & Repair of Underwater Fittings.
5. Propulsion Plant Water Chemistry & Radiochemistry.
6. Accountability and control of radioactive material.
7. Department Training.
8. Radiological controls.
9. Passive defense.
10. Radiac equipment.

SUPPORT DEPARTMENTS

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MEDICAL

1. Treatment of Sick & Wounded.
2. Health, Sanitation & Hygiene.
3. Atmosphere Analysis.
4. Personnel Dosimetry & medical aspects of radioactivity.
5. First Aid & Safety Instruction.
6. Department Training.

ıture

2

a) The rig for dive shall be broken only with the permission of the Commanding Officer, and he shall be informed when the rig for dive has been restored. When corrected, authorized departures from the rig for dive will be checked by an officer and reported checked to the Chief of the Watch who will in turn report to the OOD, the Diving Officer and the Commanding Officer.

b) When underway, men will not be permitted on the brid permission. The number of men on the bridge will be kept Personnel going to the bridge will obtain permission from th Chief of the Watch before proceeding to the bridge. They sh from the OOD before laying below and shall advise the Chief reaching Control. Personnel will not be permitted on top of superstructure or on the main deck when underway, withou Officer's permission.

Table III-A-16 Rig for Dive/Surface Bill

Personnel	Command Responsibilities / General Information	Actions (C&D Operations, Inspe
OOD		
Diving Officer	1. Ensure that a current Rig for Dive status sheet is properly completed and filed together with a list of rig for dive discrepancies in the Diving Book. 2. Designated qualified officers to carry out the provisions of this bill on a compartment or compartment level by level basis. 3. Calculate the compensation and cause the compensation to be entered as part of the Rig for Dive procedure. The completed compensation worksheet signed by the Diving Officer will be filed in the Diving Book. 4. Ensure action is being taken to expeditiously correct all Rig for Dive discrepancies. 5. Report to the Commanding Officer and Officer of the Deck when the ship has been Rigged for Dive and compensated - or Rigged for Surface. All discrepancies will be reported at this time. 6. Maintain comaprtment Rig for Dive and Rig for Surface check off lists complete and properly posted.	
Senior Petty Officer On Watch In Each Compartment	1. Be responsible for the expeditious, correct rig for dive in each compartment ensuring that designated petty officers personally rig each item against the posted compartment Rig for Dive Check off List.	Qualified petty officers, as designated by the seni each compartment or compartment level (if in port a Duty Officer) will carry out the provisions of the rig in each compartment or compartment level. The chec Never trust your memory. An individual level will n petty officer actually performing the rigging of the co report completion to the COW (and the EOOW if the c engineering spaces) along with any discr...ncies. In the Rig for Dive Status Sheet.
Designated Officers		Officers designated by the Diving Officer will per compartment against the check-off list. Each compart checked by one officer. The check-off list will be ca checked.
COW	1. Receive reports of rig for dive (surface) and officer's check of Rig for Dive. 2. Be responsible for maintaining an accurate status of Rig for Dive (surface) on the Control Room Rig for Dive Status Board. 3. Maintain the Rig for Dive (surface) status sheet and an up-to-date discrepancy list. 4. Report to the Diving Officer when the ship has been rigged for dive, checked, and compensated, including all discrepancies.	The Chief of the Watch will order the following receiving permission of the OOD. 1. Test operation of the fairwater and stern planes 2. Test blow main ballast tanks (normal); test emer in accordance with COMSUBLANTINST 05100.7. 3. Secure air to the whistle. 4. Test bridge access hatch. First shut the outboa 5. Enter the compensation. 6. Raise and lower masts.
Duty Chief Petty Officer	In Port	Immediately after setting the In-Port Watch, th company with the Below Decks Watch, shall inspect t each compartment and report the results of the inspe An Auxiliaryman will install the Main Ballast Ta to the Duty Officer when the vent covers have been i post the 'Main Ballast Tank VENT COVERS INSTALLED

GENERAL INFORMATION

, men will not be permitted on the bridge without the OOD's
mber of men on the bridge will be kept to a minimum.
he bridge will obtain permission from the OOD through the
fore proceeding to the bridge. They shall obtain permission
laying below and shall advise the Chief of the Watch upon ·
Personnel will not be permitted on top of the sail, within the
the main deck when underway, without the Commanding

Actions (C&D Operations, Inspections, Recordings, Etc.)	Communication Responsibilities
	When ordered by the Commanding Officer, the Officer of the Deck will have the Chief of the Watch pass the word on the 1MC, 'RIG SHIP FOR DIVE (SURFACE)'. 'RIG SHIP FOR DIVE (SURFACE)'.
	When the ship has been rigged for dive, checked, and compensated (or rigged for surface), the ship's Diving Officer will report to the Commanding Officer and OOD, 'THE SHIP IS RIGGED FOR DIVE (SURFACE)' enumerating any exceptions.
petty officers, as designated by the senior petty officer of the watch in ent or compartment level (if in port a qualified petty officer designated by the ill carry out the provisions of the rig for dive (surface) check-off list posted tment or compartment level. The check-off list must always be used. r memory. An individual level will not be split between petty officers. The ually performing the rigging of the compartment or compartment level will n to the COW (and the EOOW if the compartment rigged is in the aces) along with any discrepancies. In addition, he will personally sign Status Sheet.	2. Report directly to the Chief of the Watch when the rig for dive is completed, enumerating all exceptions.
signated by the Diving Officer will personally check each item in the ainst the check-off list. Each compartment or compartment level will be officer. The check-off list will be carried in hand as each item is	1. Report directly to the Chief of the Watch when he has checked the Rig for Dive. List each exception and sign the Rig for Dive status sheet.
of the Watch will order the following steps to be performed only after ission of the OOD. tion of the fairwater and stern planes in all modes of operation. main ballast tanks (normal); test emergency main ballast tank blow system with COMSUBLANTINST 05100.7. r to the whistle. access hatch. First shut the outboard induction valve if OPEN. compensation. lower masts.	
y after setting the In-Port Watch, the Duty Chief Petty Officer, in he Below Decks Watch, shall inspect the rig for surface conditions in ent and report the results of the inspection to the Duty Office. ryman will install the Main Ballast Tank vent covers. He shall report icer when the vent covers have been installed. In addition, he shall Ballast Tank VENT COVERS INSTALLED' warning sign on the BCP.	

2

a) The diving evolution will be performed on a section basis and will normally be a deliberate dive from a 'straight board' condition. Just prior to the dive, the Commanding Officer or an officer authorized by him will relieve the Officer of the Deck, receiving all information specified in U. S. Navy Regulations and indicate relief by stating (from the periscope stand) 'I relieve you as Officer of the Deck'. When directed to lay below, the just relieved Officer of the Deck will rig the bridge for dive, ensure all hands are below, proceed to the bridge access trunk and with the aid of the lookout shut and dog the upper hatch. On arriving in Control, he will report to the Officer of the Deck, 'Last man down, hatch secured.' He will become the Diving Officer of the Watch unless another DOOW has been assigned. The Officer of the Deck, having received the 'straight board' report from the Chief of the watch, will order the Diving Officer to sound the diving alarm.

b) The signal to dive the ship will be two b word, 'DIVE, DIVE' paralleled on the 1MC. Th opened on the second blast of the alarm; if the action will be taken on the second 'Dive'.

c) In those cases where a quick dive is em emergency or as an (unscheduled) evolution, th dive by ordering, 'CLEAR THE BRIDGE, CLEAR TH 'DIVE, DIVE' on the 1MC. The bridge watch wi proximity to the hatch except that the Officer of to secure the upper hatch with the Assistance o On arriving in Comtrol, the Officer of the Deck Officer of the Watch, submerge the ship to 120 order all masts/antennas/periscopes lowered. He as Officer of the Deck as expeditiously as possib

Table III-A-17 Diving Bill

Personnel	Command Responsibilities / General Information	Actions (C&D Operatio
OOD	1. Be cognizant of the state of the ship's 'Rig for Dive'. Once so rigged, he shall not permit it to be broken without the specific permission of the Commanding Officer. 2. Keep himself aware of the depth of water and know the number and status of all personnel topside. 3. Except in an emergency, ensure that the bridge and bridge equipment are secured for dive.	1. Secure the upper bridge hatch wi that it is seated and dogged completely.
DOOW		2. Proceed to ordered depth smartly a has been ordered, proceed to 120 feet, dep necessary down angle to acquire the ordere 3. When at the ordered depth and wit '______ FEET, TRIM SATISFACTORY'. U assume speed control by giving a speed ord control remains with the OOD. 4. When all compartments have report phones secured.
COW	In an emergency, when the OOD is incapacitated, the COW will act as DOOW.	1. When ordered, or on the second b Shut outboard ventilation exhaust an Press 'Snorkel Shutdown' pushdown Secure the low pressure blower. Turn headvalve control switch to clos Place two hydraulic pumps in RUN. trim satisfactory. 3. On second blast of diving alarm: Open all main vents and report, 'All Lower all masts unless otherwise dire the DOOW. At 50 feet shut all vents and report When at ordered depth and with perm cycle the main vents, one group at a time ventilation systems are lined up properly Pump or flood variable tanks as order When a satisfactory trim is obtained, 4. In a quick dive, the COW will ope diving alarm and act as DOOW until reliev obtained by the time the ship reaches 45 f the vents and preparing to blow main ball
Lee Helmsman		1. Take control of the stern planes d the planes in normal power. 3. Observe proper functioning of all attention to normal and emergency plane 4. Proceed with ordered angle to ord

GENERAL INFORMATION

a dive the ship will be two blasts on the diving alarm with the paralleled on the 1MC. The main ballast tank vents will be nd blast of the alarm; if the diving alarm does not sound, this on the second 'Dive'.

ses where a quick dive is executed from the bridge either in an (unscheduled) evolution, the Officer of the Deck will initiate the LEAR THE BRIDGE, CLEAR THE BRIDGE, and passing the word, 1MC. The bridge watch will clear the bridge in order of their th except that the Officer of the Deck shall be the last in order hatch with the Assistance of the next to the last man down. trol, the Officer of the Deck will become additionally the Diving , submerge the ship to 120 feet, depth of water permitting, and nnas/periscopes lowered. He will be relieved of the Conn and k as expeditiously as possible dependent on the circumstances.

d) Ship's hydraulic power can be lost because of either an electrical power failure or a malfunction of the hydraulic plant. Except in the case of major damage to the ship, hydraulic accumulators will remain sufficiently charged after loss of hydraulic power for the ship to execute a normal dive or surfacing. When hydraulic power is lost and hydraulic accumulators are bled down, however, members of the on-watch section shall perform additional duties as prescribed herein in order to dive the ship by hand.

Actions (C&D Operations, Inspections, Recordings, Etc.)	Communication Responsibilities
e the upper bridge hatch with the aid of the lookout, making certain d and dogged completely.	
d to ordered depth smartly and obtain 1/3 speed trim. If no depth red, proceed to 120 feet, depth of water permitting. Use the n angle to acquire the ordered depth smartly. at the ordered depth and with a satisfactory 1/3 speed trim report T, TRIM SATISFACTORY'. (At any time prior to this, the OOD may control by giving a speed order to the helm). After this, speed s with the OOD. ll compartments have reported 'CONDITIONS NORMAL', order JA d.	1. When a straight board is obtained, and the OOD so orders, order the COW to pass the word, 'DIVE, DIVE' on the 1MC, and sound two blasts on the diving alarm.
ordered, or on the second blast of the diving alarm: board ventilation exhaust and outboard induction valves. ortel Shutdown' pushdown if diesel is running. he low pressure blower. valve control switch to close. hydraulic pumps in RUN. Place Main pump back in STBY when y. ond blast of diving alarm: main vents and report, 'All Vents OPEN'. masts unless otherwise directed. Report 'All Masts Down', to shut all vents and report same to the DOOW. ordered depth and with permission of the Diving Officer of the Watch, vents, one group at a time. Ensure that the ship's snorkel and ems are lined up properly in the recirculate mode. flood variable tanks as ordered. atisfactory trim is obtained, make diving record entries. uick dive, the COW will open the vents on the second blast of the nd act as DOOW until relieved by the OOD. If a straight board is not time the ship reaches 45 feet, initiate action to surface by shutting preparing to blow main ballast tanks.	Pass the word on the 1MC 'DIVE, DIVE'. 2. Report to the OOD when straight board is obtained, or report discrepancies.
ontrol of the stern planes at the outboard control station and test normal power. e proper functioning of all instrumentation, paying particular rmal and emergency plane indication and depth indication. d with ordered angle to ordered depth as directed by the DOOW.	2. Report to the DOOW, 'STERN PLANES TESTED SATISFACTORILY', or report discrepancies.

Table III-A-17 (Concluded)

Personnel	Command Responsibilities / General Information	Acti~ (C&D Operations, Insp~tion
Lookout		1. Assist in rigging ~ idge for dive and in dogging 2. Proceed to the low ~ vel of the Operations Compa showers, heads, and crew's berthing area for flooding or o making inspection, man JA phones in crew's berthing area. 3. Secure the phones when so ordered by Control and to assume the Lee Helmsman Watch.
Helmsman		1. Retain his normal station at the inboard control s control of fairwater (FW) planes. 2. On the second blast of the diving alarm, ring up A rudder amidships; shift FW planes to normal power in two planes and then place on full dive. Report to the DOOW, ' TESTED SATISFACTORILY'. 3. Observe proper functioning of all instrumentation, attention to normal and emergency plane indication and de 4. Control FW planes to reach and maintain ordered d DOOW. When at ordered depth steer the previously ordere
Navigation Center Supervisor		1. Secure the low pressure blower. 2. Shut the inboard induction and inboard ventilation outboard induction valves when they indicate shut. Check low pressure blow stops. Line up ventilation to recirculat 3. Check shut the head valve operation air hull and t
Auxiliaryman of Watch Forward		1. Proceed to the vicinity of the BCP to be available t Diving Officer of the Watch or Chief of the Watch. 2. Be prepared to assist the Navigation Center Superv absence, carry out the provisions of his duties.
Quarter-Master Watch		1. Assist in rigging the bridge for dive as directed by 2. Standby the lower hatch, and when the last man Center, shut and dog the lower hatch, reporting it secure 3. Secure the searchlight and running light circuits reaches 45 feet, secure the IC circuits to the bridge if n Auxiliary Electrician Forward.
Auxiliary Electrician Forward		1. Remove the IC suitcase from the bridge when ord 2. Proceed to the Control Center upon the first blast 3. Secure all IC circuits to the bridge when the OO
Radar/ECM Watch		1. When ordered or on the second blast of the diving 3. Shift the Radar and/or ECM to the Standby mode
Radioman of Watch		1. On the first blast of the diving alarm, cease tran
Diesel Generator Watch		1. On the second blast of the diving alarm, secure running, shut the outboard engine exhaust valve, and r 2JV when the inboard engine exhaust valve is shut and exhaust valve is shut and locked. 2. Rig diesel engine and associated systems for norm in accordance with Engineering Department Operating Pr
Upper Level AMR Watch #2		1. Shut the inboard engine exhaust valve, lock the valve, report completion to the Diesel Generator Watch. 2. Assist Diesel Generator Watch as practicable. 3. Line up ventilation system in AMR #2 to recircul
Aux. Electrician Aft		1. On the first blast of the diving alarm, proceed to tunnel and man the 2JV phones. 2. Observe the Reactor Compartment through the vi report any abnormal conditions to Maneuvering.
Steward of Watch		1. Check the pantry, wardroom, officer staterooms, flooding or other abnormal conditions.
Each Compartment Watch		1. On the second blast of the diving alarm, comme for flooding or other abnormal conditions. 2. In case of flooding, shut bulkhead flappers and Control by fastest means and rig compartment for collis

Actions (C&D Operations, Inspections, Recordings, Etc.)	Communication Responsibilities
ging the bridge for dive and in dogging the bridge hatch. the lower level of the Operations Compartment and inspect the crew's crew's berthing area for flooding or other abnormal conditions. After man JA phones in crew's berthing area. phones when so ordered by Control and proceed to the Control Room elmsman Watch.	
normal station at the inboard control station and prepare to take (FW) planes. nd blast of the diving alarm, ring up Ahead 2/3 speed and put hift FW planes to normal power in two station control. Test e on full dive. Report to the DOOW, 'FAIRWATER PLANES RILY'. per functioning of all instrumentation, paying particular and emergency plane indication and depth indication. planes to reach and maintain ordered depth as directed by the ered depth steer the previously ordered course.	
w pressure blower. board induction and inboard ventilation exhaust and the lves when they indicate shut. Check shut the ballast tank ps. Line up ventilation to recirculate. the head valve operation air hull and backup valves (4).	4. When the above actions have been accomplished, report to the Chief of the Watch, 'OUTBOARD INDUCTION AND EXHAUST SHUT AND LOCKED, INBOARD INDUCTION AND EXHAUST SHUT, RECIRCULATING'.
e vicinity of the BCP to be available for orders from the Watch or Chief of the Watch. to assist the Navigation Center Supervisor, and in his he provisions of his duties.	
ging the bridge for dive as directed by the Officer of the Deck. lower hatch, and when the last man has entered the Control the lower hatch, reporting it secured to the OOD. searchlight and running light circuits. Before the ship ure the IC circuits to the bridge if not already secured by the Forward.	
IC suitcase from the bridge when ordered. e Control Center upon the first blast of the diving alarm. C circuits to the bridge when the OOD reaches the Control Center.	4. Man JA phones in Control. When at ordered depth, order compartments to 'Report conditions on the dive'.
d or on the second blast of the diving alarm, train radar mast for lowering. dar and/or ECM to the Standby mode unless otherwise ordered.	2. Report ' Radar mast ready for lowering' to the COW.
blast of the diving alarm, cease transmitting.	
nd blast of the diving alarm, secure the diesel engine, if utboard engine exhaust valve, and report to maneuvering on d engine exhaust valve is shut and the outboard engine exhaus t and locked. gine and associated systems for normal submerged running Engineering Department Operating Procedures.	
oard engine exhaust valve, lock the outboard engine exhaust ion to the Diesel Generator Watch. Generator Watch as practicable. ilation system in AMR #2 to recirculate.	
blast of the diving alarm, proceed to the Reactor Compartment 2JV phones. Reactor Compartment through the viewing windows and conditions to Maneuvering.	
ntry, wardroom, officer staterooms, showers and head for ormal conditions.	2. Report the conditions of the above spaces to the duty cook or messman.
nd blast of the diving alarm, commence checking compartment abnormal conditions. ooding, shut bulkhead flappers and watertight doors, notify s and rig compartment for collision.	3. Report abnormal conditions existing in the compartment to Control immediately. 4. The phones will be manned as soon as possible after each station gas determined that conditions are normal on the dive. If conditions are normal report in order only when directed by Control.

a) The signal to surface the ship will normally be the word 'SURFACE, SURFACE, SURFACE' on the 1MC. To initiate emergency surfacing procedures, three blasts on the diving alarm will be sounded. Either signal is sufficient to surface the ship.

b) Assignment of control of the stern planes to the outboard cont[...] control of the helm and FW planes to the inboard control station wi[...] accomplished prior to surfacing.

Table III-A-18 Surfacing Bill

Personnel	Command Responsibility / General Information	Actions (C&D Operations, Inspections, Recor[...]
OOD	Prepare to Surface	
COW		1. Check all vents SHUT. 2. Ensure proper lineup of hydraulic pumps. 3. Position the Head Valve Electrode selector switch on th[...] Head Valve control switch to AUTO. 4. Test the mast flooded indicator to assure satisfactory o[...]
Auxiliaryman of Watch Forward		1. Position TD-54 (Induction Mast Flood and Drain Valve) [...] valves, TD-55 in turn. Drain the induction mast. When [...] drain valves.
Navigation Center Supervisor		1. Check MBT low pressure blow system lines and ventila[...] drain valves. 2. Unlock outboard induction and outboard ventilation [...] 'POWER' position. 3. Open head valve air supply valves (4).
Quartermaster of Watch		1. Request permission from the Officer of the Deck to en[...] between sunset and sunrise unless at darkened ship. Be [...] light and Submarine Identification light. 2. Check bridge access trunk drain free of water and, a[...] periscope depth, request permission from Officer of the De[...] access trunk hatch.
Auxiliary Electrician Forward		1. Line up appropriated IC circuits.
Lee Helmsman		1. Prepare to act as lookout, attired in proper clothing a[...] 2. Have the IC suitcase ready to take to the bridge.
DOW		
OOD		1. Order, 'DIVING OFFICER, SURFACE THE SHIP,' to th[...] 2. Order speed changes as necessary. 3. When the ship is on the surface and holding, as ob[...] periscope, order the inboard and outboard induction valves [...] is equalized, order 'START THE BLOWER ON ALL MAIN BA[...] 4. Order, 'CRACK THE HATCH'. If there is no evidence [...] pressure vacuum appears equalized with outside atmospher[...] 5. When report is received that the hatch is open and [...] 'QUARTERMASTER TO THE BRIDGE' and 'RELIEVING OFFIC[...] BRIDGE'.
DOW		2. Order, 'BLOW THE FORWARD GROUP,' and as the sh[...] angle, 'BLOW THE AFTER GROUP'. 3. Control planesman and helmsman as necessary to a[...] initial up angle. 4. When the ship is on the surface and holding, order [...] 6. Turn the Control Center Watch over to the Chief of [...] 7. If the diving officer is to assume the Deck, procee[...] hatch is opened. If another officer is to assume the Deck, remain in [...] capacity. When the ship is operating on the surface, w[...] OOD, the supervisory watch may be secured. 8. Order the lookout(s) to the bridge, establish commu[...] 9. When conditions permit, order planes placed in no[...] condition. 10. When reliable communications have been establish[...] 'I AM READY TO RELIEVE YOU AS OFFICER OF THE DEC[...]

GENERAL INFORMATION

if the stern planes to the outboard control station and planes to the inboard control station will normally be ing.

c. If the DOOW is not a qualified Officer of the Deck (surfaced), a qualified officer will be present in Control and be prepared to proceed to the bridge and then relieve the Officer of the Deck upon receiving all the information specified in the U. S. Navy Regulations and indicate relief by stating, 'I RELIEVE YOU AS OFFICER OF THE DECK'.

ns (C&D Operations, Inspections, Recordings, Etc.)	Communication Responsibilities
	1. The Officer of the Deck shall have the word passed over the 1MC, 'PREPARE TO SURFACE, PREPARE TO SURFACE'.
SHUT. lineup of hydraulic pumps. ad Valve Electrode selector switch on the BCP to BOTH and the witch to AUTO. nded indicator to assure satisfactory operation.	5. Receive reports from the Auxiliaryman Forward and the Navigation Center Supervisor that they are ready to surface. 6. Report, 'READY TO SURFACE' to Diving Officer of the Watch when all required reports have been received.
(Induction Mast Flood and Drain Valve) to DRAIN and open drain n. Drain the induction mast. When mast is dry shut the	2. Report to the Chief of the Watch, 'XILIARYMAN FORWARD READY TO SURFACE'. Stand by in COC for additional orders.
pressure blow system lines and ventilation exhaust mast dry. SHUT d induction and outboard ventilation exhaust valves, check in the e air supply valves (4).	4. Report to the Chief of the Watch, 'VENTILATION EXHAUST MAST DRY, OUTBOARD INDUCTION AND EXHAUST VALVES IN POWER, READY TO SURFACE'.
sion from the Officer of the Deck to energize running lights if sunrise unless at darkened ship. Be prepared to rig masthead identification light. cess trunk drain free of water and, after ship has reached uest permission from Officer of the Deck to open lower bridge	3. Report, 'LOWER HATCH IS OPEN' to the Officer of the Deck and proceed up into the bridge access trunk.
riated IC circuits.	2. Man JA phones to receive reports and relay to the Chief of the Watch.
as lookout, attired in proper clothing and equipped with binoculars. case ready to take to the bridge.	3. Stand by the bridge access trunk ladder to relay words to personnel in the trunk.
	1. When ready, report to the Officer of the Deck, '______ INCHES PRESSURE / VACUUM IN THE SHIP, READY TO SURFACE.'
OFFICER, SURFACE THE SHIP,' to the Diving Officer of the Watch. nges as necessary. is on the surface and holding, as observed through the inboard and outboard induction valves opened. When pressure START THE BLOWER ON ALL MAIN BALLAST TANKS'. THE HATCH'. If there is no evidence of flooding, and after pears equalized with outside atmosphere, order, 'OPEN THE HATCH'. received that the hatch is open and when ready order, THE BRIDGE' and 'RELIEVING OFFICER OF THE DECK TO THE	
THE FORWARD GROUP,' and as the ship commences to take an up FTER GROUP'. ain and helmsman as necessary to achieve a 3 degree to 5 degree is on the surface and holding, order, 'SECURE THE AIR'. al Center Watch over to the Chief of the Watch. icer is to assume the Deck, proceed to the bridge when the upper er is to assume the Deck, remain in Control in a Supervisory ship is operating on the surface, with the permission of the y watch may be secured. ut(s) to the bridge, establish communications on the bridge. s permit, order planes placed in normal surfaced running ommunications have been established and when ready, report IEVE YOU AS OFFICER OF THE DECK'.	1. Have the word passed, 'SURFACE, SURFACE, SURFACE,' over the 1MC. 5. Report to the Officer of the Deck, '________ FEET AND HOLDING'.

2

Personnel	Command Responsibilities / General Information	Actions (C&D Operations, Inspections,
COW	*Table III-A-18 (Continued)*	2. Blow main ballast tanks as ordered. 3. Open the outboard induction valve when ordered. 4. Check head valve indicating open. 5. On receipt of the order 'START THE BLOWER ON ALL M order a low pressure main ballast tank blow by passing the ON ALL MAIN BALLAST TANKS'. 6. Check planes placed in normal surfaced running posit 7. After the L. P. blower has been running for 20 minut Officer of the Deck, open the L. P. blower discharge ventila the blower shifted from the main ballast tanks to the ventil passing the word 'SHIFT THE BLOWER TO VENTILATE OUTBO Note: It is extremely important that the L. P. blower requested by the EOOW since the main or auxili become air bound while blowing up after surfac 8. Report the following to the Officer of the Deck as occu Head valve indicates OPEN. Outboard induction OPEN. Blower running on all main ballast tanks. Main ballast tank blow complete, ventilating outboard.
Aux. of Watch Forward		1. When ordered to open the inboard induction valve (VH
Navigation Center Supervisor		1. When ordered to start the low pressure blower on all Open the inboard ventilation exhaust valve (ABT 25). Open the L. P. blow discharge ventilation exhaust (ABT Start the L. P. blower in slow, then shift to fast. Open forward group L. P. blow stop (ABT 17). Shut the L. P. blow discharge ventilation exhaust (ABT Open after group L. P. blow stop (ABT 13). Start the Main Induction Fan (Fan #1) in slow. 2. When ordered to shift the low pressure blower to venti blow discharge ventilation exhaust (ABT 16) and shut the valves (ABT 13 and ABT 17). 3. If ordered to secure the blower, stop the blower and s blow stop valves (ABT 13 and ABT 17) and the inboard venti
Planesman/ Helmsman		1. Maintain a 3 degree to 5 degree up angle if possible u the Diving Officer of the Watch. 2. Place the rudder amidships until the ship is surfaced, of the helm and steer ordered course. 3. Place planes in EMERGENCY on zero unless otherwise
Quartermaster of Watch		1. When ordered by the Officer of the Deck, crack open it is held on the latch. 2. When ordered by the Officer of the Deck, open the upp 3. Precede the relieving OOD to the Bridge. 4. Rig down the bridge clamshells and assist the OOD in 5. Check upper hatch rigged for dive and clear.
Lee Helmsman		1. When ordered by the Officer of the Deck, proceed to t in rigging bridge for surface.
Auxiliary Electrician Forward		1. When ordered by the Officer of the Deck, proceed to t suitcase. 2. Check the bridge IC receptacles free of water, plug in 'SUITCASE READY' to the OOD. 3. When directed by the OOD, lay below, energize the IC bridge MC switches in the proper positions.

Actions (C&D Operations, Inspections, Recordings, Etc.)	Communication Responsibilities
ain ballast tanks as ordered. e outboard induction valve when ordered. head valve indicating open. ipt of the order 'START THE BLOWER ON ALL MAIN BALLAST TANKS,' pressure main ballast tank blow by passing the word 'START THE BLOWER N BALLAST TANKS'. planes placed in normal surfaced running position when ordered. he L.P. blower has been running for 20 minutes, or when directed by the e Deck, open the L.P. blower discharge ventilation exhaust valve and order shifted from the main ballast tanks to the ventilation exhaust mast by word 'SHIFT THE BLOWER TO VENTILATE OUTBOARD'. It is extremely important that the L.P. blower be secured immediately if requested by the EOOW since the main or auxiliary sea water system may become air bound while blowing up after surfacing. the following to the Officer of the Deck as occurring: lve indicates OPEN. rd induction OPEN. running on all main ballast tanks. allast tank blow complete, ventilating outboard.	1. When ordered, pass the word 'SURFACE, SURFACE, SURFACE' on the 1MC.
ordered to open the inboard induction valve (VH-3) do so.	
ordered to start the low pressure blower on all main ballast tanks: he inboard ventilation exhaust valve (ABT 25). he L.P. blow discharge ventilation exhaust (ABT 16). he L.P. blower in slow, then shift to fast. orward group L.P. blow stop (ABT 17). he L.P. blow discharge ventilation exhaust (ABT 16). fter group L.P. blow stop (ABT 13). he Main Induction Fan (Fan #1) in slow. ordered to shift the low pressure blower to ventilate outboard, open the L.P. ge ventilation exhaust (ABT 16) and shut the MBT low pressure blow stop 13 and ABT 17). red to secure the blower, stop the blower and shut the MBT low pressure lves (ABT 13 and ABT 17) and the inboard ventilation exhaust valve (ABT 25).	
n a 3 degree to 5 degree up angle if possible until ordered otherwise by Officer of the Watch. he rudder amidships until the ship is surfaced, at which time take charge and steer ordered course. planes in EMERGENCY on zero unless otherwise ordered.	
ordered by the Officer of the Deck, crack open the upper hatch, ensuring the latch. ordered by the Officer of the Deck, open the upper hatch. the relieving OOD to the bridge. n the bridge clamshells and assist the OOD in establishing communications. upper hatch rigged for dive and clear.	
ordered by the Officer of the Deck, proceed to the bridge and assist OOD ridge for surface.	
ordered by the Officer of the Deck, proceed to the bridge with the IC the bridge IC receptacles free of water, plug in the IC suitcase and report READY' to the OOD. irected by the OOD, lay below, energize the IC circuits and place the itches in the proper positions.	

Table III-A-18 (Concluded)

AIRLESS SURFACE

a) General. An Airless surface is accomplished by planing the ship to the surface with sufficient speed to maintain a partially surfaced attitude while the induction is opened and the low pressure blower is started on the main ballast tank low pressure blow system.

b) Procedures. The normal surfacing procedure sha[ll be] modified below:

Personnel	Command Responsibility / General Information	Actions (C&D Operations, I
OOD		2. When the order, 'SURFACE THE SHIP,' is Order sufficient speed to maintain head va Raise the snorkel mast. When head valve is clear of the water and the outboard induction v[alve] opened. Order the low pressure blower started. Order speed changes as necessary. When the L.P. blow has increased byoyan[cy] surface with the planes on zero, order the up[per] evidence of flooding, [and] after pressure/vacuum atmosphere, order the [ha]tch opened. Note: The Officer of the Deck must ensur[e] ship has sufficient positive buoyanc[y] the ship to resubmerge.
DOW		The Diving Officer of the Watch shall car[ry] pressure air will not be used and the ship will degree to 5 degree up angle.
COW		The Chief of the Watch sahll carry out n[ormal] pressure air will not be used and the L.P. blo[wer] Officer of the Deck.

EMERGENCY SURFACE

Emergency Surface. Certain tactical and emergency situations may require immediate surfacing of the ship without the usual preparatory procedures associated with a normal surfacing. The following procedures shall be followed:

OOD		1. Issue specific orders for emergency blowi[ng] BLOW ALL MAIN BALLAST' or 'EMERGENCY BLO 2. When the ship is well on the surface and 3. Order the lower and upper bridge access normal procedures. 4. After surfacing, order the outboard induc[tion] report that the induction mast is dry and outb
DOW		1. Upon hearing the word to Emergency blow 2. Control up angle so as not to exceed 20 d 3. Carry out the remainder of normal surfa
COW		1. Check all vents SHUT immediately. 2. Emergency blow main ballast tanks when 3. Ensure proper lineup of hydraulic pumps 4. Carry out remainder of normal surfacing Do not order the L.P. blower started unt[il] ventilation exhaust mast have been reported d
CREW		All other members of the diving party ca[rry out] expeditiously, including those duties normally order, 'PREPARE TO SURFACE'. Make prescri

/

AIRLESS SURFACE

s. The normal surfacing procedure shall be followed except as

Actions (C&D Operations, Inspections, Recordings, Etc.)	Communication Responsibilities
hen the order, 'SURFACE THE SHIP,' is given: rder sufficient speed to maintain head valve clear of water. aise the snorkel mast. hen head valve is clear of the water and maintaining clear of the water, order board induction valve opened. rder the low pressure blower started. rder speed changes as necessary. hen the L.P. blow has increased buoyancy sufficiently to hold the ship on the with the planes on zero, order the upper hatch cracked. If there is no e of flooding, and after pressure/vacuum appears equalized with the outside here, order the hatch opened. ote: The Officer of the Deck must ensure, prior to opening the hatch, that the ship has sufficient positive buoyancy to preclude the waves from causing the ship to resubmerge.	1. The Officer of the Deck shall have the word passed over the 1MC, 'PREPARE TO SURFACE WITHOUT AIR, PREPARE TO SURFACE WITHOUT AIR'.
The Diving Officer of the Watch shall carry out normal procedures except high ure air will not be used and the ship will be planed to the surface using a 3 to 5 degree up angle.	
The Chief of the Watch sahll carry out normal procedures except that high air will not be used and the L.P. blower will be started on orders of the r of the Deck.	

EMERGENCY SURFACE

ssue specific orders for emergency blowing of main ballast, i.e., 'EMERGENCY ALL MAIN BALLAST' or 'EMERGENCY BLOW THE FORWARD GROUP'. hen the ship is well on the surface and holding, order 'SECURE THE AIR'. rder the lower and upper bridge access hatches opened in accordance with l procedures. fter surfacing, order the outboard induction valve opened after receiving the that the induction mast is dry and outbaord valves are in POWER and unlocked.	
pon hearing the word to Emergency blow, sound 3 blasts on the diving alarm. ontrol up angle so as not to exceed 20 degrees up angle. arry out the remainder of normal surfacing duties.	
heck all vents SHUT immediately. mergency blow main ballast tanks when ordered. nsure proper lineup of hydraulic pumps. arry out remainder of normal surfacing duties except: o not order the L.P. blower started until low pressure blow lines and tion exhaust mast have been reported dry.	
ll other members of the diving party carry out normal surfacing procedures iously, including those duties normally accomplished following the preparatory 'PREPARE TO SURFACE'. Make prescribed reports.	

2

a) Ship's propulsion may be accomplished by operation of the main propeller shaft using one or both main turbines or the Emergency Propulsion Motor, or by operation of the Secondary Propulsion (Outboard) Motor. The Outboard Motor may be operated singly or in conjunction with operation of the main propeller. Procedures for the control of propulsion mode, direction, and rate are established in this bill. Procedures for operation of propulsion equipment are delineated in Engineering Department Operating Procedures and Instructions.

b) Prompt and proper propulsion orders and immediate, c
orders is essential to the safe operation of the ship. The O
must be kept fully and promptly informed of limitations or c
plant modes and electric plant lineups. This information sh
Engineering Officer of the Watch (EOOW) in terms usable to
(i.e. by stating the bell or approximate numbers of turns to
limited rather than stating vacuum, temperature, etc., limi

Table III-A-19 Propulsion Bill

Personnel	Command Responsibilities / General Information	Actions (C&D Operations, Inspect
OOD		1. Direct the Engineer Officer of the Watch (EOOW be employed as follows: Shifting propulsion to the main engines: Direct the EOOW to 'Shift propulsion to the When the EOOW has reported 'Ready to shif order 'ALL STOP' to be rung up to signal the EO Shifting propulsion to the EPM: Direct the EOOW to 'Shift propulsion to the When the EOOW has reported 'Ready to shif 'ALL STOP' to be rung up to signal the EOOW to Operating the Secondary propulsion (Outboard) Direct the EOOW to 'Lower the Outboard, tes When the Outboard has been reported lower Helmsman to 'Test the Outboard'. When the Outboard is no longer needed ord 2. Control the direction and rate of propulsion by following terminology: Main Shaft To obtain standardized speed increments: 'ALL AHEAD ONE-THIRD (TWO-THIRDS, ST 'ALL BACK ONE-THIRD (TWO-THIRDS, FUL 'ALL STOP' To obtain other than a standardized speed in Engineer Officer of the Watch using following te 'MAKE (desired number) TURNS,' or ' 'MAKE (desired number) knots by log To obtain rapid response to an ordered bell cavitation, order a jump bell. Secondary Propulsion (Outboard) Motor: Direct the helmsman to 'TRAIN THE OUTBO toward which it is desired to move the ship's ste When Outboard is reported to be trained to Outboard'. When Outboard is temporarily not needed, ' 3 When advised of a Reactor Plant SCRAM: Order 'ALL STOP'. Execute the Reduced Electrical Power Bill. The Officer of the Deck will, if any emergenc requires maintaining turbine propulsion, order th be given to Maneuvering at the first opportunity. Order propulsion shifted to the EPM after it (power) is not required. Man the JA phones in control.

GENERAL INFORMATION

proper propulsion orders and immediate, correct response to these al to the safe operation of the ship. The Officer of the Deck (OOD) ly and promptly informed of limitations or changes to propulsion electric plant lineups. This information should be provided by the cer of the Watch (EOOW) in terms usable to the needs of the OOD the bell or approximate number of turns to which the plant is n stating vacuum, temperature, etc., limits).

c) The proper method of answering bells on the main engines is dependent upon the condition of the ship and the urgency of the situation. The following guidelines apply:

Surfaced: Operate propulsion equipment so as to attain the ordered bell without regard to cavitation.

Submerged:

During normal conditions operate propulsion equipment so as to prevent cavitation of the propeller while attaining the ordered bell.

During casualties which require rapid propulsion response (Flooding, jam dive/rise, etc.) or when ordered by the Officer of the Deck (signaled by a jump bell, i.e. 1/3 to Standard, 2/3 to Full, etc.) operate propulsion equipment so as to attain the ordered bell as rapidly as possible, without regard to cavitation and within plant capabilities.

Actions (C&D Operations, Inspections, Recordings, Etc.)	Communication Responsibilities
ect the Engineer Officer of the Watch (EOOW) as to the propulsion mode to yed as follows:	
iting propulsion to the main engines:	
Direct the EOOW to 'Shift propulsion to the main engines'.	
When the EOOW has reported 'Ready to shift propulsion to the main engines,' 'ALL STOP' to be rung up to signal the EOOW to shift propulsion to the main engines.	
iting propulsion to the EPM:	
Direct the EOOW to 'Shift propulsion to the EPM'.	
When the EOOW has reported 'Ready to shift propulsion to the EPM,' order STOP' to be rung up to signal the EOOW to shift propulsion to the EPM.	
rating the Secondary propulsion (Outboard) Motor:	
Direct the EOOW to 'Lower the Outboard, test, and shift to remote'.	
When the Outboard has been reported lowered and shifted to remote, order the sman to 'Test the Outboard'.	
When the Outboard is no longer needed order the EOOW to 'Rig in the Outboard'.	
ntrol the direction and rate of prop[illegible]n by orders to the Helmsman using the g terminology:	
n Shaft	
To obtain standardized speed increme[illegible]	
'ALL AHEAD ONE-THIRD (TWO-THIRDS, STANDARD, FULL OR FLANK)'.	
'ALL BACK ONE-THIRD (TWO-THIRDS, FULL OR EMERGENCY)'.	
'ALL STOP'	
To obtain other than a standardized speed increment, control speed by order to the neer Officer of the Watch using followin[illegible] minology:	
'MAKE (desired number) TURNS,' or 'MAKE TURNS FOR ________ KNOTS'.	
'MAKE (desired number) knots by log'.	
To obtain rapid response to an ordered bell when submerged, without regard to tion, order a jump bell.	
ondary Propulsion (Outboard) Motor:	
Direct the helmsman to 'TRAIN THE OUTBOARD TO ________,' (relative bearing d which it is desired to move the ship's stern).	
When Outboard is reported to be trained to the ordered bearing, 'Start the oard'.	
When Outboard is temporarily not needed, 'Stop the Outboard'.	
en advised of a Reactor Plant SCRAM:	
der 'ALL STOP'.	
ecute the Reduced Electrical Power Bill.	
e Officer of the Deck will, if any emergency ship condition exists which maintaining turbine propulsion, order the necessary bell. Confirmation will to Maneuvering at the first opportunity.	
der propulsion shifted to the EPM after it is determined that rapid response is not required.	
n the JA phones in control.	2

Table III-A-19 (Continued)

Personnel	Command Responsibility / General Informantion	Actions (C&D Operations, Insp
OOD (Cont)		Secure the rig for reduced electrical power wi Shift propulsion back to the main engines whe
EOOW	Shaft limitations shall not be exceeded except in an emergency as directed by the Commanding Officer. The Engineering Officer of the Watch will ensure that other power plant operating limitations specified in the Engineering Department Operating Procedures, the Reactor Plant Manual and other directives from higher authority are not exceeded.	1. When directed to 'Shift propulsion to the mai Warm up the main engines as necessary. 2. When directed to 'Test the shaft on the main Roll the shaft in the ahead and astern directi the ship. 3. When directed to 'Shift propulsion to the EPM Station a watch at the EPM. Establish JA phone communication between th 4. When directed to 'Test the shaft on the EPM'. Roll the shaft in the ahead and astern directi the ship. 5. When directed to 'Lower the Outboard, test an Lower the Secondary Propulsion Motor. Locally close the Secondary Propulsion Motor starts, open circuit breaker. Locally train the secondary propulsion motor motor to 0 degrees relative. Shift Secondary Propulsion Motor Control to R 6. When directed to 'Rig in the Outboard', Shift Secondary Motor Control to Local. Train the Secondary Propulsion Motor to the Retract the motor. 7. When standardized speed increments are orde Acknowledge order by matching engine order answer the ordered bell, ring up STOP and inform casualty via 7MC. Shaft RPM will be the particular RPM shown bell, unless a different RPM is specifically ordered bell signal cancels any previously ordered RPM. Operate propulsion equipment to attain the ord following RPM-Bell Table: Propulsion on Main Turbines: (Surfaced a Bell / RPM AHEAD One-third 40 Two-thirds 80 Standard 120 Full 50% (If M 160 (If M Flank 100% or R Bell / RPM BACK One-third 50 Two-thirds 75 Full 100 Emergency 200 for 5 Note: When FLANK or BACK EMERGE main Coolant Pumps will be sh Propulsion on Emergency Propulsion Motor Bell / RPM Sur and Sub AHEAD OR One-third Minimu BACK Two-thirds Maximu

Actions (C&D Operations, Inspections, Recordings, Etc.)	Communication Responsibilities
the rig for reduced electrical power when reactor plant is reported self-sustaining.	
propulsion back to the main engines when maneuvering reports ready.	
directed to 'Shift propulsion to the main engines'.	When the main engines are warmed up, report to the Officer of the Deck, 'Ready to shift propulsion to the main engines'.
up the main engines as necessary.	When 'All Stop' is rung up, answer 'All Stop,' shift propulsion to the main engines and report to the Officer of the Deck 'Answering bills on the main engines'.
directed to 'Test the shaft on the main engines'.	
shaft in the ahead and astern directions being careful not to put way on	Report to the Officer of the Deck, 'Tested the shaft on the main engines, test satisfactory.'
directed to 'Shift propulsion to the EPM'.	
a watch at the EPM.	
JA phone communication between the EPM operator and Maneuvering.	Report to the Officer of the Deck, 'Ready to shift propulsion to the EPM'.
directed to 'Test the shaft on the EPM'.	When 'ALL STOP' is rung up, answer 'ALL STOP', shift propulsion to the EPM and report to the Officer of the Deck 'Answering bells on the EPM'.
shaft in the ahead and astern directions being careful not to put way on	
directed to 'Lower the Outboard, test and shift to remote'.	Report to the Officer of the Deck, 'Tested the shaft on the EPM, test satisfactory'.
the Secondary Propulsion Motor.	
close the Secondary Propulsion Motor circuit breaker, check that motor circuit breaker.	
train the secondary propulsion motor 10 degrees in each direction, train degrees relative.	
Secondary Propulsion Motor Control to Remote.	Report to the OOD, 'Outboard Lowered, Tests satisfactory and Shifted to Remote'.
directed to 'Rig in the Outboard'.	
Secondary Motor Control to Local.	
the Secondary Propulsion Motor to the housing position.	
the motor.	Report to the OOD, 'The Outboard is rigged in'.
standardized speed increments are ordered via the Engine Order Telegraph:	
Acknowledge order by matching engine order telegraph pointers. If unable to ordered bell, ring up STOP and inform the OOD of the difficulty or 7MC.	
RPM will be the particular RPM shown on the bell table for the ordered a different RPM is specifically ordered by the Officer of the Deck. A new cancels any previously ordered RPM.	
propulsion equipment to attain the ordered speed in accordance with the RPM-Bell Table:	

pulsion on Main Turbines: (Surfaced and Submerged)

	Bell	RPM
AD	One-third	40
	Two-thirds	80
	Standard	120
	Full	50% (if MCP in SLOW) 160 (if MCP in FAST)
	Flank	100% or RPM limitation

	Bell	RPM
K	One-third	50
	Two-thirds	75
	Full	100
	Emergency	200 for 5 minutes

Note: When FLANK or BACK EMERGENCY is ordered the main Coolant Pumps will be shifted to FAST speed.

pulsion on Emergency Propulsion Motor:

	Bell	RPM Surfaced and Submerged
AD OR	One-third	Minimum (Approximately 22)
K	Two-thirds	Maximum (Approximately 37)

2

Personnel	Command Responsibility / General Information	Actions
EOOW (Cont)	*Table III-A-19 (Concluded)* It shall be the responsibility of the Engineering Officer of the Watch to answer bells promptly and accurately and comply with approved Operating Procedures, the Reactor Plant Manual and other directives from higher authority. He shall inform the Officer of the Deck of any abnormal propulsion limitations.	8. When ordered to, 'Mak Adjust the speed of 9. When ordered to 'Make Adjust the speed of the 10. If the reactor plant SC Shut the main engine Answer bells as ordere propulsion and report 'Answ Man the JA phones in JA phones, the following: Cause of SCRAM when When commencing a fa When the reactor is cri When the reactor plant When T_{avg} is in the gr
Helmsman		1. When a standardized sp Move the engine order Observe that the engine speed, acknowledging receipt acknowledgement is not recei order telegraph. If the orde the Officer of the Deck that, 2. When ordered to 'TEST Check that the LOWERE Motor Control Panel. Shut the Secondary Pr CLOSED light comes on. As soon as breaker clos Train the Secondary Pr 3. When ordered to 'TRAIN Depress the TRAIN RIG the Secondary Propulsion M points to the ordered train a 4. When ordered to 'STAR Shut the Secondary Pr Observe that the circuit 5. When ordered to 'STOP Open the Secondary Pr Observe that the circui

Actions (C&D Operations, Inspections, Recordings, Etc.)	Communication Responsibilities
8. When ordered to, 'Make ______ Turns'.	
Adjust the speed of the main shaft to obtain ordered RPM.	
9. When ordered to 'Make ______ knots by log':	
Adjust the speed of the main shaft to obtain ordered knots by underwater log.	
10. If the reactor plant SCRAMS:	
Shut the main engine throttles and indicate STOP on the Engine Order Telegraph.	Immediately advise the Officer of the Deck of the casualty.
Answer bells as ordered. If directed to shift propulsion to the EPM, shift propulsion and report 'Answering Bells on the EPM'.	
Man the JA phones in Maneuvering. Report to the Officer of the Deck via the JA phones, the following:	
Cause of SCRAM when known.	
When commencing a fast SCRAM recovery.	
When the reactor is critical.	
When the reactor plant is self sustaining.	
When T_{ave} is in the green band and maneuvering is ready to answer all bells.	
1. When a standardized speed increment is ordered (e.g. ALL AHEAD ONE-THIRD).	
Move the engine order telegraph pointer to the ordered speed.	Acknowledge the order by exact repetition (e.g. ALL AHEAD ONE-THIRD
Observe that the engine order telegraph response pointer moves to the ordered speed, acknowledging receipt of the order by the propulsion control station. If an acknowledgement is not received immediately, depress the signal button on the engine order telegraph. If the order remains unacknowledged following this action, advise the Officer of the Deck that, '(ORDERED SPEED) has not been answered'.	When engine order telegraph response pointer moves to the ordered spe to the Officer of the Deck, 'Answers (Ordered Speed)'.
2. When ordered to 'TEST THE OUTBOARD':	
Check that the LOWERED and REMOTE lights are on at the Secondary Propulsion Motor Control Panel.	
Shut the Secondary Propulsion Motor circuit breaker. Observe that the BREAKER CLOSED light comes on.	
As soon as breaker closed light is observed to be lighted, open the circuit breaker.	Report to the OOD, 'OUTBOARD TESTS SATISFACTORY'.
Train the Secondary Propulsion Motor 180 degrees in each direction.	
3. When ordered to 'TRAIN THE OUTBOARD TO ______':	
Depress the TRAIN RIGHT or TRAIN LEFT push button to move the model ship on the Secondary Propulsion Motor Control Panel, via the shortest route, until its bow points to the ordered train angle.	Acknowledge order by exact repetition. Report 'OUTBOARD TRAINED TO ______'.
4. When ordered to 'START THE OUTBOARD':	
Shut the Secondary Propulsion Motor Circuit Breaker.	Acknowledge order by exact repetition.
Observe that the circuit breaker CLOSED light goes out.	Report to the OOD, 'OUTBOARD STARTED'.
5. When ordered to 'STOP THE OUTBOARD'	
Open the Secondary Propulsion Motor Circuit Breaker.	Acknowledge the order by exact repetition.
Observe that the circuit breaker CLOSED light goes out.	Report to the OOD, 'OUTBOARD STOPPED'.

2

ections, Recordings, Etc.)	Communication Responsibilities
lered RPM.	
lered knots by underwater log.	
TOP on the Engine Order Telegraph.	Immediately advise the Officer of the Deck of the casualty.
propulsion to the EPM, shift .	
the Officer of the Deck via the	
ing is ready to answer all bells.	
d (e.g. ALL AHEAD ONE-THIRD).	
) ordered speed.	Acknowledge the order by exact repetition (e.g. ALL AHEAD ONE-THIRD)'.
se pointer moves to the ordered pulsion control station. If an s the signal button on the engine ed following this action, advise not been answered'.	When engine order telegraph response pointer moves to the ordered speed report to the Officer of the Deck, 'Answers (Ordered Speed)'.
s on at the Secondary Propulsion	
reaker. Observe that the BREAKER	
e lighted, open the circuit breaker.	Report to the OOD, 'OUTBOARD TESTS SATISFACTORY'.
ees in each direction.	
_______':	
button to move the model ship on the shortest route, until its bow	Acknowledge order by exact repetition. Report 'OUTBOARD TRAINED TO _______'.
Breaker.	Acknowledge order by exact repetition.
goes out.	Report to the OOD, 'OUTBOARD STARTED'.
Breaker.	Acknowledge the order by exact repetition.
goes out.	Report to the OOD, 'OUTBOARD STOPPED'.

2

3

Table III-A-20 Ventilation Bill

There are five basic modes in which the ventilation system may be operated. A brief description of each of these modes is as follows:

a) The RECIRCULATE mode defines the normal mode of operation of the ventilation system. By this method the air within the ship is continuously circulated in a closed system comprised of the ship's six compartments. Recirculation is normally employed during prolonged periods of submergence when it is necessary to maintain a sealed atmosphere. As the air is circulated it is purified by passage through charcoal filters, precipitators, CO_2 Scrubbers, CO/H_2 burners and is revitalized by the addition of oxygen from the oxygen generators or oxygen storage banks. RECIRCULATE is the line up to which the system will be automatically returned following completion of or securing from any other mode of ventilation.

b) The VENTILATE mode describes the means by which air is continuously drawn into the ship through the induction piping while air from the ship's interior is exhausted throught the ventilation exhaust piping using the Low Pressure Blower.

c) The SNORKEL mode describes the mean[illegible] through the induction piping as described[illegible] exhausting air from the ship's interior thr[illegible] exhaust system. Detailed procedures for s[illegible] and are not further discussed in this bill.

d) The EMERGENCY VENTILATE mode is the[illegible] compartment of atmospheric contaminents s[illegible] or other objectionable or noxious gases. [illegible] into the compartment while a second path [illegible] the diesel engine or the low pressure blow[illegible] the line up for emergency ventilation.

RECIRCULA[illegible]

Personnel	Command Responsibilities / General Information	Actions (C&D O[illegible]
OOD	The recirculate mode is the normal ventilation line up. The ventilation system will be automatically returned to 'RECIRCULATE' alignment on securing from any other ventilation evolution.	
All Compartment Watches		On receipt of this word all compa[illegible] 'RECIRCULATION' in accordance with [illegible]

VENTILAT[illegible]

Personnel	Command Responsibilities / General Information	Actions
OOD	To Initiate Ventilation	
DOW		
COW		1. Position the electrode selector sw[illegible] 2. Position the head valve control sw[illegible] 3. If icing conditions exist, place th[illegible] 5. When ordered by the Officer of th[illegible] UP indication. 6. Check that the head valve OPEN [illegible] is above the water. 7. Test the mast flooded indicator. 8. With the ship at Snorkel Depth s[illegible] 'TEST THE HEAD VALVE', cycle head v[illegible] utilizing test button and 'Manual Eme[illegible] indication at BCP with OOD's visual [illegible] 9. When no water flow is indicated [illegible] shut drain valves TD-52, TD-53, TD-5[illegible]
Auxiliaryman of Watch Forward		1. Open the drain valves (ABT 19, 2[illegible] Blow system lines and the ventilation[illegible] 2. Check MBT low pressure blow val[illegible] ventilation exhaust mast valve (ABT 1[illegible] 3. When the ventilation exhaust mas[illegible] 29 an[illegible] 4. After verifying that the induction [illegible] valve (VH-3)
Navigation Center Watch		1. Unlock the Outboard Ventilation [illegible] 2. Unlock the outboard induction val[illegible] 3. Open the hull and backup valves [illegible] control lines to the head valve (VH-1[illegible]
Each Compartment Watch		1. Line up ventilation system in acc[illegible]
Lee Helmsman		

illation system.
nd system
yed during
l atmosphere.
precipitators,
from the
which the
m any other

drawn into
exhausted

GENERAL INFORMATION

c) The SNORKEL mode describes the means for ventilating the ship by providing air through the induction piping as described above for the 'VENTILATE' mode while exhausting air from the ship's interior through the diesel engine and the snorkel exhaust system. Detailed procedures for snorkel operation are provided in the Snorkel Bill, and are not further discussed in this bill.

d) The EMERGENCY VENTILATE mode is the means used for evacuation of a specific compartment of atmospheric contaminents such as smoke, toxic gas, radioactive contamination or other objectionable or noxious gases. In this mode a supply of fresh air is established into the compartment while a second path is established to exhaust its contents using either the diesel engine or the low pressure blower. Addendum 2 and Compartment Bills specify the line up for emergency ventilation.

e) The RAPID VENTILATE mode
ship. In this mode air is con
while air from the ship's inter
and snorkel exhaust system us

Any of these modes may be
emergency conditions, as dicta
the ship is controlled by fan,
in the Compartment Bills.

Improper Alignment or ope
pressure between the compartm
acting on the area of an inter
of very real hazard to personn

RECIRCULATE MODE

formation	Actions (C&D Operations, Inspections, Recordings, Etc.)	
The ventilation system will ecuring from any other		The Officer of the Deck shall h
	On receipt of this word all compartments will rig the ventilation system for 'RECIRCULATION' in accordance with the Compartment Bill.	

VENTILATION MODE

		1. Order 'PREPARE TO VENTILATE' 2. Order snorkel mast raised.
		1. Have the word passed over the 2. When the Chief of the Watch r Officer of the Deck, 'READY TO VEN
tion	1. Position the electrode selector switch on the BCP at BOTH. 2. Position the head valve control switch on the BCP at AUTO. 3. If icing conditions exist, place the electrode heater switches on the 5. When ordered by the Officer of the Deck, raise the snorkel mast. Watch for UP indication. 6. Check that the head valve OPEN light on the BCP goes on when the head valve (VH-1) is above the water. 7. Test the mast flooded indicator. 8. With the ship at Snorkel Depth and when ordered by the Officer of the Deck 'TEST THE HEAD VALVE', cycle head valve (VH-1) and check operation of electrodes utilizing test button and 'Manual Emergency Close' valve. Check head valve position indication at BCP with OOD's visual observation of head valve position. 9. When no water flow is indicated in the induction mast drain line sight glass, shut drain valves TD-52, TD-53, TD-54, ALP 256 and ALP 257.	4. Direct the Auxiliaryman Forwar Position the induction mast dra Open vent valves (ALP 256, AL without pulling a vacuum in the in Open induction mast drain valv 10. When all reports received, rep 'READY TO VENTILATE'.
	1. Open the drain valves (ABT 19, 20, 21, 22, 23 and 39) and drain the Low Pressure Blow system lines and the ventilation exhausts masts. 2. Check MBT low pressure blow valves (ABT 13 and ABT 17) shut and check ventilation exhaust mast valve (ABT 16) open. 3. When the ventilation exhaust mast is dry, shut drain valves (ABT 19, 20, 21, 22, 23 and 39) 4. After verifying that the induction mast is drained, open the inboard induction valve (VH-3)	5. Report to the Chief of the Wat
	1. Unlock the Outboard Ventilation Exhaust Valve (ABT 24) and place it in power. 2. Unlock the outboard induction valve (VH-2) and place it in power. 3. Open the hull and backup valves (ALP 239, 240, 244 and 245) in the pneumatic control lines to the head valve (VH-1)	4. Report to the Chief of the Watc
	1. Line up ventilation system in accordance with posted compartment bills.	2. Report to Control when lined u
		1. Man JA phones to receive rep Chief of the Watch.

2

RMATION

lor ventilating the ship by providing air
ive for the 'VENTILATE' mode while
gh the diesel engine and the snorkel
rkel operation are provided in the Snorkel Bill.

eans used for evacuation of a specific
ch as smoke, toxic gas, radioactive contamination
this mode a supply of fresh air is established
established to exhaust its contents using either
. Addendum 2 and Compartment Bills specify

e) The RAPID VENTILATE mode is the means of maximum replenishment of air within the ship. In this mode air is continuously drawn into the ship through the induction system while air from the ship's interior is being exhausted through both the ventilation exhaust and snorkel exhaust system using the Low Pressure Blower and Diesel Engine Respectively.

Any of these modes may be used surfaced or at snorkel depth, under normal or emergency conditions, as dictated by the existing situation. Distribution of air within the ship is controlled by fan, valve, damper, door, and fitting conditions as specified in the Compartment Bills.

Improper Alignment or operation of the ventilation system can produce differences in pressure between the compartments of the ship. Even a one-half inch pressure differential acting on the area of an inter-compartment watertight door can produce a condition of very real hazard to personnel operating the door.

TE MODE

rations, Inspections, Recordings, Etc.)	Communication Responsibilities
	The Officer of the Deck shall have the word passed over the 1MC 'RECIRCULATE'.
ments will rig the ventilation system for e Compartment Bill.	

N MODE

	1. Order 'PREPARE TO VENTILATE'. 2. Order snorkel mast raised.
	1. Have the word passed over the 1MC, 'PREPARE TO VENTILATE, PREPARE TO VENTILATE'. 2. When the Chief of the Watch reports, 'READY TO VENTILATE', report to the Officer of the Deck, 'READY TO VENTILATE'.
h on the BCP at BOTH. ch on the BCP at AUTO. electrode heater switches on the Deck, raise the snorkel mast. Watch for ht on the BCP goes on when the head valve (VH-1) when ordered by the Officer of the Deck ve (VH-1) and check operation of electrodes ency Close' valve. Check head valve position ervation of head valve position. the induction mast drain line sight glass, ALP 256 and ALP 257.	4. Direct the Auxiliaryman Forward or Auxiliary Electrician Forward to: Position the induction mast drain valve (TD-54) to the drain position. Open vent valves (ALP 256, ALP 257) in mast blow line to allow the mast to raise without pulling a vacuum in the induction piping. Open induction mast drain valves (TD-52 and (TD-53) 10. When all reports received, report to the Diving Officer of the Watch 'READY TO VENTILATE'.
21, 22, 23 and 39) and drain the Low Pressure exhausts masts. es (ABT 13 and ABT 17) shut and check open. is dry, shut drain valves (ABT 19, 20, 21, 22, mast is drained, open the inboard induction	5. Report to the Chief of the Watch 'READY TO VENTILATE'.
haust Valve (ABT 24) and place it in power. e (VH-2) and place it in power. ALP 239, 240, 244 and 245) in the pneumatic	4. Report to the Chief of the Watch 'READY TO VENTILATE'.
rdance with posted compartment bills.	2. Report to Control when lined up.
	1. Man JA phones to receive reports from compartments for relay to the Chief of the Watch.

Table III-A-20 (Continued)

Personnel	Command Responsibilities / General Information	Actions (C&D Operations, Insp…
OOD	Securing Emergency Ventilation	1. Order 'SECURE SNORKELING / VENTILATING'.
DOW		2. Carry out procedure for 'SECURE VENTILATING' … as appropriate.
COW		Carry out procedures for 'SECURING VENTILATION… as appropriate.
Auxiliaryman of Watch Forward		Carry out procedures for 'SECURING VENTILATION… as appropriate.
Navigation Center Watch		Carry out procedures for 'SECURING VENTILATION… as appropriate.
EOW		Carry out procedures for 'SECURING VENTILATION… as appropriate.
All Compartment Watches		1. Rig the compartment for Recirculating in accord… unless otherwise directed from Control. The compart… 'RECIRCULATE MODE' even though it may have been … evolution such as fire, radiation, toxic gas, etc.
		RAPID VENTILATION MODE
OOD	The rapid ventilate mode should be used when it is deemed necessary to obtain the maximum replenishment rate of air within the ship. The basic system lineup is that for 'SNORKEL' and 'VENTILATE' modes concurrently. The specific lineup for rapid ventilation shall be in accordance with the compartment bills.	
DOW	To Initiate Rapid Ventilation	1. Insure that all compartments are rigged as rapid… the Compartment Bill.
COW		1. Carry out the preparations for Ventilate and Snor… this bill and the Snorkel Bill.
[illegible]		1. Commence immediate preparations to snorkel in …
Auxiliaryman of Watch Forward, and Navigation Center Watch		1. Rig for Ventilate and Snorkel in accordance with…
Each Compartment Watch		1. Insure the compartment is expeditiously rigged i… Compartment Bill.
OOD	To Commence Rapid Ventilation	
DOW		1. Commence ventilating in accordance with this bi…
		2. When directed, commence snorkeling in accorda…
COW		2. Commence ventilating in accordance with this bi…
		3. When directed, commence snorkeling in accorda…
OOD	To Secure Rapid Ventilation	1. Have Rapid Ventilation secured sequentially in a… the Snorkel Bill.
COW		1. Secure Rapid Ventilation in accordance with thi…

Actions (C&D Operations, Inspections, Recordings, Etc.)	Communication Responsibilities
'SECURE SNORKELING / VENTILATING'.	
out procedure for 'SECURE VENTILATING' or 'SECURE SNORKELING' riate.	1. Have appropriate word passed over 1MC. 3. When all reports received, report to the Officer of the Deck, 'SECURED FROM EMERGENCY VENTILATION, RECIRCULATING'.
out procedures for 'SECURING VENTILATION' or 'SECURING SNORKELING' riate.	
out procedures for 'SECURING VENTILATION' or 'SECURING SNORKELING' riate.	
out procedures for 'SECURING VENTILATION' or 'SECURING SNORKELING' riate.	
out procedures for 'SECURING VENTILATION' or 'SECURING SNORKELING' riate.	
the compartment for Recirculating in accordance with the compartment bill herwise directed from Control. The compartment will be returned to the LATE MODE' even though it may have been previously rigged for another such as fire, radiation, toxic gas, etc.	2. When compartments are rigged, report, 'SECURED FROM EMERGENCY VENTILATING, RECIRCULATING' to Control.
RAPID VENTILATION MODE	
	1. Ha[illegible] word passed on the 1MC, 'PREPARE TO RAPID VENTILATE, PREPARE TO SNORKE[illegible]'.
that all compartments are rigged as rapidly as possible in accordance with rtment Bill.	2. When all compartments, except Maneuvering report rigged, report to the Officer of the Deck, 'READY TO VENTILATE'. 3. When Maneuvering reports rigged and the Low Pressure Blower is running, report to the Officer of the Deck, 'READY TO SNORKEL'.
out the preparations for Ventilate and Snorkel expeditiously in accordance with and the Snorkel Bill.	2. Report to the Diving Officer of the Watch when 'READY TO VENTILATE' and when 'READY TO RAPID VENTILATE'.
ence immediate preparations to Snorkel in accordance with Snorkel Bill.	2. Report to Control when 'READY TO SNORKEL'.
r Ventilate and Snorkel in accordance with this bill and the Snorkel Bill.	2. Report to the Chief of the Watch when rigged, 'READY TO VENTILATE'.
e the compartment is expeditiously rigged in accordance with the ent Bill.	2. Report to Control, 'READY TO RAPID VENTILATE'.
	1. Upon receiving the report, 'READY TO VENTILATE', direct the word passed twice over the 1MC, 'COMMENCE VENTILATING'. 2. Upon receiving the report, 'READY TO SNORKEL', have the word passed twice over the 1MC, 'COMMENCE RAPID VENTILATING, COMMENCE SNORKELING'.
ence ventilating in accordance with this bill. directed, commence snorkeling in accordance with the Snorkel Bill.	3. When snorkeling report to the Officer of the Deck, 'RAPID VENTILATING'.
ence ventilating in accordance with this bill. directed, commence snorkeling in accordance with the Snorkel Bill.	1. Pass the word on the 1MC as directed by the Officer of the Deck.
Rapid Ventilation secured sequentially in accordance with this bill and Bill.	2. First, have the word passed on the 1MC, 'SECURE SNORKELING, CONTINUE VENTILATING'. 3. When the Diesel Engine is secured and when desired ventilating will be secured in accordance with this bill by having the word passed, 'SECURE VENTILATING'.
e Rapid Ventilation in accordance with the Compartment Bill.	2. When the compartment is rigged, report to Control, 'SECURED RAPID VENTILATING, RECIRCULATING'.

2

Table III-A-20 (Concluded)

Personnel	Command Responsibilities / General Information	Actions (C&D Operations, Inspecti
OOD		
DOW		2. Order the outboard induction (VH-2) and outboard ve OPENED.
COW	To Commence Ventilation	1. When ordered, OPEN the outboard induction valve (VH 2. Place the outboard ventilation exhaust valve switch in it in this position until the blower is running. (The sou in Control). Then release the switch to the AUTO positio
Auxiliaryman of Watch Forward		1. Open the inboard ventilation exhaust valve (ABT 25)
Navigation Center Supervisor		1. When the outboard induction (VH-2) is OPEN, start th (Fan #1) in SLOW. 2. When the outboard ventilation exhaust (ABT 24) valve Blower in SLOW speed and shift to FAST.
OOD		
DOW		2. Compensate the ship as necessary for snorkel mast e
COW	Secure Ventilating	1. When the Low Pressure Blower is stopped, shut the c place the outboard ventilation exhaust valve switch in the 2. Turn head valve (VH-1) control switch to CLOSED, tu Report 'STRAIGHT BOARD' (or exceptions) to the Diving O 3. Lower the mast, when lowered, report, 'MAST LOWER of the Watch.
Auxiliaryman of Watch Forward		1. Shut the inboard induction (VH-3) and inboard ventil 2. Lock Shut the outboard induction (VH-2) and outboard valves when they indicate SHUT.
Navigation Center Watch		1. Secure the Low Pressure Blower. 2. Secure the main induction fan (Fan #1) 3. Shut hull and backup valves (ALP 239, 240, 244 and lines to the head valve.
All Compartment Watches		1. Line up the ventilation system for 'RECIRCULATING' Compartment Bills and report to the Chief of the Watch.
		EMERGENCY VENTILATION MODE
OOD	NOTE: When the word, 'PREPARE TO EMERGENCY VENTILATE THE WITH THE DIESEL (BLOWER)' is passed, all compartments shall rig in accordance with the posted bills, except for the Compartment to be ventilated. The affected Compartment shall rig with the exception of opening watertight doors and ventilation dampers. These items shall be opened on the order, 'COMMENCE EMERGENCY VENTILATING'.	1. Order, 'PREPARE TO EMERGENCY VENTILATE THE DIESEL, PREPARE TO SNORKEL', or, 2. Order, 'PREPARE TO EMERGENCY VENTILATE THE BLOWER'. 3. When all compartments have reported ready, order, ' VENTILATING. COMMENCE SNORKELING', when using Di VENTILATING' when using Low Pressure Blower.
DOW		2. Carry out procedures for 'VENTILATE' if the Low Pres 3. Carry out procedures for 'SNORKEL' if the diesel eng
COW		1. Carry out the procedures for 'SNORKEL' or 'VENTILAT
Auxiliaryman of Watch Forward		1. Carry out the procedures for 'SNORKEL' or 'VENTILAT
Navigation Center Watch		1. Carry out the procedures for 'SNORKEL' or 'VENTILAT
EOW	NOTE: The Diesel Engine shall be lined up even when Emergency Ventilation is to be commenced with the Low Pressure Blower so that it will be ready for immediate use if the decision to shift to the diesel is made.	1. Have the diesel prepared and be ready to snorkel on Blower is to be used. 2. Carry out the procedures of the Snorkel Bill if the 4. Insure the Engineering Spaces are rigged for 'SNOR
All Compartment Watches		1. Line up the ventilation system in accordance with th 2. Man appropriate sound powered telephones.

...ctions (C&D Operations, Inspections, Recordings, Etc.)	Communication Responsibilities
	1. After receiving report 'READY TO VENTILATE' from the Diving Officer of the Watch, order "COMMENCE VENTILATING'.
...nduction (VH-2) and outboard ventilation exhaust valve (ABT 24)	1. Have the word passed on the 1MC 'COMMENCE VENTILATING, COMMENCE VENTILATING'.
... the outboard induction valve (VH-2). ...entilation exhaust valve switch in the OPEN position and hold ...the blower is running. (The sound of the blower can be heard ...se the switch to the AUTO position.	3. 'Report 'VENTILATING' to Diving Officer of the Watch.
...ntilation exhaust valve (ABT 25)	
...nduction (VH-2) is OPEN, start the main induction fan ...entilation exhaust (ABT 24) valve is OPEN, start the Low Pressure ...nd shift to FAST.	3. Report 'VENTILATING' to the Chief of the Watch.
	Order 'SECURE VENTILATING'.
... as necessary for snorkel mast operation.	1. Have the word passed over the 1MC, 'SECURE VENTILATING, SECURE VENTILATING'. 3. When report is received from the Chief of the Watch, report to the Officer of the Deck, 'SECURED VENTILATING, RECIRCULATING'.
...ure Blower is stopped, shut the outboard induction (VH-2) and ...ation exhaust valve switch in the SHUT position. ...-1) control switch to CLOSED, turn off electrode heaters. ...D' (or exceptions) to the Diving Officer of the Watch. ...n lowered, report, 'MAST LOWERED', to the Diving Officer	4. Report to the Diving Officer of the Watch, 'SECURED VENTILATING, RECIRCULATING' when reports are received.
...duction (VH-3) and inboard ventilation exhaust (ABT 25) valves. ...ard induction (VH-2) and outboard ventilation exhaust (ABT 24) ...e SHUT.	3. Report to the Chief of the Watch, 'SECURED VENTILATING'.
...ssure Blower. ...duction fan (Fan #1) ...p valves (ALP 239, 240, 244 and 245) in the pneumatic control	4. Report to the Chief of the Watch, 'SECURED VENTILATING, RECIRCULATING'.
...ion system for 'RECIRCULATING' in accordance with the ...eport to the Chief of the Watch.	

...ERGENCY VENTILATION MODE

... EMERGENCY VENTILATE THE COMPARTMENT WITH THE ...ORKEL', or, ... EMERGENCY VENTILATE THE COMPARTMENT WITH THE ...nts have reported ready, order, 'COMMENCE EMERGENCY ...CE SNORKELING', when using Diesel, or 'COMMENCE EMERGENCY ...ng Low Pressure Blower.	
...s for 'VENTILATE' if the Low Pressure Blower is used. ...s for 'SNORKEL' if the diesel engine is used.	1. Have appropriate word passed over the 1MC.
...ures for 'SNORKEL' or 'VENTILATE' as appropriate.	2. When all reports have been received, report to the Diving Officer, 'READY TO EMERGENCY VENTILATE THE COMPARTMENT WITH THE BLOWER (DIESEL)'.
...ures for 'SNORKEL' or 'VENTILATE' as appropriate.	
...ures for 'SNORKEL' or 'VENTILATE' as appropriate.	
...red and be ready to snorkel on short notice if the Low Pressure ...ures of the Snorkel Bill if the Diesel Engine is to be used. ...ing Spaces are rigged for 'SNORKEL' or 'VENTILATE' as appropriate.	3. If the diesel engine is to be used report to the OOD as soon as the diesel engine is lined up.
...on system in accordance with the compartment bils. ...nd powered telephones.	3. Report to Control when the compartment is rigged.

Table III-A-21 Snorkel Bill

GENERAL INFORMATION

a) When snorkeling for an extended period of time, the Officer of the Deck will normally order the CO_2 scrubbers, the $CO\text{-}H_2$ burners, and the oxygen bleed system secured. These equipments shall be restarted after snorkeling and secured in accordance with the ship's Air Revitalization Bill. If diesel exhaust enters the ship while snorkeling, both scrubbers and both burners should be started.

b) The controlling station for snorkeling is Control,

c) Compartments will be lined up in accordance with check-off lists

Personnel	Command Responsibilities / General Information	Actions (C&D Operations,
DOW		1. ORDER THE INDUCTION MAST RAISED WHEN
COW		1. OPEN THE INDUCTION MAST VENT VALVES MAST WHEN ORDERED BY THE DIVING OFFICER O 2. If icing conditions exist, place the electrode 3. When ordered, raise the snorkel mast. Ens opened vent valves ALP-256 and 257, to allow the vacuum in the induction piping, prior to raising 4. Report when snorkel mast indicates up. Dra 6. Check that the head valve OPEN light on the is above water. 7. Test the mast flooded indicator. 8. With the ship at snorkel depth, cycle head v utilizing test button and 'Manual Emergency Close of the Deck. 9. Order the bow compartment O_2 bleed secured
Auxiliaryman Of Watch Forward	Prepare to Snorkle	1. Open vent valves (ALP 256, 257) in the Mast without pulling a vacuum. 2. When ordered, drain the mast to the gravity (Induction Mast Flood and Drain Valve) to DRAIN and TD-53. 3. When mast is dry shut the vent valves and
Navigation Center Supervisor		1. Open the Head Valve air supply valves (ALP 2. Unlock the Outboard Induction alve (VH-2), 3. Open the Inboard Induction Valve (VH-3). 5. Standby to start main induction supply fan valve is opened.
Lee Helmsman		
Diesel Generator Watch		1. Line up the diesel engine for startup in acco Operating Procedures.
Aux. Of Watch Aft or Aux. Machinery Room No. 2 Upper Level Watch		1. Drain the area between the inboard and out opening drain valves (DSW-14 and DSW-37). Whe valve and secure the drain valves. 2. Line up damper D-3 and ventilation system in posted compartment check-off list. 3. Unlock the outboard engine exhaust valve and
EOW	Direct and supervise the Engineering Space watches in preparation for operations of the diesel engine and generators set in accordance with Engineering Department Operations Procedures and order atmosphere control equipment secured unless special circumstances dictate otherwise.	
Each Compartment Watch		1. Rig compartment for snorkel in accordance wi

GENERAL INFORMATION

for snorkeling is Control.

lined up in accordance with the posted compartment

● ROUTINELY THE SHIP SHALL PREPARE TO SNORKEL ABOVE 200 FEET BELOW SNORKEL DEPTH. ACN1/4

Actions (C&D Operations, Inspections, Recordings, Etc.)	Communication Responsibilities
CTION MAST RAISED WHEN AT SNORKEL DEPTH.	2. When satisfactory trim at snorkel depth is obtained and the Chief of the Watch has reported all stations ready to snorkel, report to the Officer of the Deck, 'READY TO SNORKEL'.
TION MAST VENT VALVES (ALP 268 AND RAISE THE INDUCTION BY THE DIVING OFFICER OF THE WATCH. ACN 1/4 s exist, place the electrode heater switches on the BCP at ON. ise the snorkel mast. Ensure the Auxiliaryman Forward has P-256 and 257, to allow the mast to raise without pulling a on piping, prior to raising the mast. rkel mast indicates up. Drain the mast to the gravity drain system. ead valve OPEN light on the BCP goes on when the head valve ded indicator. snorkel depth, cycle head valve and check operation of electrodes nd 'Manual Emergency Close' valve when ordered by the Officer mpartment O_2 bleed secured.	5. Receive report from Auxiliaryman Forward when mast is drained and the vent and drain valves are shut. 10. When all reports have been received and the above steps have been completed, report to the Diving Officer of the Watch, 'READY TO SNORKEL'.
(ALP 256, 257) in the Mast Blow Line to allow the mast to raise um. rain the mast to the gravity drain system by positioning TD-54 and Drain Valve to DRAIN and Opening drain valves TD-52 y shut the vent valves and drain valves.	4. Report to the Chief of the Watch, 'MAST IS DRY, VENT AND DRAIN VALVES SHUT'.
lve air supply valves (ALP 239, 240, 24[illegible]). ard Induction valve (VH-2), check i[illegible] position. d Induction Valve (VH-3). main induction supply fan (Fan #1) when the outboard induction	4. Report to the Chief of the Watch, 'OUTBOARD INDUCTION IN POWER INBOARD INDUCTION OPEN, NAVIGATION CENTER READY TO SNORKEL'.
	1. Man JA handset to receive reports from compartments for relay to the Chief of the Watch.
l engine for startup in accordance with Engineering Department	2. Report to Maneuvering, 'DIESEL LINED UP TO SNORKEL'.
etween the inboard and outboard engine exhaust valves by DSW-14 and DSW-37). When dry OPEN the inboard exhaust rain valves. -3 .. ventilation system in AMR #2 in accordance with the eck-off list. rd engine exhaust valve and check in POWER.	4. Report to Maneuvering, 'MACHINERY-2 LINED UP TO SNORKEL'.
	1. Report to Control, 'ENGINEERING SPACES READY TO SNORKEL'.
for snorkel in accordance with compartment check-off list.	2. When rigged report on JA circuit, '__________ COMPARTMENT READY TO SNORKEL'. 3. Man JA phones and keep phones manned until directed by Control to secure.

2

Personnel	Command Responsibilities / General Information	Actions (C&D Operations, Insp
OOD	*Table III-A-21 (Concluded)*	
DOW	Commence Snorkeling	1. Order the outboard induction opened. 2. Commence flooding approximately 8,000 pounds in
COW		1. When ordered, open the outboard induction valve
Navigation Center Supervisor		1. Start Main Induction Supply Fan (Fan #1) in Fast
Aux. of Watch Aft or Machinery Room #2 Upper Level Watch		1. Blow the exhaust line with air in accordance with Operating Procedure. 2. Watch the local pressure gage and continue blowi stabilizes, indicating a clear exhaust line. CAUTION: ENGINE STARTS.
Diesel Generator Watch		1. Check snorkel panel to ensure that the outboard exhaust valves are open. 2. Press safety circuit bypass button and start the di Engineering Department Operating Procedure.
EOW		2. When the diesel is reported ready for loading, it s otherwise directed by the Officer of the Deck.
Lee Helmsman		
OOD	Secure Snorkeling	
DOW		1. Supervise the snorkel shutdown. 2. Compensate the ship by pumping approximately 8,0 Tanks to sea.
COW		1. Press 'snorkel shutdown' button. Observe that th valve is shut. 2. Shut the outboard induction valve. 3. Turn head valve control switch to CLOSED. Turn 'STRAIGHT BOARD' to Diving Officer of the Watch. 4. L[illegible]ver the Snorkel Mast.
Navigation Center Supervisor		1. Shut the inboard induction valve (VH-3) and secur Fan, #1. 2. Lock shut the outboard induction valve (VH-2) whe 4. Shut the head valve control air supply valves (AL
Diesel Generator Watch		1. Secure the diesel engine in accordance with Engin Procedures. 2. Check shut the outboard engine exhaust valve. 3. Rig diesel engine and associated systems for norm accordance with Engineering Department Operating Proc Maneuvering, 'DIESEL SECURED'.
Auxiliaryman of Watch Aft, or Aux. Machinery Room No. 2 Upper Level Watch		1. Shut the inboard engine exhaust valve when the d 2. Lock shut the outboard engine exhaust valve after 3. Line up damper D-3 to Recirculate.
EOW		
Compartment Watches		

ns (C&D Operations, Inspections, Recordings, Etc.)	Communication Responsibilities
	The Officer of the Deck shall have the word passed twice over the 1MC, 'COMMENCE SNORKELING'. This order will initiate the following action:
uction opened. roximately 8,000 pounds into Depth Control Tank.	
e outboard induction valve.	2. When snorkel valve indication is correct report, 'NORMAL SNORKEL BOARD'. 3. When snorkel conditions are satisfactory, order the Lee Helmsman to direct all compartments to secure the phones.
Supply Fan (Fan #1) in Fast Speed.	
with air in accordance with Engineering Department ire gage and continue blowing until pressure drops and exhaust line. CAUTION: DO NOT SECURE BLOW UNTIL	3. Inform the Diesel Engine Watch that the mast is blown.
ensure that the outboard induction and inboard engine ass button and start the diesel engine in accordance with rating Procedure.	3. When engine has been started, report, 'DIESEL RUNNING' to the Engineering Officer of the Watch. 4. When the diesel is warmed up and the breaker control is in the 'CLOSE PERMISSIVE' position report, 'DIESEL READY FOR LOADING' to the EOOW.
orted ready for loading, it should be loaded unless fficer of the Deck.	1. When the diesel engine is running, report, 'SNORKELING' to the Officer of the Deck.
	1. When ordered by the Chief of the Watch, direct all compartments to secure their phones.
	The Officer of the Deck shall have the word passed over the 1MC, 'SECURE SNORKELING'.
shutdown. y pumping approximately 8,000 pounds from Depth Control	3. When report is received from the Chief of the Watch, report to the Officer of the Deck, 'SECURE FROM SNORKELING. RECIRCULATION'.
m' button. Observe that the outboard engine exhaust uction valve. l switch to CLOSED. Turn off electrode heaters. Report, Officer of the Watch. l.	5. Report, 'SNORKEL MAST IS DOWN' to the Officer of the Deck. 6. Report to the Diving Officer of the Watch, 'SECURED FROM SNORKEL' when the NAVCENTER, Operations Compartment, and Maneuvering have reported secure.
ction valve (VH-3) and secure the Main Induction Supply induction valve (VH-2) when it indicates shut. ntrol air supply valves (ALP 239, 240, 244 and 245).	3. Report, 'OUTBOARD INDUCTION VALVE SHUT AND LOCKED, INBOARD INDUCTION SHUT' to the Chief of the Watch.
ne in accordance with Engineering Department Operating rd engine exhaust valve. associated systems for normal submerged running in Department Operating Procedures. Report to RED'.	
he exhaust valve when the diesel engine is secured. l engine exhaust valve after it indicates SHUT. Recirculate.	4. Report, 'OUTBOARD INDUCTION VALVE SHUT AND LOCKED, INBOARD ENGINE EXHAUST VALVE SHUT, RECIRCULATING'.
	1. When all reports are received, report to Control, 'ENGINEERING SPACES SECURED FROM SNORKEL'.
	Compartment Watches shall report when rigged for snorkel as follows:

WATCH	CIRCUIT	REPORT TO
Torpedo Room Watch	JA	Control Center
Duty Cook/Messman	JA	Control Center
Missile Control Center Watch	JA	Control Center
Launch Operations Station Watch	JA	Control Center
Auxiliary Machinery Room #1 Watch	JA	Maneuvering Room
Auxiliaryman Aft	2JV	Maneuvering Room
Diesel Generator Watch	2JV	Maneuvering Room
Engine Room Supervisor	2JV	Maneuvering Room
Electric Plant Control Panel Watch	2JV	EOOW
Engineering Officer of the Watch	JA	Control Center

2

Table III-A-22 Battle Bill

GENERAL INFORMATION

a) The primary mission of the ship is to deliver, when directed, ballistic missile attacks against assigned targets. All other assigned tasks are secondary. The Battle Bill is designed to provide the most effective organization for conducting ballistic missile attacks with concurrent readiness to employ the torpedo battery for self defense. In addition, it provides the most effective organization for delivering a torpedo attack if that function becomes primary.

b) The Battle Bill will be implemented for all missile launch operations, actual or simulated and for torpedo firing operations, conducted concurrently with or separately from missile attack operations.

c) The Battle Bill may be implemented when conditions of special hazard to the ship exist or are foreseen.

d) Battle Organization. When the Battle Bill is implemented the following stations will be manned by personnel designated in the Watch, Quarter and Station Bill.

STATION	COMMUNICATION CIRCUIT MANNED
a. Ship Control Party	
(1) Control Room	
Officer of the Deck	
Attack Coordinator	1MC/61JS
Diving Officer	
Chief of the Watch	
BCP Missile Compensation Panel Operator	1MC
Auxiliaryman of the Watch Forward	
Auxiliary Electrician Forward	
Helmsman	
Planesman	
Lee Helmsman	
ECM/Radar Operator	
Periscope Assistant	
Sonar Status Board Operator	61JS
Periscope Camera/Tape Recorder Operator/Logs	
Telephone Talker	JA
Messenger (Lee Helm)	
Quartermaster of the Watch	
(2) Radio Room	
Communications Officer (May be in Radio or Attack Center)	
Communications Supervisor	
Radio Operators (3)	
(3) Maneuvering Room	
Engineering Officer of the Watch	
Reactor Plant Control Panel Operator	
Electrical Plant Control Panel Operator	
Steam Plant Control Panel Operator	
Telephone Talker	2JV
Bell Recorder	JA

STATION	COMM
(4) Engine Room	
Engineering Watch Supervisor	
Engine Room Supervisor	
Engine Room Upper Level Watch	
Engine Room Upper Level Watch (Phone Talker)	
Engine Room Lower Level Watch	
Engine Room Lower Level Watch (Phone Talker)	
Emergency Propulsion Motor Operator	
Auxiliaryman of the Watch Aft	
Engine Room Aft Watch	
Steam Plant Gauge Board	
Engineering Lab Technicians	
Auxiliary Electrician Aft	
(5) Auxiliary Machinery Room No. 1	
AMR #1 Watch	
Telephone Talker	
*AMR #1 Lower Level (Hovering) Watch	
(6) Auxiliary Machinery Room No. 2	
Upper Level Watch	
Upper Level Telephone Talker	
Lower Level Watch	
Feed System Gauge Board Watch	
(7) Reactor Compartment Tunnel	
Sight Glass Watch	
b. Navigation Party, Navigation Center	
Navigator	
Navigation Electronics Chief	
Navigation Console Operator	
Loran C Operator	
BQN-3 Fathometer Operator	
SINS Technician	
Telephone Talker	
Navigation Center Technician	
c. Missile Party	
(1) Missile Control Center	
*Missile Control Officer	
Fire Control Supervisor	
ITOP/Recorder	
*Computer Group Operator	
*Computer Group Operator	
*Missile Test and Readiness Equipment #7 Operator	
*Missile Test and Readiness Equipment #6 Operator	

Note: * Not manned for Battle Stations Tor

** Not manned for Battle Stations Mi

Personnel	Command Responsibilities / General Information	Actions (C&D Operations, Inspecti
OOD		2. Sound the General Alarm. 4. Coordinate the quiet and expeditious manning o the Commanding Officer when manned.

GENERAL INFORMATION

	COMMUNICATION CIRCUIT MANNED
Supervisor	
visor	
Level Watch	
Level Watch (Phone Talker)	2JV
Level Watch	
Level Watch (Phone Talker)	2JV
Motor Operator	JA
Watch Aft	
tch	
Board	
chnicians	
n Aft	
y Room No. 1	
	2JV
(Hovering) Watch	JA
y Room No. 2	
ne Talker	2JV
Board Watch	2JV
nt Tunnel	
	2JV
ation Center	
	10JC
ics Chief	
Operator	
Operator	
	10JC/X43J
Technician	
ter	
cer	10JC/X43J
visor	10JC/X43J
	X43J
erator	X43J
erator	X43J
adiness Equipment #7 Operator	X43J
adiness Equipment #6 Operator	X43J

Not manned for Battle Stations Torpedo

Not manned for Battle Stations Missile

STATION	COMMUNICATION CIRCUIT MANNED
(5) Missile Compartment	
*Missile Launch Officer	10JC
Missile Launch Supervisor	X43J
Launcher Control Panel #1 Operator	
*Launcher Control Panel #2 Operator	
*Upper Level Missile Control Team #1 (3)	X43J
Upper Level Missile Control Team #2 (3)	X43J
*Lower Level Missile Control Team #1 (2)	X43J
*Lower Level Missile Control Team #2 (2)	X43J
*Optical Alignment Group Operator	X43J
*Optical Alignment Group Operator Assistant	
*Fire Control Switchboard Operator	X43J
Middle Level Roving Watch Phone Talker	JA
d. Torpedo Party	
(1) Attack Center	
MK 113 Analyzer Operator	
MK 113 Position Keeper Operator	61JS
MK 113 Firing Panel Operator	8JP
MK 113 Torpedo Control Console (MK 48 only)	
Fire Control Co-ordinator	61JS
Plot Co-ordinator	61JS
Time Bearing Plotter	
Time Bearing Evaluator	
Geographic Plot Evaluator	
Geographic Plotter	
Time Range Plotter	
Contact Evaluation Plotter	
Bearing Recorder	61JS
(2) Torpedo Room	
**Torpedo Officer	
Torpedo Launch Supervisor	
**Torpedo Tube Operator (1)	
Torpedo Room Phone Talker	JA
**Reload Party Supervisor/Signal Ejector Operator	
**Reload Party (4)	
Torpedo Fire Control Phone Talker	8JP
(3) Sonar Room	
Sonar Supervisor	61JS
BQR-7 Operator	
BQR-2 Operator	
BQS-4 Operator	
BQQ-3 Operator	
e. Damage Control Party	
(1) Forward Party, Crew's Mess	
Petty Officer in Charge	
Telephone Talker	JA
Medical Officer	
Ratings Assigned	
(2) After Party, Engine Room	
Petty Officer in Charge	
Telephone Talker	JA
Hospital Corpsman	
Ratings Assigned	

Actions (C&D Operations, Inspections, Recordings, Etc.)	Communication Responsibilities
neral Alarm. e quiet and expeditious manning of Battle Stations and report to fficer when manned.	To implement the Battle Bill the Officer of the Deck, when directed or when required for ship's safety, shall: 1. Pass the word on the 1MC, 'MAN BATTLE STATIONS, MISSILE (or TORPEDO)'. 3. Pass the word on the 1MC, 'MAN BATTLE STATIONS, MISSILE (or TORPEDO)'.

2

Table III-A-22 (Continued)

Personnel	Command Responsibilities / General Information	Actions (C&D Operations, Ins
OOD		When implementing the Battle Bill for torpe launching and until relieved of the CONN by the the Deck shall: 1. Maneuver the ship to avoid detection, riggin Condition II required. 2. Ensure the tracking of ship contacts and pro Sonar Coordinators.
Attack Coordinator		1. Coordinate the use of sonar search equipmen 2. Direct the preparation of the torpedo battery Designate tube firing order and ejection meth Select optimum modes for the torpedo to be functions be set in the firing panel. When directed, order tubes made ready. When directed, order outer door opened on When directed to commence firing: Order, 'STAND BY TUBE______. Order, 'MATCH BEARING AND SHOOT' if Determine optimum deflection angle and o TARGET SPEED ______, MATCH BEARING AND
Fire Control Position Keeper Operator	2. Supervise the operation of the Firing Panel.	1. Operate the Position Keeper to determine and 3. When directed to, 'MATCH BEARING AND SH into position keeper and report 'SET' to Weapons C
Fire Control Analyzer Operation		Determine optimum deflection angles and advi
Sonar Plot Coordinator		1. Supervise the sonar plotting party to obtain range, bearing rate, range rate, course, speed an 2. Provide target information to position Keeper
Firing Panel Operator		1. Make settings as directed by the Attack Coor 2. Man 8JP phone circuit between Attack Cente preparation and firing of torpedo tubes. 3. Ensure correct settings made on torpedo thr Monitor Panel Operator. 4. Upon receiving 'TUBE _____ READY IN ALL supervisor. Ensure linear and angular spread knobs Position Firing Tube Select Swithch to d Check firing interlocks closed light 'ON'. Position firing key to 'STAND BY'. Check firing interlocks closed light is fla 7. When directed to 'MATCH BEARING AND SH tube when: Generated or ordered gyro angle is set in Position Keeper Operator reports, 'SET'.
Torpedo Launch Operator		1. When directed make ready designated tubes Department Operating Procedures. 2. Supervise the operation of the MK 19 Weapo 3. Direct and supervise torpedo reload when or
Weapons Monitor Panel Operator		1. When directed by the Firing Panel Operator Turn on Tube Warm-up Switch for desig Monitor Error and Limit indications and errors, if any, to Firing Panel Operator and Monitor 'FLOOD TUBE, 'OPEN DOOR', 'S indications and orders to Torpedo Launch Sup When 'STAND BY' indicator is lighted a reports, the 8JP Phone Talker will report 'ST If tube fails to fire or if 'NEXT TO FIRE' reason, inform Firing Panel Operator and c

...ions (C&D Operations, Inspections, Recordings, Etc.)	Communication Responsibilities
...ng the Battle Bill for torpedo firing, not concurrent with Missile ...lieved of the CONN by the Commanding Officer, the Officer of ...p to avoid detection, rigging for appropriate Silent Running ...ing of ship contacts and provide target information to Attack and	
...e of sonar search equipment and fire control party tracking. ...ation of the torpedo battery for firing as follows: ...ring order and ejection method. ...odes for the torpedo to be employed and direct that necessary ...e firing panel. ...rder tubes made ready. ...rder outer door opened on first tube to be fired. ... commence firing: ... BY TUBE______. ... BEARING AND SHOOT' if firing with generated gyro angle, or, ...mum deflection angle and order 'SET AOB ______, RANGE______, ____, MATCH BEARING AND SHOOT'.	
...ion Keeper to determine and maintain the best target solution. ... 'MATCH BEARING AND SHOOT,' set accurate sonar bearing ...d report 'SET' to Weapons Order Generator Operator.	
...m deflection angles and advise Attack Coordinator.	
...nar plotting party to obtain best solution of target bearing, ...range rate, course, speed and target zigs. ...formation to position Keeper Operator and Attack Coordinator.	
... directed by the Attack Coordinator. ...circuit between Attack Center and Torpedo Room, for the ... of torpedo tubes. ...ettings made on torpedo through coordination with the Weapon ...r. ...TUBE _____ READY IN ALL RESPECTS' from the Torpedo Launch. ... and angular spread knobs on zero unless spread is desired. ... Tube Select Swithch to desired tube. ...nterlocks closed light 'ON'. ... key to 'STAND BY'. ...nterlocks closed light is flashing. ... 'MATCH BEARING AND SHOOT', close firing key on designated ...ordered gyro angle is set in the torpedo. ...r Operator reports, 'SET'.	4. Ensure correct ballistic settings for tube loaded torpedoes set in the MK113 Fire Control System. 5. When directed, order Torpedo Room to: 'MAKE READY TUBE(S) ________.' 'FLOOD TUBE _______.' 'OPEN THE OUTER DOOR ON TUBE ________.' 'STAND BY TUBE ________.'
...ke ready designated tubes in accordance with Weapons ...rocedures. ...eration of the MK 19 Weapons Monitor Panel. ...vise torpedo reload when ordered.	
... the Firing Panel Operator to 'MAKE READY' a specific tube. ... Warm-up Switch for designated tube. ... and Limit indications and report function and magnitude of ...Firing Panel Operator and Torpedo Launch Supervisor. ...D TUBE, 'OPEN DOOR', 'STAND BY', and 'FIRE', lights, relaying ...rs to Torpedo Launch Supervisor. ... BY' indicator is lighted and the Torpedo Launch Supervisor so ...hone Talker will report 'STANDING BY TUBE ________. ... fire or if 'NEXT TO FIRE' sequencing does not occur for any ...ing Panel Operator and depress 'TUBE FIRED' button when ordered.	2

MISSILE LAUNCHING

Table III-A-22 (Concluded)

Personnel	Command Responsibilities / General Information	Actions (C&D Operations, Inspection
CO		1. Assume the CONN. 3. Direct the Diving Officer to 'COMMENCE HOVE 4. Maintain direct control of missile launching.
Attack Coordinator		1. Advise the Commanding Officer concerning the 2. Assist the Commanding Officer in the direct c informing him of scheduled times available for mis 3. Coordinate missile launching procedures, ens The selection and resetting of MASTER SINS. The best fire order sequence, including revisi considering target priorities. The passing of timely information to the Missi problems or other difficulties affecting launching. 4. Supervise the preparation of post-launch radio 5. Direct Urgent damage control measures. 6. As practicable, man the 10JC circuit to the p
OOD		1. Maneuver the ship to proceed to missile launch 2. Slow the ship as necessary to obtain minimum Diving Officer to 'PREPARE TO HOVER'. 3. Ensure the tracking of ship contacts and provi and Sonar Coordinators.
Diving Officer		1. Obtain a minimum speed trim at missile launc 4. When directed to commence hovering, order th opened and employ the depth control equipment to m launch depth. Keep the Commanding Officer advise maintaining depth. 5. When actual missile launches are to be conduc Compensating Panel Operator to 'LINE UP THE MISS
Fire Control Position Keeper Operator	1. Supervise the readiness for implementing torprdo firing procedures, ensuring: The best usage of sonar search equipment. The designation of ship contacts and their tracking. 2. Keep the (Coordinator appropriately informed.	
COW		1. When ordered to prepare to hover, line up hov 2. When directed, open the hovering system sea v 3. Operate trim system as directed by the Diving
Navigator		1. Determine the action required within the Navig best position and heading data to the missile fire co 3. With the approval of the Attack Coordinator an Officer advised, initiate required action to correct p
Fire Control Supervisor	1. Initiate steps to set CONDITION 1SQ utilizing the Weapons Procedures of NAVORD OD 30583.	
Missile Control Officer		1. Coordinate the quiet, expeditious manning of Party personnel and report Missile Party manned to 2. When directed to set CONDITION 1SQ, supervi ordered condition within the missile and fire contro with Weapons Procedures of NAVORD OD 30583. 3. Report any difficulty encountered and recomme
DCP Missile Compensating Panel Operator		2. When directed by the Diving Officer, for actua the Missile Compensating System in accordance wit NAVORD OL 30583.

TORPEDO FIRING

CO I		1. Assume the CONN. 2. Maneuver the ship to attain optimum firing p 3. Direct tubes made ready for firing. 4. Direct torpedo tube outer door opened. 5. Direct firing of torpedoes.

MISSILE LAUNCHING

...ions (C&D Operations, Inspections, Recordings, Etc.)	Communication Responsibilities
CONN. ...ving Officer to 'COMMENCE HOVERING'. ...nct control of missile launching.	2. Have the word passed on the 10JC, 'SET CONDITION 1SQ,' (FOR WSRT).
...ommanding Officer concerning the missile launch directive. ...ommanding Officer in the direct control of missile launching, ...scheduled times available for missile launching. ...issile launching procedures, ensuring: ... and resetting of MASTER SINS. ... order sequence, including revisions for casualties and ... priorities. ...of timely information to the Missile Party concerning ship control ... difficulties affecting launching. ...e preparation of post-launch radio reports. ...t damage control measures. ...le, man the 10JC circuit to the periscope center.	
...e ship to proceed to missile launch depth and optimum heading. ...ip as necessary to obtain minimum speed trim and direct the ...'PREPARE TO HOVER'. ...tracking of ship contacts and provide target information to Attack ...inators.	
...inimum speed trim at missile launch depth. ...ed to commence hovering, order the hovering system sea valve ...y the depth control equipment to maintain the ship at missile ...Keep the Commanding Officer advised of difficulties encountered in ...n. ...l missile launches are to be conducted, direct the BCP Missile ...nel Operator to 'LINE UP THE MISSILE COMPENSATING SYSTEM'.	2. ~~When directed to prepare to hover, order the Chief of the Watch to 'PREPARE TO HOVER'.~~ 3. When in all respects ready, report 'READY TO HOVER' to the Commanding Officer.
...ed to prepare to hover, line up hovering system for operation. ...ed, open the hovering system sea valve and commence hovering. ... system as directed by the Diving Officer.	
...e action required within the Navigation subsystem to provide the ... heading data to the missile fire control system. ...roval of the Attack Coordinator and keeping the Missile Control ...initiate required action to correct position and heading data.	2. Advise the Attack Coordinator of system status and recommended action. 4. Report, 'NAVIGATION SYSTEM READY' on the ACIP by 10JC phones to the attack center.
...e quiet, expeditious manning of Battle Stations by Missile ...and report Missile Party manned to the periscope center. ...ed to set CONDITION 1SQ, supervise the expeditious setting of the ... within the missile and fire control subsystems in accordance ...cedures of NAVORD OD 30583. ...ifficulty encountered and recommended corrective action.	
...ed by the Diving Officer, for actual launch operations, operate ...ensating System in accordance with Weapons Procedures of ...B.	1. Test communications with Launcher and report 'MANNED AND READY' to the Chief of the Watch. 3. Report difficulties encountered in compensating system operation to the Diving Officer and the Missile Launch Supervisor.

TORPEDO FIRING

... CONN. ...e ship to attain optimum firing position. ... made ready for firing. ...e tube outer door opened. ... of torpedoes.	

2

Table III-A-23 General Emergency Bill

GENERAL INFORMATION

a) In general, emergencies or casualties shall be casualties shall be categorized under the following types:

1. General Emergency - Emergency Ship recovery, Fire, high radiation in torpedo room, toxic gas, passive defense, torpedo emergency, major primary coolant leak, high radiation in engineering spaces.

2. Collision/Flooding Emergency - Collision is imminent, has occurred or a flooding casualty has occurred.

3. Power Plant Emergency - Major steam leak.

4. Missile Emergency - A potential or actual major casualty to a missile or related system which endangers personnel or hazards the ship or vital equipment.

b) Ship or Department Bills and Casualty Procedures shall set forth the crew action to be taken undereach of the aforementioned emergencies. In addition, a compartment check-off shall be posted in each compartment stating the action to be taken in that compartment in the event of each emergency and in accordance with the procedures and guidance given in the SSORM for that bill.

The Officer charged with the responsibility for the particular emergency bill is responsible for maintaining the corresponding compartment check-offs.

c) The general concept of treating emergencies is to immediately take those actions which will enhance the ability of the ship to minimize the effects of the emergency. Actions which are common to all emergencies include establishing communications, getting sufficient qualified people to the scene, and securing non-essential evolutions, particularly those which are potentially hazardous and could therefore compound the casualty. The emergency bills have been written as though the ship is submerged at the time the emergency occurs. If the ship is actually surfaced certain steps, such as those pertaining to depth control, are obviously omitted.

d) It is important to remember that a 'standard' s[illegible] emergency. Actual emergencies are unpredictable and u[illegible] unexpected and unplanned for element. The emergency [illegible] the problem and minimize the probability of compoundin[illegible] the emergency successfully requires the exercise of ju[illegible] coordinated efforts in and intelligent manner.

e) Alarms.

The following alarms shall be used to signal the [illegible]

Alarm	Control Station	Identif[illegible] Contact[illegible] Shape [illegible] Lever A[illegible]
Collision Alarm	(Various locations)	Siren Red sta[illegible]
Missile Emergency	Launcher	Fast Ju[illegible] (Orange[illegible] shaped[illegible]
General Alarm	Control Center (2)	Gong T[illegible] (Yellow[illegible] Shaped[illegible]
Power Plant Emergency Alarm	Maneuvering Room Control Center	Slow Ju[illegible] (Pink T[illegible]

Personnel	Command Responsibilities / General Information	Actions (C&D Operations, I[illegible]
OOD	6. When relieved of the Conn by the Commanding Officer act as assistant to the Commanding Officer.	2. Issue ship control orders as necessary to [illegible] 4. In case of a Propulsion Plant Casualty, r[illegible] to safely control the ship. 5. If submerged below 120 feet proceed to 12[illegible] Be ready to proceed to snorkel depth or surface e[illegible] emergency is such that snorkeling or ventilating [illegible]
DOW	4. Be prepared to surface or go deep when ordered.	1. Immediately take appropriate action as ne[illegible] and trim angle. 2. Secure snorkeling and ventilating. 3. Shut outboard and inboard inductions and [illegible] securing SNORKELING/VENTILATION.
COW	2. Supervise handling of the emergency from Control until relieved by an officer.	1. Ensure JA phones are manned in Control [illegible] to main the phones.
EOOW		Take charge of the emergency and supervise [illegible] of the Engineer Officer. (Due to the location of t[illegible] original action to combat the emergency shall be [illegible] engineering spaces). Request Control to send the Damage Control [illegible] if additional manpower is needed to combat the ca[illegible] For other plant casualties such as a reactor [illegible] EOOW shall carry out the applicable Engineering C[illegible] Control via the 7MC of the casualty and of the li[illegible] 2. For any shipboard emergency: Secure the battery charge if in progress. Secure the diesel engine. Consideration mu[illegible] distribution lineup. Shut the outboard and inboard diesel exhau[illegible] Place the electrical plant in the most secure [illegible] Reactor Plant Manual.
Executive Officer		1. Proceed to the scene of the casualty to b[illegible] the emergency.
Engineering Officer		1. If the casualty is in the Engineering Spa[illegible] 2. If the casualty is in any other space pro[illegible] JA phones and direct the overall operation of shi[illegible]

GENERAL INFORMATION

remember that a 'standard' solution is not possible for an [illegible]gencies are unpredictable and usually introduce some [illegible] for element. The emergency bills are designed to localize [illegible] the probability of compounding the problem. Combatting [illegible]lly requires the exercise of judgement and the application of [illegible] intelligent manner.

[illegible]rms shall be used to signal the indicated emergency:

Control Station	Identification Contact box color Shape of contactor Lever Arm	Emergency Used for
(Various locations)	Siren Red star shaped	Collision or Flooding
Launcher	Fast Jump Tone (Orange, round shaped)	Missile Emergency
Control Center (2)	Gong Tone (Yellow, round Shaped)	Fire, General Emergency, Passive Defensive, Toxic Gas. Battle Stations
Maneuvering Room Control Center	Slow Jump Tone (Pink Tee Shaped)	Major Steam Leak

B Damage Control Party Organization.

1. Information. The control of damage on a submarine is always an all hands evolution. It is of the utmost importance that all personnel in the vicinity of an emergency take immediate action to bring it under control and minimize damage. Additionally, in order to ensure the immediate presence of wupport personnel whose knowledge and training will be valuable in the control of damage, two highly trained damage control parties will be organized

2. Organization. The Damage Control Party shall be so organized that any emergency can be effectively combatted by the personnel designated. When at Battle Stations or when any emergency alarm is sounded, the designated members of the damage control parties will proceed as follows: At Battle Stations, the Forward Damage Control Party will muster in the crew's dinette, and the After Damage Control Party will muster in AMR #2.

Actions (C&D Operations, Inspections, Recordings, Etc.)	Communication Responsibilities
[illegible] control orders as necessary to minimize the effect of the emergency. [illegible] a Propulsion Plant Casualty, reduce speed to the minimum required [illegible] ship. [illegible]ed below 120 feet proceed to 120 feet changing speed as appropriate. [illegible] to snorkel depth or surface expeditiously if the nature of the [illegible] that snorkeling or ventilating will be necessary.	1. Have the nature and location of the emergency passed once over the 1MC than sound the appropriate alarm (for all emergencies except Missile Emergency), and then pass the nature and location of the emergency once over the 1MC. 3. Notify ships in the vicinity of the emergency, as necessary.
[illegible]y take appropriate action as necessary to maintain ordered depth [illegible]rkeling and ventilating. [illegible]ard and inboard inductions and ventilation exhaust valves after [illegible]ING/VENTILATION.	
[illegible] phones are manned in Control until the designated officer arrives [illegible]	
[illegible] the emergency and supervise control of damage until the arrival [illegible]ficer: (Due to the location of the Engineering Compartments, the [illegible] combat the emergency shall be taken by the men on watch in the [illegible] [illegible]rol to send the Damage Control Party into the affected compartment [illegible]wer is needed to combat the casualty. [illegible]nt casualties such as a reactor scram, loss of lube oil, etc., the [illegible] out the applicable Engineering Casualty Procedures and shall notify [illegible]MC of the casualty and of the limitation imposed on the power plant. [illegible]hipboard emergency: [illegible]attery charge if in progress. [illegible]iesel engine. Consideration must be given to the existing electrical [illegible] [illegible]board and inboard diesel exhaust valves when the diesel is secured [illegible]ctrical plant in the most secure lineup in accordance with the [illegible]ual.	1. For emergencies in Engineering Compartments: If the initial report is received in Maneuvering from one of the engineering watch stations, the EOOW first repeats the information once on the 2MC then relays the emergency report to Control via the 7MC or 21MC. The EOOW should decide on the basis of the circumstances whether urgency demands that he initiate activation of either the Collision Alarm or the power plant casualty alarm. (i.e. flooding or major steam leak). If so, the EOOW should announce the nature of the casualty once over the 1MC before activating the alarm in accordance with standard procedures. When a locally activated alarm cycle has ceased, Control should again pass the word on the nature of the casualty over the 1MC to ensure that the entire ship has been informed. Advise Control on requirements for Emergency Ventilation, pumping, etc., when appropriate.
[illegible] the scene of the casualty to be in charge of and coordinate combating	2. Keep the Commanding Officer and Officer of the Deck informed of all major developments.
[illegible]ualty is in the Engineering Spaces proceed to the scene. [illegible]ualty is in any other space proceed to the Control Room, man the [illegible]ect the overall operation of ships equipment to best control the emergency.	

Table III-A-23 (Concluded)

Personnel	Command Responsibilities / General Information	Actions (C&D Operations,
Weapons Officer		1. Proceed to the Missile Compartment/Tr... the Deck of any emergency action required in t... 2. The Assistant Weapons Officer shall as...
Medical Officer		1. Proceed to the Crew's Mess and keep t... Conditions injurious to personnel. When indic... will keep informed of the status of the atmosph... make recommendations to the Commanding Offic... Air Breatheing (EAB) masks. 2. Provide for the treatment of injured pe...
Electrical Officer		1. Proceed to the scene and assist the Ex... emergency. 2. Insure that effective communications a... emergency and Control. 3. If the Electrical Officer is on watch the... the Main Propulsion Assistant.
Navigator		1. Proceed to the Control Center and man... for the Engineer Officer/Damage Control Assista...
Damage Control Assistant		3. Direct the shutting of watertight doors, ... use of EAB masks, etc. 4. Direct the operation of the ship's venti... of smoke or toxic gas is minimized. 5. Insure that the Commanding Officer an... of all major developments. 6. If the emergency is in other than the ... scene and assist the Executive Officer.
All Officers All Hands		1. All officers not specifically assigned du... Control Party Staging areas or to appropriate d... affected by the emergency, take charge of emer... assistance. During casualties/emergencies in t... EOOW will proceed to the Control Cneter and m... Commanding Officer and Officer of the Deck. 2. Following the sounding of any emergen... immediately perform the following actions and f... compartment bill for that emergency: Shut all bulkhead flappers. Secure compartment recirculation blowers... MCC, Engine Room, and AMR#2 fans unless th... particular spaces. Secure bleeding oxygen into the ship. Shut all deck hatches, including lower ... Watertight doors: 1. COLLISION OR FLOODING - Shut and ... hatches immediately. 2. ALL OTHER EMERGENCIES - Watertight ... the location and extent of the casualty is deter... to route the Damage Control Party to the scen... present. 3. The senior man in each compartment ... is most important that the senior man on the ... fact that he is in charge known to all others ... affected compartment shall evacuate all unnece... powered phones are manned at the scene as ... each unaffected compartment is responsible for ... toward the scene of the casualty as prescribed ...

Actions (C&D Operations, Inspections, Recordings, Etc.)	Communication Responsibilities
he Missile Compartment/Tropedo Room and advise the Officer of gency action required in that compartment. t Weapons Officer shall assist the Weapons Officer.	
he Crew's Mess and keep the Commanding Officer informed of to personnel. When indicated, the Medical Officer or Corpsman the status of the atmosphere in the affected compartment and ns to the Commanding Officer concerning the use of Emergency masks. the treatment of injured personnel.	
he scene and assist the Executive Officer in combatting the effective communications are established [illegible] scne of the rol. ical Officer is on watch the above duties [illegible] be performed by Assistant.	
he Control Center and man the JA [illegible]nes to act as a back-up cer/Damage Control Assistant in Control.	
hutting of watertight doors, isolation of equipment or systems, etc. peration of the ship's ventilation system such that the spreading is minimized. the Commanding Officer and the Officer of the Deck are informed ents. gency is in other than the Engineering Spaces, proceed to the Executive Officer.	1. If the emergency is in the Engineering Spaces proceed to the Control Center, man the JA phones and direct the overall operation of ship's equipment to best control the emergency. 2. Keep the Commanding Officer informed of all significant developments and suspected or anticipated damage to the ship's systems.
not specifically assigned duties herein shall proceed to the Damage g areas or to appropriate departmental spaces which may be gency, take charge of emergency action, and render all possible casualties/emergencies in the Engineering Spaces a qualified the Control Center and monitor the 2JV to assist the r and Officer of the Deck. he sounding of any emergency alarm, ALL HANDS shall the following actions and then follow the provisions of the that emergency: ead flappers. ment recirculation blowers and precipitons except for NavCenter and AMR#2 fans unless the casualty is in one of those g oxygen into the ship. hatches, including lower bridge hatch. rs: OR FLOODING - Shut and dog all watertight doors and deck . EMERGENCIES - Watertight doors will be placed on the latch until ent of the casualty is determined. Doors may then be opened Control Party to the scene on the orders from senior man man in each compartment is in charge of that compartment. It hat the senior man on the scene make both his presence and the harge known to all others on the scene. The senior man in the t shall evacuate all unnecessary personnel and ensure sound manned at the scene as soon as possible. The senior man in partment is responsible for moving damage control equipment the casualty as prescribed and required.	1. The first and primary duty of the man discovering any casualty is to inform the appropriate control station - Control Center, Maneuvering Room, or Launcher - of the emergency and location via voice, MC, or sound powered phone. He must also spread the alarm by word of mouth in the affected compartment. Man designated phone circuit in the below listed locations. Maintain silence on the circuit except when originating information concerning the emergency. All stations shall report rigged for emergency only when ordered by the controlling station. Ensure that phones are manned by personnel qualified in accordance with the Submarine Interior Communications Manual. STATION — CIRCUIT — CONTROLLING STATION Torpedo Room — JA — Control Center Control Center — JA — Control Center Navigation Center — JA — Control Center Crew's Mess — JA — Control Center Crew's Living Space — JA — Control Center Missile Control Center — JA — Control Center Launch Operations Station — JA — Control Center Auxiliary Machinery Room #1 — 2JV — Maneuvering Room Auxiliary Machinery Room #2 — 2JV — Maneuvering Room Engine Room Upper Level — 2JV — Maneuvering Room Maneuvering Room — 2JV / JA — Maneuvering Room / Control Center Maneuvering shall report to the Control Center via JA phone for the Engineering Compartments.

B. TECHNOLOGY ANALYSES

1. Design Approach

Using current submarine design concepts and approaches, we determined basic equipment and crew functions required for its operation. Current systems/functions (referred to as elements) and crew members were grouped within 10 subsystems in order to aid in the systems analysis. Reorganization of watchstander functions was sometimes necessary. Table III-B-1 illustrates the grouping of the major elements within the 10 subsystems. Table III-B-2 illustrates the grouping of the normal underway watchstanders within the 10 subsystems. It is acknowledged that there must be some redistribution of watchstander duties along with any increase in mechanization and decrease in available watchstanders.

Figure III-B-1 shows a flow diagram to illustrate the basic approach applied to optimize the operation of the elements of each subsystem. This design approach was applied to individual subsystem elements to independently predict each subsystem's contribution to integrated ship operation.

The design approach, developed from our functional analysis of current submarines, was used to determine what criteria are important to the design and utilization of submarines. These "selection criteria" became an input to a matrix to determine the optimum design of the new generation submarine.

The functional analysis of the baseline submarine further disclosed that a vast amount of system control was performed manually. Our aerospace experience has shown that mechanization of mundane tasks improves operation and increases system efficiency.

2. Selection Criteria

The Selection Criteria were developed to enumerate those factors essential to submarine design and operation. We have strived to pick those criteria that can best be used to evaluate the effect of individual element change on the impact of submarine operation. Five primary selection criteria were defined: (1) decreased cost; (2) increased availability; (3) reduced crew size; (4) increased survivability; and (5) increased operability. These five selection criteria and the subfactors defining the criteria are shown in Table III-B-3.

Table III-B-1 Elements Grouping Within Subsystems

SHIP CONTROL SUBSYSTEM ELEMENTS

1. Submerging
2. Normal Surfacing
3. Emergency Surfacing
4. Alternate Surfacing (low pressure blow)
5. Trim and Buoyancy
6. Main Drain System
7. Auxiliary Drain System
8. Hovering Capability
9. Steering Control
10. Depth Control
11. Depth Sensing
12. Rig for Dive/Surface
13. Propulsion Mode
14. Propulsion Speed
15. Casualty Actions

ENGINEERING SUBSYSTEM ELEMENTS

1. Steam Generator Water Level Control
2. High Pressure Drain System Control
3. Chemical Sampling and Analysis
4. Auxiliary Fresh Water System Control
5. Makeup Feed Control
6. Main Feed System Control
7. Auxiliary Steam Control
8. Sea Water Cooling Control
9. Turbine Gland Seal
10. Condensate System Control
11. Hot Well Level Control
12. Low Pressure Drain System Control
13. Air Ejector Control
14. Main Steam System Control

ENGINEERING SUBSYSTEM ELEMENTS (Continued)

15. Fresh Water Drain System Control
16. Main Propulsion Turbines
17. Clutch Control
18. Emergency Propulsion Motor Control
19. Shaft Seal
20. Lube Oil (Main, Shaft, SSTG)
21. Ship Service Turbine Generator
22. Ship Service Motor Generator Control
23. Diesel Engine Control
24. Diesel Generator Control
25. Battery Monitoring
26. Main Electrical Distribution Control
27. Secondary Propulsion Motor Control
28. Turbine Jacking Gears
29. Lube Oil Transfer
30. Casualty Actions

AUXILIARY SUBSYSTEM ELEMENTS

1. Air Conditioning
2. High Pressure Air Compressors
3. Hydraulic Plant Control
4. Refrigeration Plant
5. High Pressure Air System
6. Low Pressure Air System
7. Evaporator Control
8. Distilling Unit Control
9. Air Conditioning Cooling Water
10. Control Air Compressors

Table III-B-1 (Continued)

AUXILIARY SUBSYSTEM ELEMENTS (Continued)

11. Electronic Equipment Cooling
12. Air Conditioning Chill Water
13. Fuel Oil and Compensating Water
14. Anchor Release
15. Windlass and Capstan

NAVIGATION SUBSYSTEM ELEMENTS

1. Gyro Compass
2. Dead Reconing Analyzer Indicator
3. Electromagnetic Log
4. Central Navigation Computer
5. Satellite Navigation Fix Capability
6. Radio Navigation Fix Capability
7. Inertial Navigation System
8. Navigation Control Console
9. Ocean Bottom Navigation Fix Capability
10. Periscope Optics

EXTERNAL COMMUNICATIONS SUBSYSTEM ELEMENTS

1. MF/HF Transmitter
2. UHF Transceiver
3. MF/HF Transceiver
4. VLF Receivers
5. MF/HF Receivers
6. Teletype Equipment
7. Security Equipment
8. Radio Telephone
9. Multicoupler
10. MF/HF/UHF Antenna Control
11. Emergency Antenna Control
12. VLF Antenna Control

EXTERNAL COMMUNICATIONS SUBSYSTEM ELEMENTS (Continued)

13. Entertainment Receiver
14. Antenna Performance Monitoring

SONAR-ECM SUBSYSTEM ELEMENTS

1. Passive Sonar (Conformal Array)
2. Active Sonar
3. Passive Sonar (Cylindrical Array)
4. Passive Sonar (Narrow Frequency Band)
5. Passive Sonar (Trailing Array)
6. Passive Sonar (Overhead Array)
7. Sonar Performance Computer
8. Fathometer
9. Underwater Telephone
10. Sound-Velocity Profile Determination
11. Sonar ECM
12. Sonar Contact Classification
13. Sonar Parameter Identification (Signal Modulation)
14. Radar
15. ECM
16. Electronic Identification System
17. Microwave Intercept Receiver
18. ECM Contact Classification
19. Sonar and ECM Antenna Control
20. Sonar Trailing Array Control
21. Sonar Array Performance Monitoring

Table III-B-1 (Concluded)

DEFENSIVE WEAPONS SUBSYSTEM ELEMENTS

1. Torpedo Tube Operation
2. Torpedo Loading
3. Torpedo Firing
4. Signal Ejector Loading
5. Signal Ejector Firing
6. Target Motion Determination
7. Torpedo Input Selection

STRATEGIC WEAPONS SUBSYSTEM ELEMENTS

1. Missile Tube Operation
2. Missile Tube Pressure Control
3. Missile Gas System
4. Missile Launch Compensation
5. Missile Tube Hydraulics
6. Missile Tube Humidity Control
7. Missile Tube Temperature Control
8. Missile Launch Preparation
9. Missile Launch Initiation

HABITABILITY SUBSYSTEM ELEMENTS

1. Ventilation System
2. Compartment Recirculation Fans
3. CO_2 Scrubber Control
4. O_2 Generator Control
5. CO/H_2 Burner Control
6. O_2 System Control
7. Potable Water System
8. Plumbing-Sanitary Tanks
9. Temperature and Humidity Control
10. Trash Disposal
11. Food Preparation
12. Laundry

CASUALTY AND DAMAGE CONTROL SUBSYSTEM ELEMENTS

1. Emergency Lighting
2. Hydrogen Detectors
3. Watertight Doors
4. Radiation Detection (Status and Survey)
5. Ship Casualty Message Release
6. Casualty Alarms
7. Ship Control Casualty Detection
8. Casualty Response
9. Solution Evaluation
10. Smoke Detection

Table III-B-2 Existing Crew Subsystem Division

1. Ship Control Subsystem

   Commanding Officer
   Officer of the Deck
   Diving Officer of the Watch
   Chief of the Watch
   Helmsman
   Planesman
   Lee Helm

2. Engineering Subsystem

   Engineering Officer of the Watch
   Engineering Watch Supervisor
   Engine Room Supervisor
   Engine Room Upper Level
   Engine Room Lower Level
   Machinery Room 2 Upper Level
   Machinery Room 2 Lower Level
   Reactor Operator
   Electrical Operator
   Auxiliary Electrician Aft
   Throttleman
   Engineering Laboratory Technician

3. Navigation Subsystem

   Navigation Center Supervisor
   Navigation Equipment Technician
   Navigation Center Watch
   Quartermaster of the Watch

4. Auxiliary Subsystem

   Auxiliaryman Forward
   Auxiliaryman Aft

5. Defensive Weapons Subsystem

   Torpedoman (bow compartment)

6. Strategic Weapons Subsystem

   Missile Control Center Supervisor
   Missile Control Center Watch
   Launch Operations Station Watch
   Assistant Launch Operation Station Watch
   Missile Compartment Roving Watch

Table III-B-2 (Concluded)

7. Habitability Subsystem

   Machinery Room 1 Watch
   Auxiliary Electrician Forward
   Corpsman
   Mess Cooks
   Mess Specialists
   Yeoman
   Storekeeper

8. External Communications Subsystem

   Radioman Supervisor
   Radioman Watch

9. Sonar-ECM Subsystem

   Sonarman Supervisor
   Sonarman Watch

10. Damage Control Subsystem

    All Personnel

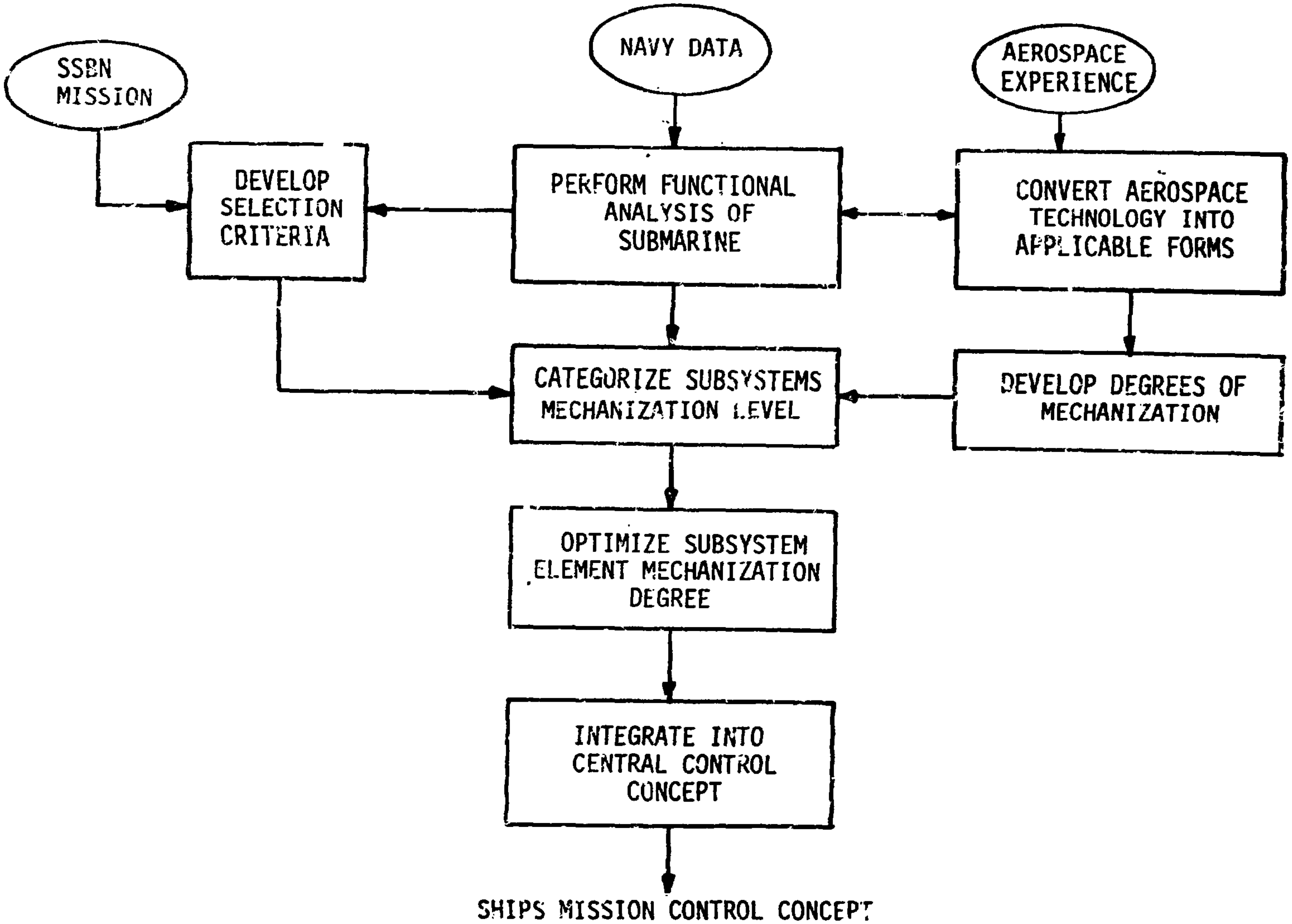


Figure III-B-1 Approach Used to Optimize Operation of Subsystem Elements

Table III-B-3 Selection Criteria

1. <u>Decrease Cost</u>

This criteria includes the costs of design, construction, testing, and lifetime maintenance, but does not include any savings due to a possible crew reduction.

2. <u>Increase Availability</u>

This criteria is defined by the following items:

a. Improved strategic weapon and navigation subsystem operation:

1) Reduction or elimination of ship motion limits or events (i.e., fewer trips to periscope depth).

2) Reduction of physical equipment limitations (i.e., required navigational fix frequency to maintain the desired inertial navigation platform accuracy).

3) Improved accuracy.

4) Equipment is maintainable by technicians trained in Navy schools.

b. Improved communications reception and transmission:

1) Reduce operational antenna limits as a result of ship motion and detectability.

2) Increase equipment reliability.

3) Improve equipment operational capabilities, including frequency limitations and choice of operating equipment.

c. Improved command and control action:

1) Message completion validation.

2) Message validity.

d. Reduced refit time (in-port repair time).

1) Reduced equipment failure rates.

2) Increased at-sea repair of equipment.

Table III-B-3 (Continued)

e. Increase reliability of the element, subsystem and ship in the operating condition:

   1) Improved mean time between failure.

   2) Reduced mean time to repair.

f. Improve the operating cycles.

   1) The capability to vary the time cycle between crew transfers.

   2) To provide the capability to select the place (i.e., at sea, in port) of the crew transfer.

   3) To determine the requirement for a refit period ahead of time, set necessary work loads and equipment repair.

3. Reduce Crew Size

This criteria evaluates the reduction of crew size with increased mechanization.

a. Reduction of control station locations through:

   1) Centralization of control areas.

   2) Reorganization of watchstanding requirements and functions.

b. Reduced maintenance training requirements.

   1) Equipment technology improved.

   2) Modular design.

   3) Equipment designed for maintainability.

c. Decreased life cycle costs.

   1) Fewer equipment operators required.

   2) Use of Navy's "Standard Hardware Program" (MIL-STD-1378A).

   3) Less maintenance (fewer maintenance men required).

d. Improved use of personnel.

   1) Diversified training improves individual efficiency.

Table III-B-3 (Continued)

2) Undesirable tasks reduced and/or accomplished by computer assistance.

3) Boring watches eliminated.

4) Increased skill utilization.

e. Improved operational capability.

1) Normal watch conditions minimized.

2) Improved response to abnormal conditions

3) Centralized information displays.

4) Reduced requirement on voice interior communications lines.

f. Requirement for in-port support.

1) Non-technical support required.

2) Effect on tender support required due to increased technology.

3) Support requirements can be predetermined.

4. Increased Survivability

This criteria defines improvement in the survivability of the submarine.

a. Reduced own-ship detectability.

1) New equipment is quieter due to technology and operation.

2) Noisy events are grouped and randomized by using computer predictions.

3) Computer control reduces ship operational noise.

b. Covert escape on detection.

1) Computer recommendations based on all tactical input to provide the best possibility of escape.

2) Improved maneuvering capabilities.

3) Control of own ship noise.

Table III-B-3 (Continued)

c. Improved tactical weapon capability.

1) Computer recommendation of tactical maneuver.

2) Target motion analysis techniques.

3) Torpedo control capability.

4) Decrease fire control party requirement.

d. Improved detection capability.

1) Automated antenna control.

2) Analysis of sonar data.

3) Better control of own-ship to:

(a) minimize noise

(b) maximize the capability to obtain data.

e. Automated contact analysis.

1) Computer recommendation for maximum data (equipment use and own-ship maneuvering.

2) Noise signature profiles in memory.

3) Automated classification of contact.

f. Faster reaction time.

1) Data transfer time.

2) Computer recommendations to minimize detection.

3) Casualty control recommendations (or actions).

5. <u>Improved Operability</u>

This criteria evaluates the ease in operating the submarine with increased mechanization.

a. Is the technology available.

1) State-of-the-art concepts.

Table III-B-8 (Concluded)

2) Reliable equipment.

3) Ease of maintenance.

b. Is ship safety improved

1) Ship status displayed to operator.

2) Less communication delay time.

3) Computer recommendation and evaluation of control actions.

c. Are secondary functions provided

1) Alarm formats

2) Trend analysis

3) Failure diagnosis

4) Data recording and analysis

5) Tactical and operational data storage and retrieval

6) Maintenance administration

7) Medical diagnosis

8) Training information

d. Is human error reduced

1) Operating errors

2) Maintenance errors

e. Is the equipment fully utilized

1) Does it duplicate equipment in other subsystems

2) Is the equipment standardized to facilitate maintenance and training

3) What is its frequency of use

f. Additional operational training required

1) Man must know more about more equipment

2) Greater skills required

3) Diversified training required

To provide a numerical method of weighing the relative value of each criteria to the total, a weighting matrix as shown in Figure III-B-2 was developed. Each prime selection criteria was evaluated relative to the others. A numeric 2 was assigned to a criteria if it is more important than the criteria it was compared to; a 1 was assigned if the criteria was less important. From this matrix the relationship of the raw weight of each selection criteria was determined by summing its comparative values. The normalized weight factor for each selection criteria was determined for actual use in the evaluation process.

3. Degree of Mechanization

Our review of current and potential submarine control systems indicated that five steps or degrees of mechanization are identifiable. These steps are shown in Figure III-B-3 and illustrate the change between the completely manual to the completely automatic system control. Increased mechanization is reflected by proceeding from left to right within the figure.

The first degree of mechanization as shown in Figure III-B-3 is the "manual/oral" mode. An abnormal condition is detected by a watchstander who vocally relays via an interior communications system the condition to the OOD. The OOD must understand what has been verbally transmitted, acknowledge, and using past experience, or judgment, issue a command to be relayed via an interior communications system, to the same or another watchstander for manual operation of a valve or switch to correct the problem or condition. Such a "manual/oral" mode is highly subject to the possibility of a misunderstanding and human error. If multiple problems develop concurrently, the stress situation, an information overload, placed on the OOD further complicates a correct solution to the problems.

The second step in the mechanization process is to bring all pertinent data to a central monitoring panel and to present status data to the OOD in a convenient organized manner. This step, "central statusing", requires the telemetering of all pertinent data to the central monitor. The amount of data handled is limited by the organization and physical size of the central monitoring panel. To telemeter the data, many conventional, visually read, sensors must be replaced with transducers whose electrical outputs can be transmitted over data buses to the centrally located display. The data buses can be co-axial cable, or using the latest technology, fiber optic data light pipes.

SELECTION CRITERIA

	COST	AVAILABILITY	CREW SIZE	SURVIVABILITY	OPERABILITY	RAW WEIGHT	NORMALIZED WEIGHT FACTOR
Cost	---	1	1	1	1	4	.133
Availability	2	---	2	2	2	8	.267
Crew Size	2	1	---	1	1	5	.167
Survivability	2	1	2	---	2	7	.233
Operability	2	1	2	1	---	6	.200
						30	1.000

Figure III-B-2 Selection Criteria Weighting Values

DEGREES OF MECHANIZATION

ACTIVITIES	I MANUAL/ORAL	II CENTRAL STATUSING	III MAN-MACHINE CONTROL	IV REMOTE CONTROL	V COMPUTER CONTROL
SENSING	METERS AND INDICATORS VISUALLY READ BY WATCH STANDER	AUTOMATIC SENSORS WITH ELECTRICAL OUTPUT	→	→	→
DATA TRANSMISSION	VOCAL BY WATCH STANDER OVER COMM SYSTEM	TELEMETERED VIA DATA BUS TO CENTRAL DISPLAY PANEL	TELEMETERED VIA DATA BUS TO SHIP MISSION CONTROL COMPUTER	→	→
DISPLAY	LOCAL. OOD RELIES ON VERBAL INFORMATION	METERS AND CRT DISPLAYS HARD COPY	→	→	→
DECISION	OOD MAKES DECISION BASED ON PAST KNOWLEDGE	→	COMPUTER PREPARES DIAGNOSTICS AND MAKES RECOMMENDATIONS	→ OOD IS IN COMMAND LOOP	COMPUTER IN FULL CONTROL. OOD CAN OVERRIDE COMMANDS
COMMAND	VOCAL COMMAND TO WATCH STANDER OVER COMM SYSTEM	→	→	CONTROLS ARE ON THE CENTRAL CONSOLE. COMMANDS TELEMETERED TO ACTUATORS	COMPUTER AUTOMATICALLY SENDS APPROPRIATE COMMANDS VIA DATA BUS TO ACTUATORS
ACTUATION	LOCAL ACTUATION BY WATCH STANDER	→	→	AUTOMATIC LOCAL ACTUATORS REMOTELY CONTROLLED BY OOD.	AUTOMATIC LOCAL ACTUATORS CONTROLLED DIRECTLY BY THE COMPUTER
ACKNOWLEDGEMENT	WATCH STANDER REPEATS COMMAND BACK OVER COMM SYSTEM. OOD VERIFIES. (NOTE: ACTUATION HAS NOT BEEN MADE AS YET.)	→	→	AUTOMATIC ACKNOWLEDGEMENT TO COMPUTER WITH SELF-CORRECTION IN CASE OF DATA TRANSMISSION ERROR	→

Figure III-B-3 Degrees of Mechanization

In the next step, "man-machine control", it is appropriate to use a computer driven CRT as the central monitor. The computer is used to reduce the data and present it to the operators in easily understood formats. Since all information is processed by the computer, diverse analog or digital data such as pressure and temperature can be codisplayed on the CRT in tabular or graphical form.

The OOD is only presented pertinent, changing, requested, or alarm information on the display. The computer using a CRT or printer can also provide the OOD with trend data, diagnostic suggestions and operational recommendations. The OOD must still verbally pass his commands to appropriate watchstanders for corrective action.

The next progressive step in the mechanization process, "remote control", is to provide local actuators throughout the ship that can be controlled remotely by an officer from a central control console. The officer is aware of ship conditions on his CRT display and can take appropriate actions through push-buttons or through keyboard commands entered on the console. The officer is in control of all actions and makes decisions aided by computer recommendations.

The next step, "computer control", uses the ship control computers to constantly evaluate all conditions and to automatically make the appropriate decisions and command the designated actuators to control their related equipments. All abnormal conditions are displayed to the officer in addition to the action the computer is taking. Provision is provided for the officer to override any computer action.

4. Mechanization Values

The next phase of our study was to quantify the extent of mechanization desirable for each element of each subsystem. Each subsystem element (ref: Table III-B-1) was evaluated using the "Selection Criteria" to determine the effect of each incremental advancement in Degrees of Mechanization. In order to determine the extent of mechanization, the evaluation criteria were applied to each incremental advancement. The criteria used determined whether or not a change in the level of mechanization of the element would enhance or degrade cost, availability, crew size, survivability, and operability. The individual criteria were measured in terms of the factors shown in Table III-B-3, Selection Criteria.

a. Element Mechanization Values - The numbers +1, 0, or -1 were assigned at the selection criteria factor level. A "+1" was assigned to a selection criteria factor if it enhanced that step. A "0" indicated no change and a "-1" indicated a detrimental effect. The numbers were summed for the factors of each of the five criteria, proceeding one mechanization step at a time.

The results were weighted according to the relative worth (normalized weight fa[illegible]) of the five selection criteria as determined in Figure III-B-2. [illegible] weighted criterion values constitute the net value of making th[illegible]e change.

The entire process was repeated for the next level of change in mechanization until a numerical value has been determined for each change in level of mechanization. Figure III-B-4 provides a pictorial representation of this optimum mechanization evaluation process.

The element mechanization values are shown in Figures III-B-5 through III-B-14. Changes in every element of each subsystem were evaluated and plotted. The curves were used to assess the optimal level of mechanization for each element.

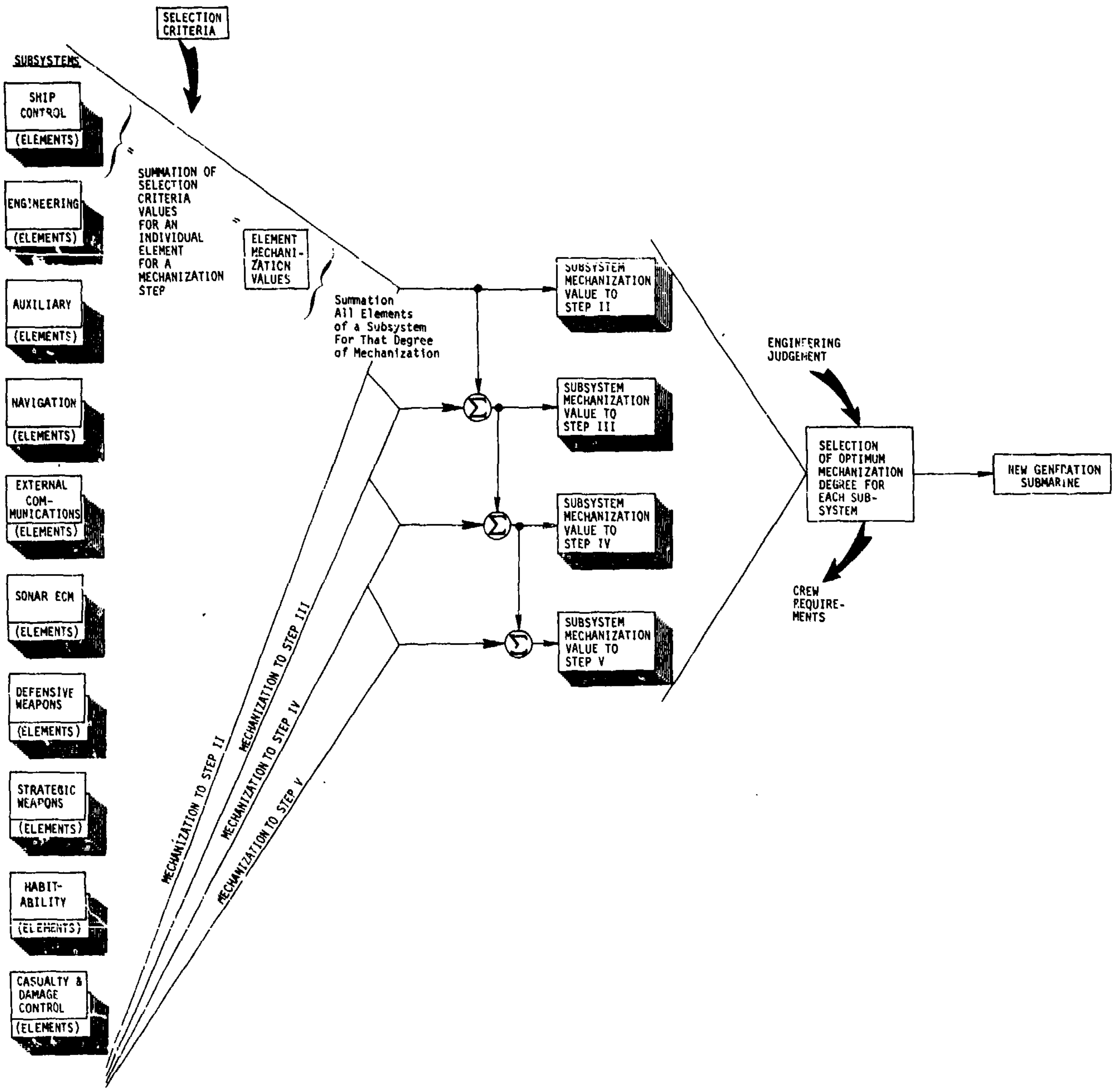


Figure III-B-4 Flow Diagram Depicting Determination of Optimum Element and Subsystem Mechanization Values

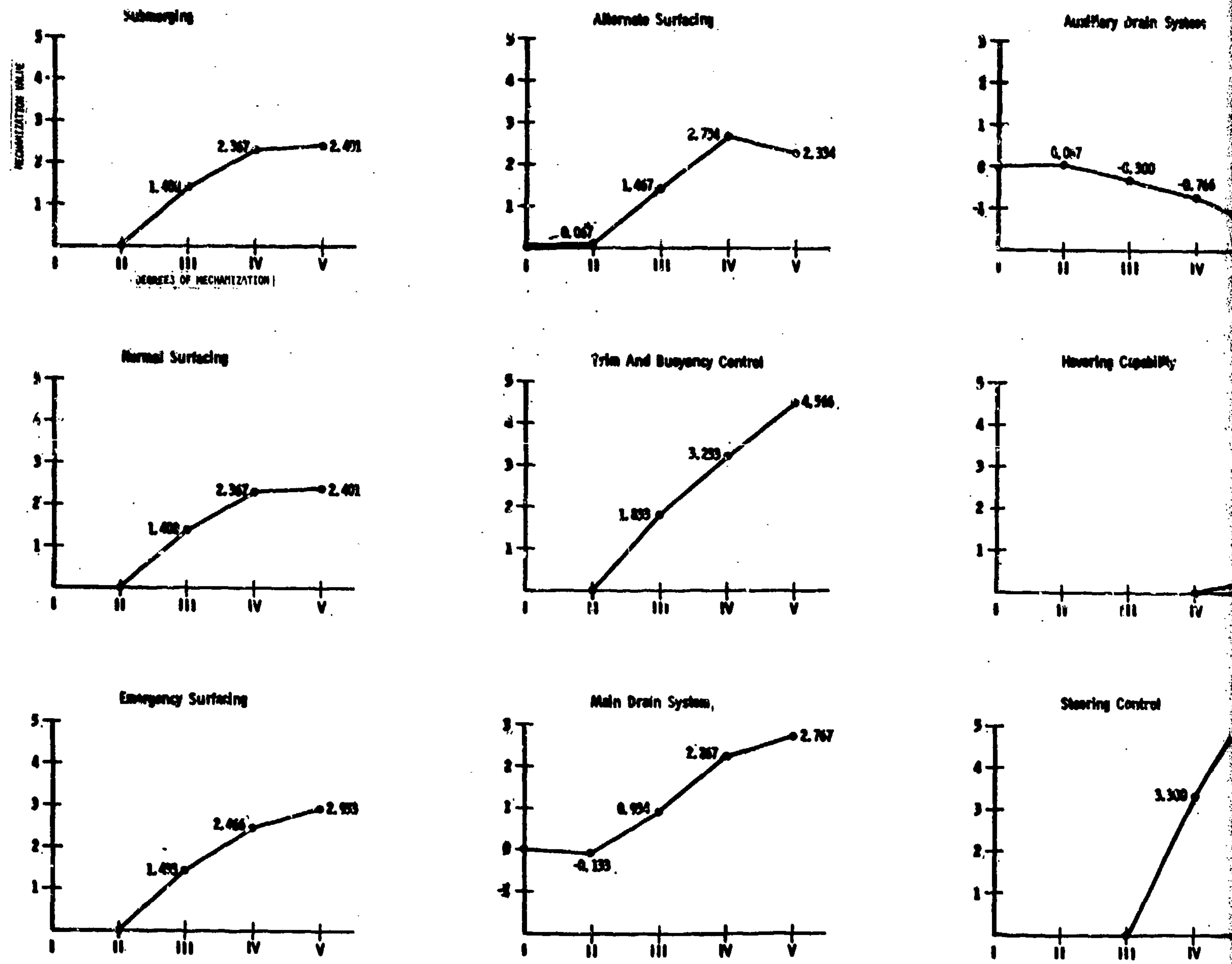
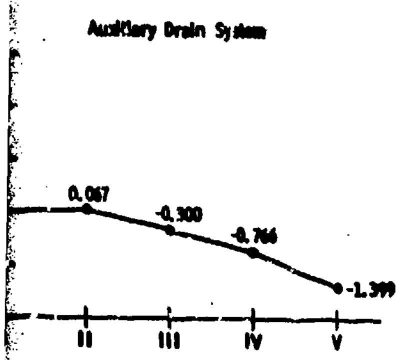
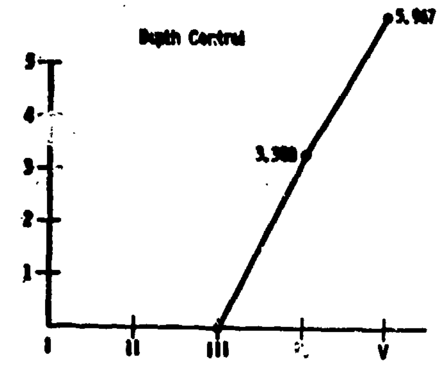
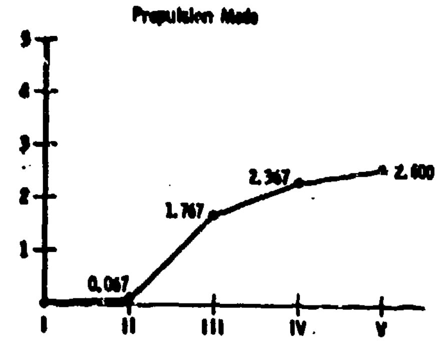
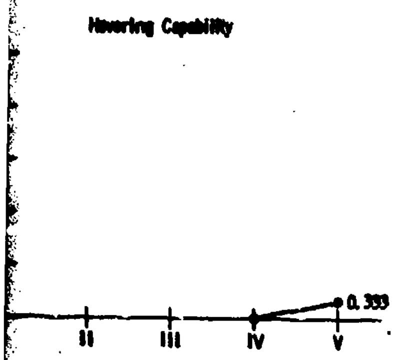


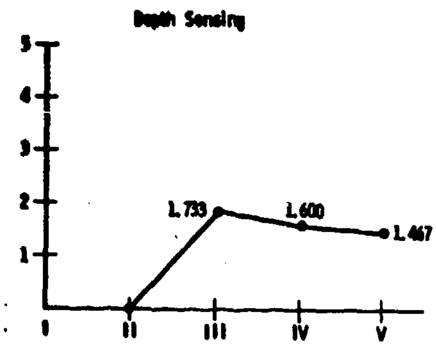
Figure III-B-5 Ship Control Subsystem Element Mechanization Values

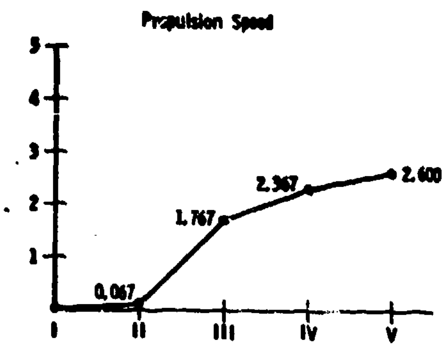

Auxiliary Drain System
0.067
-0.300
-0.766
-1.399
II
III
IV
V

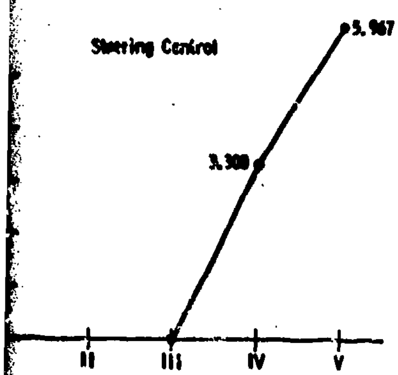

Depth Control
5.967
3.300
I
II
III
V

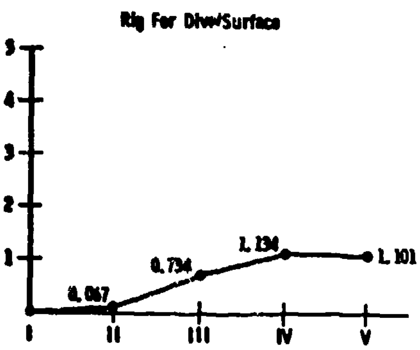

Propulsion Mode
0.067
1.767
2.367
2.600
I
II
III
IV
V

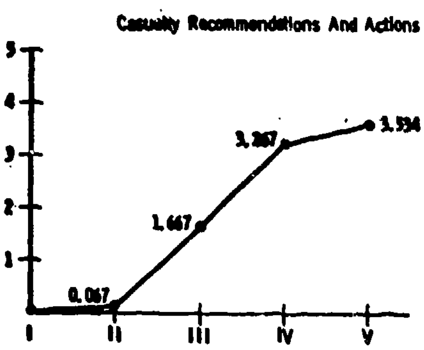

Hovering Capability
0.333
II
III
IV
V


Depth Sensing
1.733
1.600
1.467
I
II
III
IV
V


Propulsion Speed
0.067
1.767
2.367
2.600
I
II
III
IV
V


Steering Control
3.300
5.967
II
III
IV
V


Rig For Dive/Surface
0.067
0.734
1.134
1.101
I
II
III
IV
V


Casualty Recommendations And Actions
0.067
1.667
3.267
3.534
I
II
III
IV
V

2

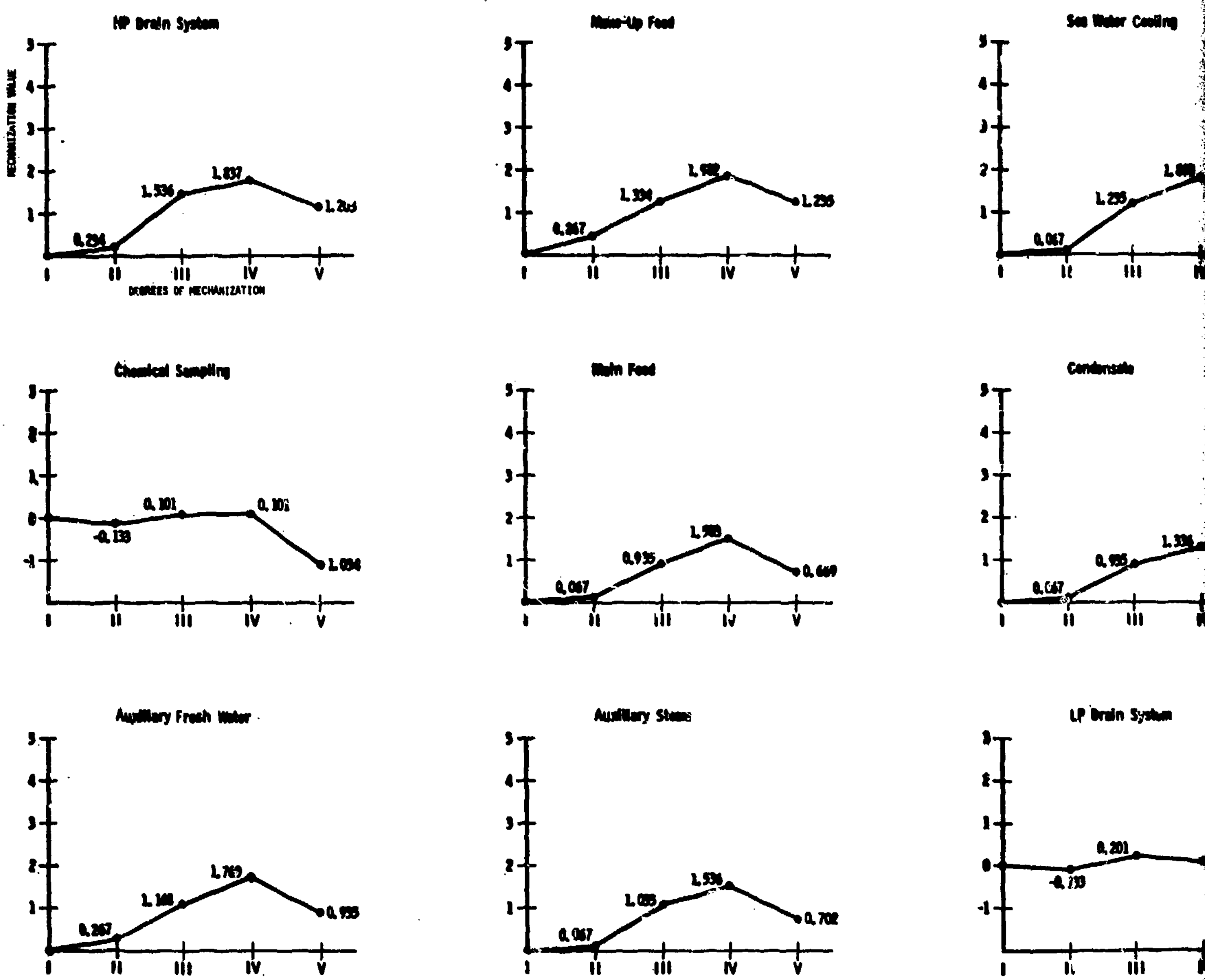
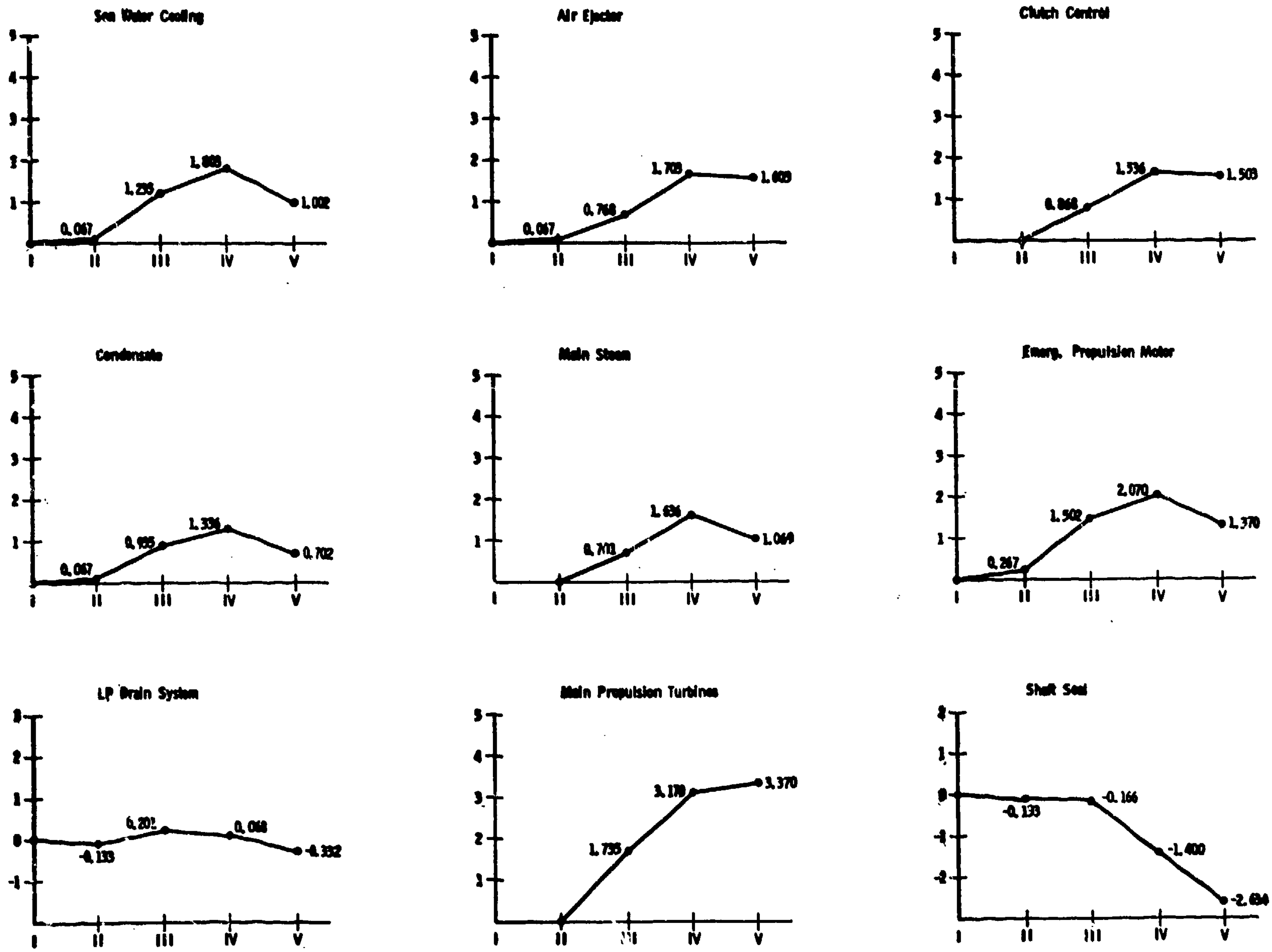


Figure III-B-6 Engineering Subsystem Element Mechanization Values



Sea Water Cooling
0.067
1.002
Air Ejector
0.067
0.768
Clutch Control
0.868
1.503
Condensate
0.067
0.702
Main Steam
Emerg. Propulsion Motor
0.267
1.502
2.070
1.370
LP Drain System
-0.133
0.068
Main Propulsion Turbines
3.370
Shaft Seal
-0.133
-0.166
-1.400
I
II
III
IV
V

Values

2

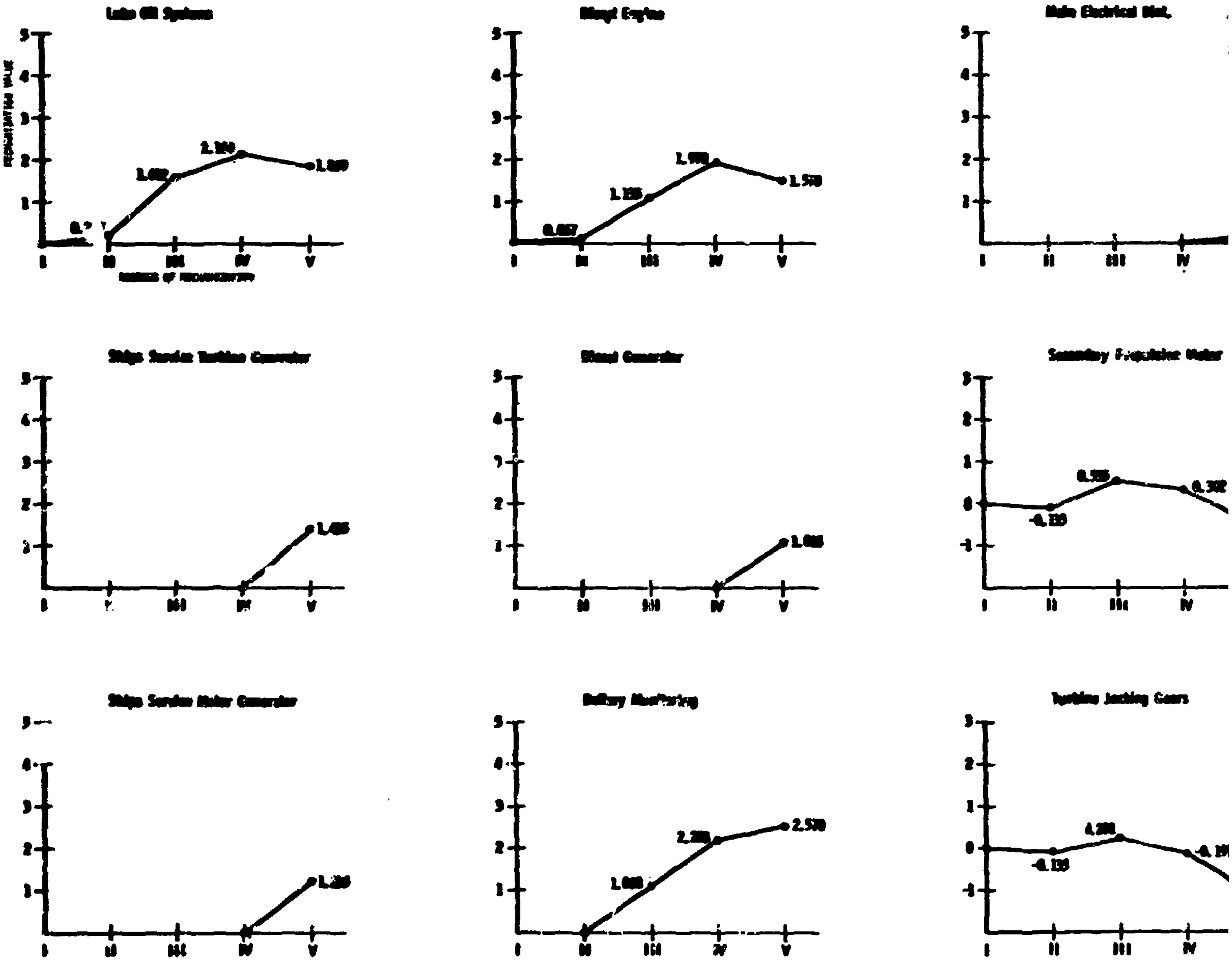
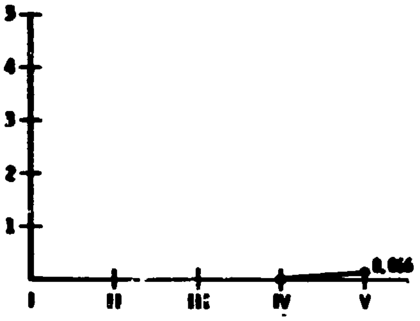
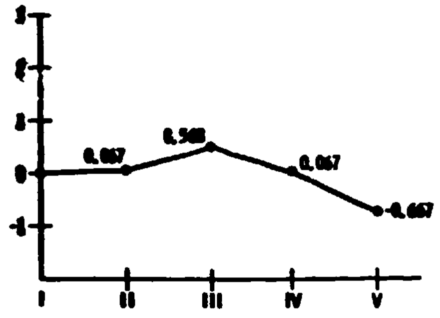


Figure III-B-6 (Concluded)

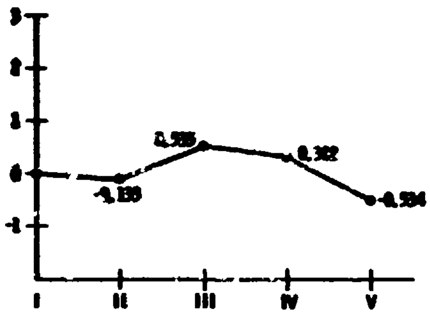
Main Electrical Bkr.



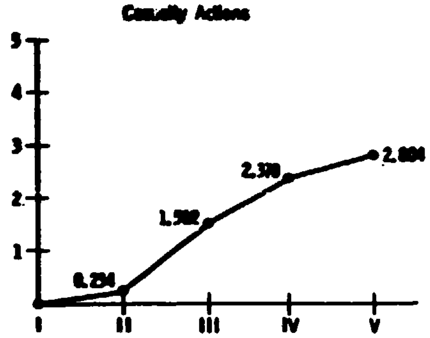
Lube Oil Transfer



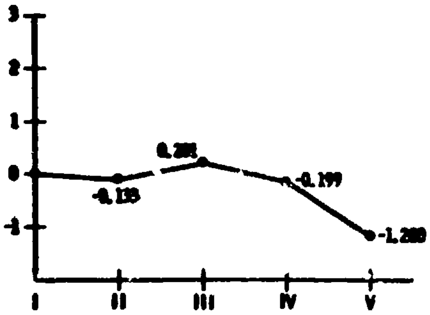
Secondary Propulsion Motor



Casualty Actions



Turbine Jacking Gears



2

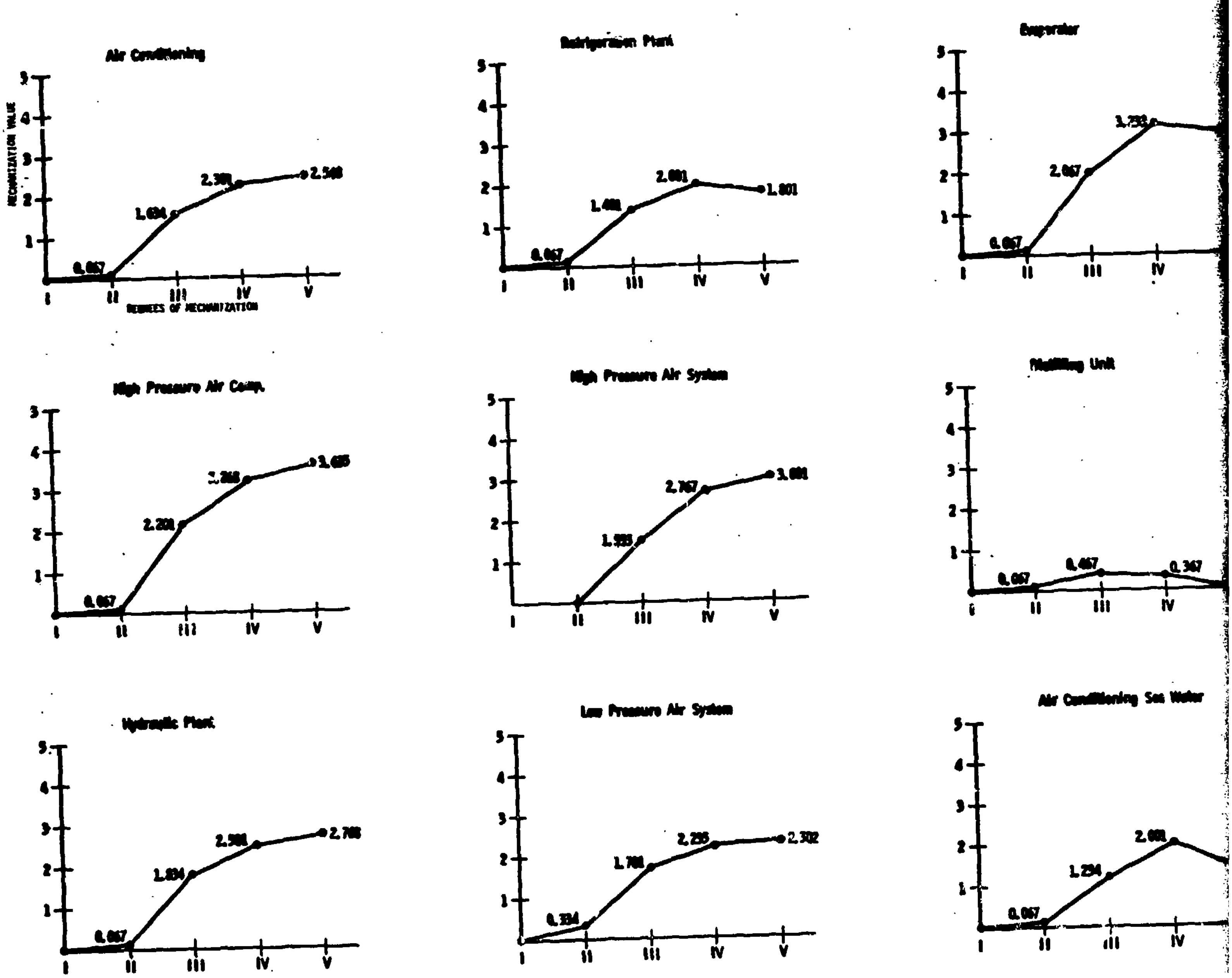
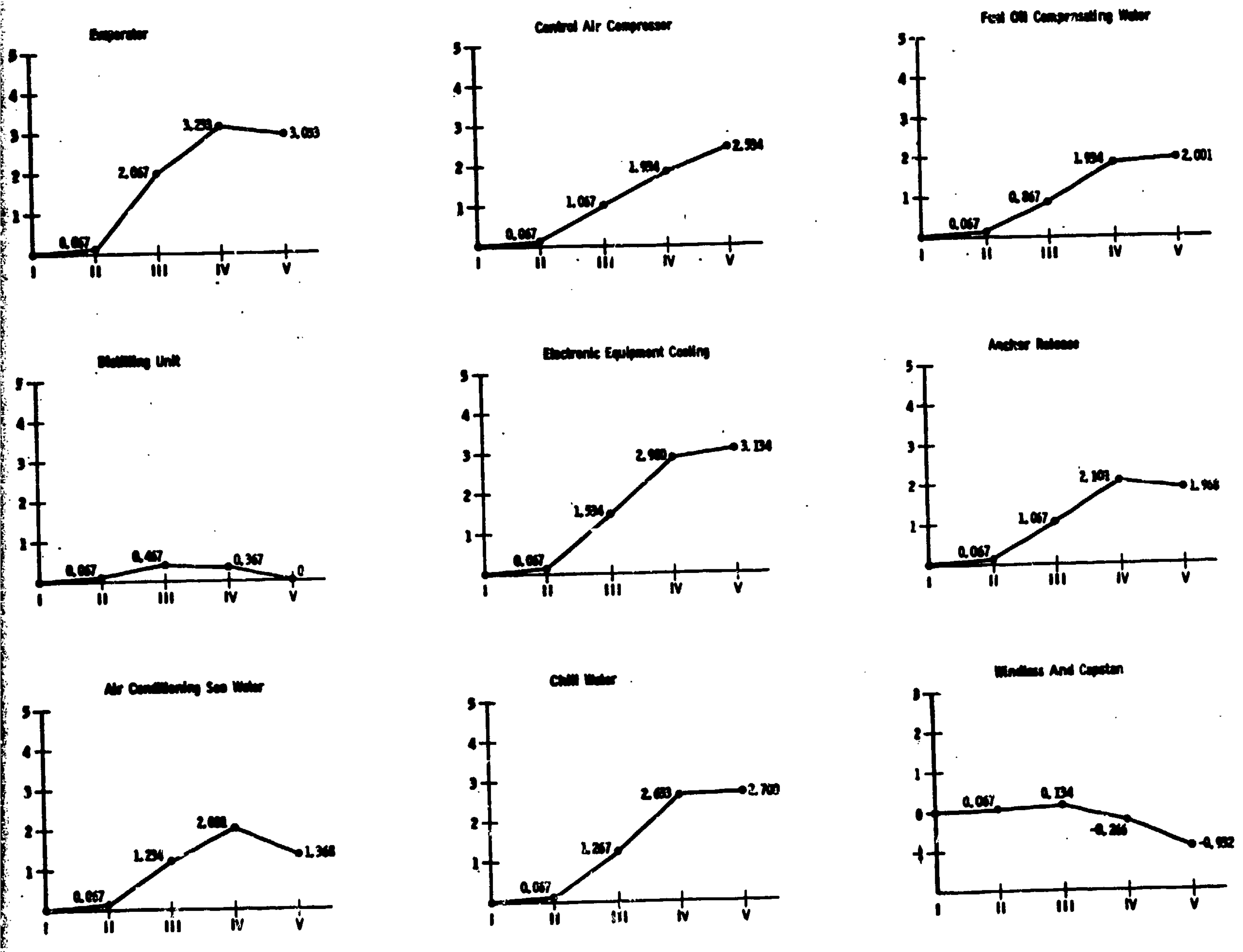


Figure III-B-7 Auxiliary Subsystem Element Mechanization Values


Central Air Compressor
0.067
1.067
2.594
Electronic Equipment Cooling
0.067
1.534
3.134
Anchor Release
0.067
1.067
Air Conditioning Sea Water
0.067
1.234
1.368
Chill Water
0.067
1.267
2.700
Windlass And Capstan
0.067

Values

2

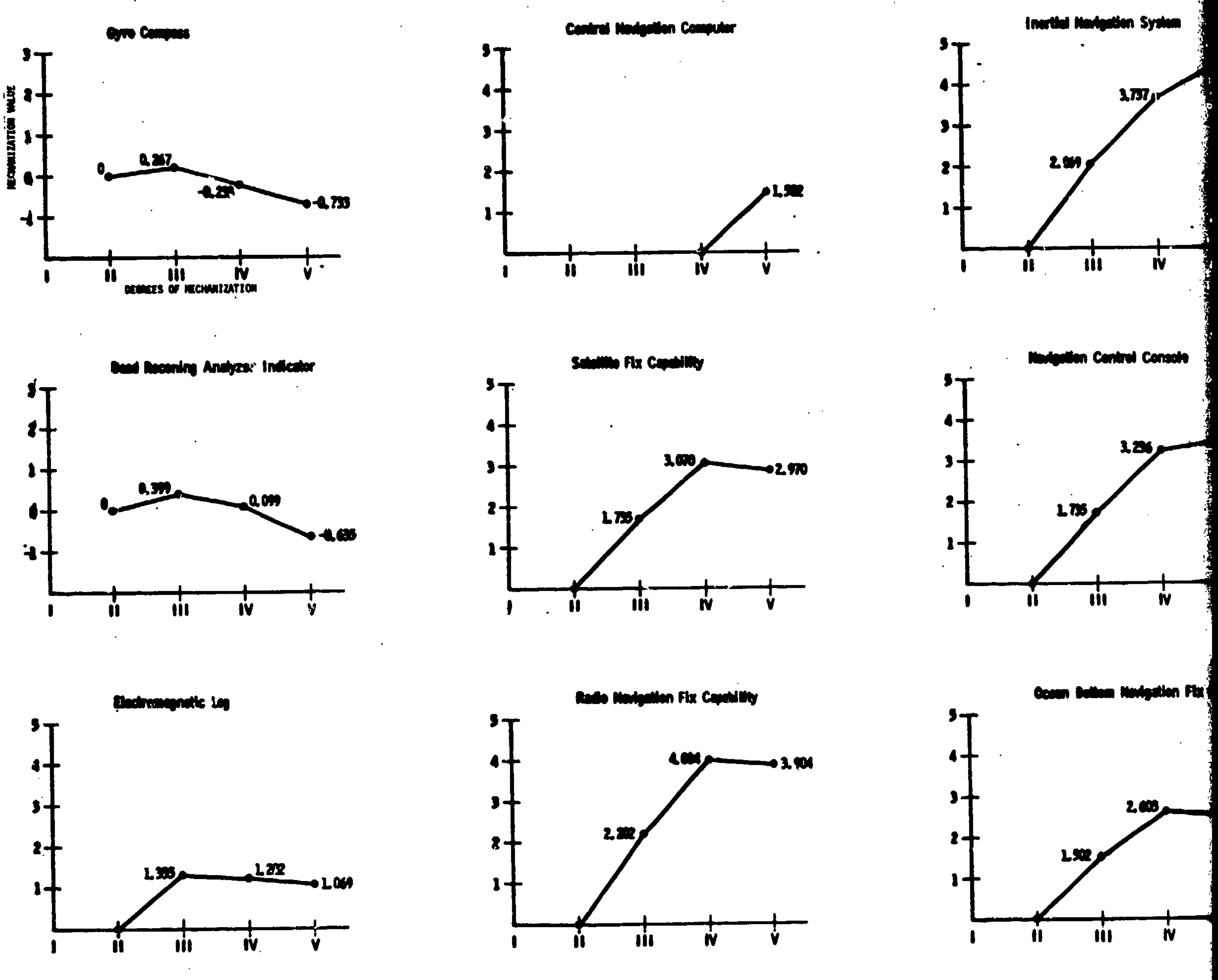
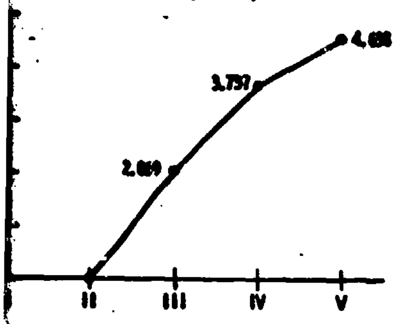
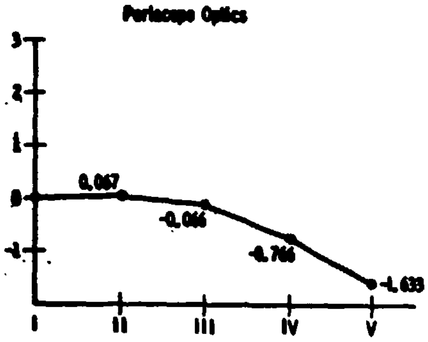


Figure III-B-8 Navigation Subsystem Element Mechanization Values

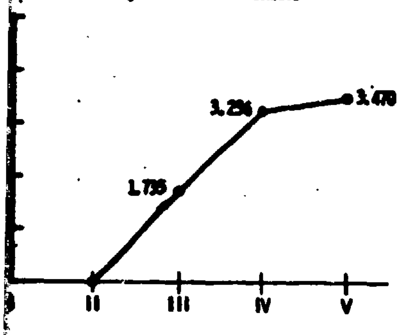
Inertial Navigation System



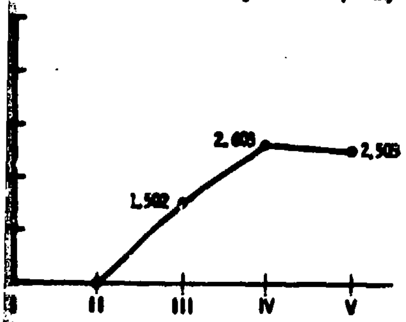
Periscope Optics



Navigation Control Console



Ocean Bottom Navigation Fix Capability



2

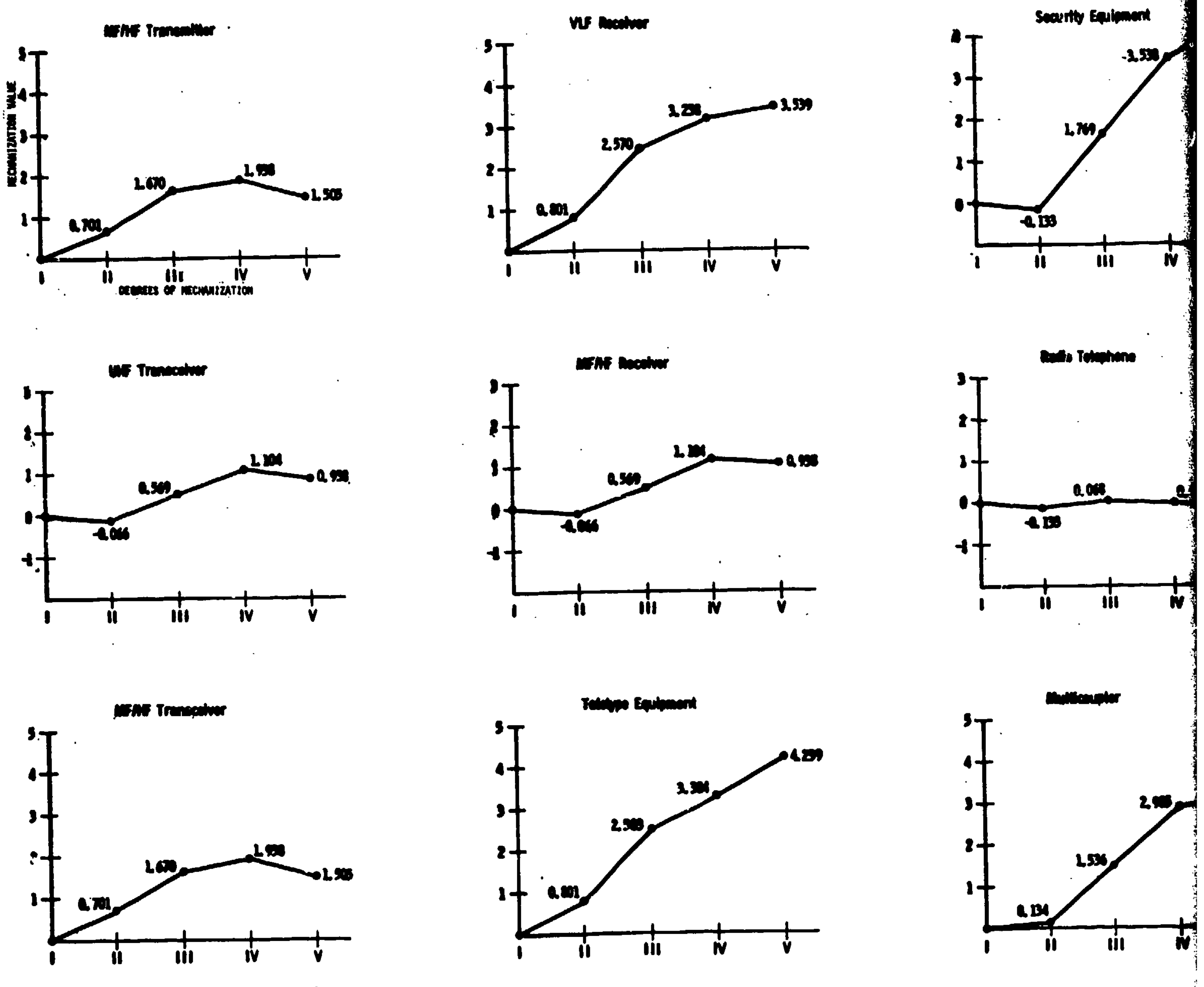
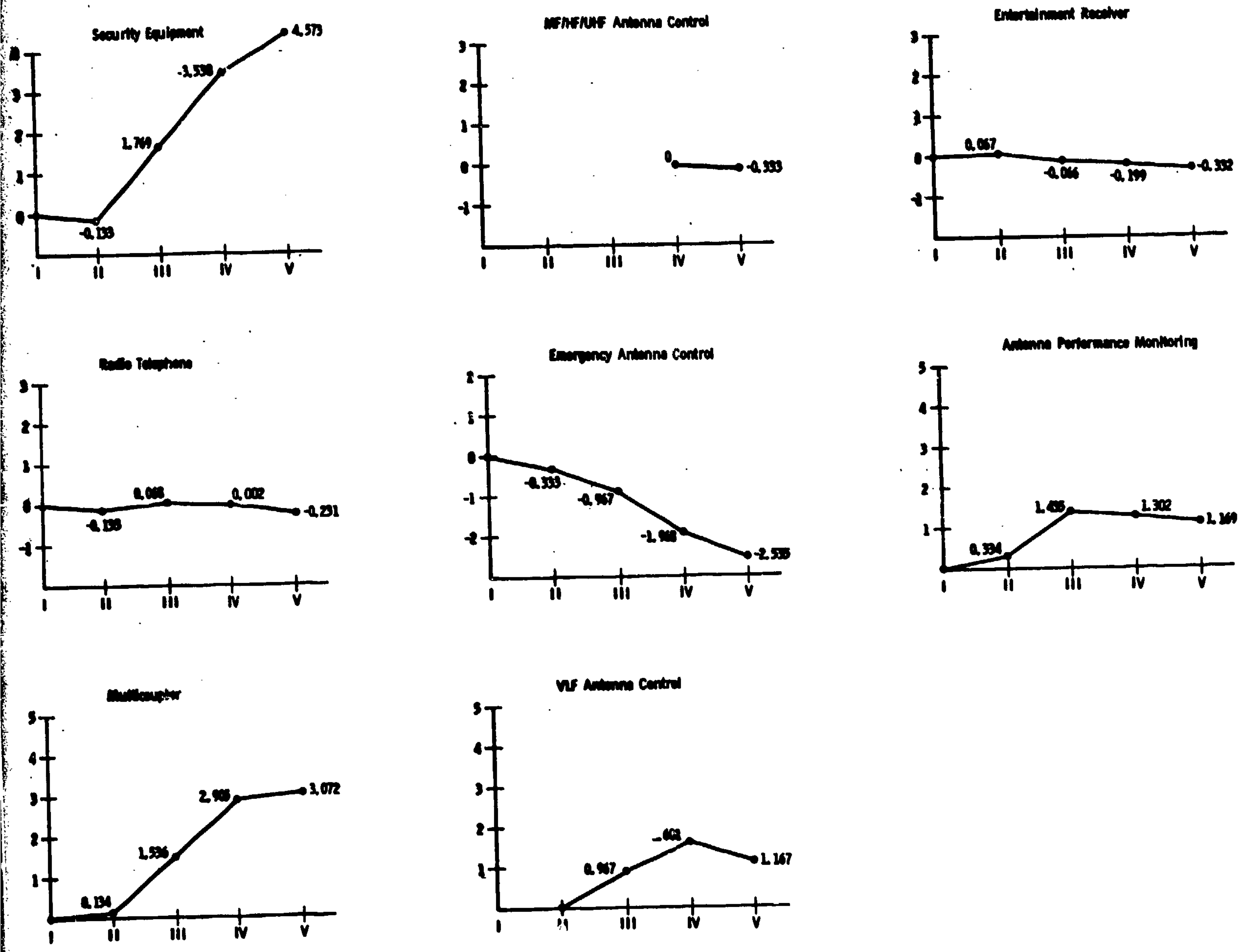


Figure III-B-9 External Communications Subsystem Element Mechanization Values



Mechanization Values

2

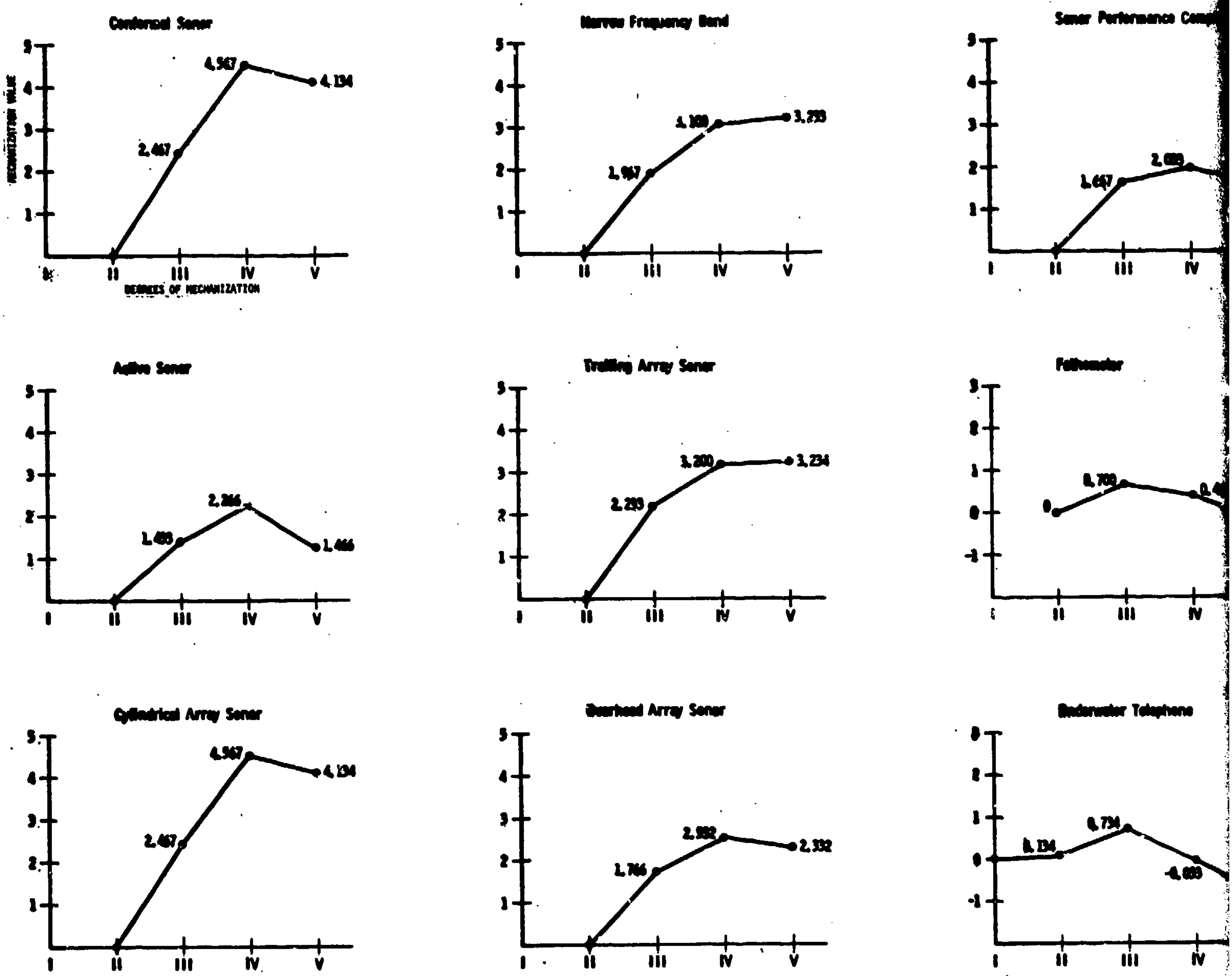
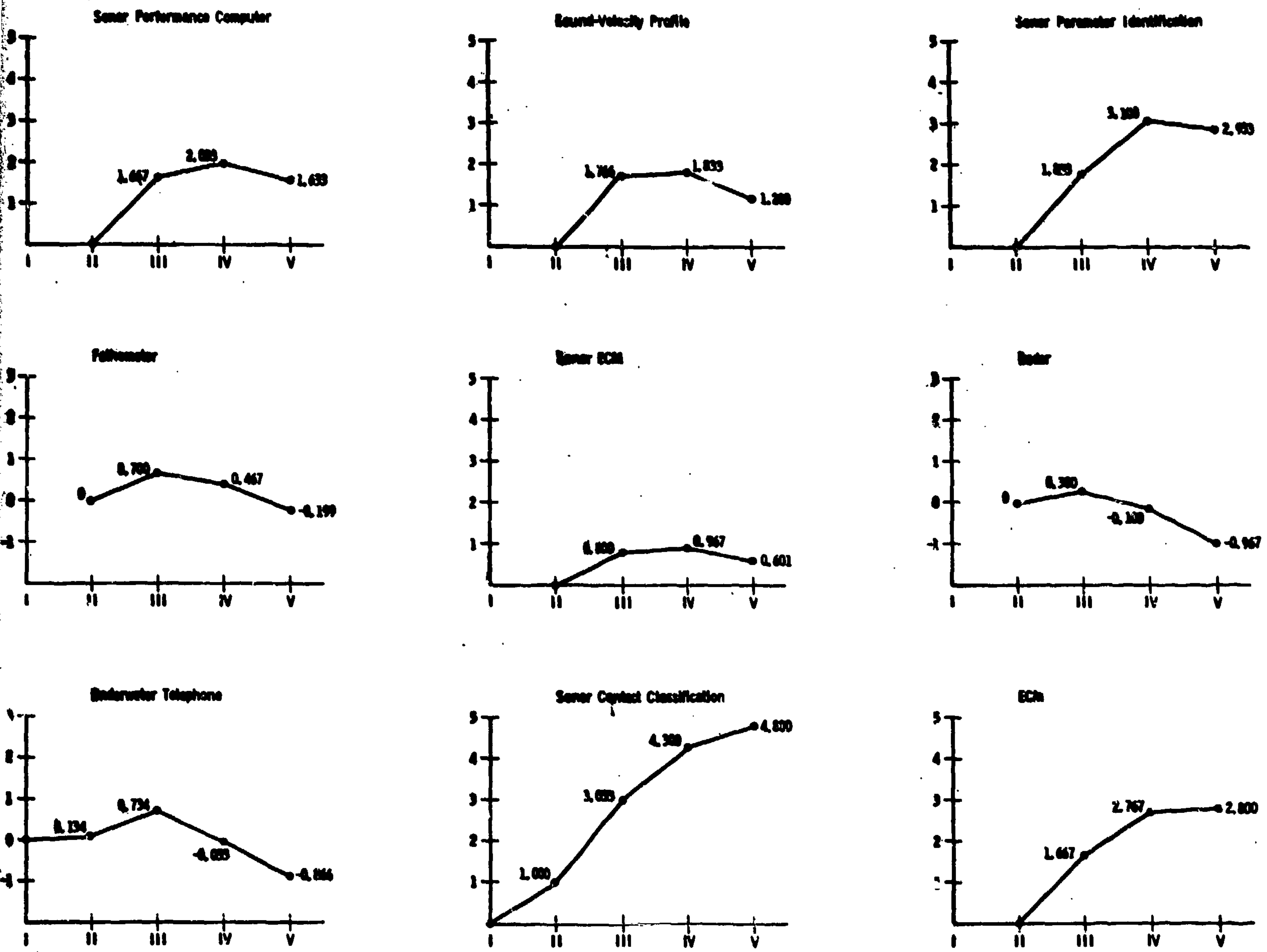


Figure III-B-10 Sonar/ECM Subsystem Element Mechanization Values



Sonar Performance Computer
1.667
1.633
Sound-Velocity Profile
1.833
1.200
Sonar Parameter Identification
2.933
Sonar ECM
0.967
0.601
Radar
-0.967
Underwater Telephone
0.734
Sonar Contact Classification
1.000
4.300
4.800
ECMs
1.667
2.767
2.800

Values

2

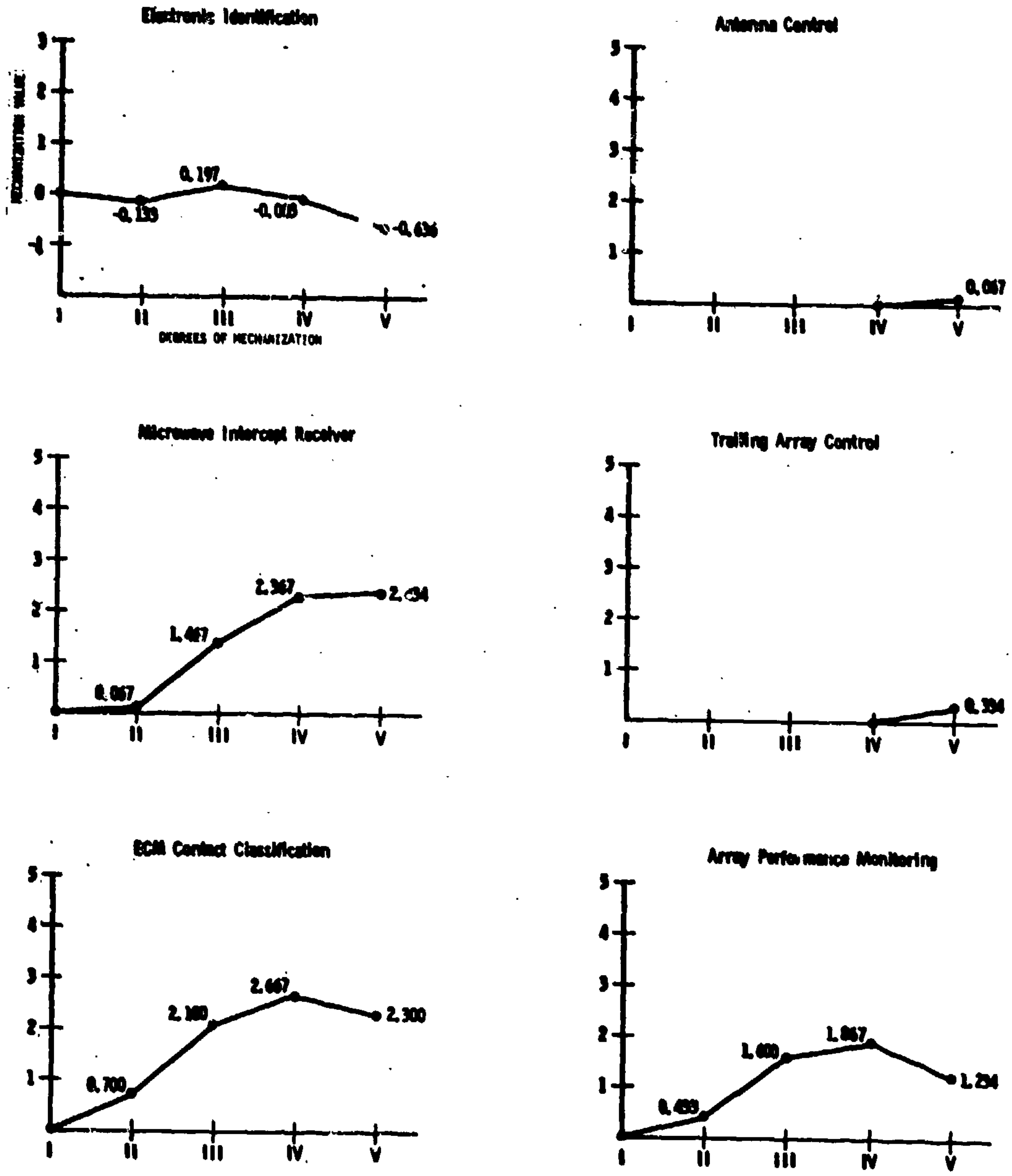


Figure III-B-10 (Concluded)

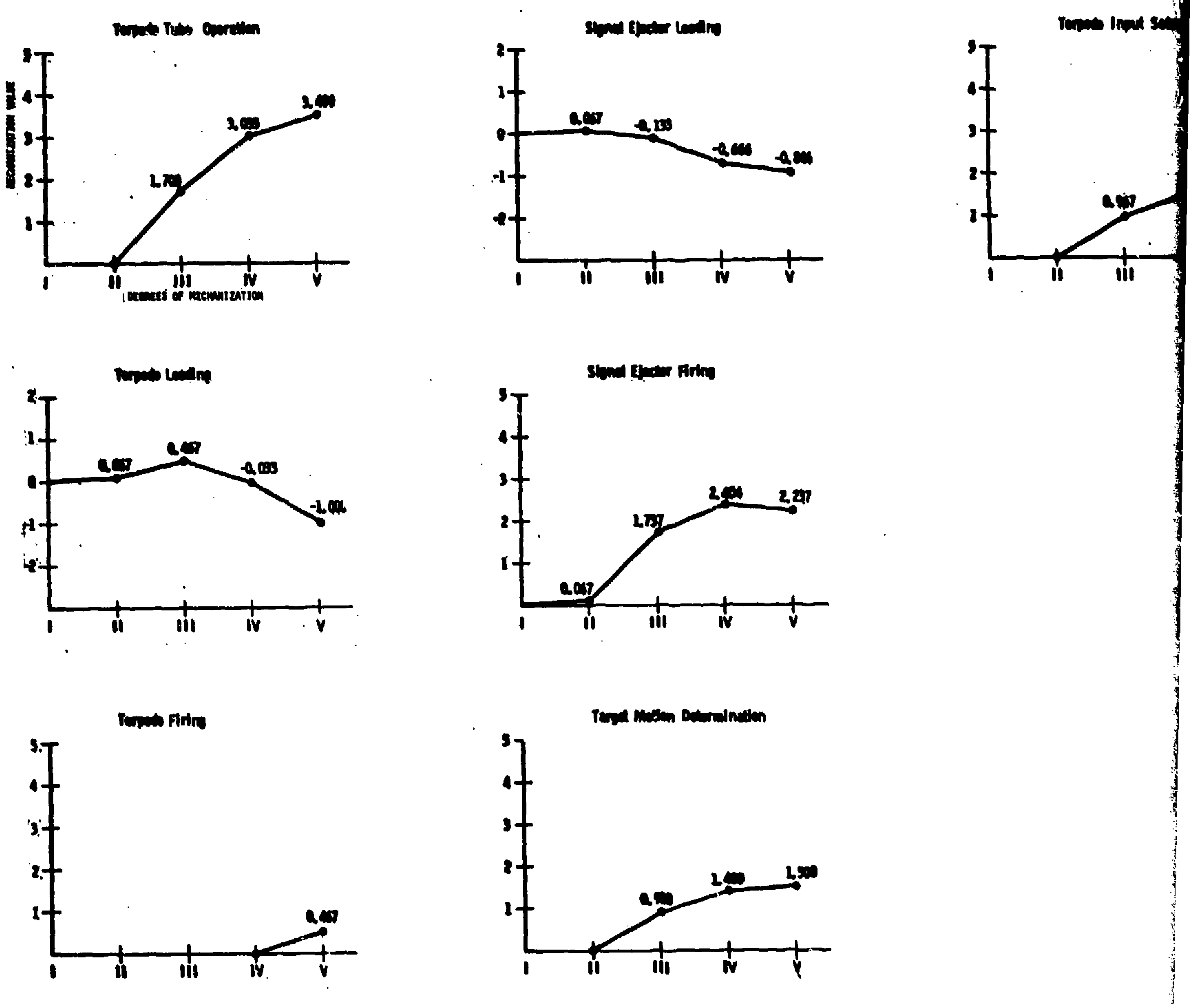
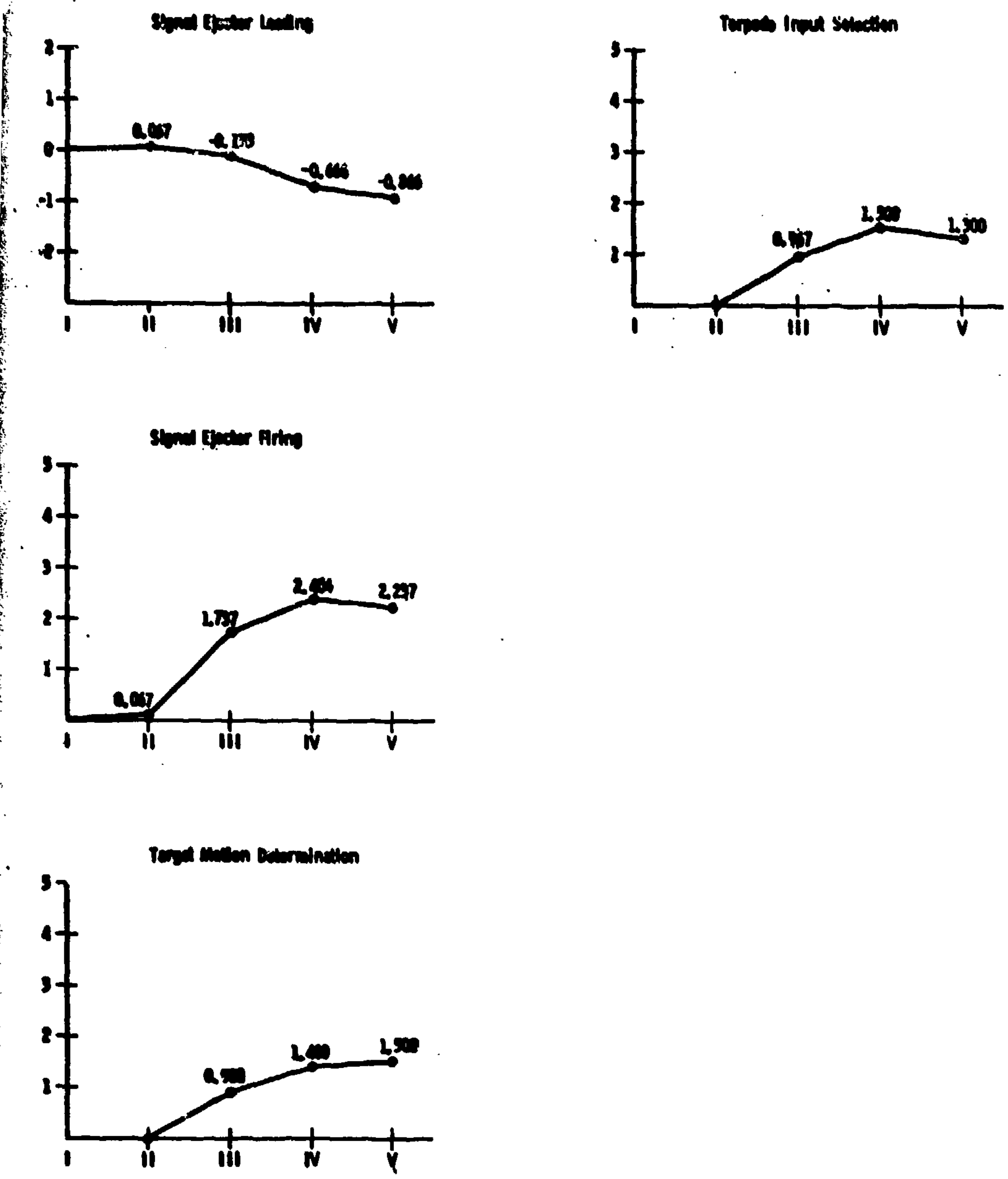


Figure III-B-11 Defensive Weapons Subsystem Element Mechanization Values



nsive Weapons Subsystem Element Mechanization Values

2

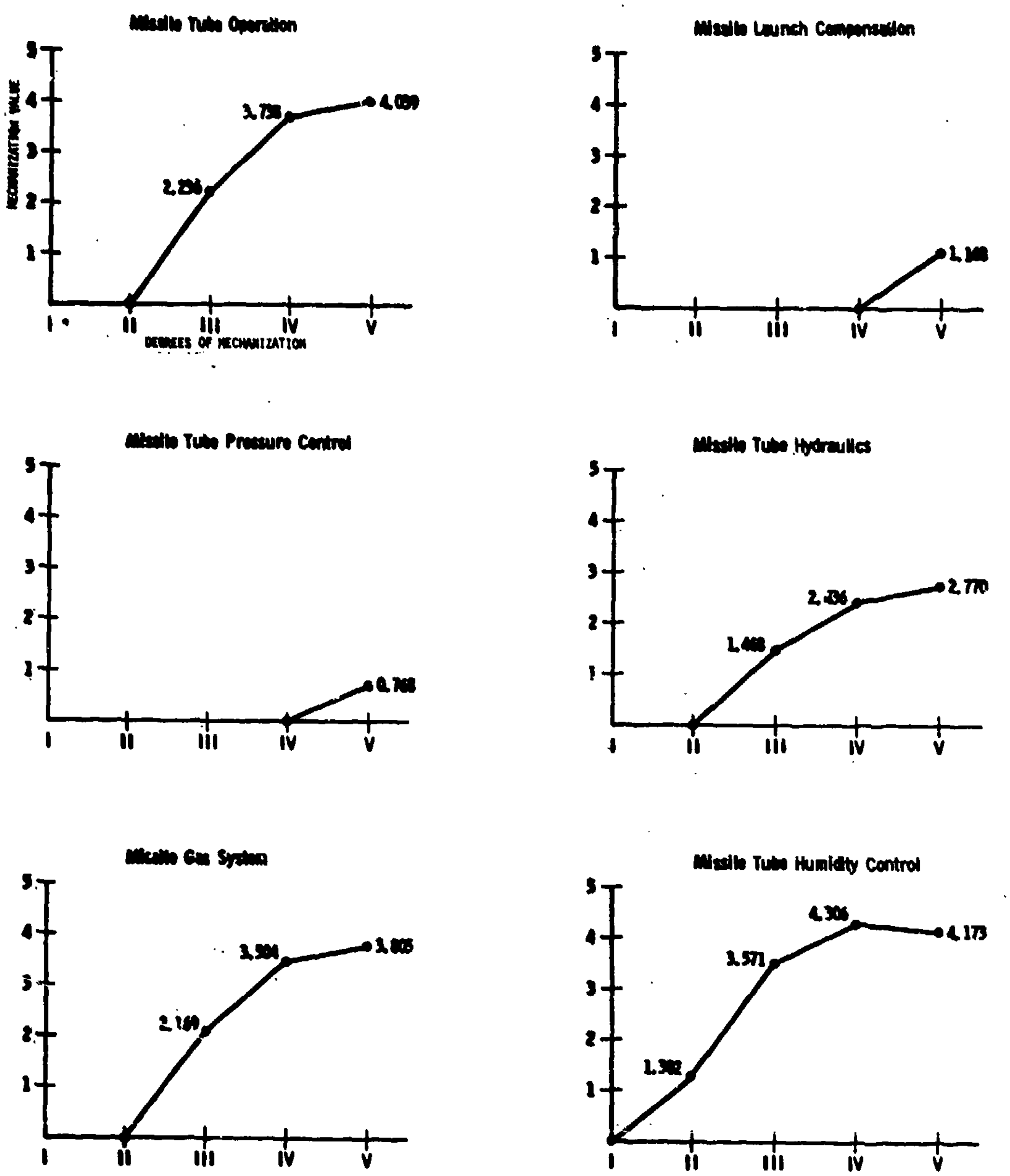


Figure III-B-12 Strategic Weapons Subsystem Element Mechanization Values

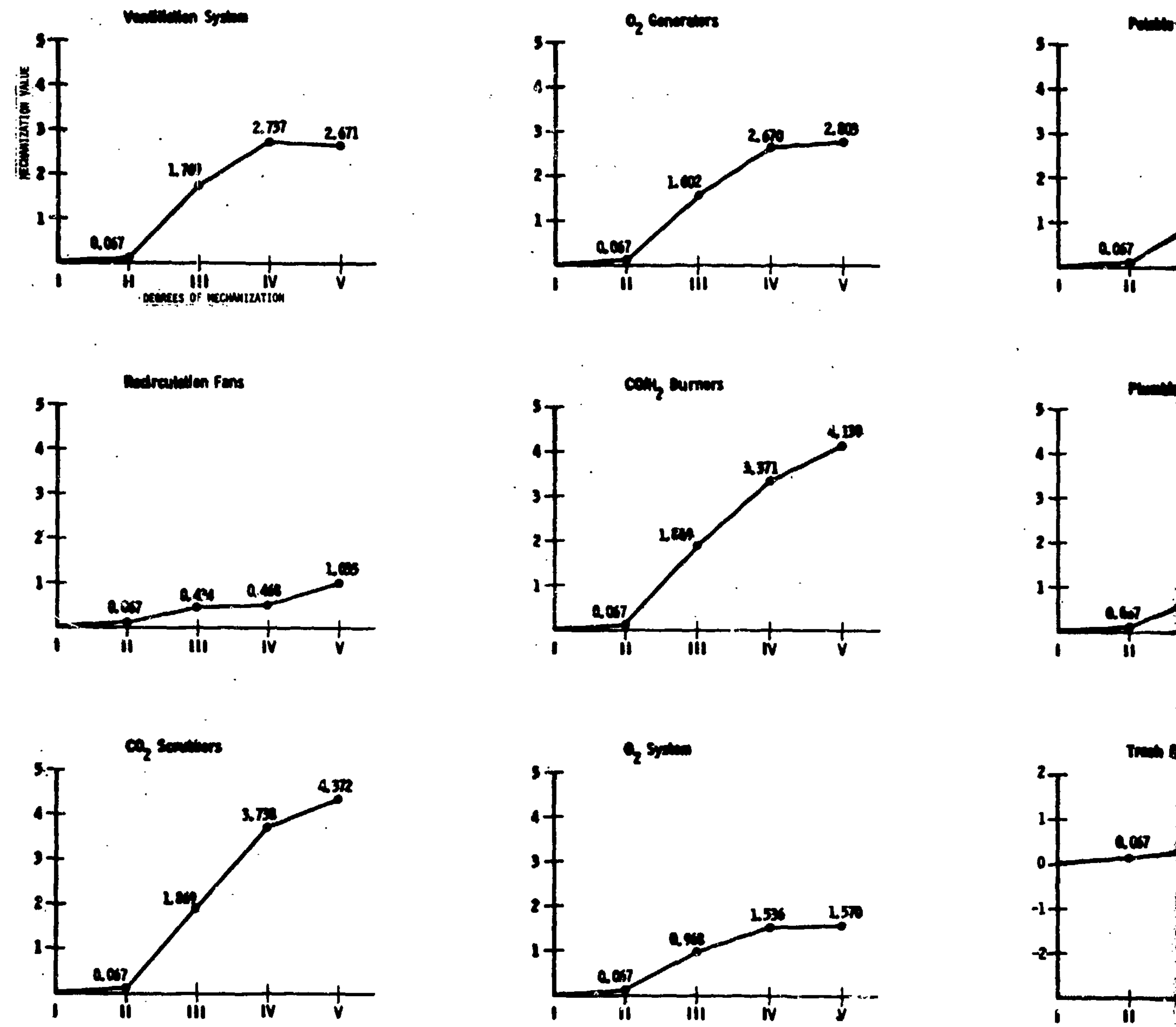
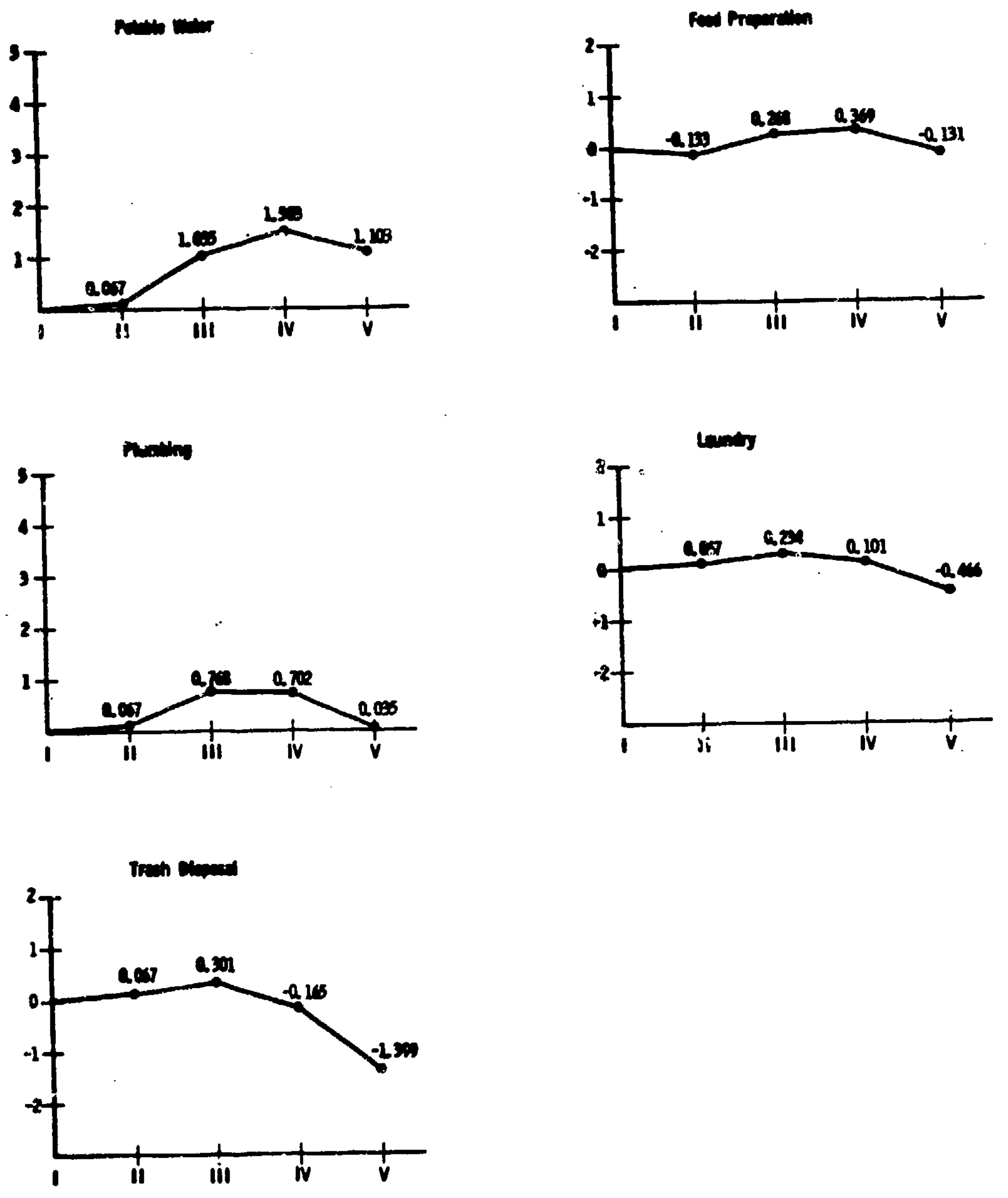


Figure III-B-13 Habitability Subsystem Element Mechanization Values



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nt Mechanization Values

2

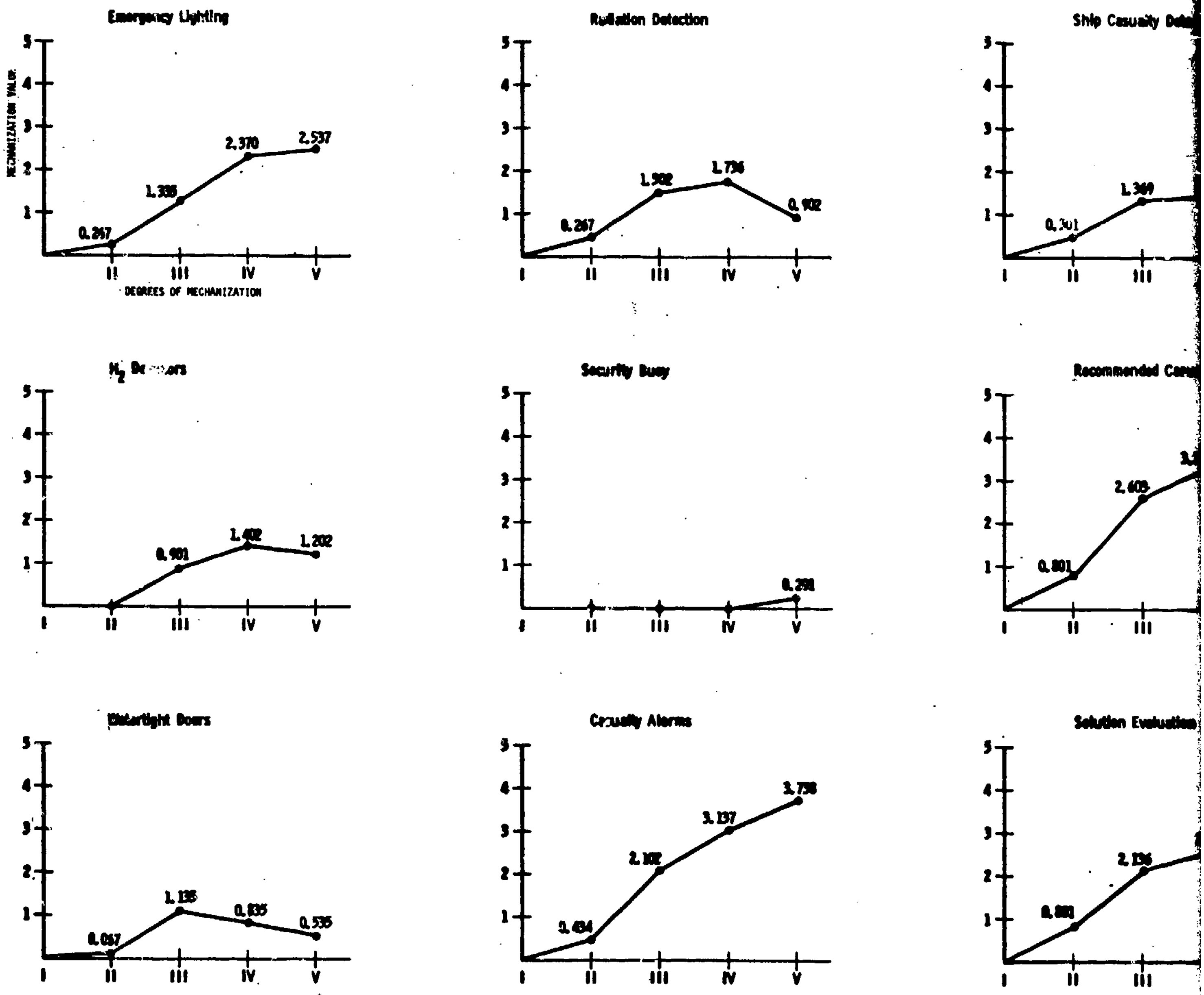
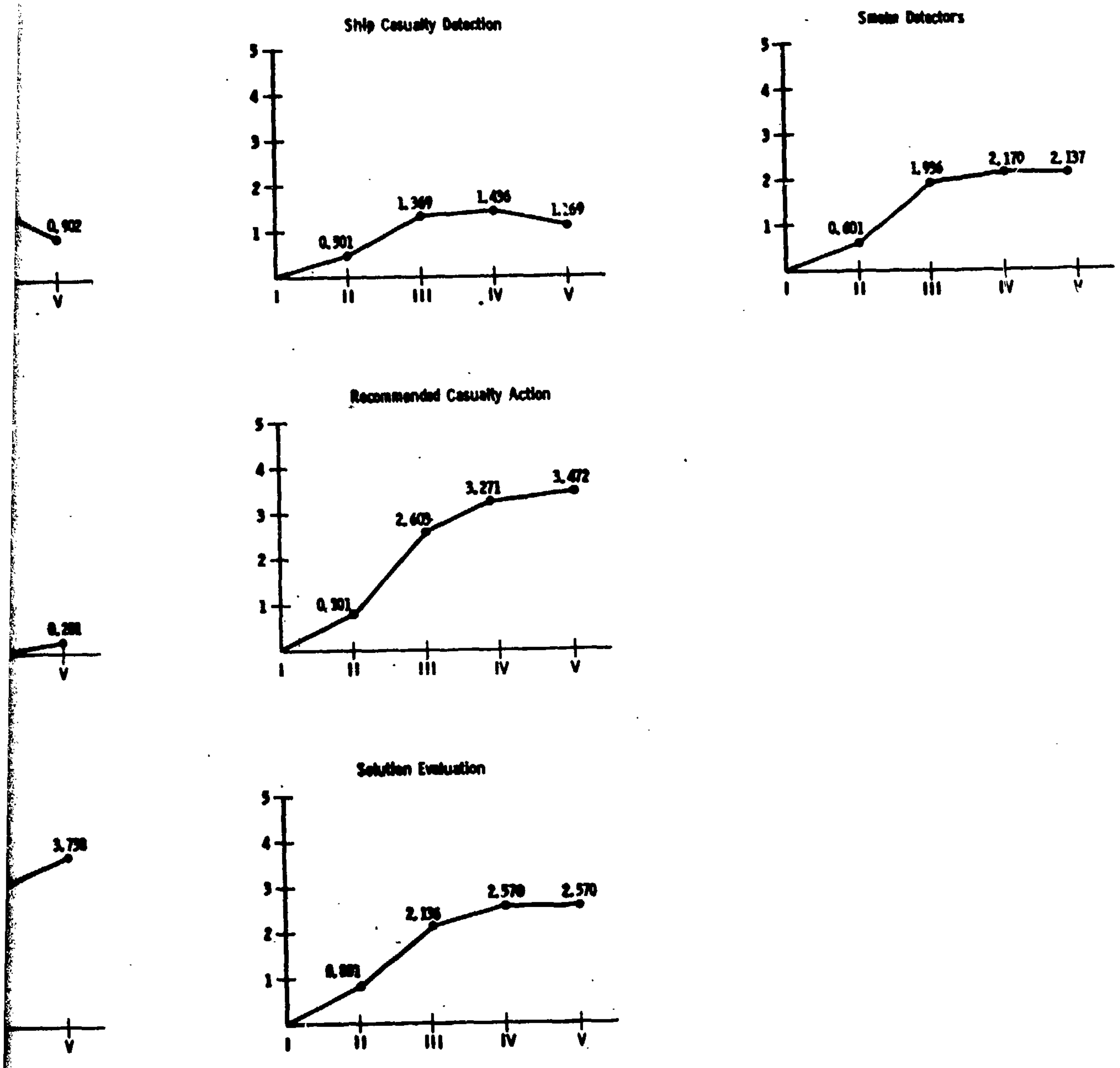


Figure III-B-14 Casualty and Damage Control Element Mechanization Values



rol Element Mechanization Values

b. Subsystem Mechanization Values - It was deemed desirable to determine each subsystem's mechanization value for each step of increase in mechanization. A subsystem's total "mechanization value" for a particular mechanization step was determined by summing the contribution of the individual elements considered within that subsystem for that mechanization step. Thus, to determine the total subsystem's mechanization value, the numeric value of each element for a given mechanization step for a specific subsystem was summed and is shown by mechanization steps in bar-graph form in Figures III-B-15 through III-B-24.

The subsystem mechanization values illustrated on these bar-graphs indicate a measure of the total value that would be achieved if each element in that subsystem was advanced to the next level of mechanization. The values were derived without regard to an "optimum" level of element mechanization and therefore they should not be construed to illustrate the most efficient or desirable amount of mechanization that should be utilized. The optimum points of mechanization were derived for each element by consideration of the inflection points on Figures III-B-5 through III-B-14 and by the integration of elements into operable subsystems. This consideration must be made since each subsystem and the ship generally operate as a whole and individual elements cannot always be considered independently.

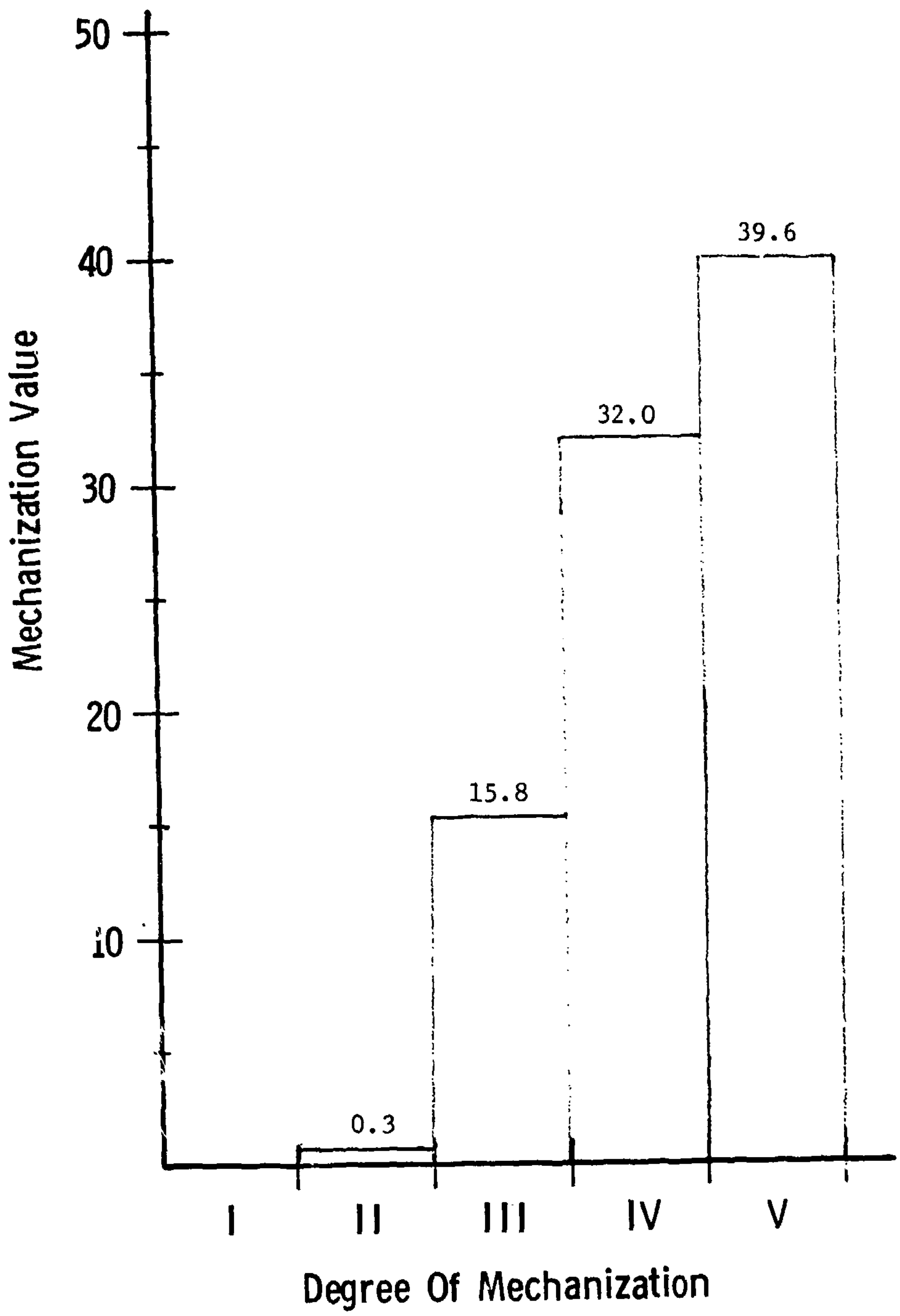


Figure III-B-15 Ship Control Subsystem Mechanization Value

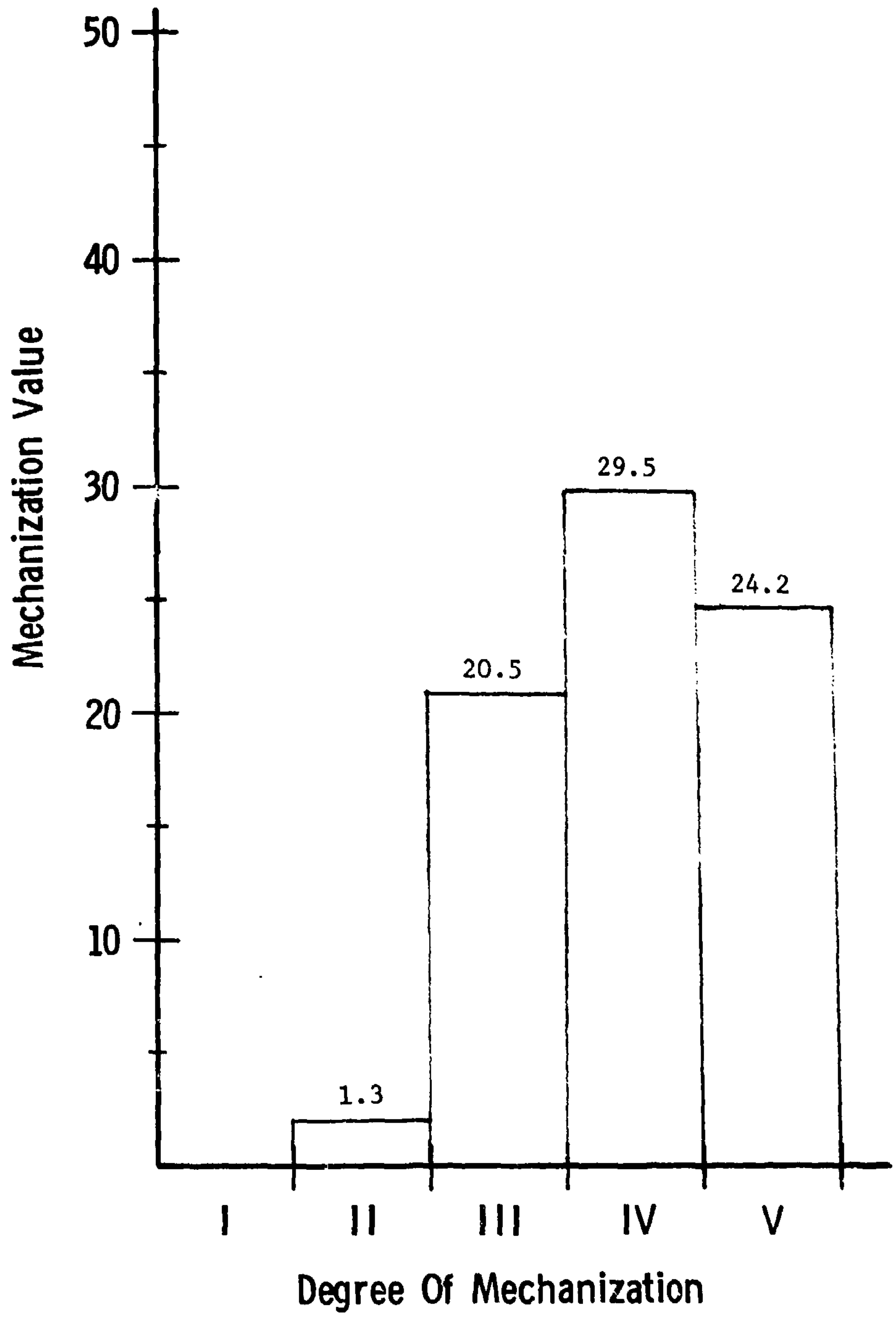


Figure III-B-16 Engineering Subsystem Mechanization Value

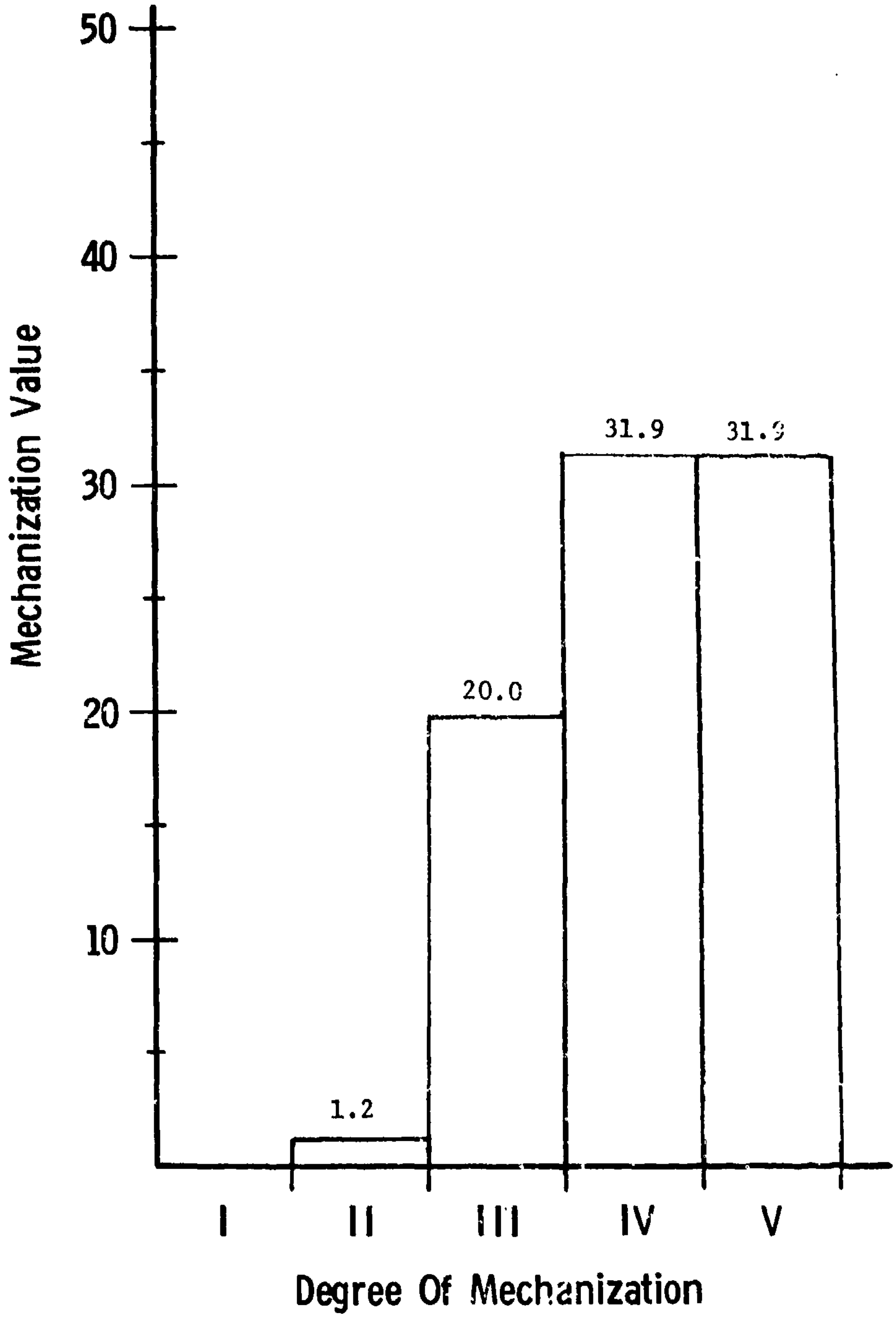


Figure III-B-17 Auxiliary Subsystem Mechanization Value

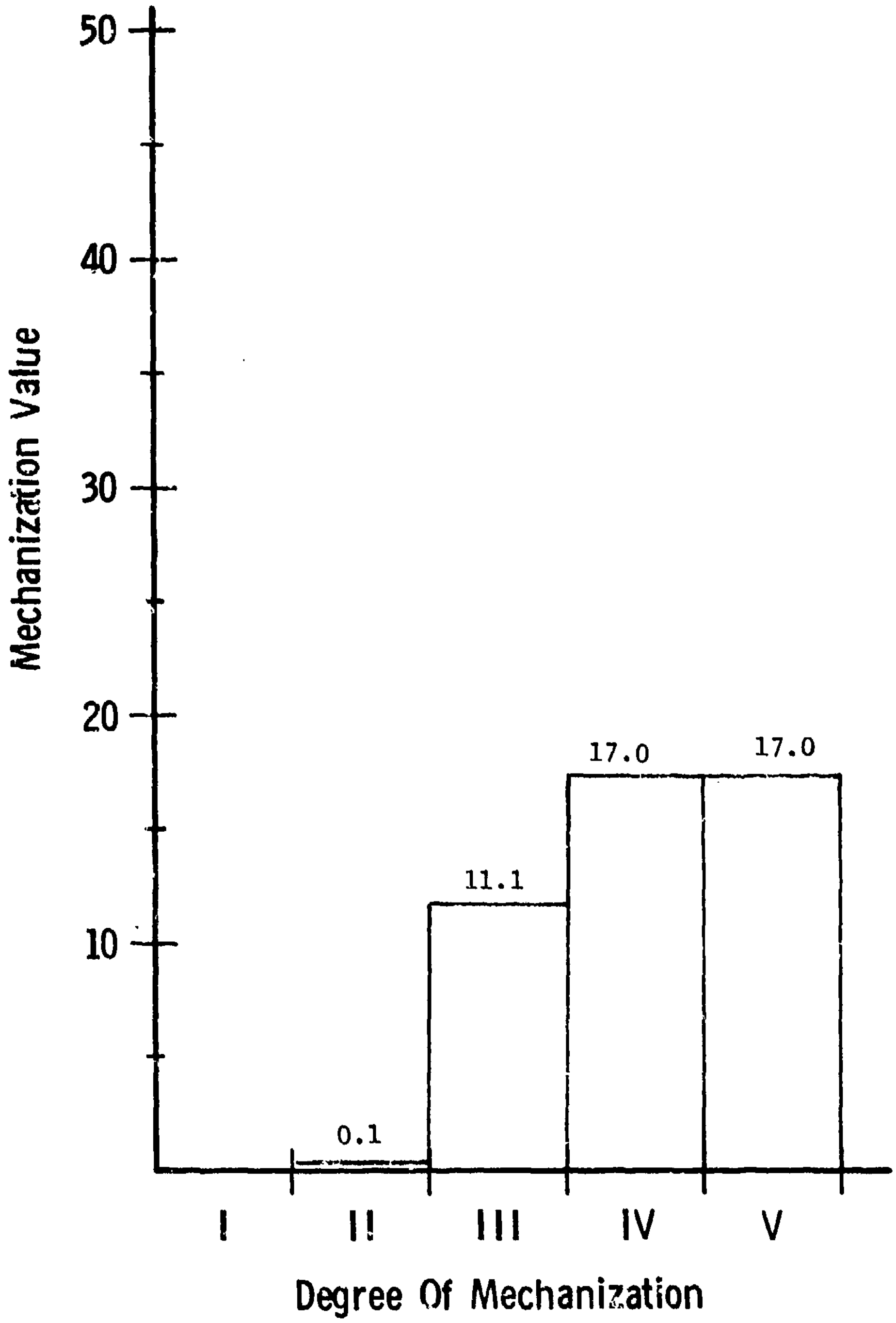


Figure III-B-18 Navigation Subsystem Mechanization Value

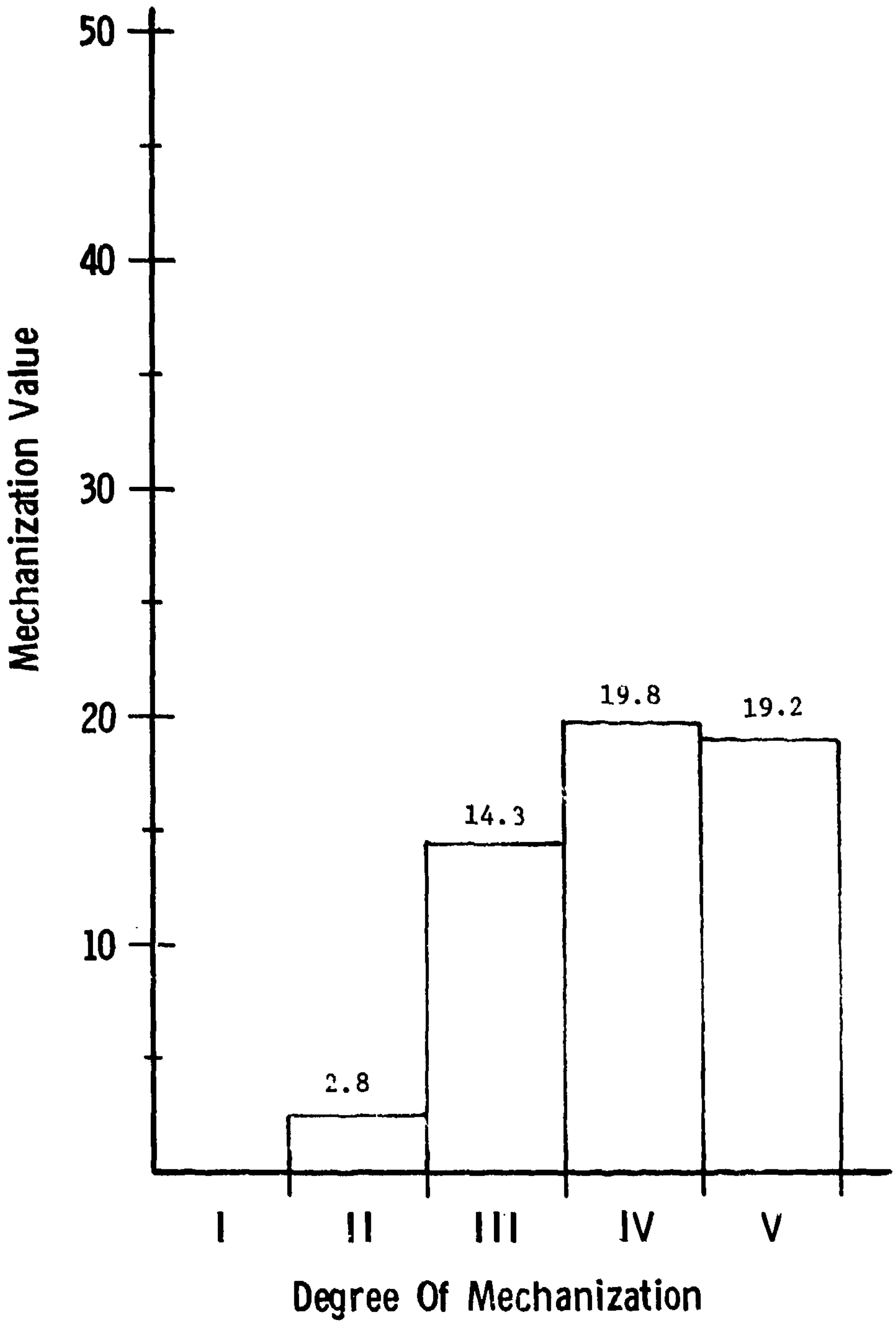


Figure III-B-19 External Communications Subsystem Mechanization Value

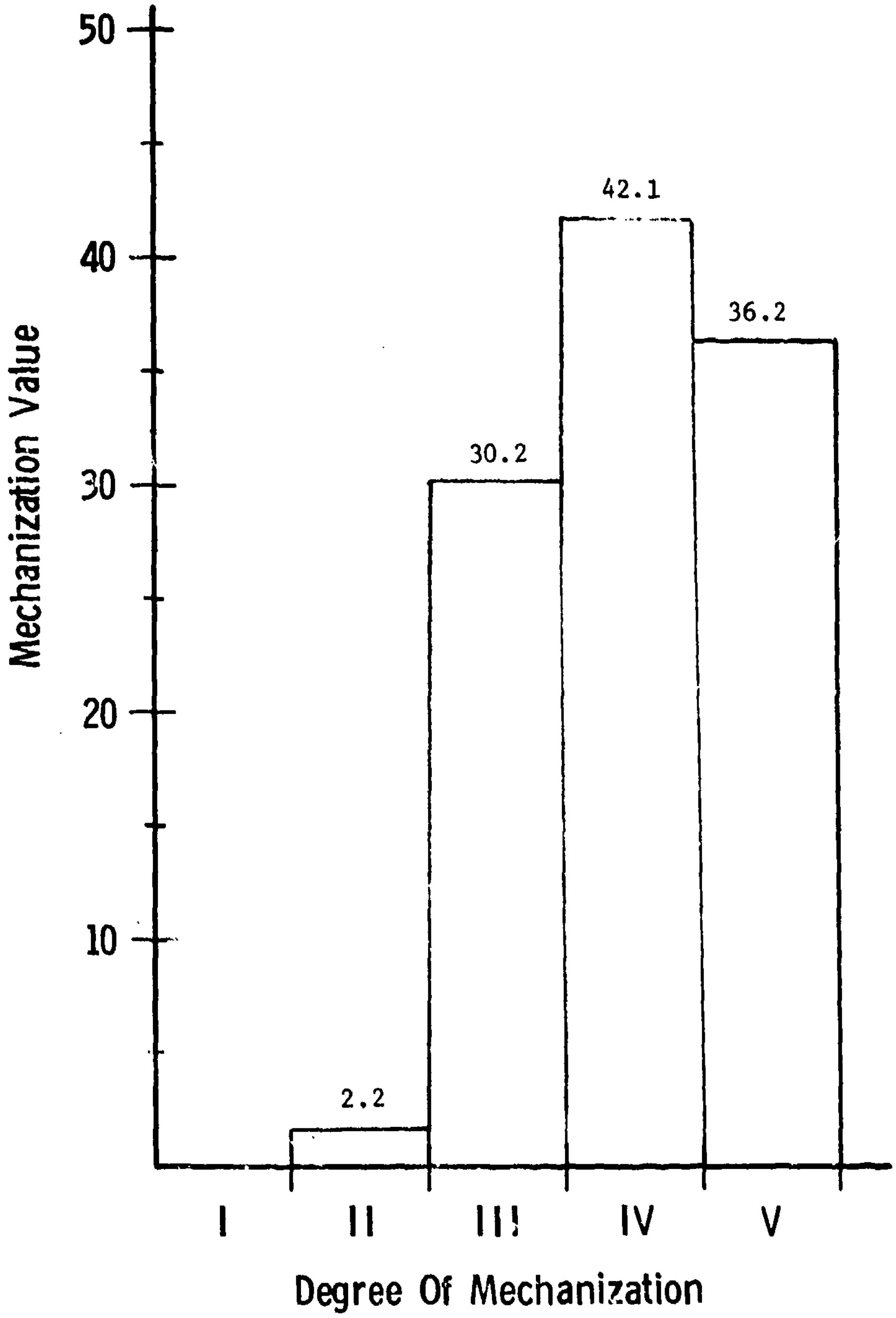


Figure III-B-20 Sonar/ECM Subsystem Mechanization Value

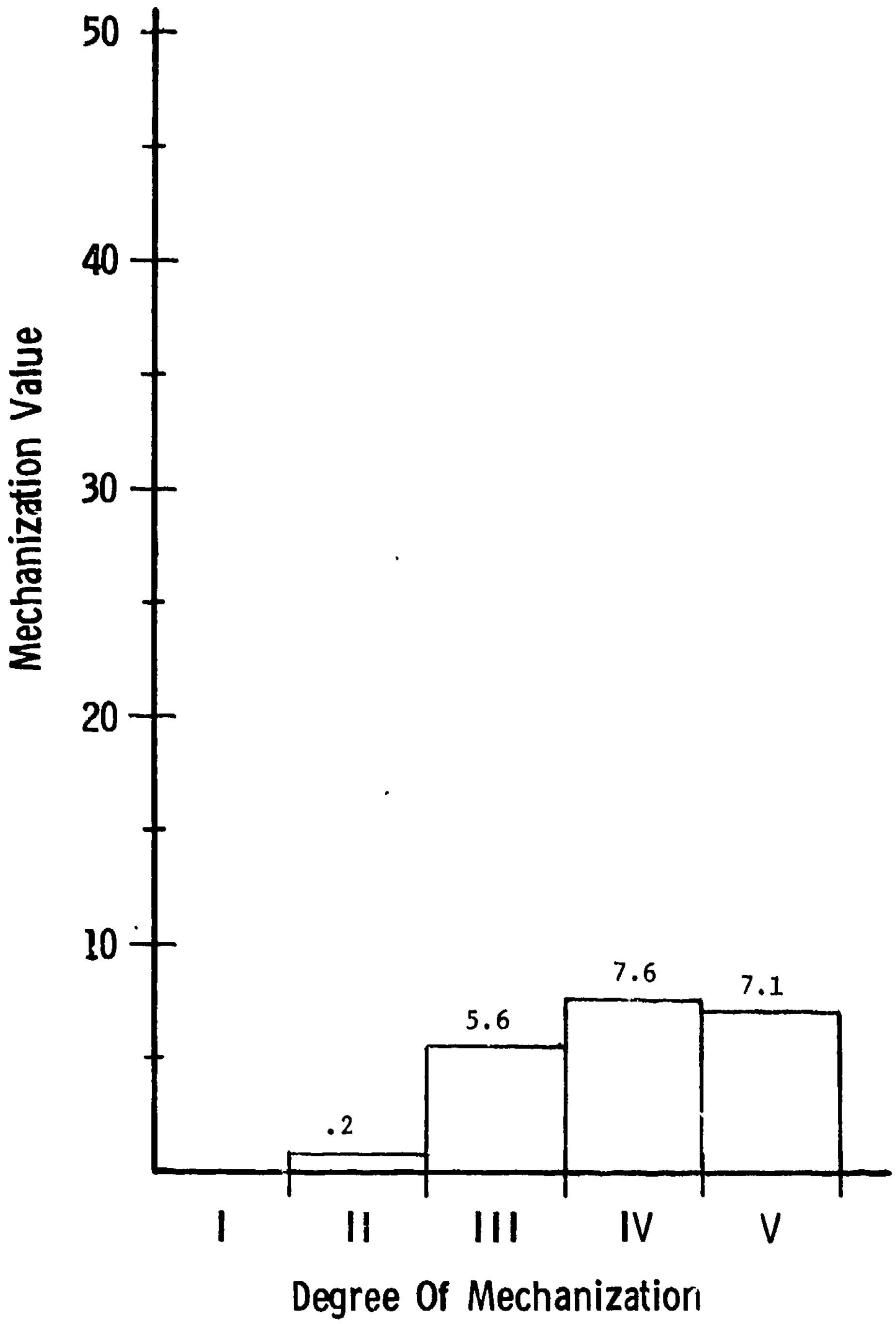


Figure III-B-21 Defensive Weapons Subsystem Mechanization Value

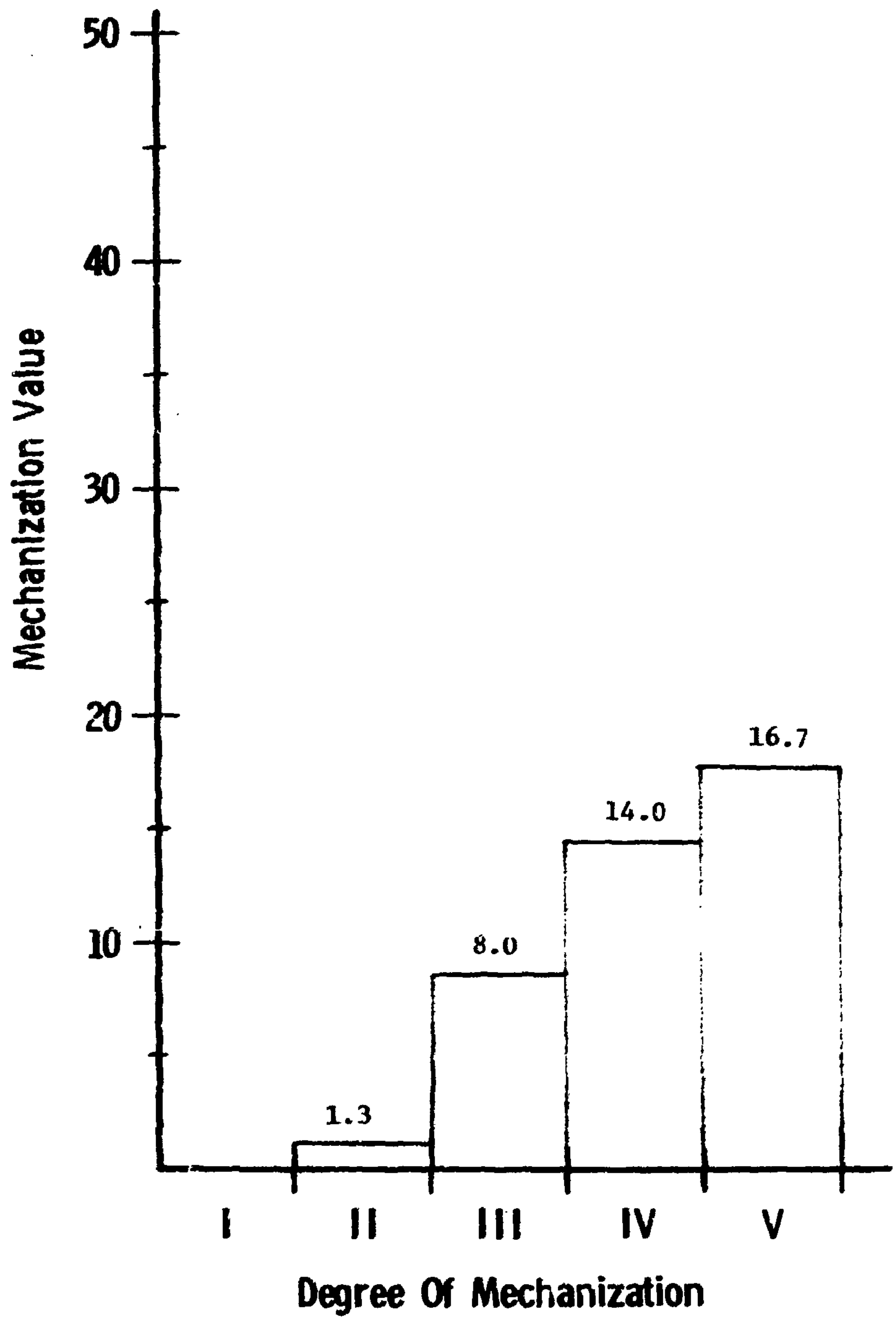


Figure III-B-22 Strategic Weapons Subsystem Mechanization Value

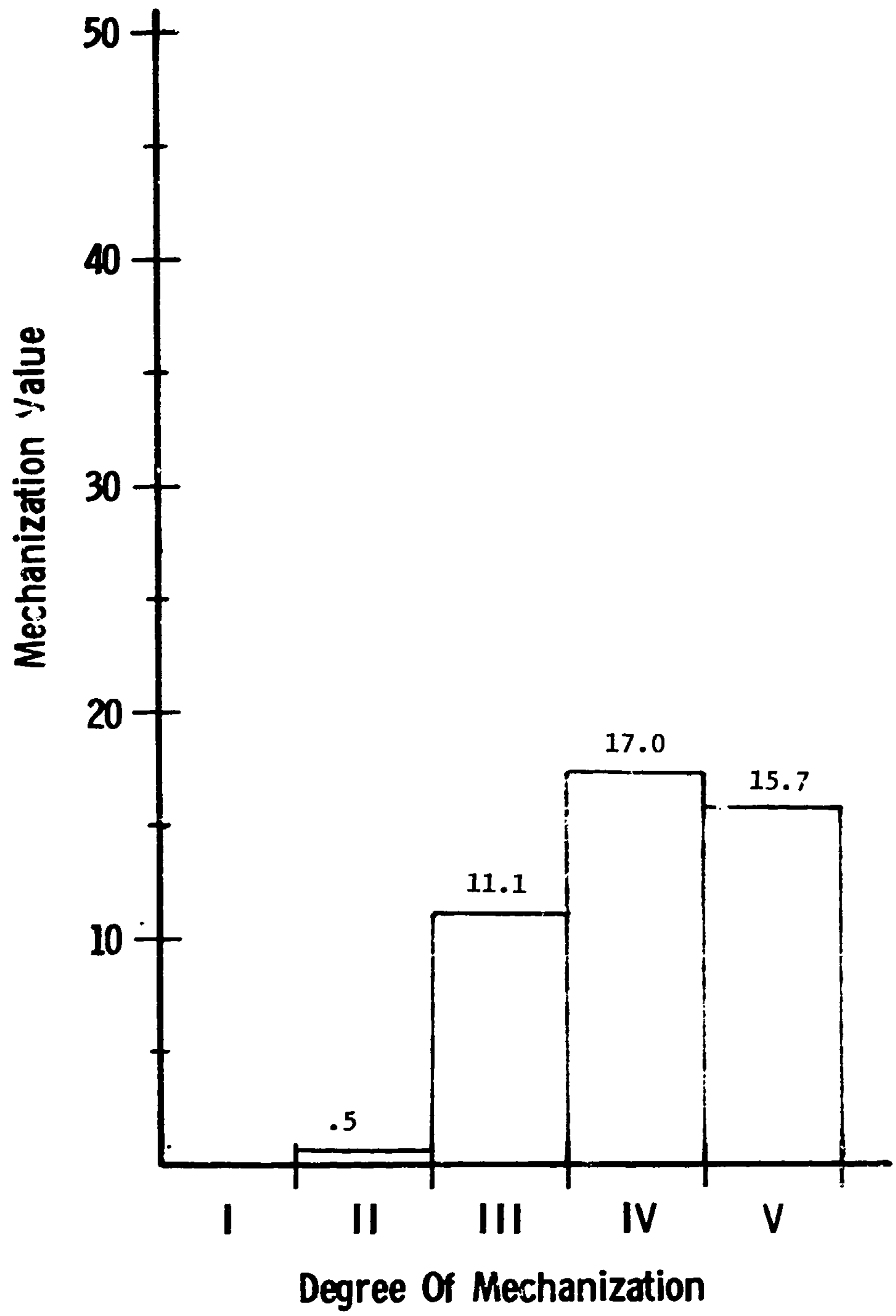


Figure III-B-23 Habitability Subsystem Mechanization Value

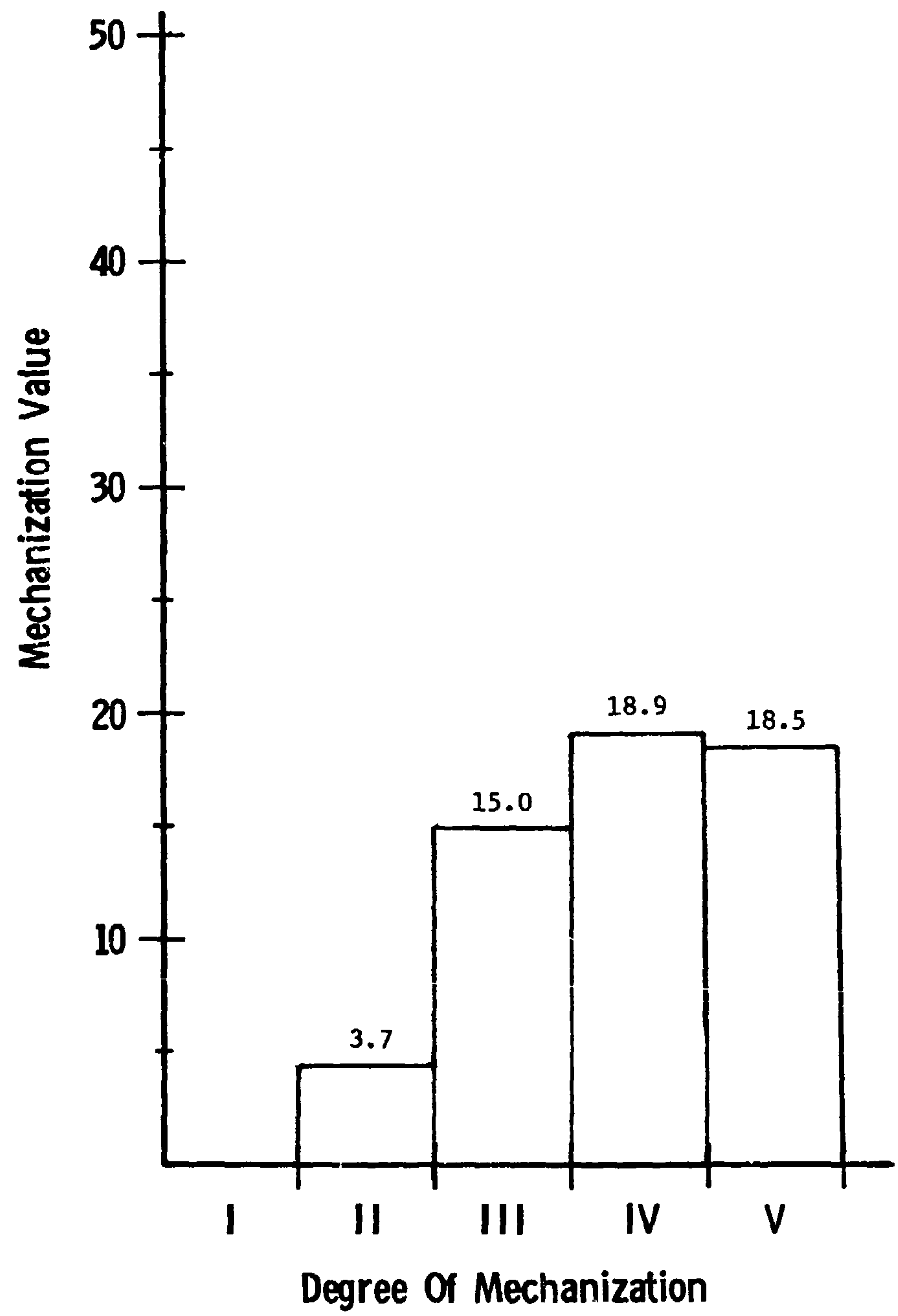


Figure III-B-24 Casualty and Damage Control Subsystem Mechanization Value

5. Mechanization Recommendations

The optimum degree of mechanization for each element was determined based on gain of advancing through additional steps of mechanization. The inflection point (change in direction of the slope) of the curves shown in Figures III-B-5 through III-B-14 served as a guide to the selection of the optimum degree of mechanization for the various elements of each subsystem. The inflection point provided the basis for determining the recommended mechanization for each subsystem element.

Figure III-B-25 illustrates the optimum degree of mechanization selected for each element. The dot (•) on the figures represents an indication of the average current state of mechanization on a baseline SSBN. The arrow (⟶) indicates the degree of mechanization recommended as a result of the analyses performed in this study. The relative length of the arrow represents a measure of the amount of mechanization advancement for each subsystem element.

Figure III-B-25 Optimum Element Mechanization Selection for an Integrated Ship

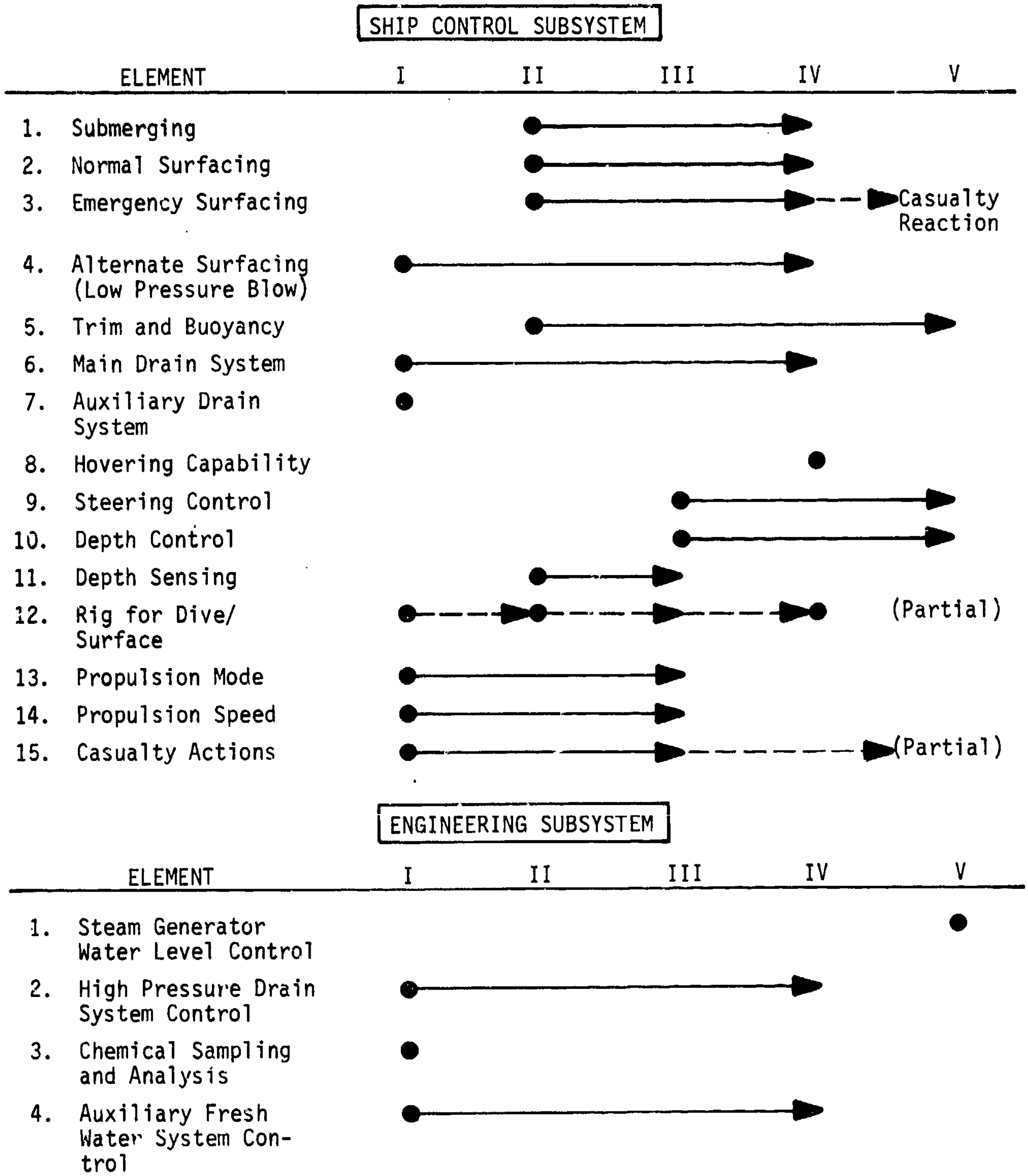


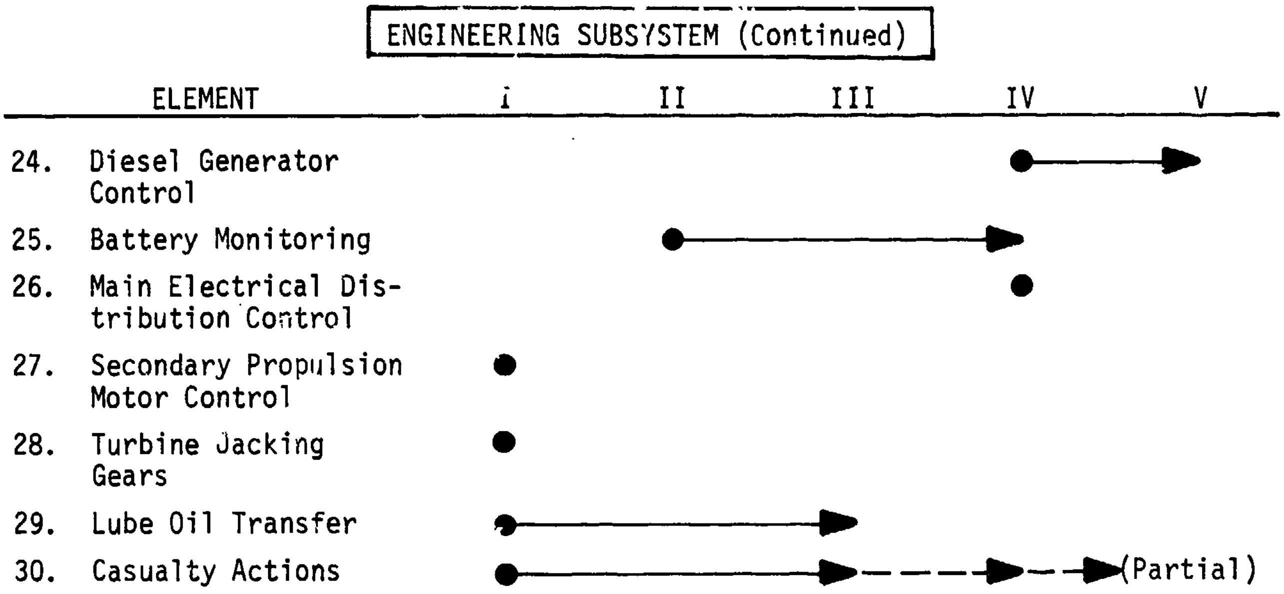
Figure III-B-25 (Continued)

ENGINEERING SUBSYSTEM (Continued)

● Initiation

	ELEMENT	I	II	III	IV	V
5.	Makeup Feed Control	●	—	—	→	
6.	Main Feed System Control	●	—	—	→	
7.	Auxiliary Steam Control	●	—	—	→	
8.	Sea Water Cooling Control	●	—	—	→	
9.	Turbine Gland Seal					●
10.	Condensate System Control	●	—	—	→	
11.	Hot Well Level Control	●	—	—	→	●
12.	Low Pressure Drain System Control	●				
13.	Air Ejector Control	●	—	—	→	
14.	Main Steam System Control		●	—	→	
15.	Fresh Water Drain System Control					●
16.	Main Propulsion Turbines		●	—	→	
17.	Clutch Control		●	—	→	
18.	Emergency Propulsion Motor Control	●	—	—	→	
19.	Shaft Seal	●				
20.	Lube Oil (Main, Shaft, SSTG)	●	—	—	→	
21.	Ship Service Turbine Generator				●	→
22.	Ship Service Motor Generator Control				●	→
23.	Diesel Engine Control	●	—	—	→	

Figure III-B-25 (Continued)



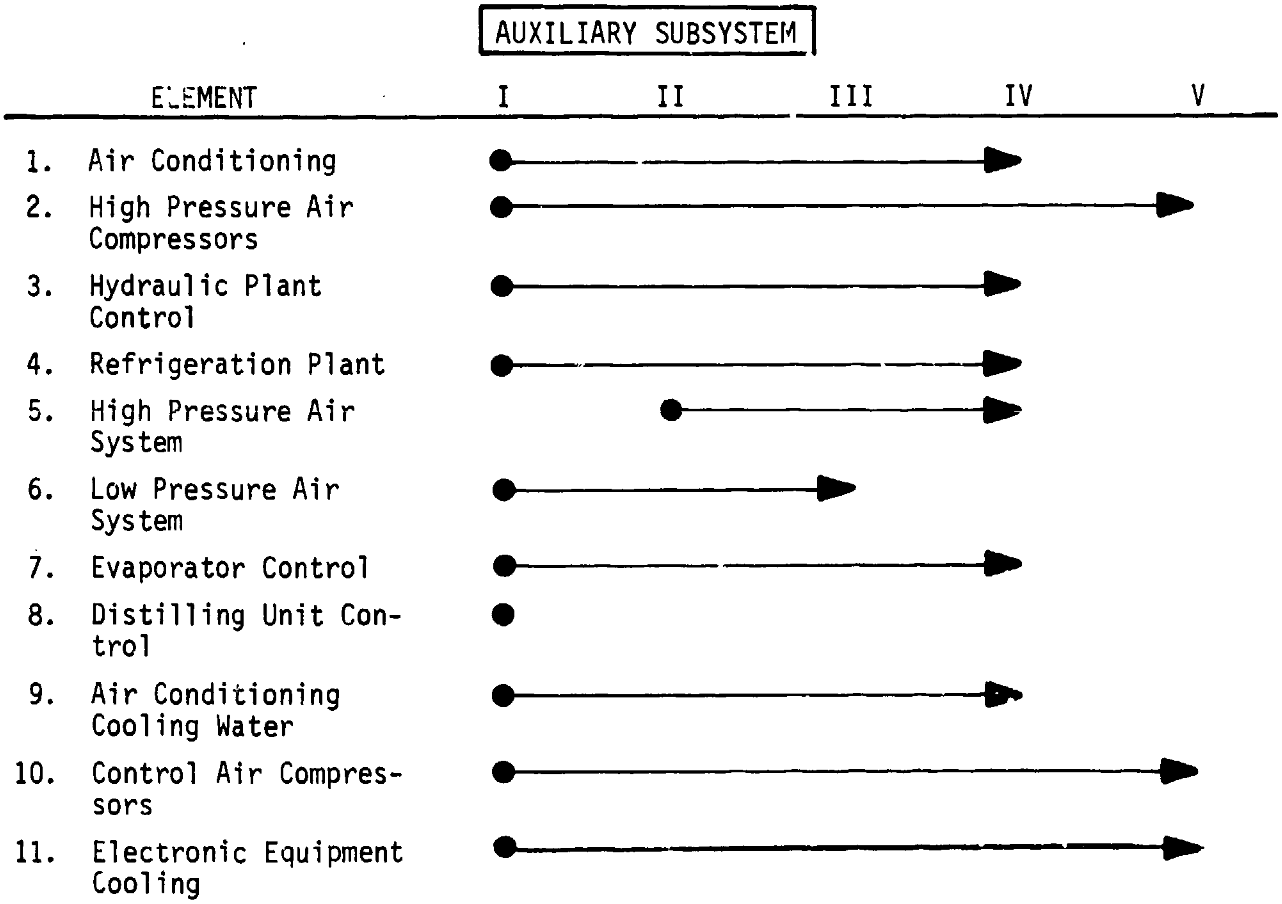


Figure III-B-25 (Continued)

AUXILIARY SUBSYSTEM (Continued)

ELEMENT	I	II	III	IV	V
12. Air Conditioning Chill Water	●	—	—	▶	
13. Fuel Oil and Compensating Water	●	—	—	▶	
14. Anchor Release	●	—	—	▶	
15. Windlass and Capstan	●				

NAVIGATION SUBSYSTEM

ELEMENT	I	II	III	IV	V
1. Gyro Compass		●			
2. Dead Reconing Analyzer Indicator		●			
3. Electromagnetic Log		●	▶		
4. Central Navigation Computer				●	▶
5. Satellite Navigation Fix Capability		●	—	▶	
6. Radio Navigation Fix Capability		●	—	▶	
7. Inertial Navigation System		●	—	—	▶
8. Navigation Control Console		●	—	▶	
9. Ocean Bottom Navigation Fix Capability		●	—	▶	
10. Periscope Optics	●				

Figure III-B-25 (Continued)

EXTERNAL COMMUNICATIONS SUBSYSTEM

ELEMENT	I	II	III	IV	V
1. MF/HF Transmitter	●	—	▶		
2. UHF Transceiver	●	—	—	▶	
3. MF/HF Transceiver	●	—	▶		
4. VLF Receivers	●	—	—	▶	
5. MF/HF Receivers	●	—	—	▶	
6. Teletype Equipment	●	—	—	—	▶
7. Security Equipment	●	—	—	—	▶
8. Radio Telephone	●				
9. Multicoupler	●	—	—	▶	
10. MF/HF/UHF Antenna Control				●	
11. Emergency Antenna Control	●				
12. VLF Antenna Control		●	—	▶	
13. Entertainment Receiver	●				
14. Antenna Performance Monitoring	●	—	▶		

SONAR ECM SUBSYSTEM

ELEMENT	I	II	III	IV	V
1. Passive Sonar (Conformal Array)		●	—	▶	
2. Active Sonar		●	—	▶	
3. Passive Sonar (Cylindrical Array)		●	—	▶	
4. Passive Sonar (Narrow Frequency Band)		●	—	▶	
5. Passive Sonar (Trailing Array)		●	—	▶	

Figure III-B-25 (Continued)

SONAR ECM SUBSYSTEM (Continued)

ELEMENT	I	II	III	IV	V
6. Passive Sonar (Overhead Array)		●	—	▶	
7. Sonar Performance Computer		●	▶		
8. Fathometer		●	▶		
9. Underwater Telephone	●				
10. Sound-Velocity Profile Determination		●	▶		
11. Sonar ECM		●	▶		
12. Sonar Contact Classification	●	—	—	—	▶
13. Sonar Parameter Identification (Frequency Modulation)		●	—	▶	
14. Radar		●			
15. ECM		●	—	▶	
16. Electronic Identification System	●				
17. Microwave Intercept Receiver	●	—	—	▶	
18. ECM Contact Classification	●	—	—	▶	
19. Sonar and ECM Antenna Control				●	
20. Sonar Trailing Array Control				●	
21. Sonar Array Performance Monitoring	●	—	▶		

Figure III-B-25 (Continued)

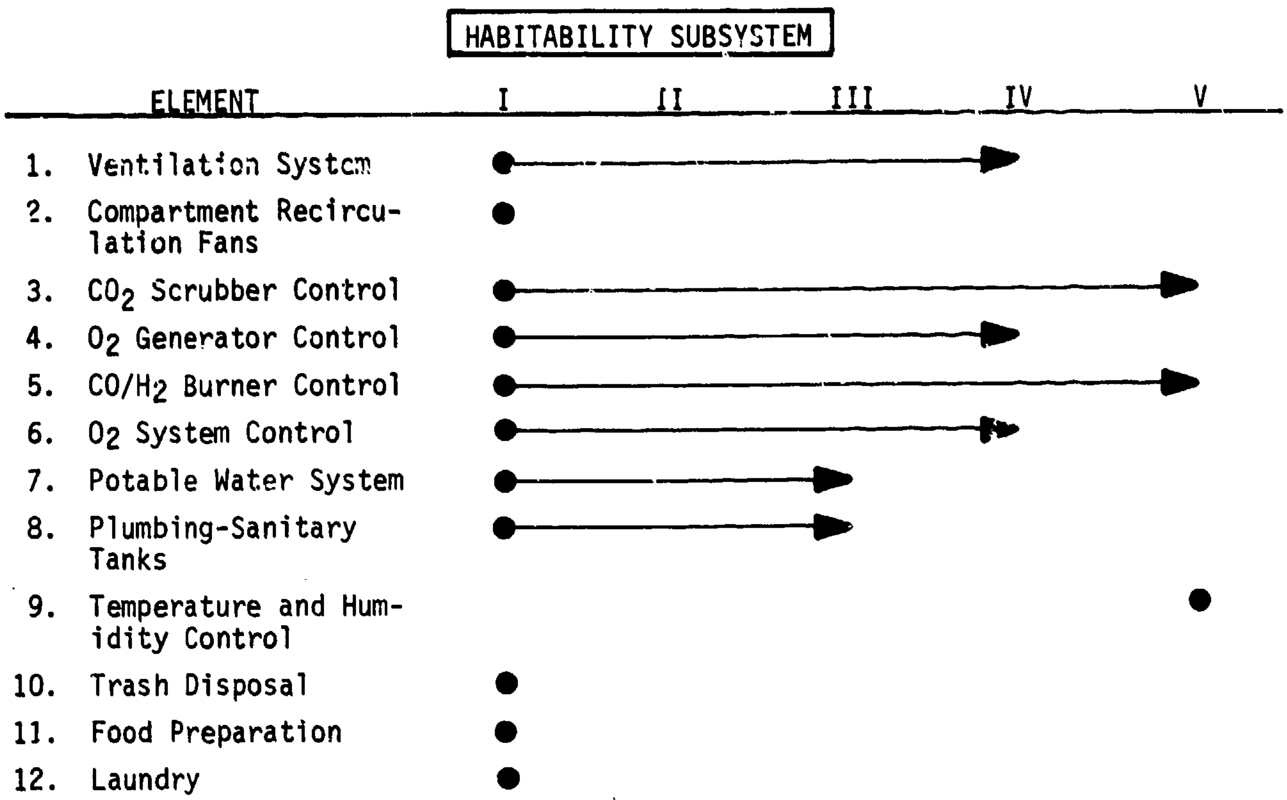
DEFENSIVE WEAPONS SUBSYSTEM

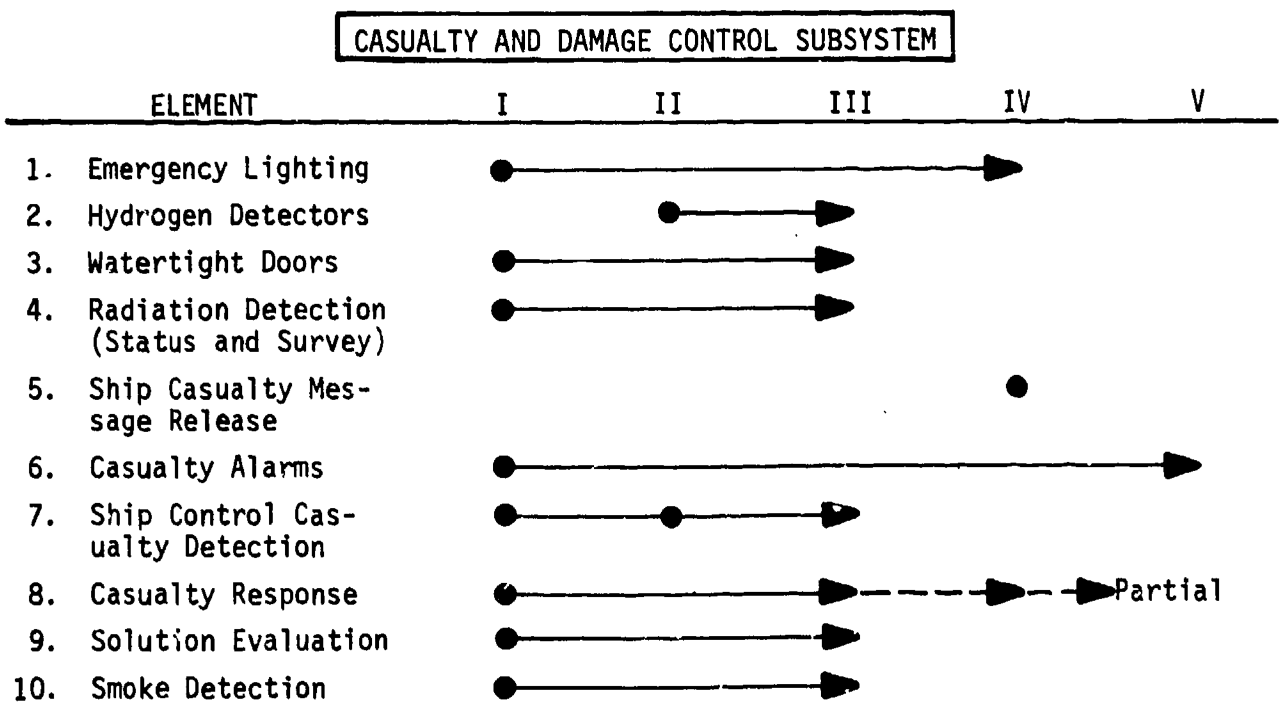
ELEMENT	I	II	III	IV	V
1. Torpedo Tube Operation		●	—	▶	
2. Torpedo Loading	●				
3. Torpedo Firing				●	
4. Signal Ejector Loading	●				
5. Signal Ejector Firing	●	—	—	▶	
6. Target Motion Determination		●	—	▶	
7. Torpedo Input Selection	●	—	—	▶	

STRATEGIC WEAPONS SUBSYSTEM

ELEMENT	I	II	III	IV	V
1. Missile Tube Operation		●	—	▶	
2. Missile Tube Pressure Control				●	▶
3. Missile Gas System		●	—	▶	
4. Missile Launch Compensation				●	▶
5. Missile Tube Hydraulics		●	—	▶	
6. Missile Tube Humidity Control	●	—	—	▶	
7. Missile Tube Temperature Control					●
8. Missile Launch Preparation				●	
9. Missile Launch Initiation				●	

Figure III-B-25 (Concluded)





6. Crew Requirements

Analyses of the approximate number of crewmen that would be required to operate each of the 10 subsystems at each of the five levels of mechanization were performed. The results of these analyses and a discussion of their meaning and manner of interpretation is presented in Appendix III. The material presented in the present section is directed to a discussion of the crew requirements for a new generation SSBN designed as an integrated ship to meet the optimum mechanization concepts recommended in our study.

These crew requirements were developed through comparisons of existing crew manning requirements for the baseline SSBN and the mechanization concepts developed for ship's subsystems as identified in Table III-B-25. An in-depth analysis of the mechanization concepts indicated that nine broad classes of crew functions would be required for the crew of the new generation SSBN:

(1) Decision-making;

(2) Console (C&D) tasks;

(3) Response to computer-initiated alerts;

(4) Manual operation of equipment;

(5) Preventive maintenance;

(6) Corrective maintenance (replacement of modules put off-line by computers and computer-assisted disassembly and repair);

(7) Inspection tasks;

(8) Casualty and damage control;

(9) Override computerized functions.

The watch structure as it currently exists was discarded in the new generation SSBN concept. However, certain aspects of a watch-type structure have been retained. Specifically, two watch stations have been identified--one at the Ship's Control Console and one at the Engineering Plant Console. Both of these watch stations utilize officer watchstanders. The officer on watch at the Ship's Control Console has been designated Officer of the Deck (OOD) and the officer on watch at the Engineering Plant Console has been designated Engineering Officer of the Watch (EOOW). These two designations were retained because the duties and responsibilities of the two officers will be essentially the same as the current responsibilities for the OOD and EOOW shown in Table III-A-13.

The essential differences will be that the OOD and EOOW will effect their responsibilities not be receiving verbal reports and issuing verbal commands, but rather by interfacing with the computer through their respective consoles.

The new generation SSBN concept requires minimal manual actions to accomplish nominal and contingency evolutions; however, certain manual operations were retained. The requirement to perform a limited number of manual operations plus the requirement for maintenance and casualty control dictated additional crew members to assist the OOD and EOOW. An in-depth analysis of the retained manual operations, maintenance requirements, and response to various forms of casualty situations resuled in the assignment of three enlisted crewmen to OOD and three to the EOOW. These six crewmen would not be watchstanders in the traditional sense; rather, they will be available to the OOD and EOOW during their watch to perform tasks at their discretion. Their major responsibilities would be to perform operational tasks, and preventive and corrective maintenance under direction of the OOD and EOOW.

Since the requirement for personnel services will be essentially unchanged on the new generation SSBN, an analysis of the crew required to perform functions of food preparation, storekeeping, medical, and records (yeoman) preparation, etc was performed. The number of crewmen required to perform these functions is dependent on the total crew size. Our analyses indicated that a total of three crewmen can perform the personnel services on the new generation SSBN. Two crewmen would be assigned to perform cook/storekeeper functions and one crewman would perform medical/yeoman functions.

A nominal crew complement of 30 crewmen would be required to operate the new generation SSBN for all nominal and contingency evolutions. Seven of the 30 are officers--Commanding Officer, three to serve as OOD and three to serve as EOOW. The requirement for three OODs and EOOWs arises from the requirement for a three section watch rotation. A nominal complement of 18 enlisted crewmen would serve as operational personnel for the OOD and EOOW; they will be designated Maintenance Technicians (MT). The MTs will have two basic skill specialties--electronics and mechanics (including hydraulics). A majority of the new generation SSBN maintenance requirements will be electronic (including computer); therefore, 12 MTs will be electronic specialists and six will be mechanics specialists. The MTs will have secondary skill specialties which may come from specialized short courses; e.g., weapons, navigation, communications, etc or from on-the-job training. Three electronics MTs will be assigned to the OOD watch--one will have a sonar skill specialty and one a computer skill specialty. Two electronic MTs and one mechanics MT will be assigned to the EOOW watch. It is anticipated that in an operational enviornment some crew members will be new trainees; therefore, two new trainee crewmen were added to bring the total crew size to 30.

It is reasonable to assume that administrative functions will be essentially unchanged in a new generation SSBN; therefore, a preliminary administrative structure was proposed. The administrative structure for a crew size of 30 is shown in Figure III-B- 26

Analysis of the crew operations for nominal and casualty evolutions on the new generation SSBN were performed to insure that a crew of 30 could accomplish the SSBN mission. For nominal evolutions, the analyses indicated that all could be successfully performed by the OOD, EOOW, and six Maintenance Technicians on a three section watch rotation. Tables III-B-4, III-B-5, and III-B-6 present the results of these analyses for three major ship control evolutions of diving, surfacing, and snorkeling. Each table presents a comparison of the crew activity sequence and the involved crewmen required on the baseline SSBN (on the left) and the crew activities required on the new generation SSBN concept (on the right).

Obviously, the major difference between activities for new generation as compared to baseline SSBN for all three evolutions is the dramatic reduction in manual operations and verbal reports, and a concomitant reduction in personnel requirements. For example, nominal performance of diving in the baseline SSBN requires 37 identifiable activities, and the active participation of 12 crew members plus the participation of all watchstanders to rig the ship and report conditions to control. Diving in the new generation SSBN requires 13 identifiable activities, three crewmen (OOD, his temporary relief, and a Maintenance Technician), vastly reduced requirements for manual rigging of the ship, and no nominal requirements for verbal reports. For surfacing, the corresponding comparison between baseline and new generation SSBN are 39 activities and nine crewmen versus six activities and two crewmen. For snorkeling the figures are 45 activities and 12 crewmen versus seven activities and two crewmen.

It needs to be emphasized that comparisons of numbers of activities and crewmen between baseline and new generation SSBNs overlook another major difference between the two concepts. Activities for baseline SSBN are manually complex in many instances while crew activities for the new generation SSBN are manually and perceptually simple (control/display operations). Decision-making requirements are similar in both, but data relevant to decisions are more reliable, less susceptible to human error, and more quickly and readily obtainable in the new generation concept.

Table III-B-4 Comparison of Crew Operations for Diving Evolution in Baseline and New Generatio

BASELINE SSBN		
ACTIVITY SEQUENCE	**CREW**	
1. Rig ship for dive.	All compartment watch standers and designated officers.	Some riggin in compartm matically. duced. Com statuses ma Control Con signal at S
2. Normally the OOD would order: Secure Snorkeling (Snorkel Bill) or Secure Ventilating (Ventilation Bill) before the order to submerge the ship.		All systems either manu displayed a would be in Control Con equipment w specific qu would be di
3. Man the outboard ship control station.	Lee Helmsman	These funct bridge for nician. OO supervises ted, OOD wo orary relie for visual
4. OOD relieved by person in control room.	"New" OOD	
5. Assist in rigging the bridge for dive.	Lookout	
6. Assist in rigging the bridge for dive.	Quartermaster of Watch	
7. Remove IC suitcase from bridge	Auxiliary Electrician Forward	
8. Ensure bridge properly rigged for dive.	"Old" OOD	
9. Secure the bridge access hatch.	"Old" OOD	
10. Secure all IC circuits to the bridge.	Auxiliary Electrician Forward	
11. Secure lower bridge hatch	Quartermaster of Watch	
12. Secure navigational lights and search light.	Quartermaster of Watch	
13. Report "straight board" to OOD.	COW	
14. "Old" OOD relieve "New" OOD.	OOD	
15. Order the DOW to submerge the ship (with CO's permission).	OOD	Submergence at Ship's C pronibit di trol would
16. Order the COW to pass "Dive, dive" on the IMC and sound the diving alarm twice.	DOW	
17. Pass "Dive, Dive" on IMC and sound diving alarm. Assist COW as necessary.	COW Auxiliary Watch Forward	
18. Place two hydraulic pumps in run (main and one lead).	COW	Activities sequenced a accomplish they would initiate a could inte initiate a
19. Train the radar mast for lowering.	Radar/ECM	
20. Cease transmitting from radio	Radar Operator	

ion in Baseline and New Generation SSBN

CREW	NEW GENERATION SSBN
t watch standers and icers.	Some rigging for dive would be done manually by maintenance technicians in compartments; however, most rigging would be accomplished automatically. Requirements for manual rigging would be considerably reduced. Computer would sense status of systems rigged for dive and statuses may be requested for visual verification by OOD at Ship's Control Console. Failure of proper rigging status would initiate signal at Ship Control Console.
	All systems requiring "secured status" for diving would be secured either manually or automatically. Confirmation of status would be displayed at Ship's Control Console. Automatic securing functions would be initiated by OOD by manipulation of manual controls at Ship's Control Console. Status of individual systems, subsystems, or items of equipment would not necessarily be displayed but OOD could request specific questions to computer. "Ship rigged for dive" indication would be displayed as baseline case.
of Watch ctrician Forward ctrician Forward of Watch of Watch	These functional activities would be basically unchanged. Rigging the bridge for dive would be accomplished by OOD and a Maintenance technician. OOD would be temporarily relieved by "new" OOD while he supervises the activities at the bridge. When activities are completed, OOD would return to Ship's Control Console and relieve his temporary relief. Verification of their accomplishment would be available for visual display at Ship's Control Console.
ch Forward	Submergence would be accomplished by OOD's initiation of manual control at Ship's Control Console. Desired depth would be set. Computer would prohibit diving if required statuses are not met. Diving dynamic control would be automatic.
r	Activities and operations 18 through 26 would be accomplished and sequenced automatically under computer control. Verification of their accomplishment can be requested by OOD at Ship's Control Console but they would not nominally be displayed. Failure of any action would initiate an alarm at Console and computer would "hold" sequence. OOD could interrogate computer for malfunction diagnosis and he could initiate automatic corrective action or direct maintenance technicians

2

Table III-B-4 (Conclud d)

BASELINE SSBN		
ACTIVITY SEQUENCE	CREW	
21. Ring up Ahead 2/3 and place rudder amidships.	Helmsman	to perform
22. Open all main vents	COW	
23. Lower all masts and report to OOD	COW	
24. Proceed to ordered depth	DOW	
25. Shut all vents at 50'.	COW	
26. Operate rudder and planes as ordered.	Helmsman Planesman	
27. Man the JA phones in Control.	Auxiliary Electrician Forward	There will backup mode ride.
28. Man the JA phones in Ops LL compartment.	Lookout	
29. Man the JA or 2JV phones in all compartments.	All Watch Standers	
30. Analyze trim condition	DOW	Trim condit OOD may inte (by manual
31. Pump or flood variable ballast tanks as ordered.	COW	
32. Secure the radar or ECM when ordered.	Radar/ECM	
33. Obtain neutral trim condition and report to OOD.	DOW	
34. Place main hydraulic pump in Standby.	COW	
35. Cycle main vents one group at a time.	COW	
36. Report compartment/equipment condition to control.	All Watch Standers	All conditi information Console.
37. Secure sound powered phones on order when all reports received.	All Watch Standers	

CREW	NEW GENERATION SSBN
	to perform manual corrective action.
ctrician Forward nders	There will be no requirements to man phones. Phones will be used as backup mode only in case of computer malfunction or computer override.
	Trim condition will be sensed, analyzed, and controlled by computer. OOD may interrogate computer concerning trim situation and command (by manual input at Ship's Control Console) any desired changes.
nders nders	All conditions relevant to submergence will be sensed by computer and information may be requested for visual display at Ship's Control Console.

2

Table III-B-6 Comparison of Crew Operations for Surfacing Evolution in Baseline and New Gener

BASELINE SSBN		
ACTIVITY SEQUENCE	CREW	
OOD relieved.		
1. Order COW to pass "prepare to surface" on IMC.	OOD	OOD initiates Ship's Contro and command i Plant Control
2. Pass "prepare to surface" on IMC.	COW	
3. Check all MBT vents shut.	COW	These actions Verification trol Console any action wo would "hold". malfunction d direct mainte
4. Check hydraulic pump line up.	COW	
5. Position head valve electrode selector switch to "both"; head valve control switch to "auto".	COW	
6. Test mast flooded indicator	COW	
7. Drain induction mast.	Auxiliary Watch Forward	
8. Check MBT low pressure blow and exhaust mast dry.	Navigation Center Supervisor	
9. Unlock outboard induction and outboard ventilation.	Navigation Center Supervisor	
10. Open head valve air supply valves.	Navigation Center Supervisor	
11. Receive reports from Navigation Center Supervisor and Auxiliary Watch Forward that they are ready	COW	All status re be visually d
12. Obtain permission from OOD, drain, and enter bridge access trunk.	Quartermaster of Watch	These activit ance technici
13. Line up IC circuits to bridge	Auxiliary Electrician Forward	
14. Man JA phones in control and inform COW when all compartments reported ready to surface.	Auxiliary Electrician Forward	All status ra visually disp
15. Report "ready to surface" to DOW.	COW	
16. Secure JA phones when ordered	Auxiliary Electrician Forward	
17. Report "ready to surface" and pressure in boat to OOD.	DOW	
18. Order DOW to "surface the ship"	OOD	OOD initiates Ship's Contro and command i Plant Control
19. Have COW pass "surface, surface, surface" on IMC.	DOW	
20. Order COW to "blow forward group"	DOW	These actions Verification trol Console action would "hold" sequen tion diagnost maintenance t
21. As ship takes an up angle order "blow aft group".	DOW	
22. Attempt to maintain 3° to 5° up angle.	Planesman	

lution in Baseline and New Generation SSBN

	NEW GENERATION SSBN
CREW	
	OOD initiates "prepare to surface" by manual initiation of control at Ship's Control Console. Maintenance technician passes word on comm and command is visually displayed on Ship's Control and Engineering Plant Control Consoles.
h Forward ter Supervisor ter Supervisor ter Supervisor	These actions would be performed automatically by computer control. Verification of their accomplishment would be displayed at Ship Control Console and at Engineering Plant Control Console. Failure of any action would initiate an alarm at each console and computer would "hold" sequence. OOD and EOOW could interrogate computer for malfunction diagnosis and initiate automatic corrective action or direct maintenance technicians to perform manual corrective actions.
	All status reports would result from remote sensing by computer and be visually displayed at Ship's Control Console.
of Watch trician Forward	These activities would be performed as they are currently by Maintenance technicians on watch at Ship's Control Console.
trician Forward trician Forward	All status reports would result from remote sensing by computer and be visually displayed at Ship's Control Console.
	OOD initiates "surface the ship" by manual initiation of control at Ship's Control Console. Maintenance technician passes word on comm and command is visually displayed on Ship's Control and Engineering Plant Control Consoles.
	These actions would be performed automatically by computer control. Verification of their accomplishment would be displayed at Ship Control Console and at Engineering Plant Control Console. Failure of any action would initiate an alarm at each console and computer would "hold" sequence. OOD and EOOW could interrogate computer for malfunction diagnosis and initiate automatic corrective action or direct maintenance technicians to perform manual corrective actions.

2

Table III-B-5 (Concluded)

BASELINE SSBN		
ACTIVITY SEQUENCE	CREW	
23. When ship on surface, order COW to "secure the air" then report to OOD "X feet and holding".	DOW	Computer wil initiate "se Control Cons matically by
24. Lock planes at ordered angle in emergency mode.	Planesman	
25. Maintain ordered course.	Helmsman	
26. Order COW to open the outboard induction.	OOD	
27. Check head valve open.	COW	
28. Report pressure equalized.	COW	
29. When pressure is equalized order Quartermaster of Watch to crack, then open the bridge.	OOD	This will be
30. Order "start the low pressure blower on all main ballast tanks".	OOD	This command by computer OOD.
31. Order OOD and Lookout to bridge (Old OOD, Lee Helsman)	OOD	Commanding o
32. Open inboard induction valve	Auxiliary Watch Forward	These action Verification Console and action would "hold" seque function dia maintenance
33. Line up low pressure blower discharge valves, start blower and #1 vent fan.	Navigation Center Supervisor	
34. Report "low pressure blower running on all MBTs".	COW	
35. On indication of air escaping from all MBTs, order "shift the blower to ventilate outboard".	OOD	
36. Shift the blower and report to COW.	Navigation Center Supervisor	
37. Rig the bridge	Quartermaster of Watch	Activities w
38. Install communications to bridge.	Auxiliary Electrician Forward	
39. Bridge OOD relieve OOD in control.	OOD	

CREW	NEW GENERATION SSBN
	Computer will inform OOD when ship is on the surface. OOD will initiate "secure the air" by manual initiation of control at Ship's Control Console. Activities 24 through 28 will be accomplished automatically by computer control.
	This will be performed manually by Maintenance technician.
	This command will be automatically initiated in proper time sequence by computer upon initiation of "secure the air" control activation by OOD.
	Commanding officer will relieve OOD. Activity will be same as shown.
atch Forward Center Supervisor Center Supervisor	These actions would be performed automatically by computer control. Verification of their accomplishment would be displayed at Ship Control Console and at Engineering Plant Control Console. Failure of any action would initiate an alarm at each console and computer would "hold" sequence. OOD and EOOW could interrogate computer for malfunction diagnosis and initiate automatic corrective action or direct maintenance technicians to perform manual corrective actions.
er of Watch lectrician Forward	Activities will be accomplished manually as shown.

2

Table III-B-6 Comparison of Crew Operations for Snorkeling Evolution in Baseline and New Generati

BASELINE SSBN		
ACTIVITY SEQUENCE	CREW	
1. Order COW to pass the word on IMC - "Prepare to Snorkel".	OOD	OOD initiates at Ship Contro command. Comm Engineering Pl
2. Man JA phones in control.	Lee Helmsman	JA phones woul manual overrid
3. Open induction pipe vent valves.	Auxiliaryman of Watch Forward	These actions Verification o Console and at action would i "hold" sequenc function diagn maintenance te
4. Open Air Supply to head valve.	Navigation Center Supervisor	
5. Unlock outboard induction valve, place in power.	Navigation Center Supervisor	
6. Open inboard induction valve.	Navigation Center Supervisor	
7. Line up diesel for startup.	Diesel Generator Watch	
8. Drain snorkel exhaust pipe between inboard and outboard exhaust valve.	Auxiliary Machinery Room 2 Upper Level	
9. Line up ventilation supply in Auxiliary Machinery Room 2	Auxiliary Machinery Room 2 Upper Level	
10. Unlock the diesel exhaust valve and place in power.	Auxiliary Machinery Room 2 Upper Level	
11. When at periscope depth, direct the DOW to raise the snorkel mast.	OOD	Periscope dept depth by manua achieved, DOD snorkel mast w
12. Open the induction mast vent valves.	COW	These actions Verification o Control Consol any action wou "hold" sequenc tion diagnosis maintenance te
13. Raise snorkel mast.	COW	
14. Drain induction mast, shut drain and vent valve.	Auxiliary Watch Forward	
15. Test induction mast flooded indicator.	COW	
16. Obtain permission from OOD and test head valve.	COW	
17. Rig compartments for snorkel	Mess Cook and Auxiliary Machinery Room 1	Most rigging f number of rigg
18. Pass reports of prepared to snorkel from each compartment: Computer Lee Helmsman COW DOW OOD		Computer will for snorkeling Sensors will p manually as we
19. Order "Commence Snorkeling".	OOD	OOD initiates Ship's Control

CREW	NEW GENERATION SSBN
	OOD initiates "prepare to snorkel" by manual initiation of control at Ship Control Console. Maintenance technician passes the word on command. Command is visually displayed on Ship's Control and Engineering Plant Control Consoles.
	JA phones would be available for use as emergency only--in case of manual override of computer functions.
of Watch Forward enter Supervisor enter Supervisor enter Supervisor ator Watch chinery Room 2 Upper chinery Room 2 Upper chinery Room 2 Upper	These actions would be performed automatically by computer control. Verification of their accomplishment would be displayed at Ship Control Console and at Engineering Plant Control Console. Failure of any action would initiate an alarm at each console and computer would "hold" sequence. OOD and EOOW could interrogate computer for malfunction diagnosis and initiate automatic corrective action or direct maintenance technicians to perform manual corrective actions.
	Periscope depth would be controlled (set) by OOD. He would set desired depth by manual input to Ship Control Console. When that depth is achieved, DOD would receive displayed verification and raising of snorkel mast would be initiated by manual control at console.
tch Forward	These actions would be performed automatically by computer control. Verification of their accomplishment would be displayed at Ship Control Console and at Engineering Plant Control Console. Failure of any action would initiate an alarm at each console and computer would "hold" sequence. OOD and EOOW could interrogate computer for malfunction diagnosis and initiate automatic corrective action or direct maintenance technicians to perform manual corrective actions.
nd Auxiliary Machinery	Most rigging functions will be done automatically; however, a reduced number of riggings will still have to be accomplished manually.
	Computer will inform OOD and EOOW that all conditions have been met for snorkeling. Verbal reports from crewmen will not be necessary. Sensors will provide computer verification of actions accomplished manually as well as automatically.
	OOD initiates "commence snorkeling" by manual initiation of control at Ship's Control Console.

Table III-6 (Continued)

BASELINE SSBN		
ACTIVITY SEQUENCE	CREW	
20. Order COW to open outboard induction valve.	DOW	These action Verification Control Cons any action w "hold" seque tion diagnos maintenance
21. Order COW to flood into depth control (about 8000# to trim compensate for snorkel exhaust line).	DOW	
22. Blow water from snorkel exhaust line.	Auxiliary Machinery Room 2 Upper Level	
23. Start diesel and report running to EOOW	Diesel Generator Watch	EOOW will in Plant Consol factory to s under comput Engineering
24. Start #1 vent fan.	Navigation Center Supervisor	
25. Report "snorkeling" to OOD.	EOOW	Computer wil
26. Report "normal snorkel board".	COW	
27. Secure JA phones.	COW	JA phones wo manual overr
28. Report to EOOW when diesel warmed up.	Diesel Generator Watch	Diesel statu The decision and will be Plant Consol
29. Electrically load diesel.	Electrical Operator	
30. Secure O_2 bleed, CO_2 scrubber, $CO-H_2$ burner.	OOD	These action request of O
31. Order EOOW to unload and cooldown the diesel.	OOD	The OOD will communicatio manual input of diesel by of diesel sh console. OO at Ship's Co
32. Pass the word on IMC "Secure Snorkeling".	OOD	
33. Shut down and secure diesel.	Diesel Generator Watch	
34. Shut outboard induction.	COW	
35. Pump from DCTs outboard by order of OOD to trim compensate.	COW	
36. Shut inboard induction.	Navigation Center Supervisor	Activities 3 control. Ve Ship Control ure of any a would "hold" malfunction direct maint
37. Secure #1 vent fan.	Navigation Center Supervisor	
38. Shut inboard snorkel exhaust	Auxiliary Machinery Room 2 Upper Level	
39. Shut head valve.	COW	
40. Lower snorkel mast.	COW	
41. Secure air to head valve.	Navigation Center Supervisor	

CREW	NEW GENERATION SSBN
inery Room 2 Upper	These actions would be performed automatically by computer control. Verification of their accomplishment would be displayed at Ship Control Console and at Engineering Plant Control Console. Failure of any action would initiate an alarm at each console and computer would "hold" sequence. OOD and EOOW could interrogate computer for malfunction diagnosis and initiate automatic corrective action or direct maintenance technicians to perform manual corrective actions.
or Watch ter Supervisor	EOOW will initiate "Start Diesel" by manual action at Engineering Plant Console. Computer will inform EOOW when conditions are satisfactory to start diesel. Startup and verification of running will be under computer control and displayed at Ship's Control Console and Engineering Plant Console.
	Computer will inform OOD and EOOW of snorkeling status.
	JA phones would be available for use as emergency only--in case of manual override of computer functions.
or Watch rator	Diesel status will be displayed to EOOW at Engineering Plant Console. The decision to electrically load the diesel will be made by EOOW and will be initiated by him by a manual control action at Engineering Plant Console.
	These actions will be accomplished automatically and verified (by request of OOD) at Ship's Control Console.
or Watch	The OOD will inform EOOW of intent to secure snorkeling (method of communication may be verbal via comm or through computer bus via manual input). EOOW will initiate unloading, cooldown, and shutdown of diesel by manual input at Engineering Plant Console. Verification of diesel shutdown will be automatically displayed to OOD at his console. OOD will have capability for emergency shutdown of diesel at Ship's Control Console.
er Supervisor er Supervisor nery Room 2 Upper er Supervisor	Activities 34 through 44 would be performed automatically by computer control. Verification of their accomplishment would be displayed at Ship Control Console and at Engineering Plant Control Console. Failure of any action would initiate an alarm at each console and computer would "hold" sequence. OOD and EOOW could interrogate computer for malfunction diagnosis and initiate automatic corrective action or direct maintenance technicians to perform manual corrective actions.

2

Table III-6 (Concluded)

BASELINE SSBN		
ACTIVITY SEQUENCE	CREW	
42. Lock shut outboard snorkel induction.	Navigation Center Supervisor.	
43. Lock shut outboard snorkel exhaust.	Auxiliary Machinery Room 2 Upper Level	
44. Line up ventilation system to recirculate.	Mess Cook Auxiliary Machinery Room 1 Auxiliary Machinery Room 2 Upper Level	
45. Pass reports of secured from snorkel: COW DOW EOOW	OOD	Verbal report to snorkeling Ship's Contro

CREW	NEW GENERATION SSBN
uter Supervisor. hinery Room 2 Upper hinery Room 1 hinery Room 2 Upper	
	Verbal reports will not be required. All systems statuses relevant to snorkeling secured condition will be visually displayed to OOD at Ship's Control Console.

2

Analyses of casualty situations presented a more difficult analysis task since there are so many different kinds of emergency situations to consider. Analyses of several kinds of major casualties (fire, atmospheric contamination, and flooding indicated that a crew complement of 30 could successfully handle the casualty situations. The entire crew would be involved in similar fashion to the baseline SSBN. The essential aspects of crew response to casualty situations in the new generation SSBN are that when damage occurs:

- sensed data from the ship automatic sensors are received and displayed;
- annunciation may be automatic;
- diagnosis is displayed;
- suggested solutions (with effects) are displayed;
- corrective action is initiated remotely (time sensitive corrections may be automatically initiated);
- equipment status is continuously and rapidly updated.

The usual method of responding to the emergency would be to initiate corrective action remotely (that is, under computer control). However, if remote corrective action could not be initiated:

- a damage control crew would be immediately available;
- individual diagnostic information would be provided (mechanical or electrical isolation);
- unaffected areas of the ship may be automatically controlled;
- change in ship equipment status would be rapidly updated and may be announced;
- the capability for local manual operation would be provided.

A final analysis of battle stations, torpedo and missile, evolutions indicated that the evolutions could be performed successfully by the crew complement of 30 crewmen. The crew's support of battle evolutions, torpedo is shown in Figure III-B-27 and battle evolution, missile is shown in Figure III-B-28.

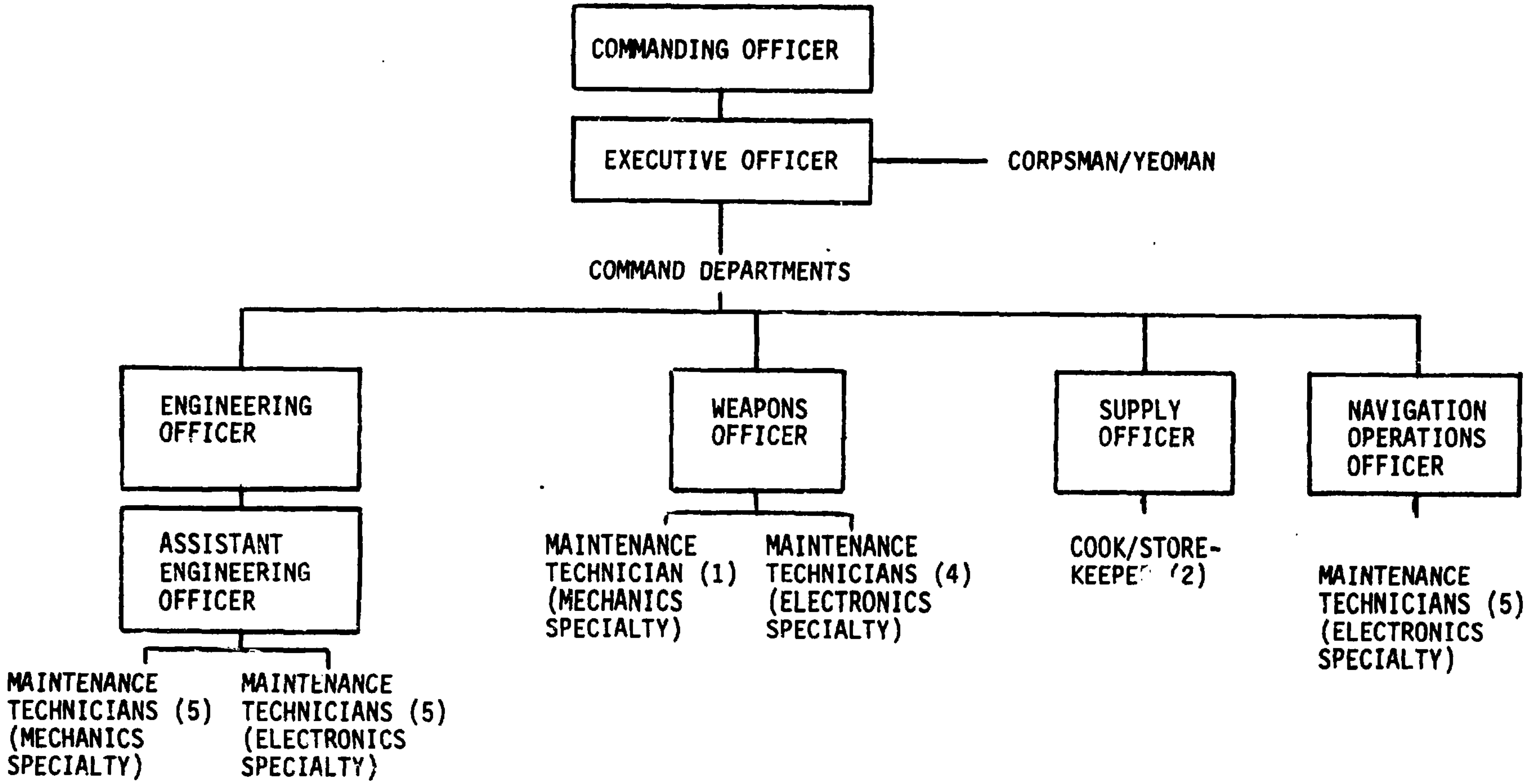


Figure III-B-26 New Generation SSBN Administrative Structure

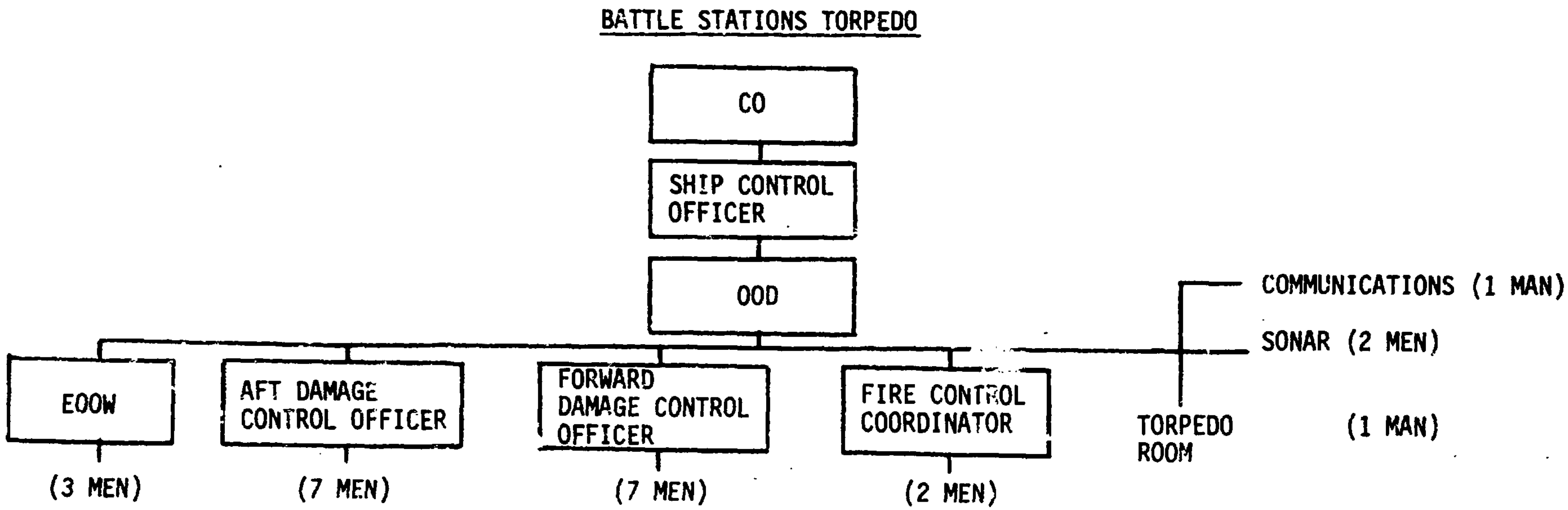


Figure III-B-27 Crew Support of Battle Evolution Torpedo

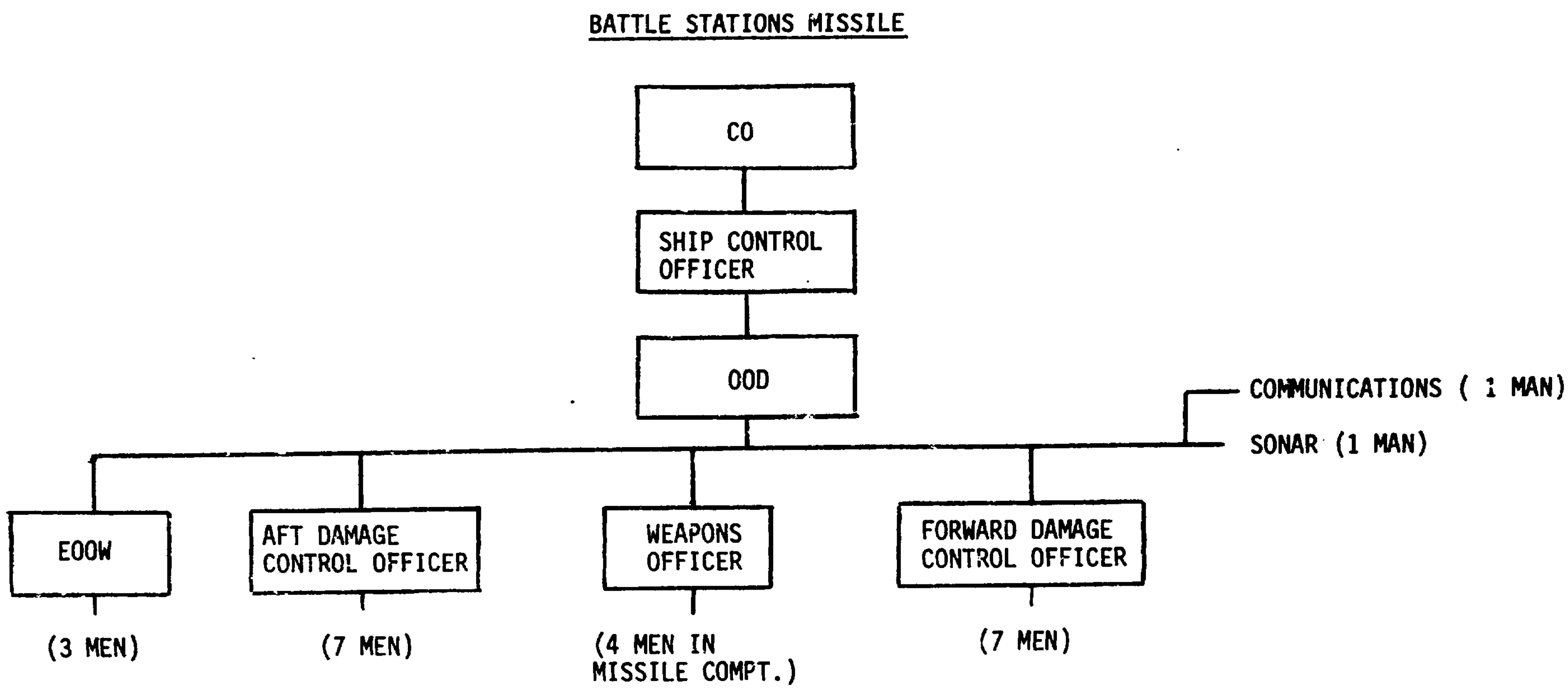


Figure III-B-28 Crew Support of Battle Evolution Missile

C. ECONOMIC ANALYSIS

In this section we describe the economic implications of providing the technology to augment the crew's capability to operate the submarine. It will be noted that cost was included as one of the factors in the evaluation criteria to select the optimum degree of mechanization (sections B and C). Thus, the selection process establishes the best balance of performance, availability, and cost. Cost is an important factor and in the following paragraphs we describe the economic implications of adding automation to a new generation strategic submarine.

The primary objective of the study was to evaluate the feasibility of applying new technology to the submarine to enhance its availability on station. We achieved this objective through an optional allocation of operation and maintenance functions to crew and machines. The economics of the study thus centered on investment cost for mechanization and redundancy and on crew costs.

As shown in Figure III-C-1, the results of this economic evaluation substantiated the results of the system/cost effectiveness evaluation in that the automation concept which corresponds to a crew of 30 is the most cost effective based on a life cycle cost analysis. Further, significant cost savings over a 25-year period--$3.7 billion in 1976 dollars--are indicated by this analysis. This result is consistent with the economic results found in other applications of machine automation to assist operation and maintenance personnel.

Figure III-C-2 describes the study approach and the economic analysis functions we performed in the conduct of the study. The technical study elements resulted in a point design concept for applying automation to the new generation submarine. It was established by applying a selection criteria that assessed the relative performance, availability, and cost effectiveness of automating detailed system functions. From this selection evolved a point design solution for all systems of the submarine.

The economic analysis elements are shown to be a cost estimate, a life cycle cost analysis, and a sensitivity analysis. The cost estimating was based on a set of ground rules and assumptions which defined the economic boundary conditions and the cost elements and classes of cost pertinent to the evaluation. The sources of data are shown to encompass all possible methods of forward pricing. These methods were applied to various elements as appropriate.

The life cycle cost analysis consisted of evaluating the new design submarine acquisition and ownership in terms of the cost elements selected in the assumptions and evaluated the economic characteristics over a 25-year planning horizon. The sensitivity analysis examined

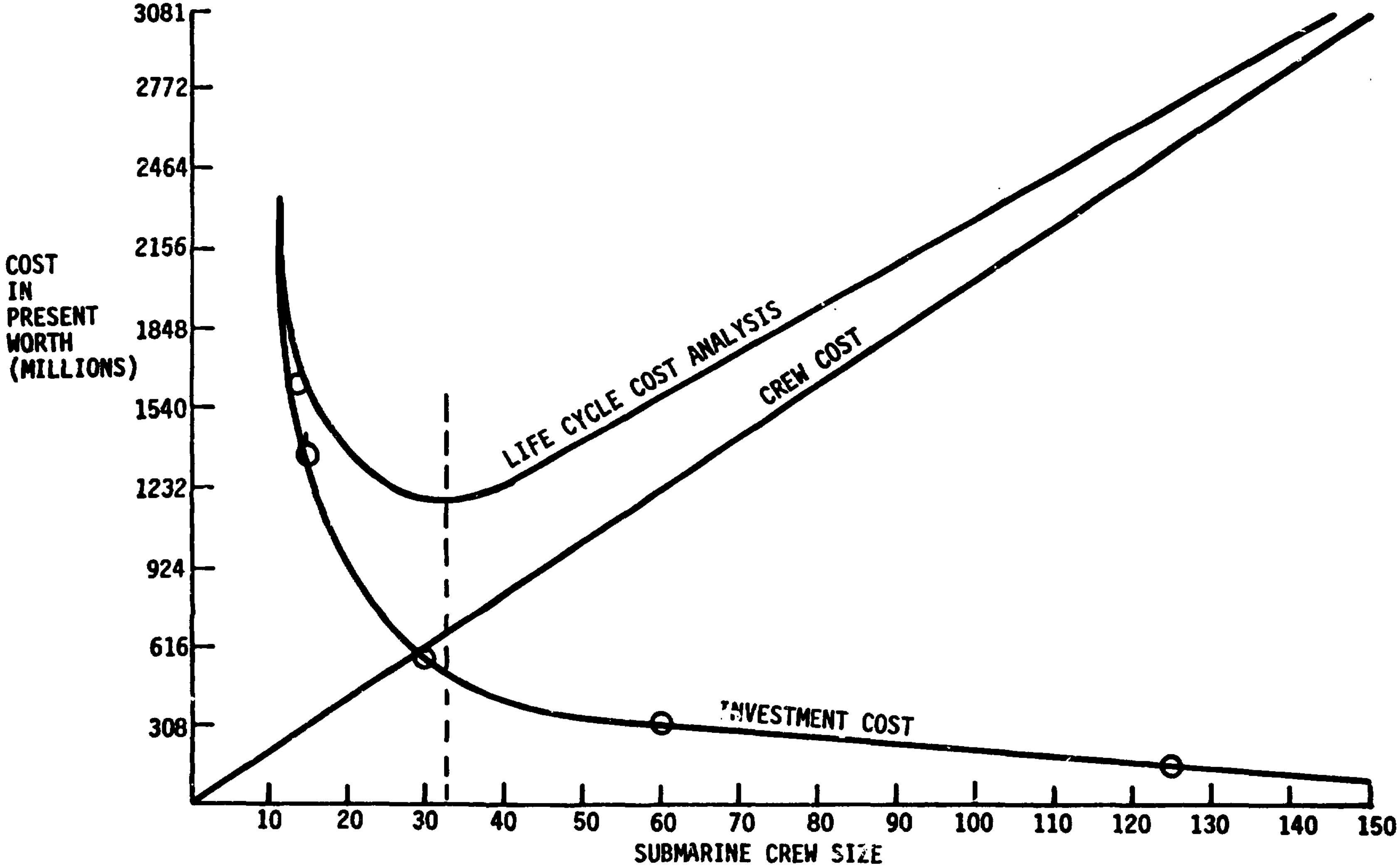


Figure III-C-1 Life Cycle Cost

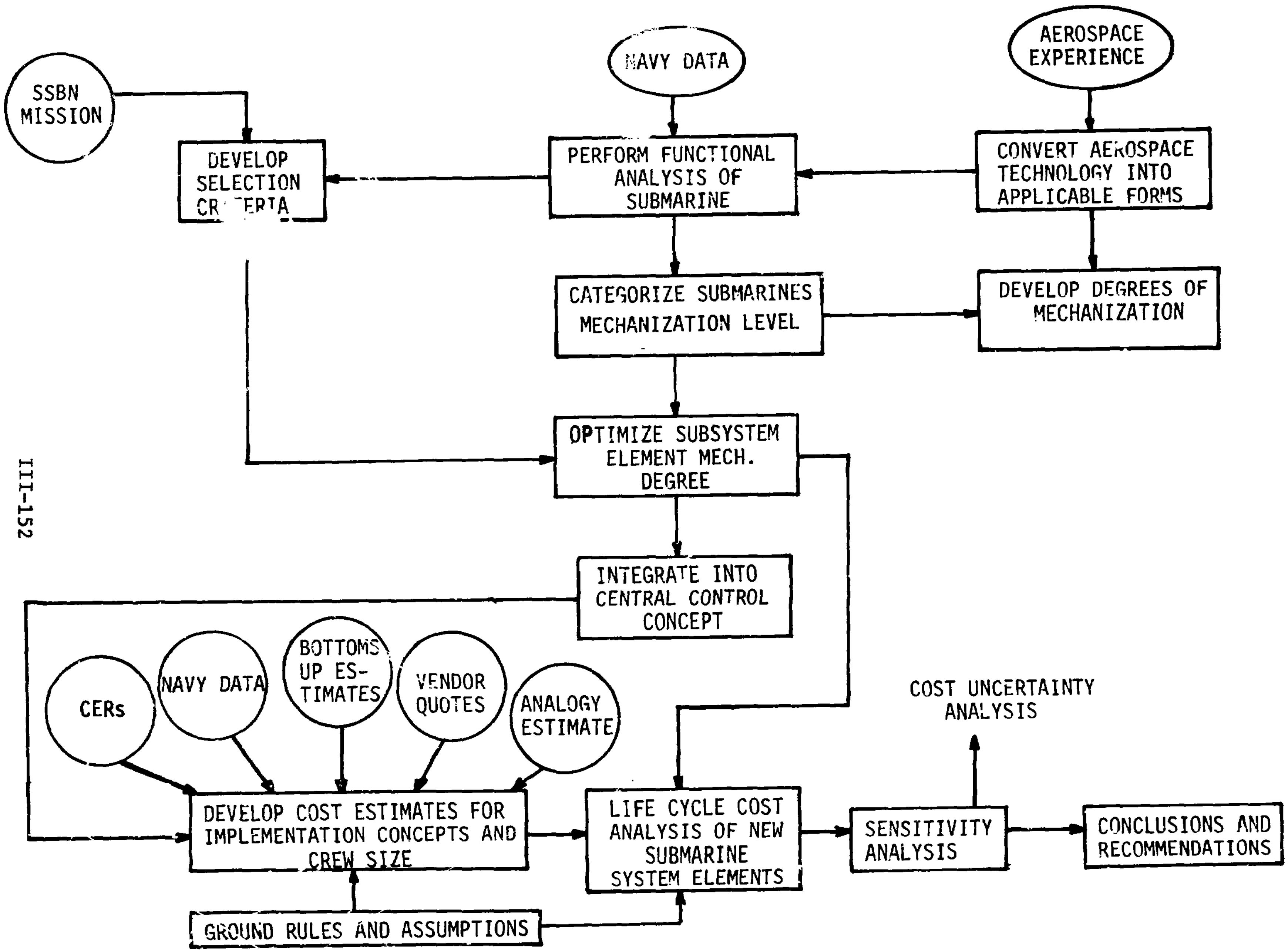


Figure III-C-2 Approach

the sensitivity of the life cycle cost in terms of variation in crew billet cost, investment cost uncertainty, and degree of automation (and equivalent crew size). The following paragraphs discuss each of these elements and describe the analysis results.

1. <u>Assumptions</u>

Assumptions provide the framework for estimating and modeling the economic problem and defines the reference point for conclusions inferred from the analysis. The objective of this analysis was to use the 640 class submarine as a reference and to examine economic impact of augmenting a crew capability with machine automation. The economic analysis was not aimed at modifying the 640 class submarine, but to infer from the reference economic data about a new generation submarine. This means that the assumptions for estimating investment costs do not consider refit or overhaul approaches, but rather that the design and integration of mechanization is an integral part of a "new build".

The governing assumptions are listed in Figure III-C-3. As shown, these establish schedule, types of cost, and economic factors such as escalation/discount rates, fleet size and crew size. Most of these assumptions need no explanation. Those that deserve further detailing are discussed in the following paragraphs.

a. Schedule - As shown in Figure III-C-4, the 25-year planning horizon was broken down into a 3-year development, 6-year production, and 20-year ownership. Figure III-C-4 shows how these periods relate in time and show how an assumed fleet of 40 new generation submarines would be acquired.

b. Present Value - The analysis of costs is made in escalated and discounted dollars (present value) using a 7% constant escalation and a 10% discount rate. Present value provides the means for time weighting the use of money and is required by DOD DIR 7043.1 for economic evaluation of major new programs.

A seven percent escalation rate was chosen as a conservative estimate of aerospace and military labor and automation material. This rate together with a 10% discount rate results in a bias of economic advantage in the favor of large crew and no mechanization. This means that if the results show a cost benefit in favor of machine augmentation, it will occur under unfavorable conditions. This approach should in part cancel out tendencies to be optimistic about mechanization costs.

• 3 YEAR DEVELOPMENT, 6 YEAR PRODUCTION • 20 YEAR OWNERSHIP	25 YEAR PLANNING HORIZON

- 3 YEAR DEVELOPMENT, 6 YEAR PRODUCTION
- 20 YEAR OWNERSHIP

$\Big\}$ 25 YEAR PLANNING HORIZON

- EVALUATION BASED ON PRESENT WORTH

  7% ESCALATION OVER PLANNING HORIZON

  10% DISCOUNT RATE

- INVESTMENT COST OF DESIGN, DEVELOPMENT, PRODUCTION AND OWNERSHIP
- INVESTMENT COST INCLUDES LABOR, MATERIAL, ODC, G&A AND FEE--COST TO GOVERNMENT
- CREW COST (1976) - $19,000/YEAR
- FLEET OF 40 SUBMARINES
- TWO CREW SYSTEM--300 FOR 640 SUBMARINE
- COST OF INSTALLATION ON BOAT NOT INCLUDED
- LIMITED CONTRACTOR ON SITE SUPPORT DURING 20 YEAR OPERATION

Figure III-C-3 Cost Evaluation Assumptions

Present value is defined as:

$$PV = \int_0^t V_1 e^{-rt} dt \cong V_1 (1 - r)^{-t}$$

where V_1 is current year cost and r is the discount rate. Table III-C-1 lists the discount rates used in this analysis.

c. Cost Elements - As shown in Table III-C-1, investment costs include labor, material and services, burdened with overhead, general and administrative, and fee and also include estimates for other direct charges (ODC) such as travel and computer time. These classes of cost were applied to the cost elements shown in Table III-C-2. This table describes the work breakdown structure for estimating investment costs for RDT&E, production and operations phases.

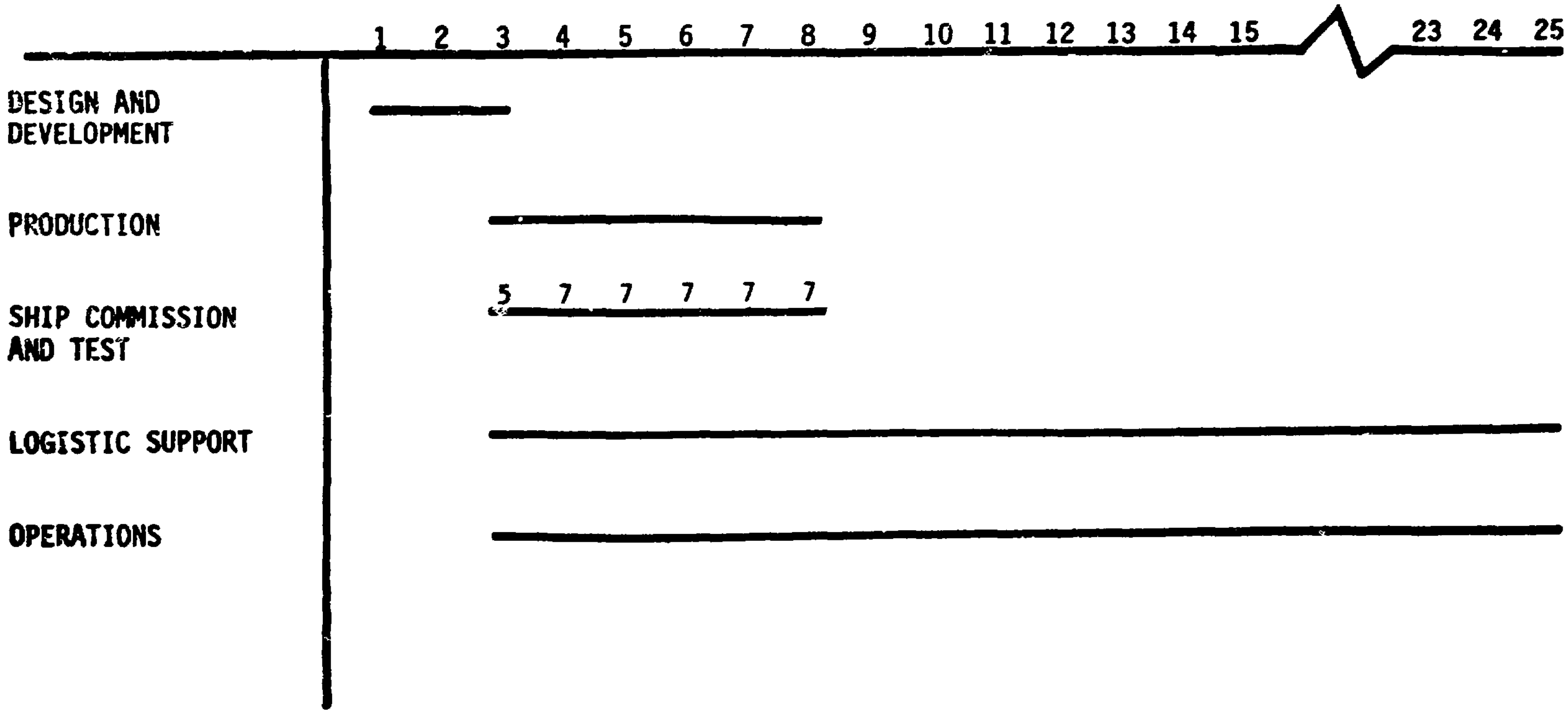


Figure III-C-4 Cost Analysis Schedule

Table III-C-1 Present Value of $1 (Single Amount--to be used when cash flows accrue in different amounts each year.)

Project Year	10%	Project Year	10%
1	0.954	14	0.276
2	0.867	15	0.251
3	0.788	16	0.223
4	0.717	17	0.208
5	0.652	18	0.189
6	0.592	19	0.172
7	0.538	20	0.156
8	0.489	21	0.142
9	0.445	22	0.129
10	0.405	23	0.117
11	0.368	24	0.107
12	0.334	25	0.097
13	0.304		

Table III-C-2 Investment Cost Elements

Program Management	C&DM, Planning and Control, Project Management
Systems Engineering and Integration	Requirements Definition, Specification Control, ICD Definition and Control
Design	Mechanical, Electrical, Electronic, Structural
Manufacturing/Tooling/Quality Control	Detail Manufacturing, Material Procurement, Assembly
GSE Design	Mechanical, Electrical, Electronic, Structures
GSE Manufacturing/Tooling/Quality Control	Detail Manufacturing, Material Procurement, Assembly
Software Design/Development	Requirements Definition, Program Design, and Test
Test	Development, Qualification, Integration, and Ship Trial
Reliability and Safety	Reliability Allocation, FMEA, Hazard Analysis
Logistics	Analysis and System Design for Transportation, Maintenance, Spares, Training

d. Crew Cost - To facilitate the economic analysis an average cost of $19,000 per man year was used. This cost includes all DOD attributable cost--an average mix of rating on a 150-man submarine. It includes basic pay, training cost, retirement cost, and re-enlistment cost. This average was arrived at based on a study of *Navy Military Manpower Billet Cost Data for Life Cycle Planning Purposes*, NAVPERS 15163 and R-1790-ARPA, November 1975, *The Economics of Naval Ship Automation: An Analysis of Proposed Automation of the DE-1052.* Considerable question exists as to the validity of an averate rate, but it concluded that this average was within ±20% which is equivalent to estimates of other cost elements.

e. Cost of Installation on the Boat Not Included - The study is aimed at definition of mechanization of existing subsystems on a new generation submarine and not conceiving totally new systems. As such, the installation of the automation systems by the boat company would be only a small additional cost and this was judged to be insignificant in comparison with the design and production of the automation systems. Cost of integration by the designer of the automation systems was included as a part of the RDT&E and production cost based on support to the boat company.

2. Cost Evaluation

Cost evaluation proceeded from a mechanization concept for the submarine. This concept consisted of a point design solution described in terms of block diagrams, description of the automation functions, and an estimate of the hardware and software required to implement it. This concept definition was made for each subsystem and included monitoring, control, diagnostic and redundancy requirements. Cost estimates were developed for each subsystem based on these data and then the central control computer capability was sized to accommodate the aggregate of the subsystem requirements.

The initial cost analysis was performed on the single point design which corresponds to a system requiring 30 crewmen. Subsequently, a sensitivity of cost vs crew size was performed using the optimal design as a reference point. Feasible combinations of subsystems automation that corresponded to crews of 60 and 125 were defined and their corresponding investment and crew costs were computed. We also postulated a crew of 15 and configured the automation increase that would be required to accommodate it. It should be noted that the operational feasibility of a crew of 15 is questionable, particularly from a damage/emergency standpoint. The only purpose of this effort was to examine the investment cost impact of going beyond the optional solution which corresponds to a crew of 30.

These data provided the means for defining the relationship between investment and crew costs over a range of degrees of automation. The methods and results of these efforts are described below.

a. Cost Equation - The life cycle cost model used in determining the cost of the point design solution is shown below.

$$C_T = C_1 + C_2 + C_3 + C_4 + C_5 \text{ (all other costs considered sunk)}$$

C_1 = New equipment design/development cost

C_2 = Production cost

C_3 = Integration and support cost

C_4 = Material and labor maintenance cost

C_5 = New crew cost

The cost benefits are therefore the difference between C_T and the 150-man crew of the 640 submarine. The terms of the equation were quantified using appropriate estimating methods. Major hardware was selected from existing equipment used in the fleet and quotes from vendors were obtained. Where analogy could be drawn to similar design, development, or production costs, these were used. Other estimates were based on cost estimating relationships and bottoms-up estimate constructions.

b. Cost Analysis Results - Cost estimates were developed for each of the subsystems and these cost elements were distributed in time streams as shown in Figure III-C-5. In this development of cost, the nucleus control system was kept as a separate "new" system. This system represents the command and control and computer capability to support the submarine subsystem monitoring, diagnostics, displays for recommended action, and remote initiation of corrective actions.

The hardware estimated for each subsystem is shown in Figure III-C-6. As noted on the figure, the nucleus central control includes executive and controls and displays software and each subsystem is charged with its unique control software. A significant difference in cost exists between the two ($26 per word for Executive and Display vs $200 per word for Control software). This hardware estimate was arrived at by surveying each subsystem design, identifying additional automation, and the approximate number and types of components required.

Years	Nucleus Automation System	Ships Control	Habit-ability and Environment	Defensive Weapons	Engineering	Strategic Weapons	Auxiliary Systems	Navi-gation
1	1.8	2.03	0.552	1.14	2.62	1.74	2.85	2.03
2	1.92	5.5	0.727	2.55	3.16	3.89	6.37	2.33
3	15.97	15.42	13.44	4.56	15.64	15.34	11.39	2.79
4	16.00	14.59	10.82	4.43	14.31	14.74	11.07	2.30
5	15.49	11.79	10.82	3.99	13.76	12.53	9.89	2.18
6	14.1	9.21	6.34	3.73	13.12	11.49	9.33	1.37
7	14.1	9.21	6.32	3.73	13.12	11.49	9.33	1.37
8	14.1	9.21	6.32	3.73	13.12	11.49	9.33	1.37
9	0.42	1.0	0.2	0.88	0.45	0.4	1.1	0.04
10	0.62	1.0	0.2	0.88	0.45	0.4	1.1	0.04
11	0.62	1.0	0.2	0.88	0.45	0.4	1.1	0.04
12	0.62	1.0	0.2	0.88	0.45	0.4	1.1	0.04
13	0.62	1.0	0.2	0.88	0.45	0.4	1.1	0.04
14	0.62	1.0	0.2	0.88	0.45	0.4	1.1	0.04
15	0.62	1.0	0.2	0.88	0.45	0.4	1.1	0.04
16	0.62	1.0	0.2	0.88	0.45	0.4	1.1	0.04
17	0.62	1.0	0.2	0.88	0.45	0.4	1.1	0.04
18	0.62	1.0	0.2	0.88	0.45	0.4	1.1	0.04
19	0.62	1.0	0.2	0.88	0.45	0.4	1.1	0.04
20	0.62	1.0	0.2	0.88	0.45	0.4	1.1	0.04
21	0.62	1.0	0.2	0.88	0.45	0.4	1.1	0.04
22	0.62	1.0	0.2	0.88	0.45	0.4	1.1	0.04
23	0.62	1.0	0.2	0.88	0.45	0.4	1.1	0.04
24	0.62	1.0	0.2	0.88	0.45	0.4	1.1	0.04
25	0.62	1.0	0.2	0.88	0.45	0.4	1.1	0.04
TOTAL	103.82	93.96	58.74	42.82	96.5	89.51	88.26	16.42

Figure III-C-5 Estimated Investment Cost for Crew of 30 Point Design in 1976 Dollars

...eering	Strategic Weapons	Auxiliary Systems	Navi- gation	Sonar/ECM	Casualty and Damage	External Communi- cations	Total
.62	1.74	2.85	2.03	1.95	0.84	1.56	19.11
.16	3.89	6.37	2.33	2.56	1.13	2.05	32.19
.64	15.34	11.39	2.79	7.49	3.69	5.99	111.72
.31	14.74	11.07	2.30	7.08	3.38	5.66	104.38
.76	12.53	9.89	2.18	6.47	3.38	5.18	95.48
.12	11.49	9.33	1.37	4.87	3.14	3.90	80.6
.12	11.49	9.33	1.37	4.87	2.95	3.90	80.39
.12	11.49	9.33	1.37	4.87	2.94	3.90	80.38
.45	0.4	1.1	0.04	0.16	0.54	0.15	5.34
.45	0.4	1.1	0.04	0.16	0.54	0.15	5.54
.45	0.4	1.1	0.04	0.16	0.54	0.15	5.54
.45	0.4	1.1	0.04	0.16	0.54	0.15	5.54
.45	0.4	1.1	0.04	0.16	0.54	0.15	5.54
.45	0.4	1.1	0.04	0.16	0.54	0.15	5.54
.45	0.4	1.1	0.04	0.16	0.54	0.15	5.54
.45	0.4	1.1	0.04	0.16	0.54	0.15	5.54
.45	0.4	1.1	0.04	0.16	0.54	0.15	5.54
.45	0.4	1.1	0.04	0.16	0.54	0.15	5.54
.45	0.4	1.1	0.04	0.16	0.54	0.15	5.54
.45	0.4	1.1	0.04	0.16	0.54	0.15	5.54
.45	0.4	1.1	0.04	0.16	0.54	0.15	5.54
.45	0.4	1.1	0.04	0.16	0.54	0.15	5.54
.45	0.4	1.1	0.04	0.16	0.54	0.15	5.54
.45	0.4	1.1	0.04	0.16	0.54	0.15	5.54
.45	0.4	1.1	0.04	0.16	0.54	0.15	5.54
.5	89.51	88.26	16.42	42.88	30.63	34.69	698.23

...ew of 30 Point Design in 1976 Dollars (Millions)

2

	Computers	Software** Words	Micro-Processors	Actuators/Controls	Sensors	Displays***	Monitors
Central Automation System	2*	200,000	-	-	-	-	-
Ship Control	-	5,000	3	150	300	1D	2
Habitability/Environment	-	1,500	1	60	121	1S	180
Defense Weapons	-	1,500	-	30	5	1S	-
Engineering	-	5,000	3	200	320	1D	500
Strategic Weapons	-	4,000	2	200	300	1D	400
Auxiliary Systems	-	4,000	2	-	330	1D	400
Navigation	-	2,500	1	75	-	-	100
Sonar/ECM	-	2,500	2	1	-	1D	40
External Communications	-	4,000	1	1	-	-	45
Casualty and Damage Control	-	2,000	1	4	90	-	35

These hardware and software elements are in addition to those in the 640 reference configuration.

* AN/UYQ-20

** Central automation system includes all executive and display software; ship systems software is for control

*** OJ-326(U)/UYK - S = single tube unit; D = double tube unit

Figure III-C-6 Hardware and Software Estimate for Cost Analysis - Point Design Crew of 30

Figure III-C-7 summarizes the investment cost (with nucleus control cost and damage control cost apportioned to each submarine system) and shows the relative savings accrued from automation of selected submarine functions. The figure shows original crew costs and new crew costs for each subsystem. New crew assignments were based on where the majority of work assignments exist. Even though certain subsystems show no crew costs, appropriately trained personnel are available from other areas for maintenance functions. Damage and casualty control has been left off since there is no definitive way of expressing savings. This subsystem is a "red light" or emergency function where all personnel on the submarine contribute as required to restore the boat to a safe condition. The investment cost for this subsystem is apportioned among the other subsystems.

The figure shows the relative ranking of cost benefits for each of the subsystems. This ranking provides a guide to the relative value gained by introducing automation to augment crew capabilities. It should be remembered that the point design concept is integral and cannot be arbitrarily considered separable. Crew sizing and skill mix across all subsystems is consistent and only logical and feasible variations can be made. It would be tempting to divide the savings by the investment cost and only elect to automate those subsystems having a good return on investment. This, however, is not possible with the initial concept definition. Such an optimization could be accomplished in a later definition phase.

The preceding data presented the point design cost in 1976 dollars. Table III-C-3 presents the cost in escalated and discounted present worth.

Table III-C-3 Cost of Point Design (Crew of 30) in Present Worth

Subsystem	Investment Cost In Present Worth	Crew Cost In Present Worth
Central Control	$ 91.98	$616.1 millions
Ship Control	77.17	
Auxiliary Systems	71.7	
Habitability and Environmental Control	49.84	
Defensive Systems	29.8	
Engineering	80.94	
Strategic Systems	75.3	
Navigation	14.3	
Sonar and ECM	36.61	
External Comm.	29.3	
Casualty and Damage Control	24.13	
	$581.1 millions	

Subsystem	Original Crew Cost	New Crew Cost	Automation Investment Cost	Savings	Rank
Ship Control	557.46	185.82	119.04	252.6	4
Habitability and Environment	371.64	77.43	74.42	219.79	5
Defensive Systems	92.91	0	56.46	38.66	7
Engineering	1,114.90	371.64	122.21	621.05	1
Strategic Weapons	464.55	0	113.39	351.16	2
Auxiliary Systems	185.82	0	99.23	86.53	6
Navigation	371.64	0	20.8	350.84	3
Sonar and ECM	185.82	92.91	50.88	42.03	8
External Communication	185.82	0	43.23	42.59	9

Savings = Original Crew Cost - (New Crew Cost + Automation Cost)

Figure III-C-7 Estimated Cost Benefits of a Crew of 30 Point Design - 1976 Dollars in Millions

Present worth weights the time value of money and in this case weights heavily (see Table III-C-1) crew costs which occur in the latter portion of the 25 year period of performance. The original crew costs for the 150 man crew in present worth is $3,081 millions, therefore the net savings is:

$$3{,}081 - (581.1 + 616.1) = \$1{,}884 \text{ millions in present worth}$$

and the return on investment is $\frac{1,884}{481.1} = 3.24$.

This shows that the point design which relegates function to machines that machines can do best and functions to crew which they can do best has a significant and positive value.

This data on the point design represents only one point and therefore does not show how automation and cost savings vary with crew size which is a significant element of cost in the submarine fleet ownership. In the following section, the results of a sensitivity study are presented which show how the life cycle costs vary as a function of crew size and other program parameters.

c. Sensitivity Analysis - The purpose of the cost sensitivity analysis is twofold--to determine if cost as a function of crew size substantiates the point design corresponding to a crew of 30 was optimum, and to determine if uncertainty factors in the analysis would significantly impact the conclusion that the point design solution represented a large cost benefit over a 25-year planning horizon. The selection approach used to synthesize and size the mechanization of subsystem elements and size the crew to 30 combined system and cost effective considerations. This approach showed the crew of 30 concept yielded the greatest total effectiveness. To establish the sensitivity of cost savings to crew size, feasible combinations of subsystems within the point design which corresponded to crews of 60 and 125 were identified and the investment and crew costs for these combinations were computed. The subsystem combinations used are shown in Figure III-C-8.

Two candidates were found for a crew of 60 which satisfied the requirement of the functional task analysis. The equipment complement for these configurations is shown in Figures III-C-9 and -10.

Crew Size	Subsystems Automated
125	Engineering
60	Ship Control Navigation External Communications Engineering Auxiliary Systems
60	Ship Control Navigation Auxiliary Systems Habitability and Environment Strategic Systems External Communications

Figure III-C-8 Automated Subsystems for Crews of 60 and 125

	Computer*	Soft-ware** Words	Proces-sors	Actua-tors/ Controls	Sensors	Displays ***	Monitors
Central Automation System	1	40,000	-	-	-	-	-
Engineering		5,000	3	200	320	1D	500

Hardware and software estimates are in addition to those in the 640 reference configuration.

* AN/UYQ-20
** Central automation display includes executive and display software; subsystems include control software
*** OJ-326(U)/UYK--S = single display; D = double display

Figure III-C-9 Hardware and Software Estimate for Cost Analysis - Crew 125

To investigate the life cycle cost effects of a mechanization greater than the point design (crew of 30), we determined the impact on investment for a hypothetical design which used a crew of 15. This configuration is hypothetical because analysis showed that 15 men could

	Computers*	Software** Words	Micro-processors	Actuators/ Controls	Sensors	Displays***	Monitors
Central Automation System	2	120,000	-	-	-	-	-
Engineering	-	5,000	3	200	320	1D	500
Ship Control	-	5,000	3	150	300	1D	2
Navigation	-	2,500	1	75	-	-	100
Auxiliary Systems	-	4,000	2	-	330	1D	400
External Communications	-	4,000	1	1	-	-	45

* AN/UYQ-20
** Central automation system includes executive and display software; subsystem software is for control
*** OJ-326(U)/UYK--S = single display; D = double display

Figure III-C-10 Hardware and Software Estimate for Cost Analysis--Crew 60

not efficiently man the submarine, particulary under emergency conditions. Figures III-C-11 and -12 show the relative increase in equipment.

In addition to hardware impact evaluation, the additional cost for RDT&E, production, operations, and support was considered. The crew costs in this initial analysis were held constant at $19,000 per man year. The resulting cost data were plotted as two separate terms--investment and crew cost. The sum of these two terms represents expected program life cycle cost as a function of crew size as shown in Figure III-C-13. This curve shows that the minimum life cycle cost (LCC) occurs at about a crew of 30, thus substantiating the results of the evaluation used to select the point design solution. The investment curve has a characteristic shape seen in most automation problems. It is obvious from the shape of the LCC curve that design solutions equivalent to crew sizes less than 30 are not cost effective since the same value LCC can be obtained at a design equivalent to a larger crew where the only difference is the ratio between investment and crew costs.

	Computers	Software Words	Micro-Processors	Controls	Sensors	Displays	Monitors	Development Complexity
Central Automation System	100%							
Ship Control	-	10%	10%	10%	10%	-	10%	-
Habitability and Environment	-	20%	50%	50%	20%	10%	20%	20%
Defense Weapons	-	50%	50%	50%	20%	10%	20%	20%
Engineering	100%	100%	-	200%	200%	100%	200%	100%
Strategic Weapons	-	20%	50%	50%	50%	-	50%	20%
Auxiliary Systems	-	10%	-	20%	20%	-	20%	10%
Navigation	-	10%	20%	20%	10%	-	10%	10%
Sonar/ECM	-	100%	100%	100%	100%	50%	100%	50%
External Communications	-	100%	200%	200%	500%	20%	100%	100%
Casualty and Damage Control	-	200%	300%	300%	500%	100%	300%	300%

Figure III-C-11 Percent Increase in Software and Hardware from Crew of 30 to Crew of 15 Configuration

	Computers*	Software Words**	Micro-Processors	Actuators/ Controls	Sensors	Displays ***	Monitors
Central Automatic Control System	4	325,000	-	-	-	-	-
Ship Control	-	5,500	4	165	330	2D	4
Habitability/ Environment	-	2,000	2	90	145	1D	215
Defense Weapons	-	2,000	-	45	7	1D	-
Engineering	-	10,000	-	600	960	3D	1,500
Strategic Weapons	-	5,000	3	300	500	-	600
Auxiliary Systems	-	5,000	2	-	400	1D	500
Navigation	-	3,000	1	100	-	-	150
Sonar/ECM	-	5,000	3	2	-	1D, 1S	70
External Communications	-	8,000	3	3	-	-	90
Casualty and Damage Control	-	6,000	3	12	450	-	100

These hardware and software estimates represent additions to those currently in the 640 reference configuration.

* AN/UYQ-20
** Central automation system includes executive and display software; subsystems include control software
*** OJ-326(U)/UYK - S = single display; D = double display

Figure III-C-12 Hardware and Software Estimate for Cost Analysis - Crew of 15

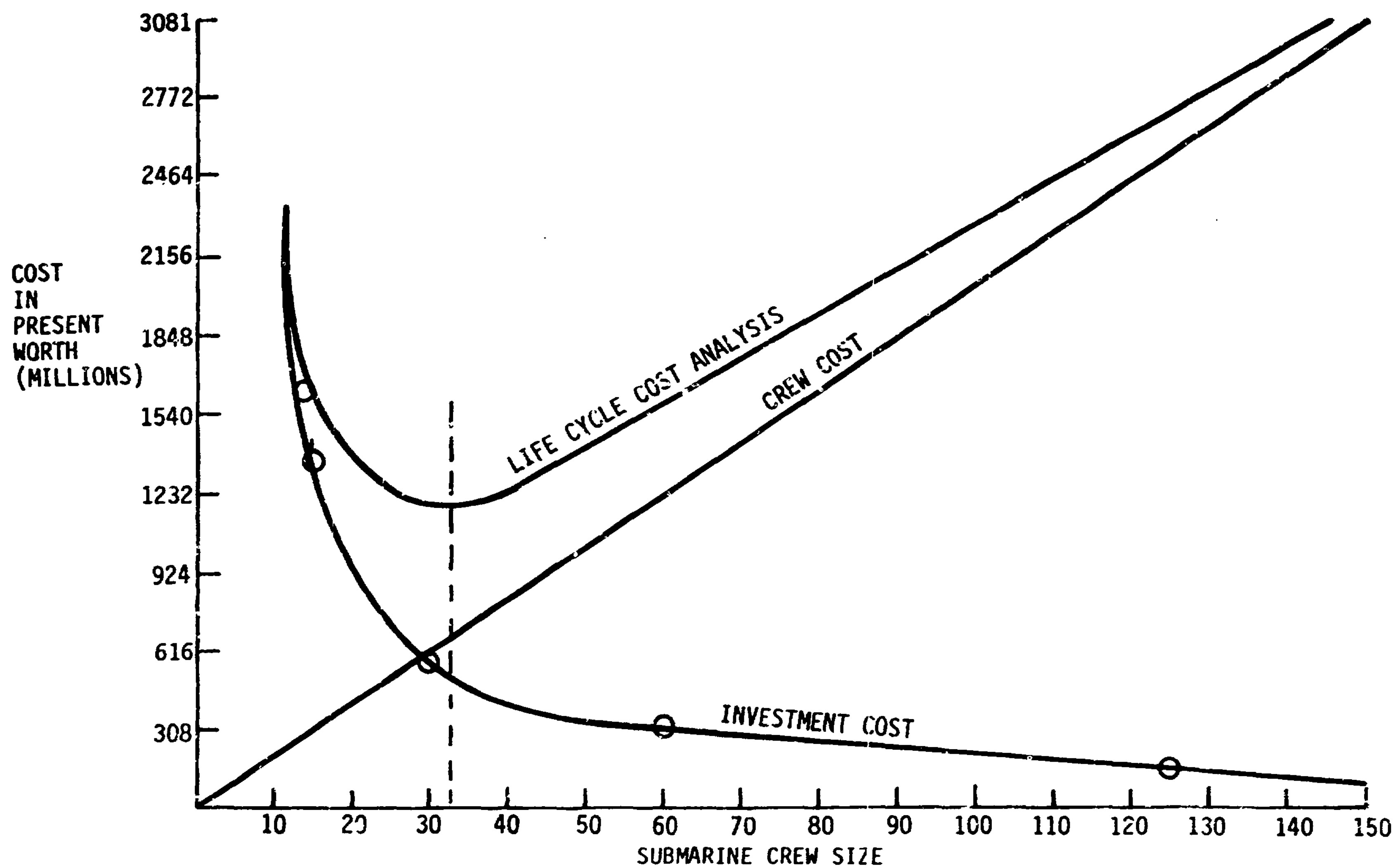


Figure III-C-13 Life Cycle Cost as a Function of Crew Size

This curve provided one additional important piece of data. The reference 640 crew size was 150 and the total LCC for this point on the curve is $3,081 millions in present worth. The difference between this value and the LCC for any crew configuration is the potential savings. For a crew of 30 this savings is:

150 Crew Configuration	$3,081.0
30 Crew Configuration	1,197.2
Savings over 25 years	$1,883.8 millions

This shows that potentially a more realistic division of work functions with increased redundancy between automated systems and crew can result in significant savings in weighted dollars. The same results in 1976 dollars are more dramatic, but less meaningful since this does not consider the time value of money:

1976 Dollars (in millions)

150 Crew Configuration	$5,700
30 Crew Configuration	1,938
	$3,762

To further examine the validity of the cost data we observed that because of the early stage of maturity of the concept definition, the cost estimates have a high degree of uncertainty. Table III-C-4 shows estimating accuracy as a function of various states of design maturity. The studied area identifies the accuracies associated with this analysis.

Judgment indicated the best approach to evaluating the sensitivity in light of the concept maturity was to determine the effect of doubling the investment cost. The data presented in the curve is more in line with a more in-depth concept study. The resulting LCC for double investment cost is shown in Figure III-C-14. The minimum LCC point changes slightly (to 42 crewmen) which is well within the accuracy of the point design.

Next we examined the crew cost term of the LCC equation. The average of $19,000 per man year for a 150 man crew would not necessarily apply to a new crew of smaller size. The ship manning requirements would move to higher ratings and more skilled personnel. To determine the sensitivity to changes in average rate, we assumed the rate would vary linearly from a crew of 1 to 150 and assumed the average would double over this range, i.e., $38,000 to $19,000 per man

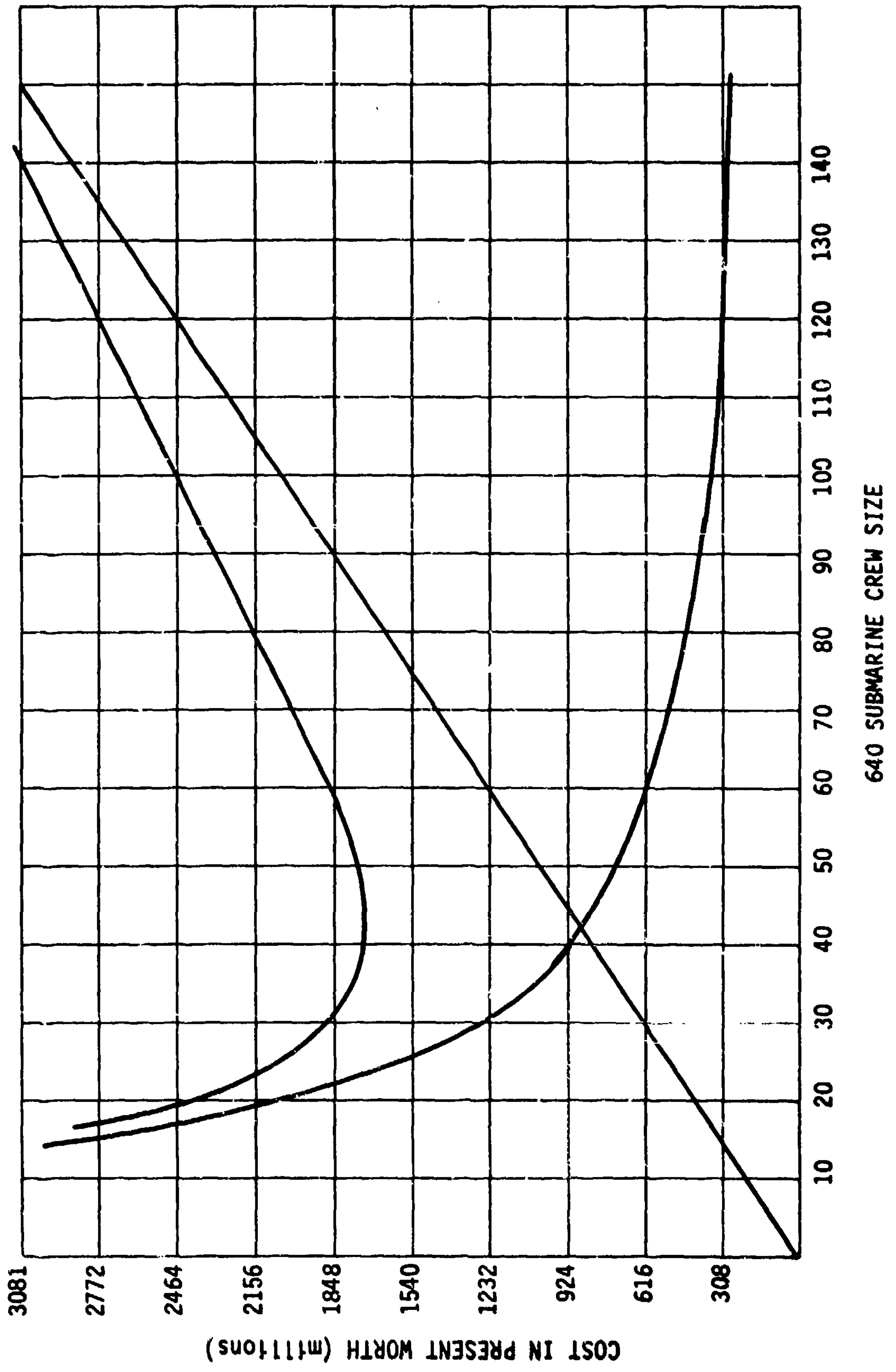


Figure III-C-14 Investment Cost + 100% Error

Table III-C-4 Estimating Accuracy

Estimating Approach	Design Maturity Status				
	New Design		Existing Design		
	1*	2**	Major Mod.	Minor Mod.	Off-the-Shelf
General CERs	±100%	±50%	±50%	±50%	±50%
Specific Applicable CERs	±50%	±15%	±15%	±15%	±15%
Point Design Estimate	±30%	±15%	±10%	±5%	±5%
Analogy to Existing Design	±20%	±10%	±10%	±5%	±5%
Vendor Quote	±20%	±10%	±10%	±5%	±5%

* Some design features either pushing or exceeding state of the art

** New design using existing state of the art technology

year as shown in Figure III-C-15. The resulting impact on the LCC vs crew size is shown in Figure III-C-16. Again, this verifies that the crew of 30 represents approximately the right value for minimum LCC and conversely, maximum savings over the 640 reference configuration. It is obvious that the assumed variations in minimum LCC due to uncertainty in investment cost and crew cost do not change the decision that the point design equivalent to a crew of 30 is near optimum and that the expected savings are as indicated.

The estimated cost for the point design solution in 1976 dollars is shown in Figure III-C-17. Noted on the figure is the percentages for the program cost components. These are shown below compared to the average cost breakdown for major weapons systems.

	Development	Production	Operations and Support
Point Design	5%	33%	62%
Weapon System Average	15%	35%	50%

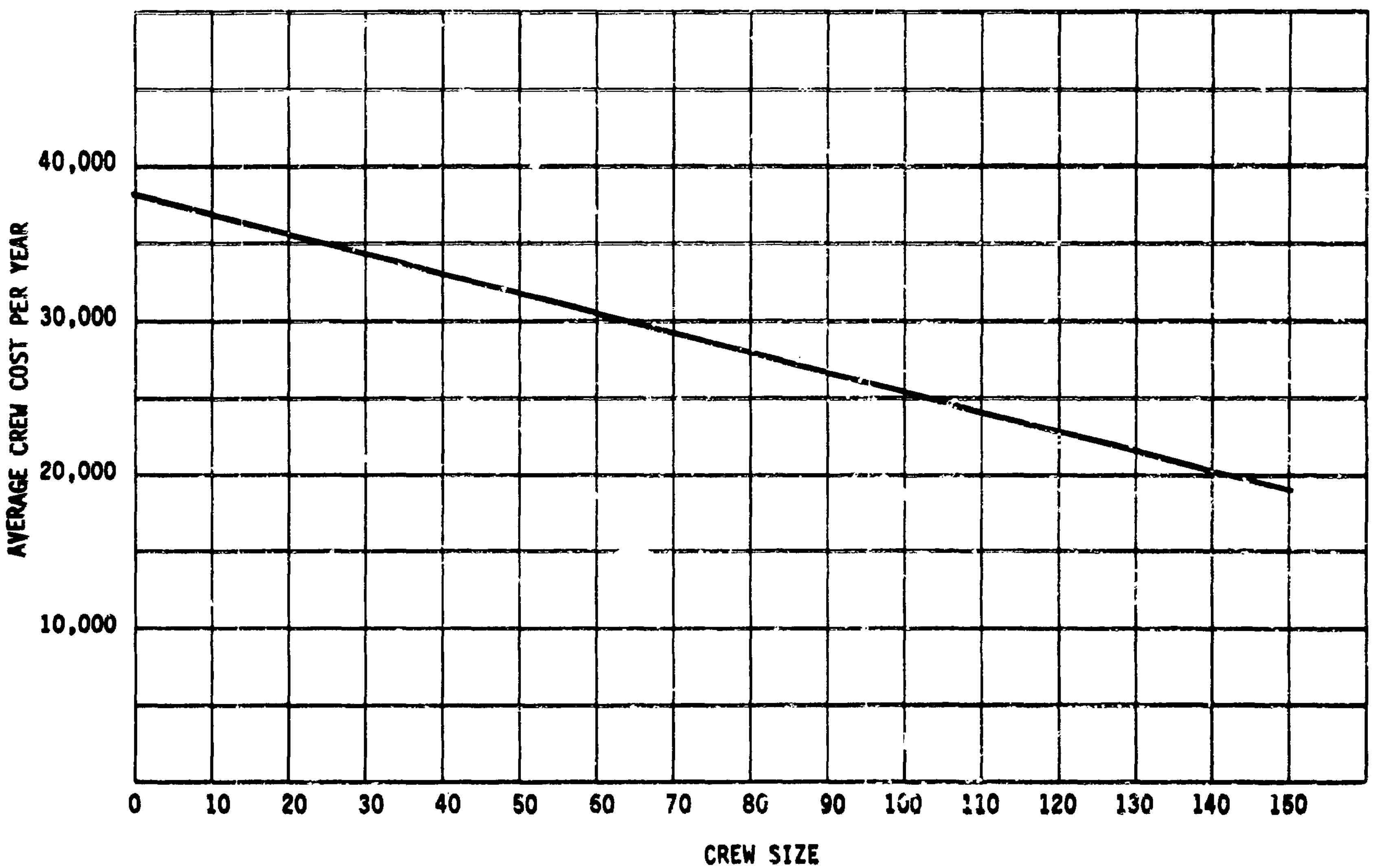


Figure III-C-15 Average Crew Billet Cost as a Function of Crew Size

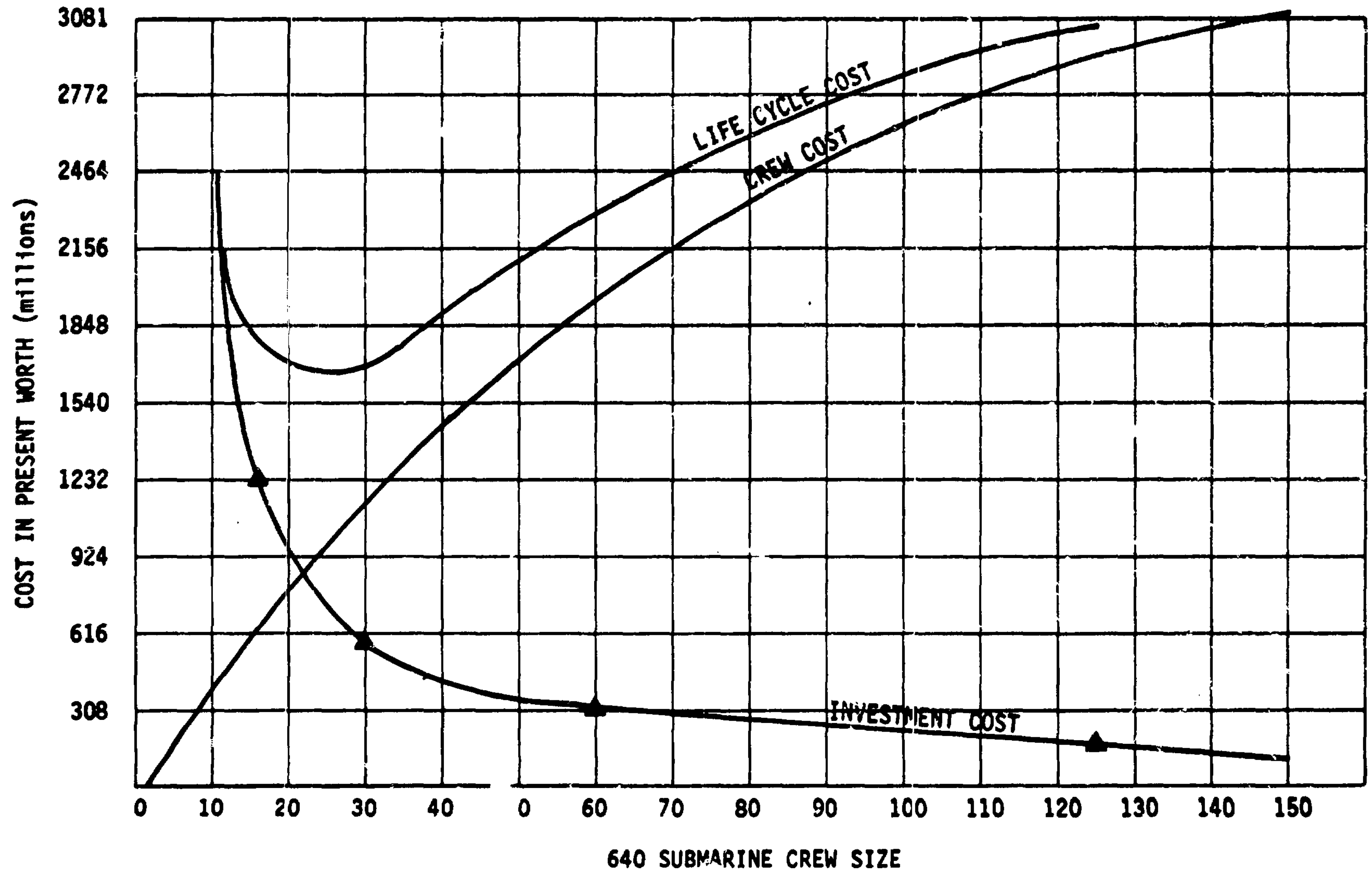


Figure III-C-16 Life Cycle Cost Analysis Based on Distributed Average Crew Cost

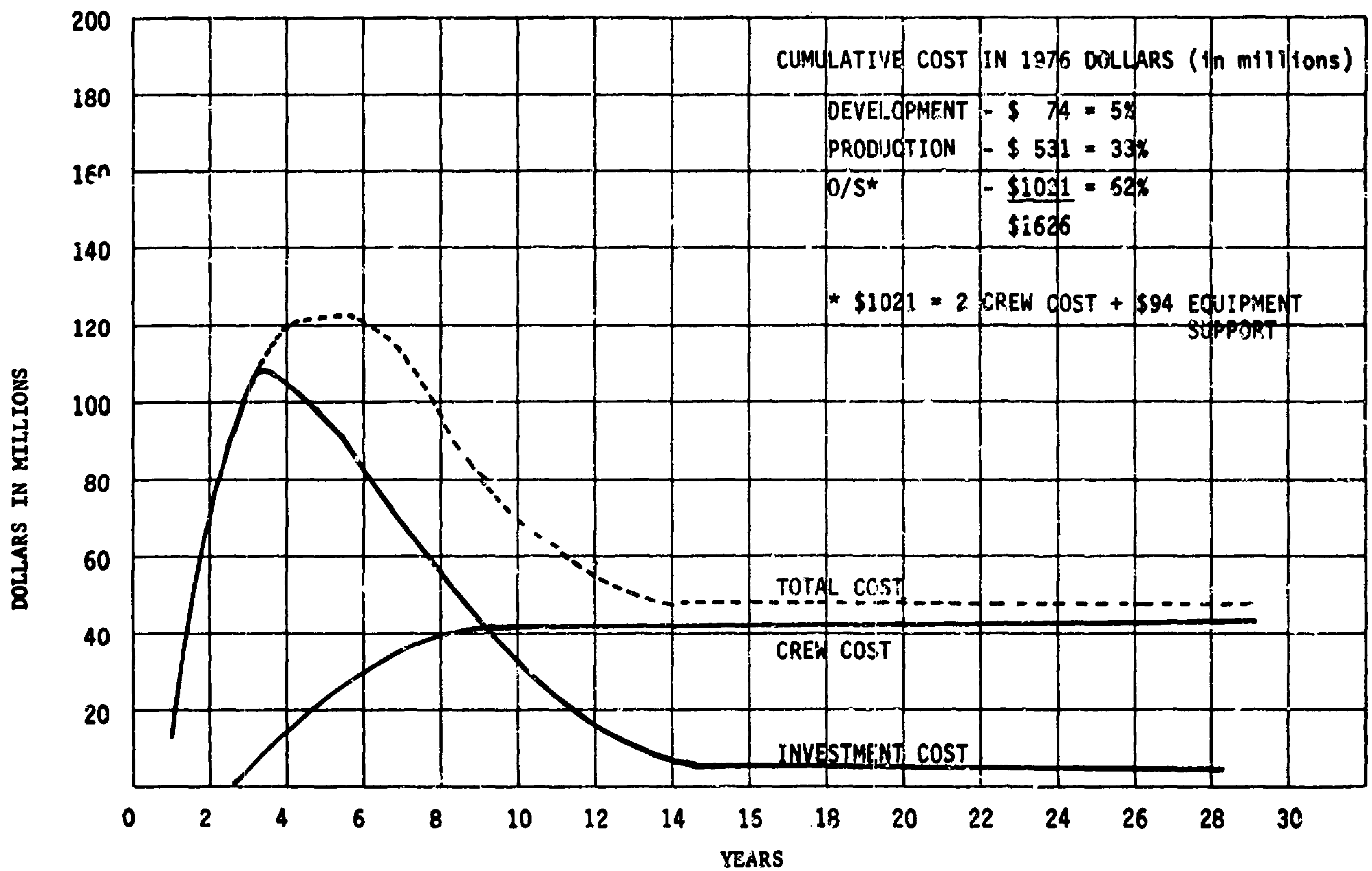


Figure III-C-17 Cost Estimate for Crew of 30 Concept

These are in sufficient agreement for the state of maturity of the concept definition.

In summary, an orderly and methodical economic analysis substantiated the evaluation and selection results used to select the degrees of automation for each subsystem and to define a mechanization concept which established an allocation of submarine functions between machine automation and crew. This balance between automation and crew resulted in a crew of 30 with the same officer complement presently used to man the 640 submarine sensitivity analysis substantiated the economics and showed potentially large life cycle cost savings over current crew costs could be achieved by an integrated, systems approach to the design of a new generation submarine.

IV. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

A crew of 30 officers and men interacting with computers via controls and displays provides the OOD and EOOW more information, diagnostic capability, and control capability than currently exists in the baseline SSBN.

Other advantages of the new generation SSBN when compared to the baseline SSBN are:

(a) it makes less noise;

(b) redundant equipment minimizes system failures;

(c) computerized data transfer eliminates communication problems;

(d) automated response to emergency situations minimized casualties;

(e) response to casualty situations is prompt and efficient;

(f) mechanization could allow submarine to be made smaller and faster;

(g) smaller crew complement permits large scale improvements in habitability;

(h) human error potential is minimized;

(i) equipment standardization can be utilized;

(j) choice of operating cycles is varied;

(k) in-port maintenance time can be predicted and scheduled; and

(l) more efficient personnel usage contributes to higher job satisfaction.

Our study shows that present-day technology readily permits the mechanization of many of the submarine subsystems. Solid-state integrated circuitry has reached the state where thousands of hours of failure-free life may be expected from currently available equipments. Use of redundancy techniques further assures that a component can fail without degrading operation of a subsystem. Redundancy improves availability such that the new generation submarine could stay on station for periods up to one year. Automatic failure reporting enables the faulted part to be readily replaced or repaired and the subsystem returned to its "fail-operate" status. This repair can easily be made at sea. The utilization of computers and microprocessors permits the design of automated equipment to relieve man of mundane or repetitive operations and either takes over for him or provides him with recommendations for operation during unusual (casualty) conditions. The computer can operate under stress conditions faster than man and without errors. Implementing these concepts would save several billion dollars in life cycle costs when applied to the strategic submarine force.

B. RECOMMENDATIONS

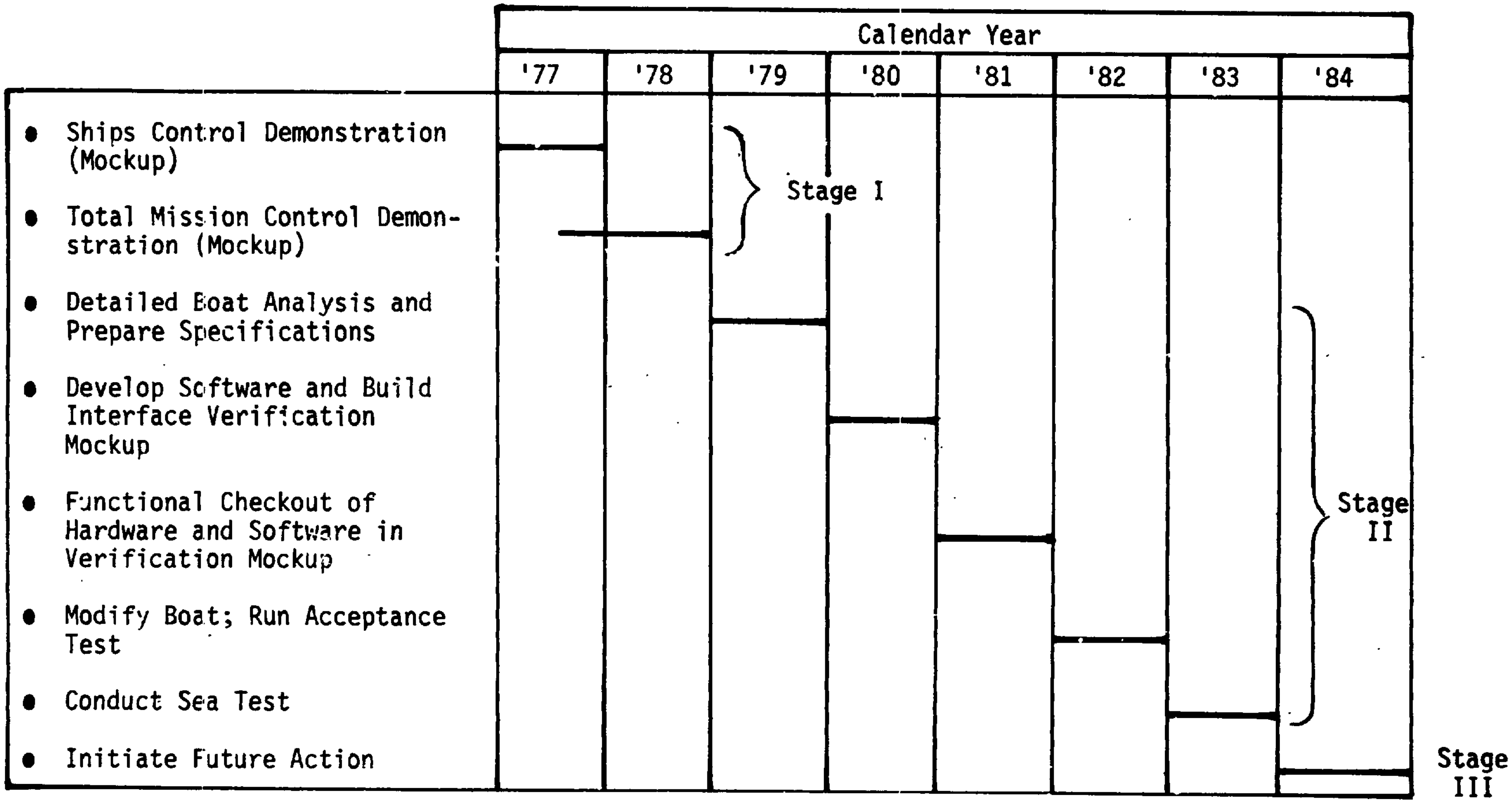
It is recommended that the man/machine interactive concept presented in this report be implemented. A three-stage development plan spanning seven years is recommended with assessment of the success on a yearly basis allowing decisions to continue or terminate the project. A schedule to accomplish the activities is presented in Table IV-B-1. The schedule is conservative and could be shortened if desired. No great expenditure of funds is required in any but Stage 3, thereby minimizing the cost risk of the project. The three stages are:

Stage 1

Establish that a submarine can be automated by demonstrating the replacement of a manual operations with computer-controlled operations using a laboratory mockup.

- Select scenarios; e.g., cruise, strategic and tactical operation, with both a nominal and a damaged boat.
- Write the equation of motion which models the boat and its systems; derive the control laws to automate the systems--formulate in computer language.
- Build the control and display station; program the software in computers so a closed loop model is achieved.
- Design a series of simulated boat exercises; for example, ships control system, strategic weapons system, and defense weapons systems.

Table IV-B-1 Development Plan Schedule



- Demonstrate the automatic action by having a submarine officer initiate, monitor, and alter the exercises while operating from the control and display console.

Stage 2

Gain user acceptance by choosing a test submarine for modification. The boat selected could be one which is entering its normal five-year overhaul time or one which would normally have been replaced by a trident, or by use of one of the test program tactical boats.

- Select a major system of the submarine for automation; e.g., ships control:
  - submerging and surfacing,
  - buoyancy (trim, depth, and drain),
  - steering and diving.
- Design the computerized system.
- Build it into the selected submarine.
- Conduct sea test.
- Demonstrate man/machine interactive operation.

Stage 3

Exercise option to modify current SSBNs or complete the design of the new generation SSBN applying this concept.

C. ADDITIONAL TECHNOLOGY ISSUES

As a result of the analysis to determine the concepts and design criteria for a new generation submarine several technology areas were identified where further development is deemed advantageous. These areas of new technology are discussed in the following paragraphs.

(1) Control of the new generation submarine is based on centralized operation from the Ship Control Console. Multiple CRT displays are proposed to present status and operational data to the OOD. Additional study must be done in the design of

this console to minimize operator fatigue in watching these displays; also the best method of alerting the operator to changing or alarm information must be determined. Optimization of the man/machine interface must be accomplished. The nature and format of what information is displayed on which CRT must be determined. The TV display from a Type 18 periscope should be incorporated into the console.

(2) The proposed centralized ship control station utilizes a distributed processor system controlled by a master computer. Further investigation should determine the exact configuration of this master computer to assure maximum use of this computer. Various redundancy techniques should be studied to provide high computer availability.

(3) Communication between the master computer and the locally positioned satellite computers is by data bus. It is believed desirable that redundant data buses be used. Further study should be performed to determine whether conventional co-axial cable or fiber optic light pipes should be used in this transmission path. Consideration should be given as to the nature of redundancy of the data buses.

(4) Preprogrammed microprocessors have been proposed as the satellite computers. Additional study should be done on their acceptability to gather data and issue control orders on command from the master computer in the submarine environment.

(5) Further design on the triple redundant majority voting LSI Device Controllers should be undertaken to prove its acceptability for submarine use.

(6) Present external communication techniques must be improved. Loss of communication reduces the submarine's availability. Determination of "windows" in the sea water, new antenna design, error correcting codes, and automated message processing should all be investigated.

(7) Automation of sonar techniques should be developed enabling the computers to identify specific ships or other objects from their sonar signatures.

(8) Standardization of power voltages and frequencies should be reviewed. The use of 400 cycle power will reduce the size of components. DC to AC converters are now highly efficient and reliable. Their use in conjunction with the ship batteries could minimize DC requirements.

(9) New concepts in pneumatic/hydraulic/electrical actuators should be studied to improve reliability and minimize the need for high pressure control lines.

(10) Utilization of the ship's computers for trend analysis, failure reporting, inventory control, and other record keeping functions should be studied.

(11) The smaller crew complement required should make more space available and effective utilization to improve crew quarters should be investigated.

It is further recommended that investigation into the additional technology issues listed in Table IV-C-1 is warranted. Each one is an area where improvement in a design or an increase in knowledge of physical limitation would lead to more effective submarine operation.

Table IV-C-1 Additional Technology Issues

1. Covert message acceptance with no operational constraints.
2. Command and control validation of messages.
3. Sound isolation mounts.
4. Propulsion plant efficiency.
5. Steam generator corrosion.
6. Battery charge/discharge characteristics and lifetime.
7. Shaft torque limits (properller drive).
8. Casualty sensing detectors.
9. Secondary velocity sensor (non-inertial).
10. Covert navigation fix capability.
11. Covert heading fix.
12. Message copy capability.
13. Passive sonar detector (bandwidth and discrete frequency).
14. Target motion analysis determination (with limited input).
15. Hydrodynamic flow restrictions.
16. Control surface flow cavitation limitations.
17. Atmospheric detectors/analyzers.
18. Human atmospheric tolerance bounds.
19. Food storage.
20. Trash disposal.
21. Radiation detectors and human tolerance.
22. Heat transfer capabilities versus size of heat exchangers.

APPENDICES

I. DESIGN CONCEPTS

A. CENTRALIZED CONTROL

Current submarine design concepts rely heavily upon manually performed or manually initiated tasks. Our study has indicated that mechanization of a selected number of these tasks would improve submarine operation and improve system efficiency.

The study has shown that a minimum sized crew could strategically operate a mechanized submarine. To accomplish this, selected operational information and control capability would be centralized in a control console manned by the Officer of the Deck (OOD). An additional manned console to support engineering plant functions would be operated by the Engineering Officer of the Watch (EOOW). Other consoles, normally unmanned, are provided for use in special strategic or tactical situations. Figure A-I-1 shows the physical concept of ship mission control capability.

A computerized system is suggested to achieve the centralized control discussed above. Figure A-I-2 presents a block diagram of a candidate centralized ship mission control system.

A distributed computer system design concept has been selected to allow the main control computers the maximum opportunity to support the OOD and EOOW. Distributed computers perform functions as commanded by the main computer. The distributed computers execute checklists, check equipment status, make decisions, actuate control devices, and collect data, which is filtered to remove unwanted, unnecessary, or routine information before being transmitted to the primary computer. This reduces the functional control activity of the main control computer, allowing maximum time to be devoted to the system management and support of the console and its displays.

The OOD and EOOW may select the desired level of operator/computer interaction. Basic levels of interaction are to command the individual action, subfunction, function, or mission segments to be performed. For each level of interaction the computer system provides controls and displays with the appropriate level of detail.

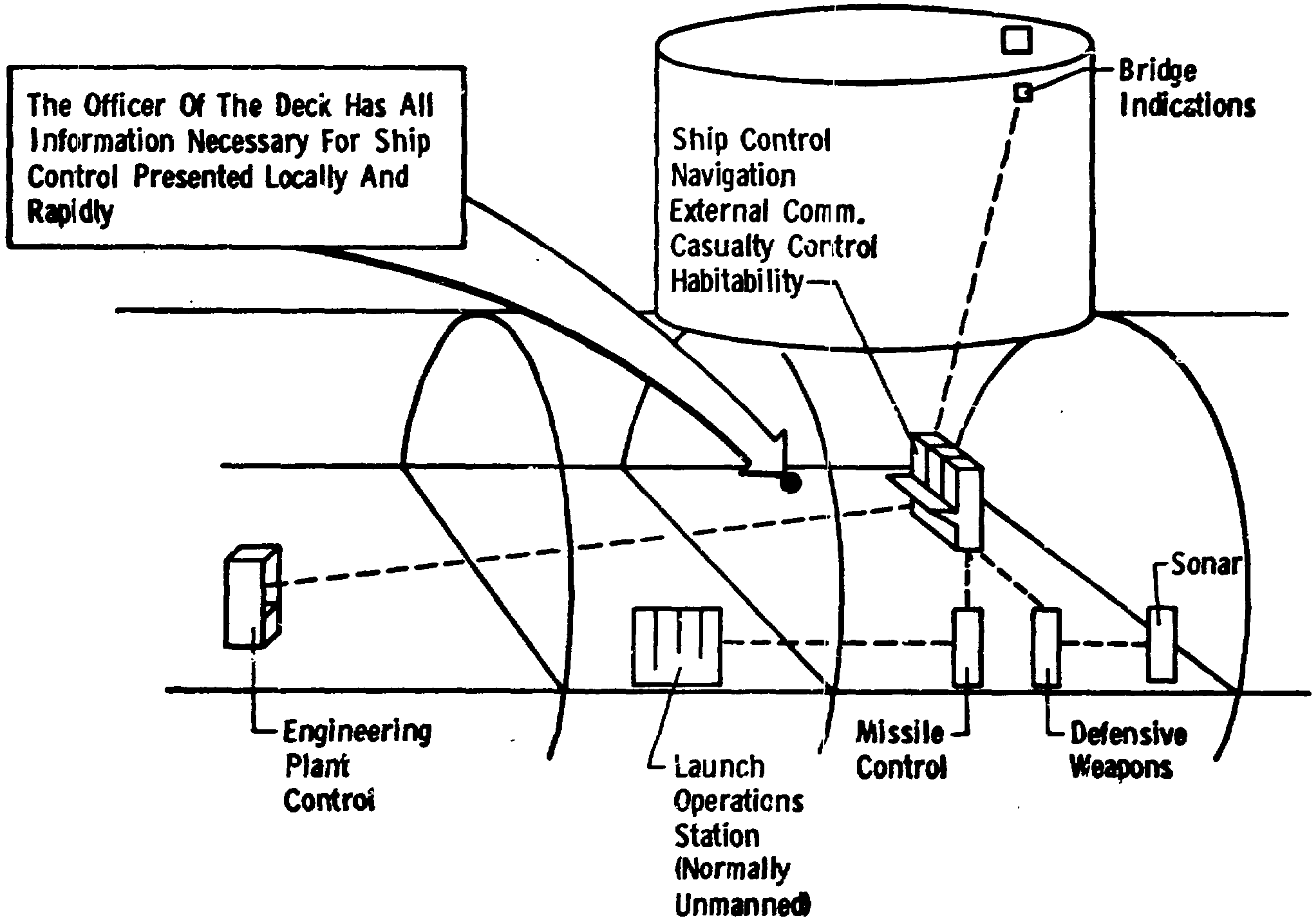


Figure A-I-1 Concept of Ship Mission Control Capability

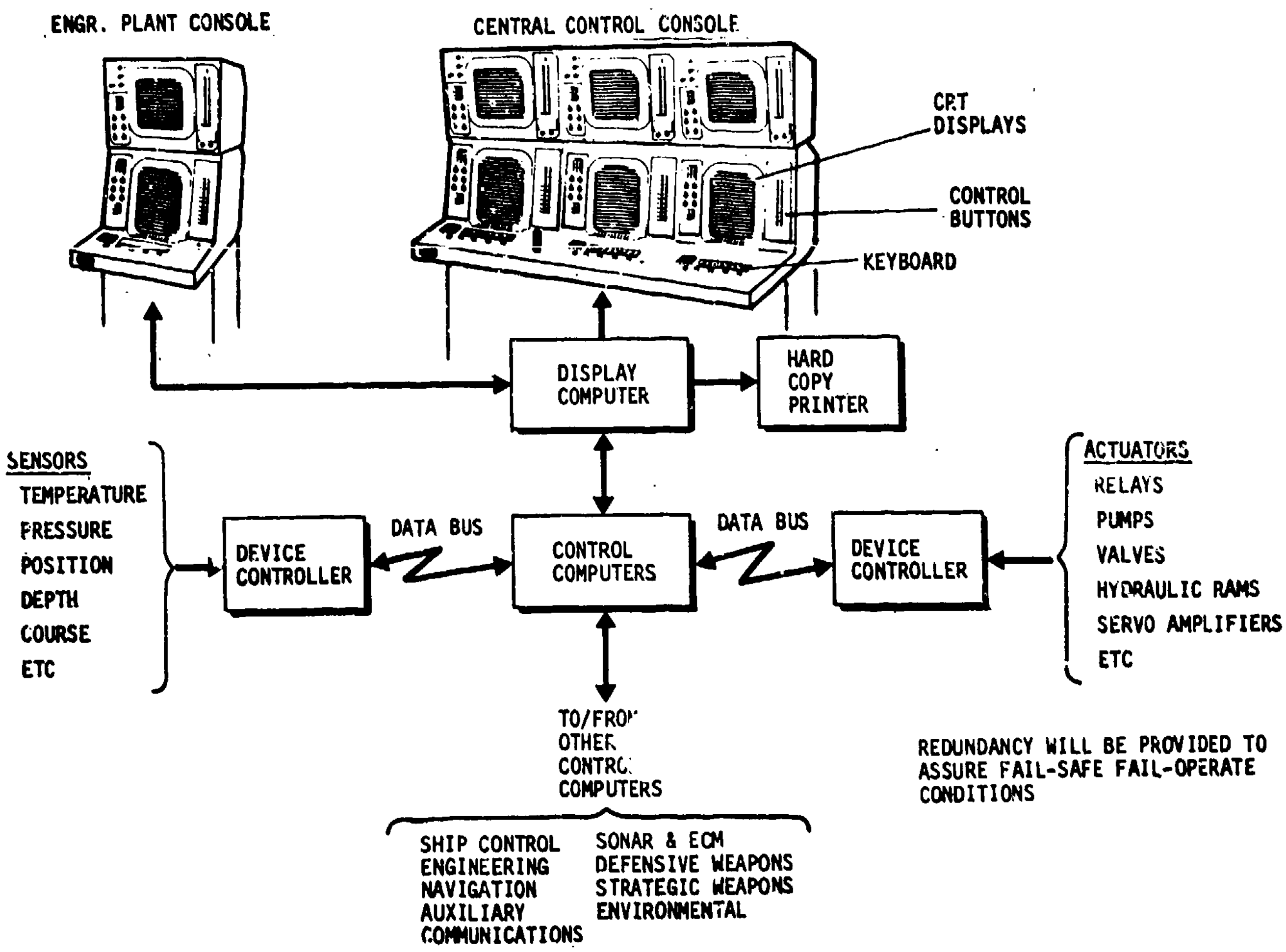
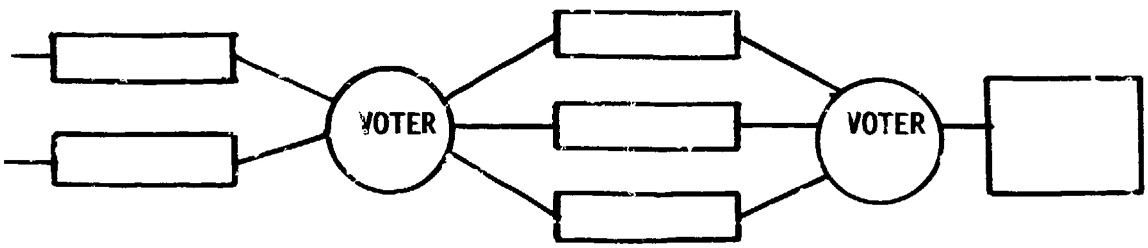


Figure A-I-2 Ships Mission Control System

B. REDUNDANCY

Redundancy techniques and use of highly reliable equipment and components will assure high availability of the systems. Figure A-I-3 shows the basic redundancy concept to increase time on station. Equipment failures do not result in system failures. Backup equipment automatically takes over through internal test algorithms, programmed to detect imminent failures. Switchover to the parallel redundant equipment takes place with the "about-to-fail" hardware placed off-line.



- Equipment failures do not cause subsystem failures.
- Low MTBF component modules are configured in parallel redundancy and voted.
- System still functions if modules fail.
- Failed modules are put off-line and replaced or repaired by the crew.
- Repaired modules are easily returned to the system.

Figure A-I-3 Increased Time on Station through Redundancy

Standby redundant display and main computers are utilized. (Appendix I-D evaluates computer configurations and provides the rationale for this selection.) It is suggested that three identical computers each be used for ship control and display management. Two of the three are active at any given time while the third is a "cold standby" (unpowered) condition. In order to assure the fail-operate requirement for key functions, one machine is programmed to check the other. If the check fails, the standby machine is turned on to take over the functions of the #1 processor. Similarly, check parameters are sent to locally distributed microprocessors from the main computers and memory so that control over standby circuits in the microprocessors is maintained.

Redundant data buses provide the communication links to the locally distributed microprocessors. These microprocessors, in response to commands from the main control computer, gather data or activate controls. Results are telemetered to the main control computer.

Martin Marietta is developing extremely reliable microprocessor oriented units suitable for use as the Device Controllers. These device controllers receive data over three redundant data buses and majority vote the signals to assure proper command interpretation. At least two out of the three signals on the buses must be the same for a command to be implemented. Control over device controller redundancy circuits is accomplished by routine limit checks carried on by its controlling microprocessors.

A failed computer, microprocessor, data bus, or device controller is automatically determined, and placed off-line. The failure is annunciated on a CRT. A subsystem will continue to operate in a normal manner with only two of the triply redundant units in operation. Under emergency conditions, a system can be forced to operate with only a single computer, microprocessor, data bus or device controller operable for an element.

Figure A-I-4 shows the basic control system.

C. SYSTEM COMPONENTS

Component items of the New Generation Submarine's Ship Mission Control System include:

Hardware

- Parallel redundant subsystem modules
- Computerized fault isolation
- Computerized module switching
- Redundant data buses

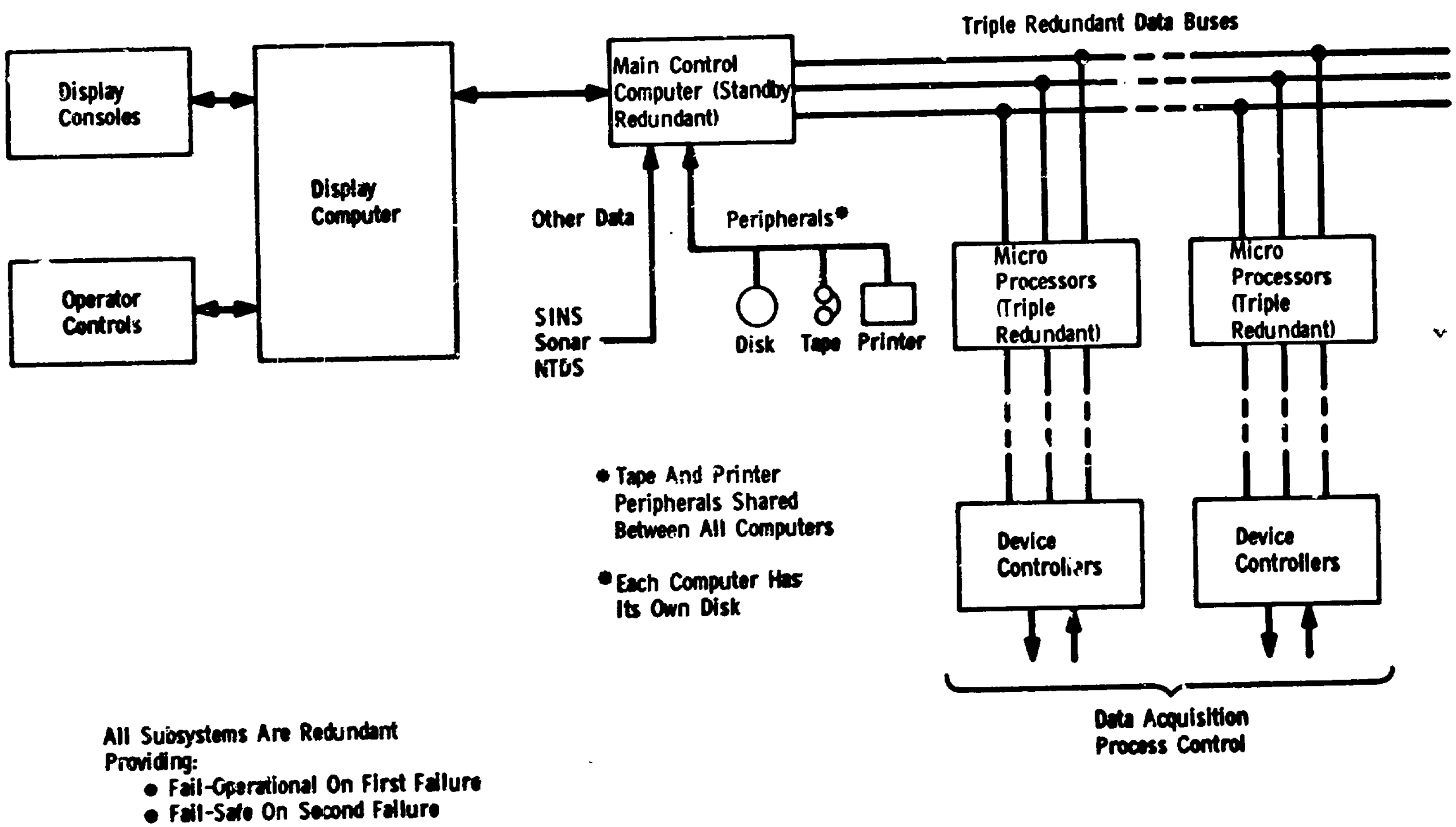


Figure A-I-4 Computer Controlled Mechanization

- Sensors throughout the ship
- Control and display consoles

Software

- Servo control of most ship systems
- Mission control for ordered segments
- Combat analysis
- Combat control (option)
- Display driver and formatting
- Diagnosis and alerts
- Running status of all boat hardware, trend and failure analysis
- Sonar control and data diagnosis
- Intraboat communication
- Automatic message processing
- Redundancy management, self-check, and cross-check logic

Man/Machine Interactions

- Central control console
- Engineering plant console
- Evaluations initiated individually or in sets
- CRTs display
- CRTs display status of all subsystems
- Caution and warning alert annunciation
- Automatic priority interrupt for C&W
- Control via keyboard, hand cont ollers, switches
- Dedicated readouts where desired

- Video monitoring on demand
- Printer

Crew Functions

- Decisions
- Console operators
- Respond to alerts from computers
- Hand operation of specific systems
- Override computerized functions
- Replacement of modules put off-line by computers
- Preventive maintenance
- Inspection when indicated
- Damage and casualty operation

1. Display and Control Consoles

The command and control functions are performed at display consoles utilized as the Central Control Consoles, Engineering Plant Consoles, Sonar Console, etc. These items, while new to the New Generation Submarine, are readily configured from the Navy's OJ-326 (V)5/UYK Standard Information Displays (SID). The SID is a modular, multi-function digital display utilizing plug-in components and programmable assemblies which can be combined in a variety of ways to meet current as well as future operational requirements. The SID Display Console OJ-326 provides a 13 x 10 inch useful area on a high quality, high, high brightness CRT. The upper IP-1181 display utilizes a similar 10 x 10 inch CRT. The SID console is capable of displaying a wide variety of text, graphic, tactical, and surveillance data for monitor and control applications. (The SID system is based on the technology introduced with the MK 81 Mod 0 Weapon Control Console, already in production and environmentally qualified for submarine applications.)

2. Computers

The computer controlled New Generation Submarine as proposed will use standard Navy computers such as the AN/UYK-20(V) as the Display Data Processor and the Main Ship Control Computer.

The AN/UYK-20(V) is a general purpose, militarized, high speed mini-computer with great computing power in a small, ruggedized package. It is designed to meet the requirements of submarine installation and operation.

3. Data Management

The physical configuration of a submarine suggests the use of a distributed computer system in the implementation of data management.

Main computers are located in the Control Center and at the Engineering Plant. Satellite command and control microprocessors are strategically located throughout the ship near the devices they control.

In the past a "central hub" approach to data management has been used. Its mechanization, as its name suggests, is to bring signals from a central station to control stations located throughout the ship. Its most significant feature was, literally, miles of wire and a large number of individual interface boxes for each function at each control station.

In our conceptual design of the new generation submarine, we are recommending a serial data bus approach to a distributed command and control system. From the control centers computer(s), high speed data buses are used in a party-line manner to request and transfer information to local microprocessors (μPs). All μPs monitor the data bus (or redundant buses) and determine whether or not a message is for him. If it is, it performs the requested action and responds via the data bus to the central computer.

High speed data transfers, at one million bits per second, enable each device to think that it has the full attention of the computers.

Advantages of this data management technique are:

- Significant savings in design, integration, and testing;
- Ease of refurbishment, rework, and addition of future improvements;
- Reduction in total numbers of wires;
- Reliability readily improved through use of redundancy;
- Standard interface hardware used;

- Functional flexibility through simple software changes.

It is suggested that the data formats as defined in MIL-STD-1553A be used in the transfer of data between the central computers and the local microprocessors.

D. COMPUTER CONFIGURATIONS

1. Introduction

This report lists several computer configurations studied to provide automation and control on a New Generation Strategic Submarine.

The fundamental design requirement of the computer system is to provide information and control of the submarine to the system operator. All submarine functions are to be performed by the crew with varying levels of computer assistance. The use of a computer system provides centralized control of actions to be completed throughout the submarine.

The most important computer system interface is between the computer and system operator. Several distributed computer system design concepts have been configured to allow the Ship Control Computer the maximum opportunity to support the system operator. Distributed microprocessors perform functions as commanded by the Ship Control Computer. The distributed microprocessors execute checklists, check equipment status, make decisions, actuate control devices, and collect data, which is filtered to remove unwanted, unnecessary, or routine information before being transmitted to the Ship Control Computer. This reduces the functional control activity of the Ship Control Computer, allowing maximum time to be devoted to the system operator interface.

Figure A-I-5 shows the basic computer system configuration. Figure A-I-6 shows an alternative configuration.

All of the conceptual distributed computer systems are designed for at least fail-operate/fail-safe operation. Mechanization of the main computer--the Ship Control Computer--is either triple redundant, dual redundant, or standby redundant to assure high system reliability. The system operator is informed of all malfunctions and system switchouts so that repairs can be made by the maintenance personnel to restore redundancy. The Ship Control Computer orchestrates the performance of each microprocessor,

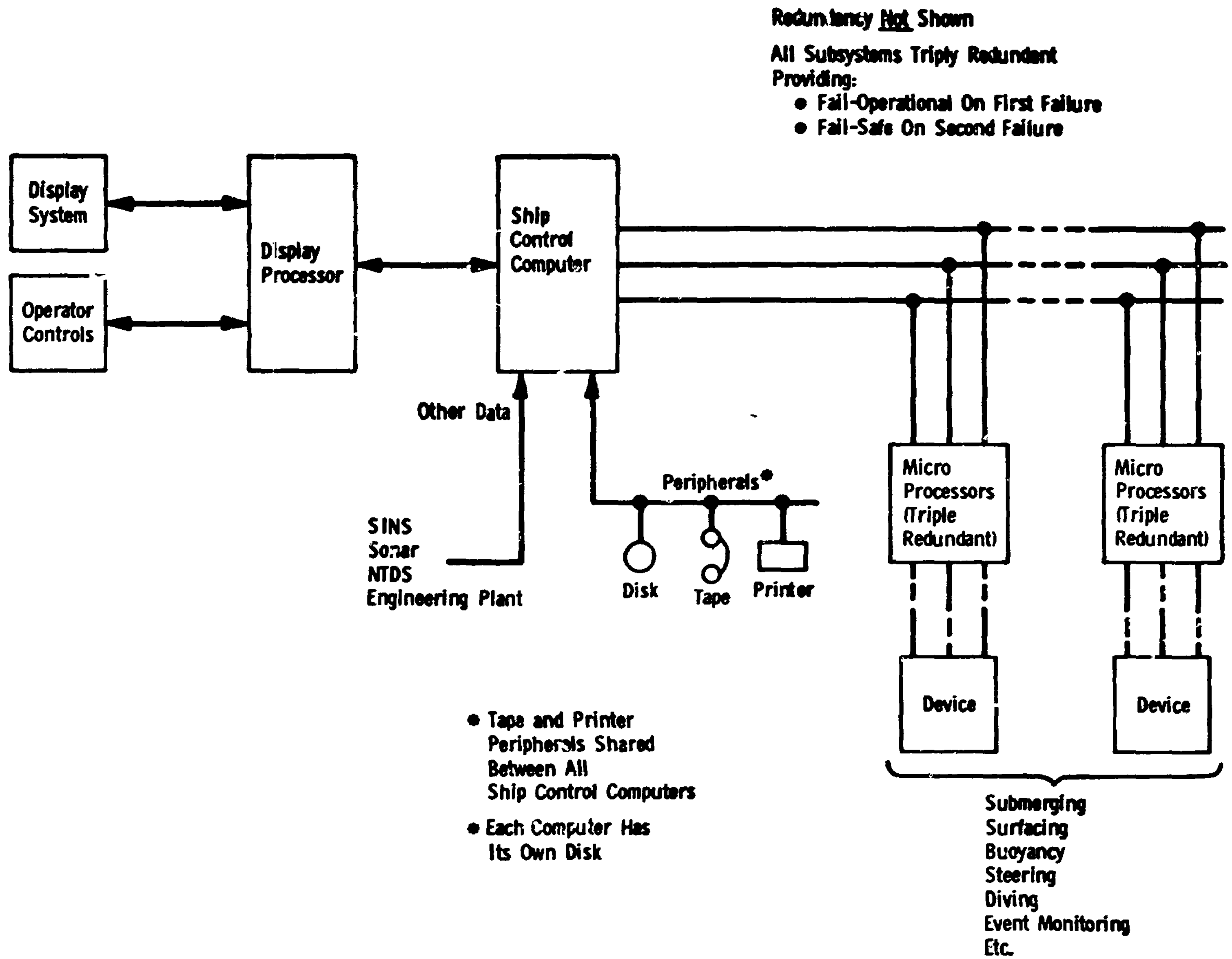
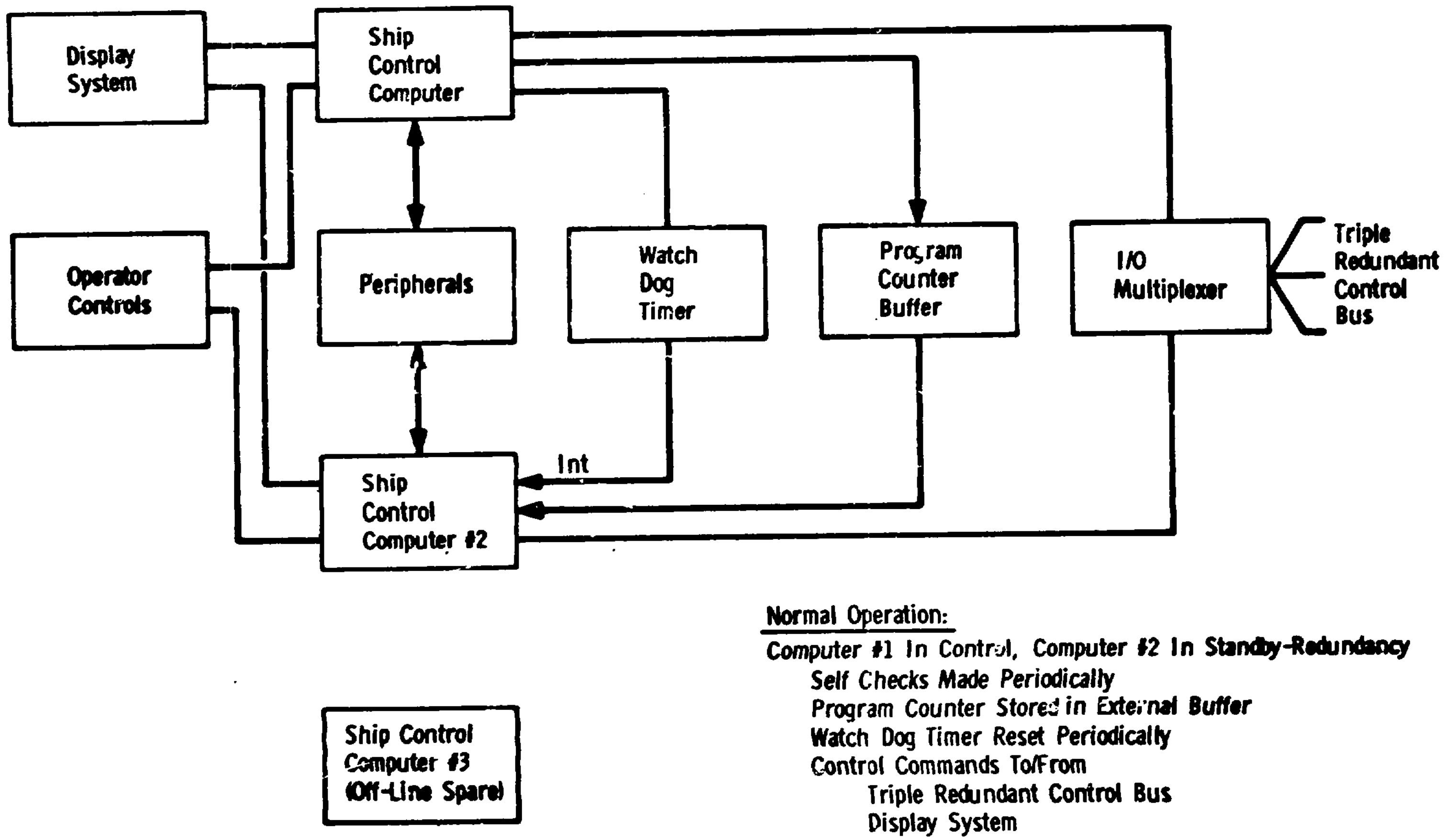


Figure A-I-5 Basic Concept Automated Submarine Control



Normal Operation:

Computer #1 In Control, Computer #2 In Standby-Redundancy
- Self Checks Made Periodically
- Program Counter Stored in External Buffer
- Watch Dog Timer Reset Periodically
- Control Commands To/From
  - Triple Redundant Control Bus
  - Display System
  - Operator Controls
  - Peripheral Equipments

Failed Operation:

- Watch Dog Timer Times-Out
- Computer #2 Reads Program Counter Position
- Computer #2 Re-Synchronizes Its Self

Computer #2 In Control
- Self Checks Made Periodically

Computer #1 Repaired Off-Line

Figure A-I-6 Alternate Concept Automated Submarine Control transmitting commands and collecting data for display to the system operator. Each state-of-the-art, solid-state microprocessor is either dual or triply redundant, providing high reliability at low cost. Failure of a microprocessor is diagnosed and the failed microprocessor is automatically bypassed, allowing normal system operations to continue without interruption.

Besides physically controlling the submarine, the computer system will assist the system operator by presenting "off-line" information, such as displays of strategic or tactical data, equipment failure trend data, damage control status, training information, medical diagnostics, or other displays, many with computer predictions or recommended courses of action, all designed to enhance the ability of the system operator to control the submarine.

2. Ship Control Computer Configurations

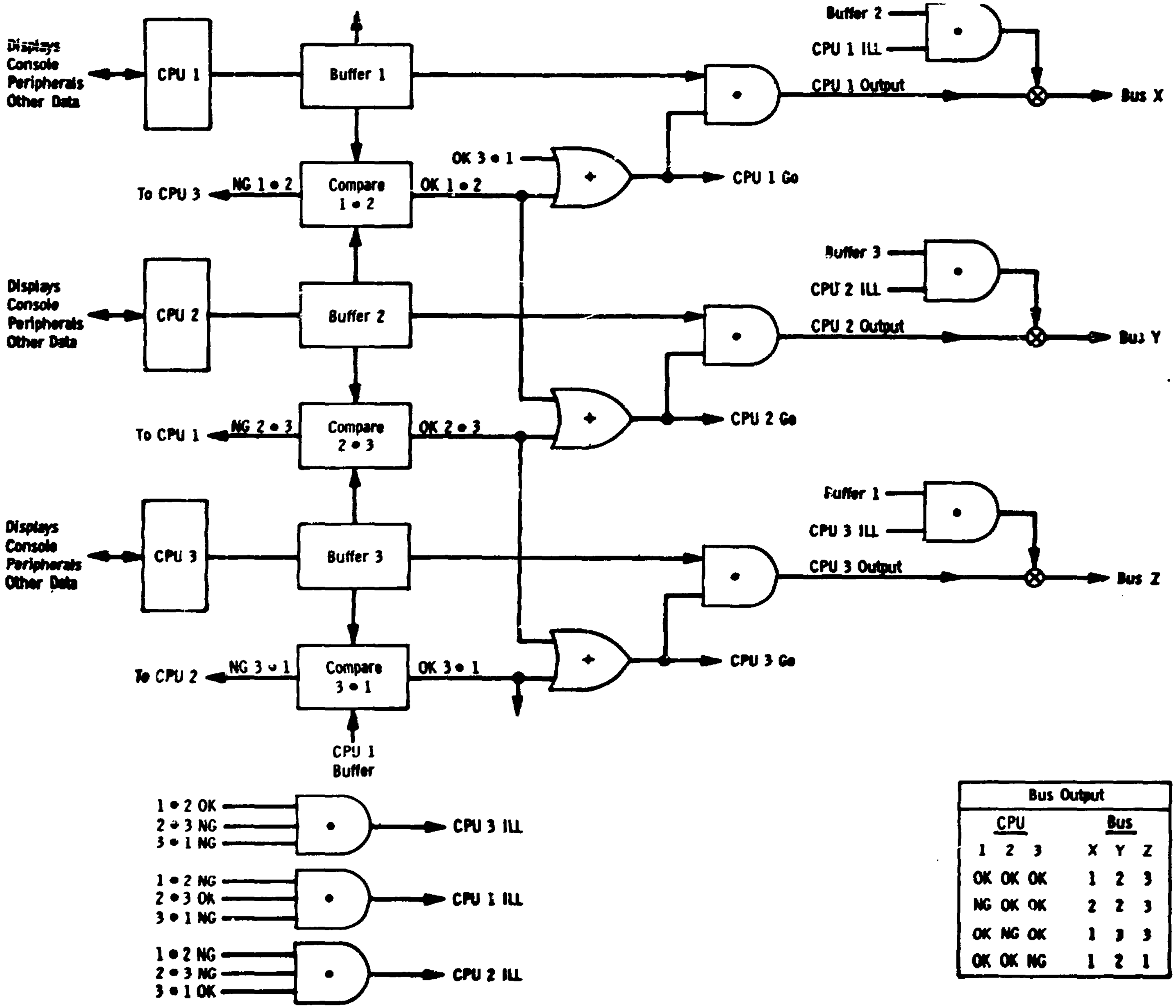
The Ship Control Computer will control submerging, surfacing, buoyancy, steering, speed, and the engineering plant. It will also receive applicable data from the Ship's Inertial Navigation System (SINS), Weapons Systems, the Naval Tactical Data System (NTDS), Communications System, and from the Sonar System. Data will be displayed and Ship Operating Commands will be received on the Operations Console.

a. Configuration 1 - This configuration for the Ship Control Computer uses three separate active computers each with its own memory. Synchronization of the three computers is external to the computers using special purpose logic. The synchronization logic assures that each computer is performing the same programmed function. The synchronization logic assures that output instructions are released simultaneously to the output command buses and the microprocessors. Figure A-I-7 shows the synchronizing circuitry in block diagram form.

The three computers run from identical software programs. Programming is "somewhat" complicated as the necessary "wait" steps for synchronization must be included in the programming.

Failure of any one of the computers will not effect operation and the system will continue to run without a "glitch". The system can continue to operate, with operator guidance, on only one computer.

b. Configuration 2 - This configuration provides dual redundant computers. Operation is similar to configuration 1



Bus Output

CPU 1	CPU 2	CPU 3	Bus X	Bus Y	Bus Z
OK	OK	OK	1	2	3
NG	OK	OK	2	2	3
OK	NG	OK	1	3	3
OK	OK	NG	1	2	1

Figure A-I-7 Ship Control Computer Output Control Circuitry (after the first computer has failed). A third identical computer is provided in a "cold standby" (unpowered) condition as a spare.

Synchronization logic provides an output if both on-line computers issue the same command. Should the computers not issue the same command, the computers are forced into a self-check mode and the "correct" computer is allowed to issue commands under operator guidance. Two data buses, one per computer, are provided to control the microprocessors. This configuration sacrifices some reliability at the cost savings of one computer and several microprocessors.

c. Configuration 3 - This configuration also uses two computers, but with only one of the computers in control. If the active computer in control should fail a self-check that is periodically performed, the second computer automatically takes over control. External synchronization logic assures that the second computer keeps up with the first such that it can take control if the first computer fails.

d. Configuration 4 - This configuration is similar to 2 or 3 with the exception that both on-line computers share the same dual ported memory. Memory reliability is such that these configurations are worthy of consideration. Synchronizing logic is minimized. Operation is similar to either configurations 2 or 3. Maintenance on a disabled computer is a problem and, thus, this configuration is not recommended.

e. Configuration 5 - This configuration uses a single "fault-tolerant" computer. Such a computer is presently being developed for the military. This type computer is in reality redundant computers with fault detecting and error correcting logic packaged in a single enclosure.

3. Control Bus to the Microprocessor

The physical configuration of a submarine suggests use of a distributed computer system to provide the ship's data management system. The suggested distributed data system consists of AN/UYK-20 type minicomputers at the Central Control Console and the Engineering Plant Console with locally located microprocessors placed at appropriate action centers.

Redundant control buses provide the intercommunications between the main computers and the satellite microprocessors. Commands over these buses will cause the microprocessors to issue specific commands or fetch data or status information.

4. Microprocessors

Microprocessors (μPs) will control and monitor specific device controllers. The Ps will execute commands and gather data on command from the main computers. Depending on the selected configuration of the main computers, the μPs will be either triply or dual redundant.

The redundant μPs will verify all commands from the Ship Control Computers prior to executing them. An about-to-fail or malfunctioning μP is automatically removed from its on-line position without effecting system operation.

Figure A-I-8 shows the operation of redundant microprocessors.

5. Data Bus

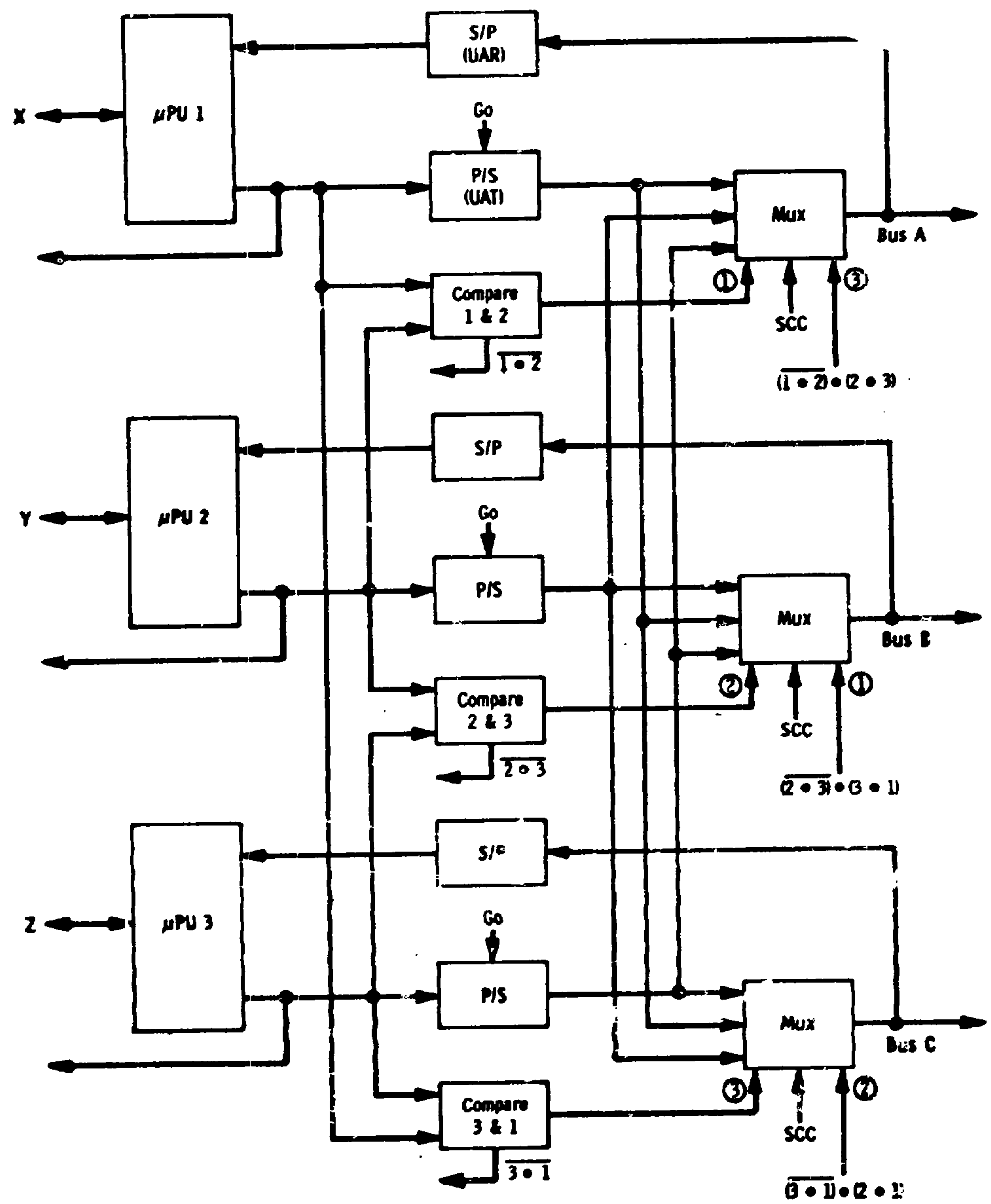
Input and output signals between the microprocessors and the control devices are transmitted in serial code. Standard large-scale integrated (LSI) circuit modules are readily available to process this data. A suggested data transmission method over the serial data bus is shown in Figure A-I-9.

6. Control Devices

The use of existing submarine control devices and actuators is proposed. A majority vote control circuit will be placed adjacent to each control device. This circuit will monitor the control bus. Upon detection of a valid control signal on at least two out of the three control buses for that device, it will initiate the requested action.

The control circuit will utilize high reliability semiconductor circuits. The control circuit module will be identical for all devices to minimize spacing and eas maintenance. Figure A-I-10 shows a suggested block diagram of this control circuit.

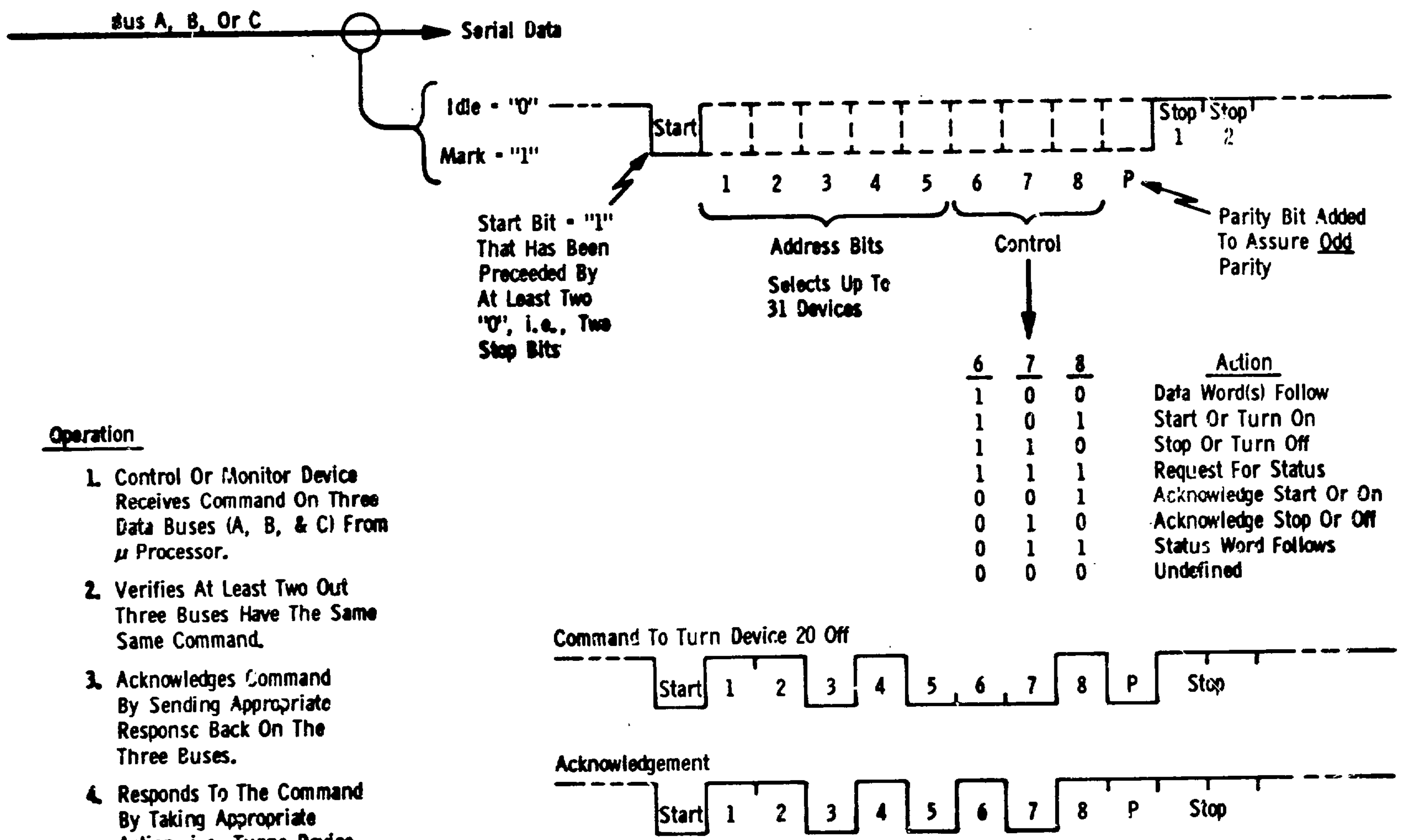
All the computer system configurations studied provide for fail-operate/fail-safe operation. Further study is suggested to determine which computer subsystem best fulfills the new generation submarine.



SCC = Ship Control Computer

Bus μPU 1	Bus μPU 2	Bus μPU 3	Output Bus A	Output Bus B	Output Bus C
OK	OK	OK	1	2	3
NG	OK	OK	3	2	3
OK	NG	OK	1	1	3
OK	OK	NG	1	2	2
NG	NG	OK	3	3	3
NG	OK	NG	2	2	2
OK	NG	NG	1	1	1

Figure A-I-8 Triple Redundancy μPU Circuits, Fail-Operate/Fail-Safe



6	7	8	Action
1	0	0	Data Word(s) Follow
1	0	1	Start Or Turn On
1	1	0	Stop Or Turn Off
1	1	1	Request For Status
0	0	1	Acknowledge Start Or On
0	1	0	Acknowledge Stop Or Off
0	1	1	Status Word Follows
0	0	0	Undefined

Operation

1. Control Or Monitor Device Receives Command On Three Data Buses (A, B, & C) From μ Processor.
2. Verifies At Least Two Out Three Buses Have The Same Same Command.
3. Acknowledges Command By Sending Appropriate Response Back On The Three Buses.
4. Responds To The Command By Taking Appropriate Action; i.e. Turns Device On Or Off, Returns Status, Etc.

Note:
Analog Status Words Such As Temperature, Position, Depth, Course, Etc. Can Be Double Precision.

Figure A-I-9 EIA RS-232C Data Stream, µP/Control or Monitor Device Actions

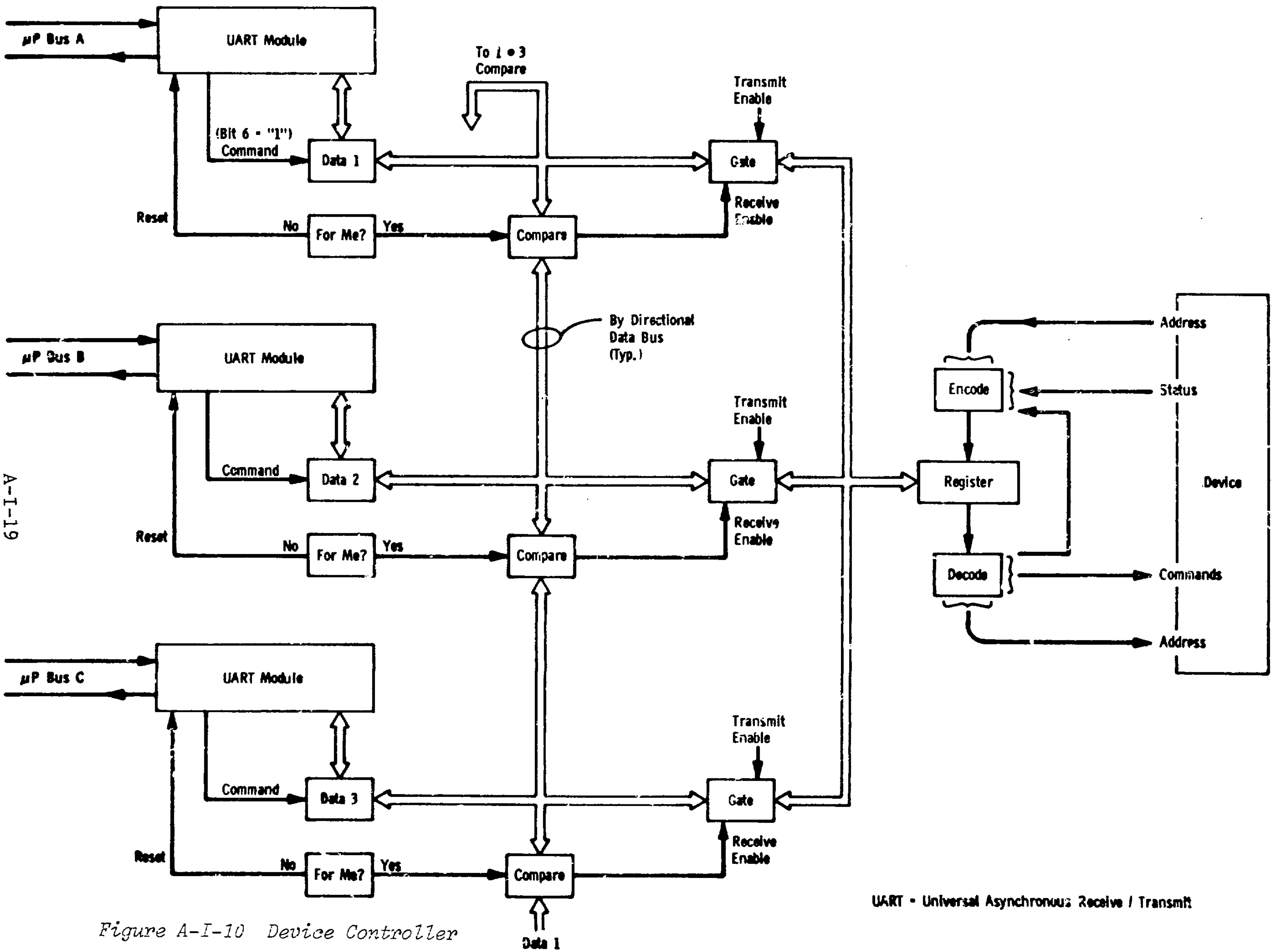


Figure A-I-10 Device Controller

II. MISSION CONTROL

A. CONCEPT

The basic Ship's Mission Control concept presented in this appendix involves a central executive software structure under the direct management of the officer in control of the submarine. This executive structure is driven by a stored mission profile in the form of tables of time-ordered command (e.g., position, attitude, velocity, events) leading ultimately to ship control activities such as maneuvering, steering, diving, and surfacing. The officer can treat this as a means of implementing mission plans on either a near-real time or long-term basis (i.e., minutes vs days), or it can be overridden in response to changes in plans or emergency situations. The underlying assumption is that the officer of the deck might choose to conduct certain phases of ship control in the same way an airline pilot does when he chooses "automatic pilot".

The executive structure logically governs access to subordinate software modules, where sequences of control commands (e.g., control plane deflections, sea water pumping rates, etc.) are generated in such a manner as to satisfy the mission profile. This is accomplished by setting up and maintaining logic flags, relying heavily on information returned from the subordinate modules as to the status of various ship control sequences under way. By manual input of these flags, the officer in charge can override programmed activities and gain ship control to whatever degree required.

B. SOFTWARE ORGANIZATION AND FLOW

The executive logic of Figure A-II-1 is cycled through at a fundamental frequency great enough for all control activities (possibly every .5 sec), with the time reference being GMT or some other suitable choice. Briefly, the activities during each pass are as follows.

The mission profile, residing in computer memory in the form of tables of navigation, and ship control commands, is first accessed, and required updates made accordingly. These reflect any changes manually entered subsequent to the previous pass.

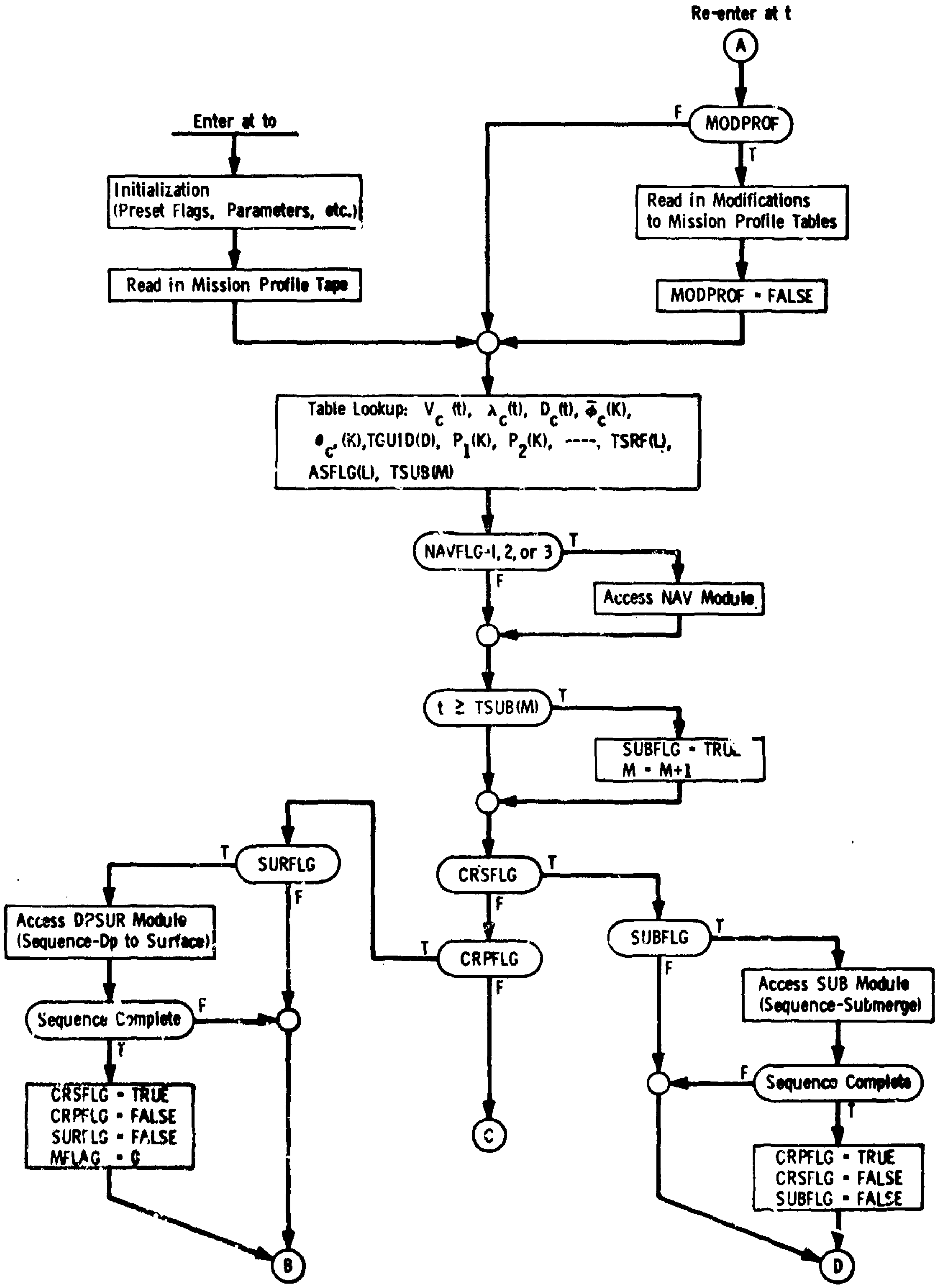


Figure A-II-1 Executive Structure

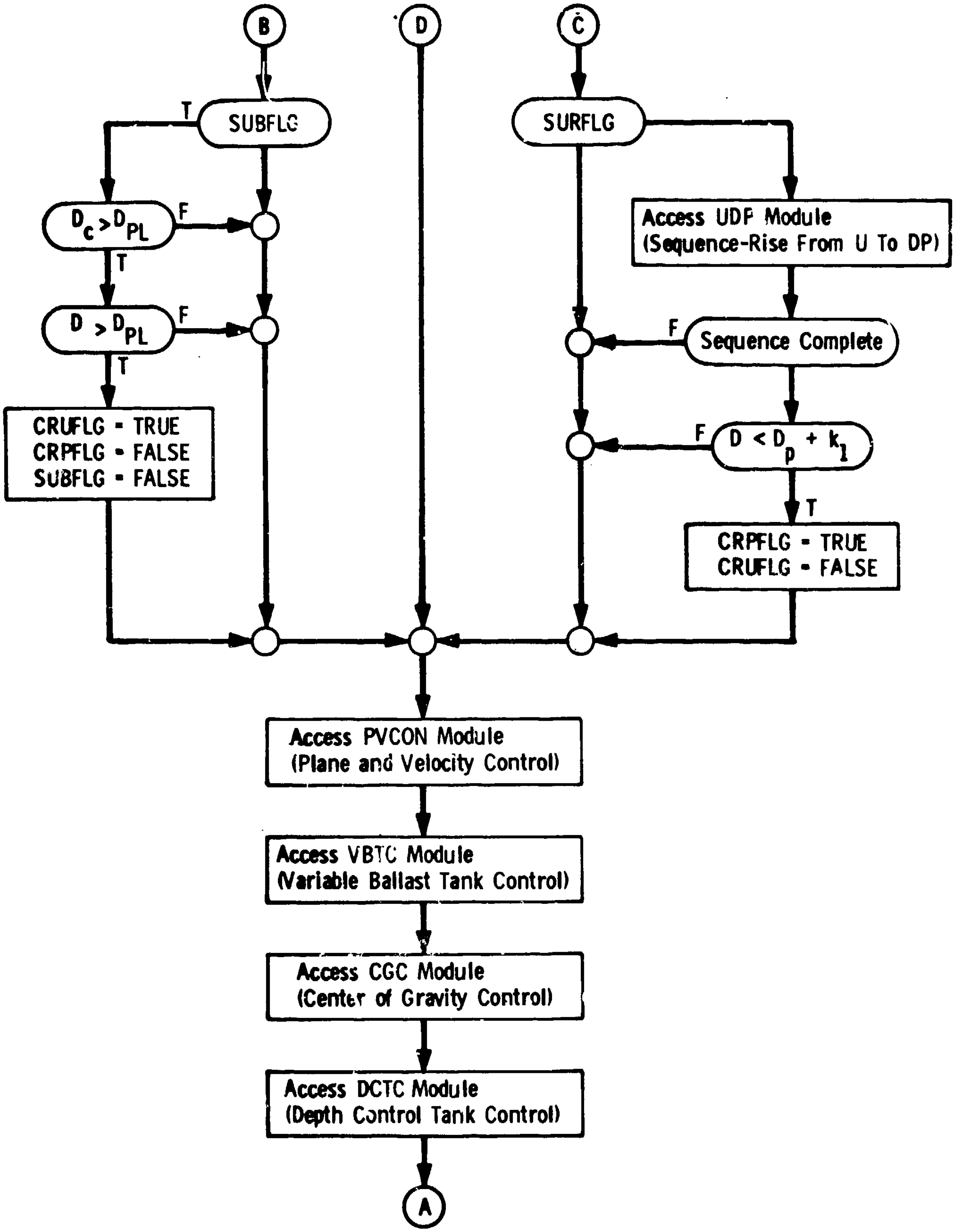


Figure A-II-1 (Concluded)

C. SOFTWARE DESCRIPTION

The executive logic will first be discussed in some detail, followed by descriptions of the individual modules. Emphasis will be on basic concepts, rather than on implementing detail.

1. Executive Structure

Reference should be made to Figure A-II-1 when reading the following description.

a. Initialization - At initial time t_o, which can be when leaving port or at any other convenient time or times during the mission, various flags and parameters are preset. Those pertinent to the present discussion are identified in Table A-II-1; others would be added as the software evolves.

b. Mission Profile - This consists of tabular data residing in the computer memory as arrays of time and index sequenced navigation and ship control commands. They will be described in the appropriate discussions of individual software modules. In the initialization pass, data for these arrays are read in from a Mission Profile tape. During each computing cycle these tables are accessed to provide values for the variables, parameters, and control flags actually utilized by the various modules. At any time the officer in charge can designate additions or changes to the Mission Profile tables. These are incorporated into the tables at the start of the first computation cycle following his setting of the flag MODPROF.

c. Navigation Module Access - The Navigation Module is accessed at a low frequency whenever the officer in charge exercises this option by setting NAVFLG to TRUE. There the current values of the arrays ϕ_c, θ_c, TGUID, P_1, P_2, ... are processed to compute and return values of V_{R_c} and λ_c which override the values read from the V_{R_c} and λ_c arrays in the previous step. NAVFLG can be manually reset to False at any time, in which case the ϕ_c, θ_c, TGUID, P_1, P_2, ... arrays are used no where by the software.

d. Programmed Surfacing and Submerging Logic - These activities, when and if desired as preprogrammed maneuvers conducted in accordance with all prevailing constraints, are scheduled through the time arrays TSRF(L) and TSUB(M). In any cycle when time has reached the next scheduled surfacing time TSRF(L) flags are set to initiate the surfacing sequence in either the normal or airless modes, in accordance with the mode flag MFLG. Similarly, when time has reached the

Table A-II-1 Arrays, Logic Flags and Iarameters, Etc.

SYMBOL	DESCRIPTION	PRESET VALUE
MODPROF	Flag manually set for reading in modifications to Mission Profile Tables.	F
NAVFLG	Flag manually set for assessing module NAV.	F
$V_c(t)$	Velocity command array.	
$\lambda_c(t)$	Azimuth command array.	
$D_c(t)$	Depth command array.	
$\bar{\phi}_c(K)$	Latitude command array.	
$\bar{\theta}_c(K)$	Longitude command array.	
TGUID(K)	Time command array.	
$P_i(K)$, K = 1, 2, ...	Guidance Parameters	
K	Index for $\bar{\phi}_c$, $\bar{\theta}_c$, TGUID, Pi	1
TSRF(L)	Time to surface array	
ASFLG(L)	Airless surface flag array	
L	Index for TSRF and ASFLG arrays	1
TSUB(M)	Time to submerge array	
M	Index for TSUB array	1
ψ, θ, ϕ	Evler Angles defining ship attitude	
V_W	Measured water-relative velocity	
V_{W_c}	Commanded water-relative velocity	
V_R	Planet-relative velocity	
D_{P_u}, D_{P_L}	Upper and lower values defining periscope depth range.	

next scheduled submerge time, TSUB(M), a flag is set to initiate the normal submerging sequence. Either schedule can be simply suppressed or reactivated by manual input. The officer in charge can initiate an unscheduled surface or submerge sequence by manually setting the flags SURFLG and MFLG or SUBFLG, respectively. Or, as will be discussed later, the maneuvers can be directly accomplished by manual override of appropriate controls.

Software-sequenced maneuvers are based on three regimes--surfaced, for which CRSFLG is set TRUE; submerged, within periscope depth range, for which CRPFLG is TRUE; and submerged, below periscope depth range, for which CRUFLG is TRUE.

This permits the use of regime-dependent sub-sequences and control laws for both surfacing and submerging. In practice, however, the second regime may exist during a maneuver only momentarily as the ship passes through the periscope depth range.

e. Control Module Accesses - Plane and Velocity Control and Depth Control Tank Control are high frequency modules, with Variable Ballast Tank Control and Center of Gravity Control being low frequency. These control modules are always accessed, at their designated frequencies, with provision for manual override of any or all of their output commands.

2. Navigation Module NAV

This module is entered by manual designation of NAVFLG as either 1, 2, or 3. A test of t against TGUID (K + 1) as read from the Mission Profile table is made in order that the index K always be properly adjusted to provide destination latitude $\phi_c(K)$ and longitude $\theta_c(K)$ corresponding to a future time TGUID(K). The current estiamtes of latitude ϕ and longitude θ are read in from the SINS. Three navigation options are provided for, depending on the NAVFLG setting. Option 1 is a simple scheme that provides an azimuth command λ_c for a great circle route between present position and destination, with no time of arrival specified. (In this case the preprogrammed velocity command or manual override prevails.) Option 2 computes, in addition, a planet-relative velocity command on the basis of time remaining to reach the destination. Option 3 is left open to provide for some other need not yet identified. Commands thus computed are available to the control modules for generation of actual steering and velocity commands. See Figure A-II-2.

Periodically the navigation process is interrupted by the PVCON module in order to command a random baffle clearing maneuver. This will be discussed in paragraph 6.

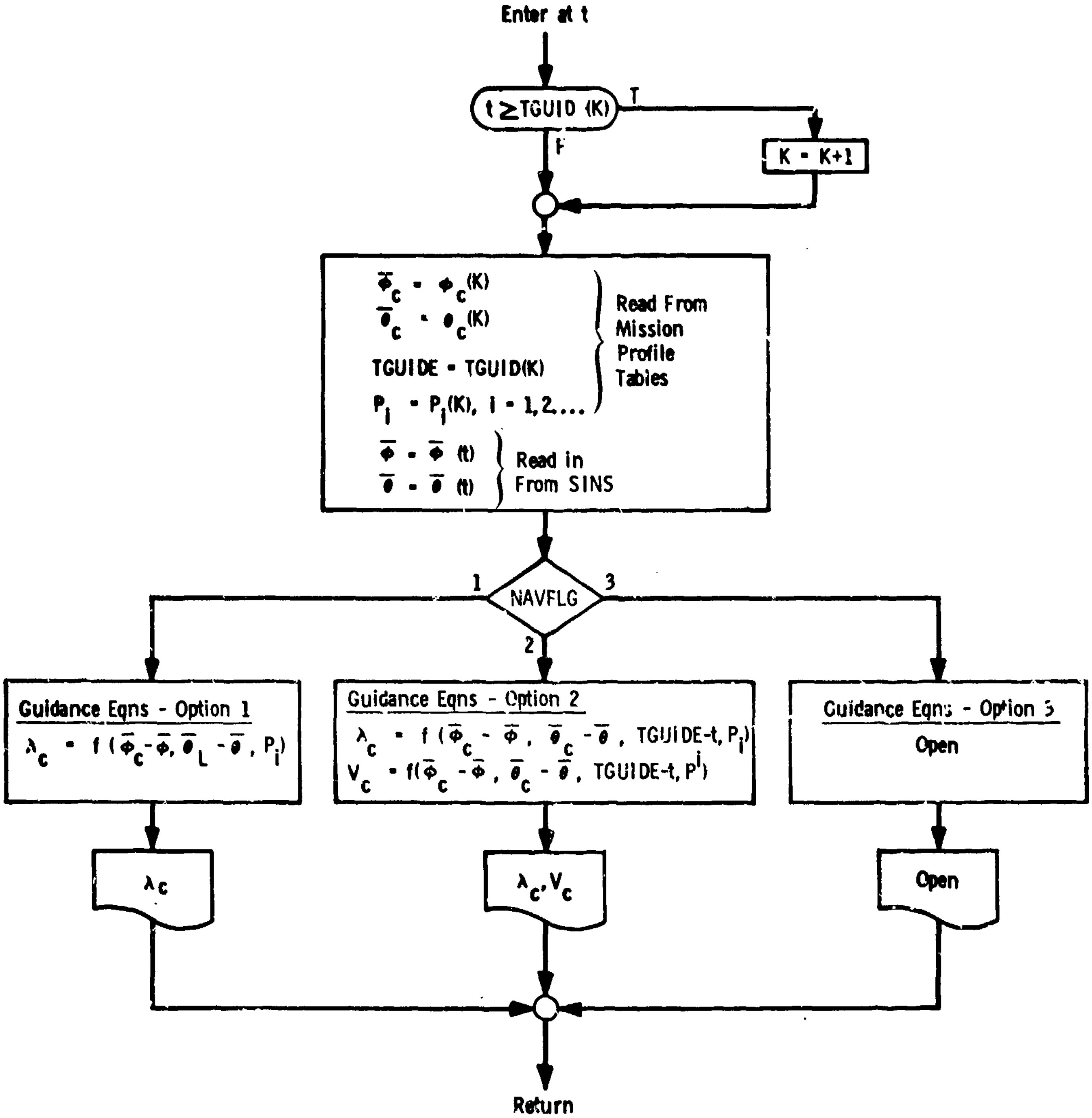


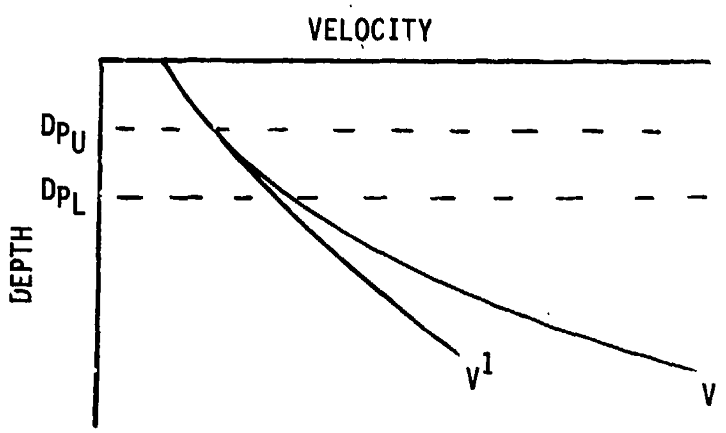
Figure A-II-2 Navigation Module NAV

3. <u>Submerging Module SUB</u>

This module controls the sequence of activities required to submerge. This is expected to be completely in accordance with present practice, obeying all constraints, and conducted in the manner of a missile launch countdown.

4. <u>Module UDP</u>

Here the sequence is implemented for rising from any undersea depth to periscope depth range. Based on the value of MFLG (as obtained from the Mission Profile Table, or manually input), sequences provide for either 1 normal, 2 airless, or 3 emergency surfacing. The module is entered at each computation cycle and commands V_{W_c} generated such that the ship will experience an appropriate horizontal velocity history as it rises to the surface. The commands are based on measured depth, with a set of curves such as that shown below presented for each surfacing mode. These are stored as tables of velocity vs depth. The intent is to automatically generate commands during surfacing that are satisfactory for several standard situations. For others, they can be manually overriden when the PVCON Module is subsequently accessed. See Figure A-II-3 for details.



The logic in VDP is such that if the measured ship velocity lies between the V^1 and V curves, no command is generated. If it is less than V^1 or greater than V, V_{W_c} is set to either V^1 or V, respectively.

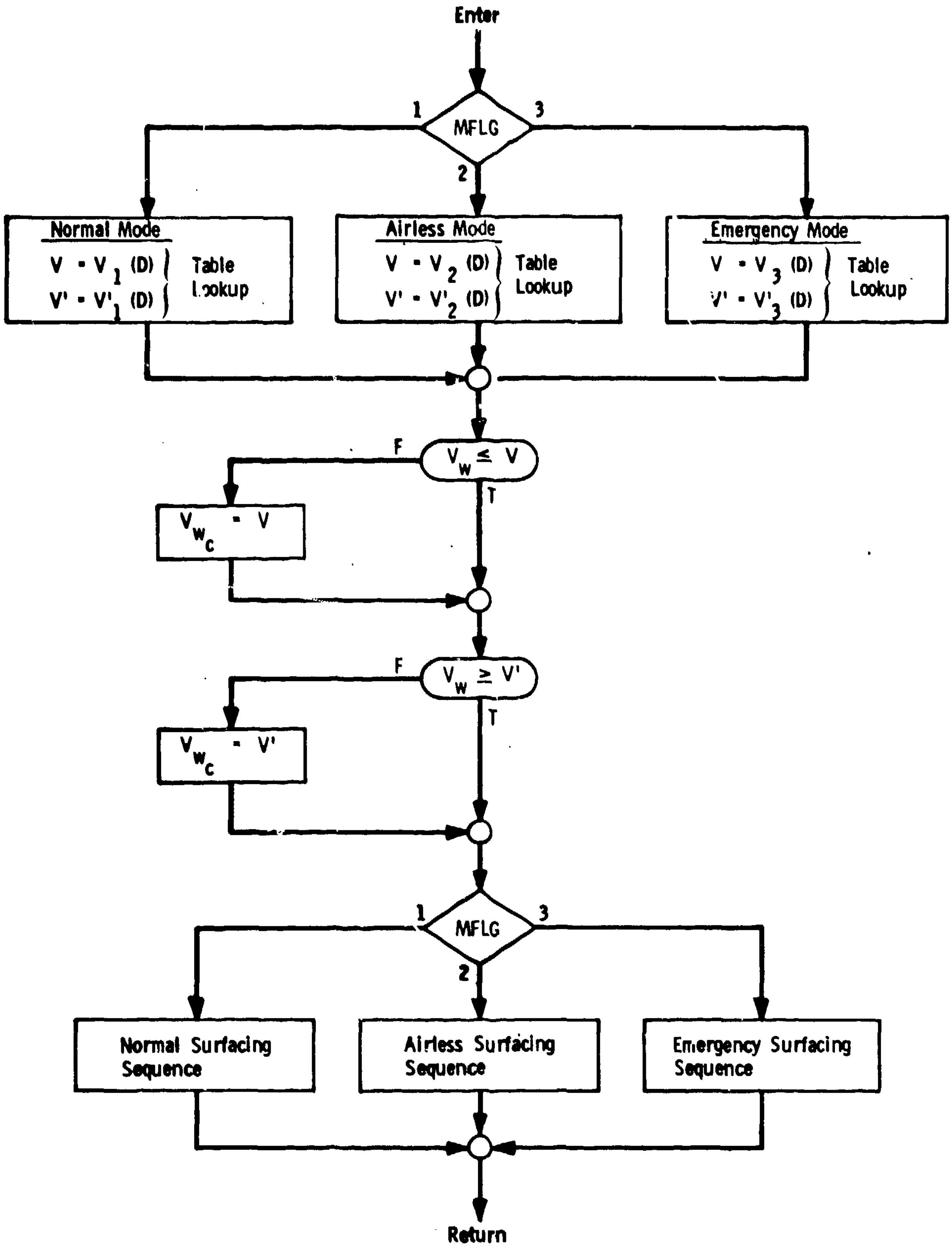


Figure A-II-3 Surfacing Module UDP

The Navigation Module (NAV) is then accessed, if called for by manual input of the Flag NAVFLG. Here, on the basis of latitude, longitude, and time, guidance and maneuvering equations generate azimuth and velocity values which will ultimately result in steering and velocity commands.

Next, current time is tested against programmed surfacing and submerging times and flags set such that an appropriate schedule is subsequently initiated if called for. These sequences are based on three operating regimes:

Submarine surfaced;
Submarine within periscope depth range; and
Submarine below periscope depth range.

The rationale for this will become clear as detailed explanations are given.

The Plane and Velocity Control Module (PVCON) is then accessed. Here, on the basis of azimuth and velocity commands (from the Mission Profile Tables or the Navigation Module), navigation data from the SINS, and inferred water-relative velocity, control plane and propulsion commands are generated.

In the Variable Ballast Tank Control Module (VBTC), which is entered at a low frequency, overall flow into or out of the VBTs is commanded in response to measured depth, temperature, salinity, commanded buoyancy, and to changes in ship weight due to various random and scheduled activities.

The Center of Gravity Control Module (CGC) generates commands for shifting water between the VBTs in response to pitch and roll attitude information from the SINS, and to steady-state deflection of the stern and fairwater planes under forward motion. This too is a low frequency module.

Finally, the Depth Control Tank Control Module (DCTC) working at the highest frequency generates commands for pumping operations associated with the depth control tanks. This is in response to commanded and measured depth, velocity, and pitch attitude measurements, and to steady-state deflection of the fairwater planes under forward motion.

The ship responds statically and dynamically to the output commands of the PVCON, VBTC, BALC, and DCTC modules in a complex and interrelated manner. As a result, strong coupling exists between those modules, affecting choice of error signals and control laws used therein.

5. Module DPSUR

Here control commands are generated for surfacing from periscope depth. The module is not accessed until activities of the UDP module have been completed. The sequence commanded is expected to conform with present surfacing practice, and to be conducted in the manner of a missile launch countdown.

6. Module PVCON

In this module commands are generated for rudder, fairwater and stern plane deflections, and for water-relative velocity. These are δ_R, δ_{F_C}, δ_S and V_{W_C}, respectively. In addition, commanded depth D_C is set. Any or all of these may be overridden by manual control devices. In the discussion which follows, reference should be made to Figure A-II-4.

Upon entry, a commanded depth D_c is selected. If the ship is operating in the Under-Periscope Depth regime, this is the value read from the Mission Profile tables, unless overridden by manual control. Otherwise it is set at either of the fixed values D_s or D_{P_L}, denoting surface or periscope depth.

If NAVFLG has been set 0, bypassing the Navigation Module, the velocity and azimuth commands V_c and λ_c from the Mission Profile tables (or as overridden manually or by UDP or DPSUR) are treated as heading and water-relative velocity for steering purposes. Otherwise they are regarded as planet-relative velocity magnitude and azimuth commands, and water-relative commands V_{W_c} and ψ_c computed therefrom. This is a simple procedure involving estimation of the ambient ocean current velocity from SINS measurements and ship operating characteristics. The SINS-measured heading ψ is then compared with the command ψ_c, providing an error ϵ_ψ on which the rudder plane command δ_R is based. In Figure A-II-4 a simple linear control law utilizing displacement and rate gains K_D and K_R is shown, with provision for manual override of commanded rudder deflection and/or water-relative velocity.

The stern planes are used to directly control pitch attitude θ, as measured by SINS. Because the sensitivity of rate of change of depth to pitch attitude varies with both velocity and buoyancy, the control law must be a function of those variables. A nominal value of θ is first computed as a function of depth and velocity by means of a bivariate table stored in the computer. A deviation from nominal is then computed as a function of depth error, velocity, depth, and buoyancy, and added to the nomainal value to yield a commanded attitude θ_c. This command can be manually overridden at any time. The stern plane control law then utilizes the error $\epsilon_\theta = \theta - \theta_c$ to

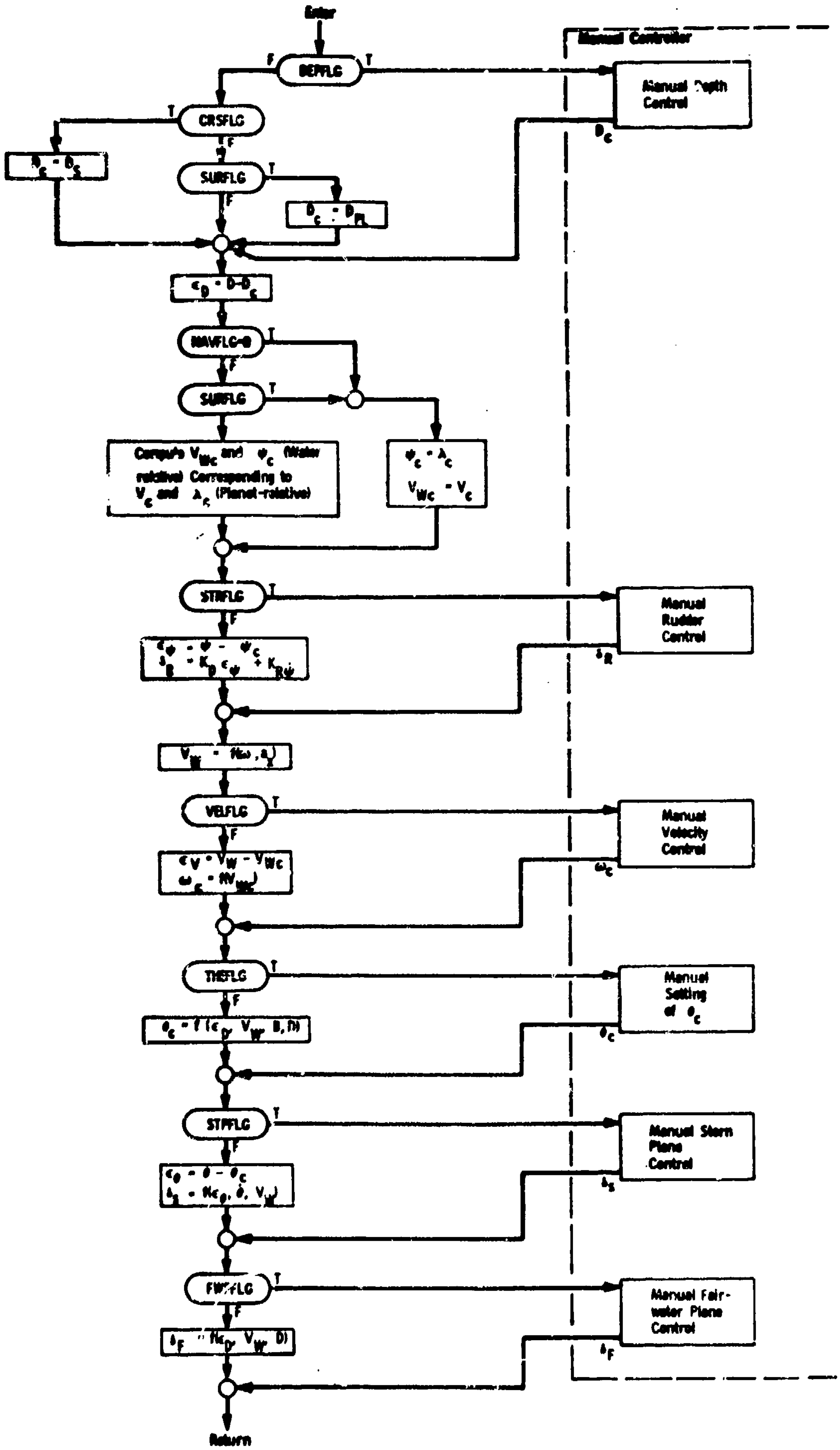


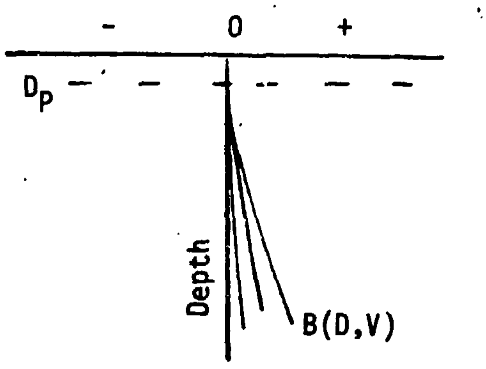
Figure A-II-4 PVCON Module

generate a deflection command δ_S for the stern planes. Figure A-II-4 also includes a damping term involving $\dot{\theta}$ and a dependence on velocity to allow for the manner in which control characteristics change with that variable.

The fairwater planes are used to provide depth control in a manner dependent on velocity. The control law shown in Figure A-II-4 also provides for variation in operating regimes and coordination with stern plane commands. Manual override of the commanded fairwater plane deflection is provided for, with optional coupling to the stern plane control device being allowed for.

7. Module VBTC

This module controls flow into and out of the Variable Ballast Tanks. It is accessed at a low frequency rate and, by utilizing a limit cycle, can be inactive most of the time. A nominal buoyancy B is prescribed as a function of depth and velocity. This may appear qualitatively as a family of curves as shown below, and is input as a bivariate table.



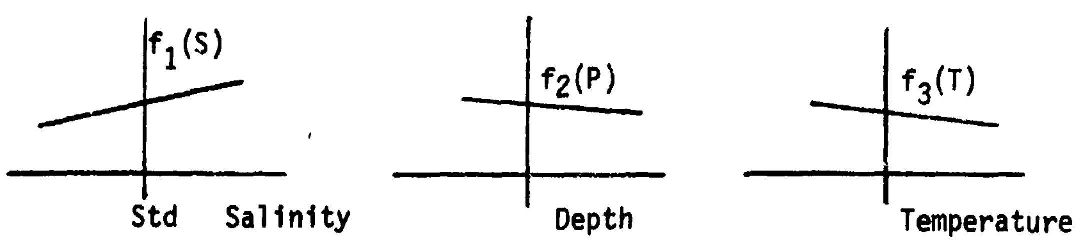
The commanded weight of variable ballast is obtained from the equation defining buoyancy:

B = weight of water displaced - weight of ship

This leads to the desired expression

$$W_{VB} = V_o \rho_o f_1 f_2 f_3 - W_o - W_V - B,$$

where W_o is the fixed dry weight of the ship, W_V is the variable weight excluding ballast (i.e., crew, cargo, etc), V_o is the volume of the ship at some reference depth, ρ is the density of seawater at the surface, and f_1, f_2, f_3 are density correction factors for salinity, depth, and temperature. The latter appear qualitatively as follows, and are input as tables.



As terms of the equation vary due to changes in operating regime, events such as waste disposal (but not activities of the DCTs), a command W_{VB_C} is computed and compared with the value being carried in a VBT bookkeeping subroutine. This gives an error signal which, if outside a designated range, actuates flow into or out of the VBTs until that error has been reduced to within some inner range. Selection of tanks for filling and draining, as well as maintenance of inventory of their contents, is handled by the aforementioned bookkeeping subroutine.

Course control of the ship's buoyancy is thus provided for undersea cruising. Time control is implemented by the DCTC module. This approach is expected to cope with the inaccuracies associated with keeping reasonably accurate W_{BV} and W_V inventories during a lengthy cruise, by regularly correcting for drift in the totals away from their true values.

8. Module DCTC

The Depth Control Tank Control Module commands flow into and out of the DCTs in accordance with error signals based on depth errors and steady-state control plane deflections.

At very low velocities buoyancy is responsible primarily for any vertical force affecting depth. At higher velocities, under steady state conditions, the vertical force due to the combined effects of pitch and deflections of stern and fairwater planes predominates. Thus, a possible error signal for controlling flow to the DCTs is

$$\epsilon_{DC} = (k_1 \sin \theta + k_2 \delta_S + k_3 \delta_{FP})V_W - \dot{D},$$

where the k_i are constants characteristic of the ship. The control law would also require damping terms and a means to switch gains for hovering.

Flow to and from the VBTs by way of the DCTs is mathematically segregated from that commanded by the DCTC Module.

9. Module CGC

This module commands flow between the Variable Ballast Tanks in order to control the position of the center of gravity. It does this in response to attitude measurements from the SINS, allowing for steady-state deflections of stern and fairwater planes in response to forward motion. Pitching moments due to sail, stern planes, and fairwater planes are proportional to V_W, $\delta_S V_W$, and $\delta_f VW$, respectively.

Under steady-state conditions, then, the sum of these moments constitutes an error signal which can be the basis of flow commands between the VBTs. As balance is restored, the DCTC and PVCON modules are relied on to steadily bring pitch attitude and control plane deflections to their proper values.

III. CREW MANNING SENSITIVITY

Analyses of crew size requirements for the five levels of mechanization were performed to obtain approximations of the net reduction in crew size that could be obtained by independently advancing each subsystem design through each of the five levels of mechanization. These analyses were performed for two separate conditions: (1) advancing the elements in each subsystem up to but no farther than their recommended optimum point of advancement as identified in Table III-B-25; and (2) advancing all subsystem elements through the five levels of mechanization regardless of their recommended optimum point of advancement. In developing the subsystem crew size requirements for each level of mechanization, watchstander functions were evaluated at each level to determine function reorganization between watchstanders and mechanized control/display devices.

Analysis of condition 1 thus identifies the subsystem crew requirements that would exist if all elements for a given subsystem were progressively moved to a particular level of mechanization but advanced no farther than their recommended point of advancement.

Analysis of condition 2 identifies the subsystem crew requirements that would exist if <u>all</u> elements for a given subsystem were progressively advanced through the five levels of mechanization; i.e., up to and beyond their recommended or optimum point of advancement.

It must be understood, however, that subsystem elements which are located at higher levels of mechanization in the baseline SSBN were not moved backwards in performing these analyses; i.e., the crew requirements numbers shown for each level of mechanization assume that elements currently mechanized to a higher level would continue to operate at that higher level of mechanization.

Figures A-III-1 through A-III-10 represent the results of these analyses. The solid line indicates crew requirements for condition 1, the dotted line represents the crew requirements for condition 2. Figure A-III-11 presents crew requirements as a result of the summation of all subsystems mechanized independently. These numbers cannot be interpreted to illustrate the crew required as a result of integrated subsystem mechanization. Crew requirements for an integrated ship mechanization would be less since:

(1) watchstander duties are not completely related to any one subsystem;

(2) maintenance responsibilities can be combined;

(3) operational and maintenance training can be diversified;

(4) any one control station can monitor requirements of more than one subsystem.

As discussed in the body of the report, crew requirements are not the only or most important reason to mechanize any submarine subsystem or the entire ship. Therefore, no such decisions should be based upon interpretations of Figure A-III-11.

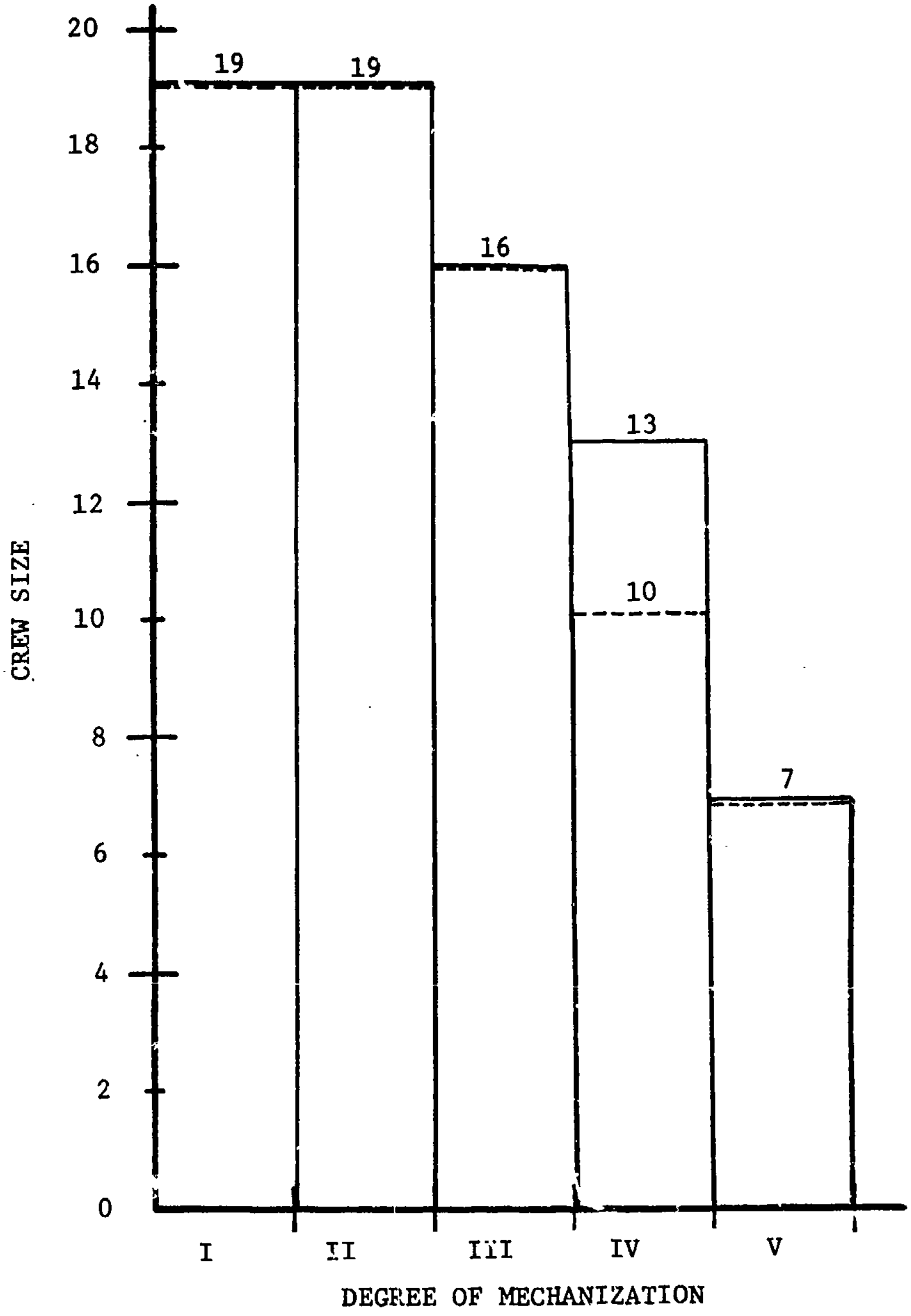


Figure A-III-1 Ship Control Subsystem Crew Sensitivity

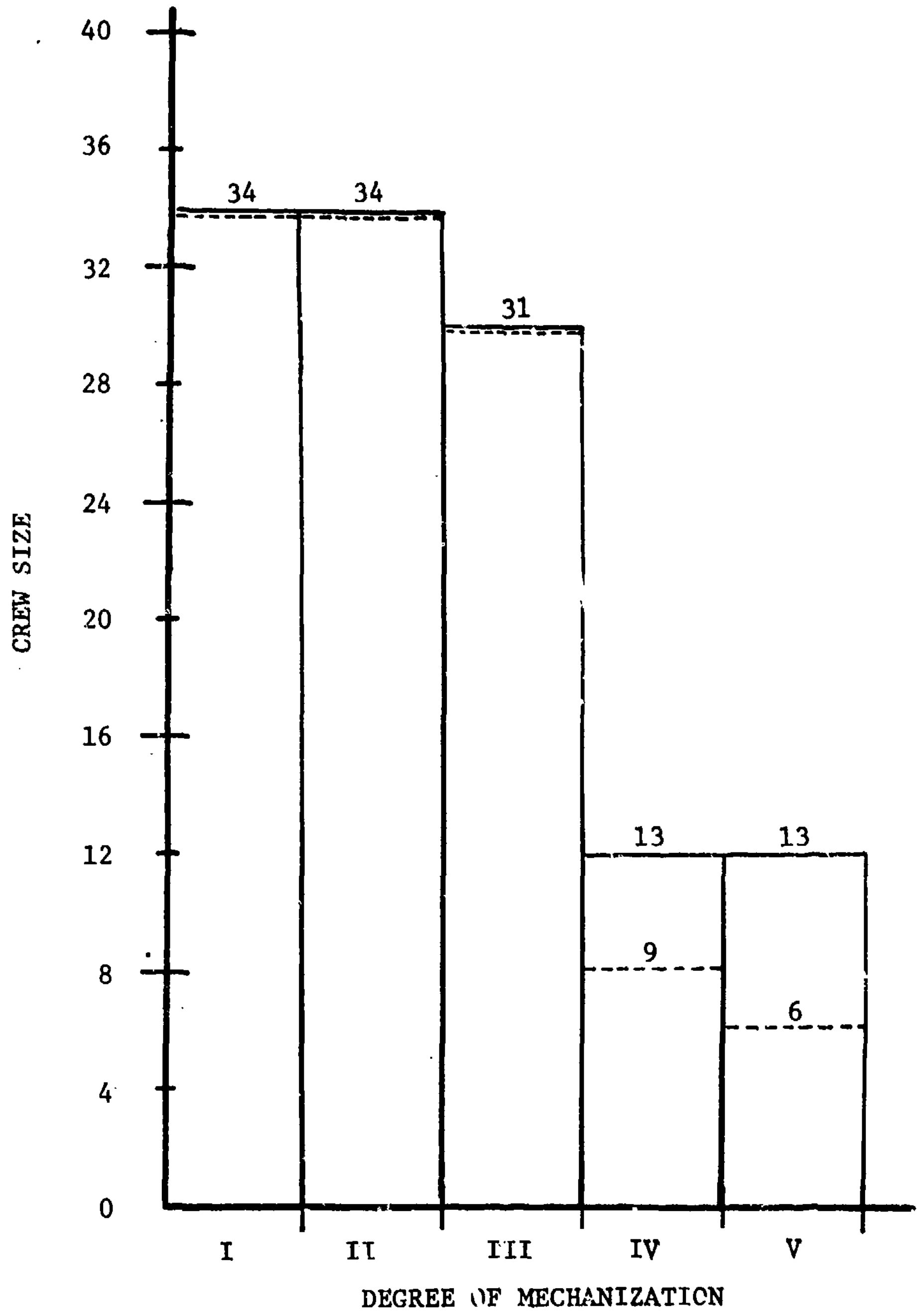


Figure A-III-2 Engineering Subsystem Crew Sensitivity

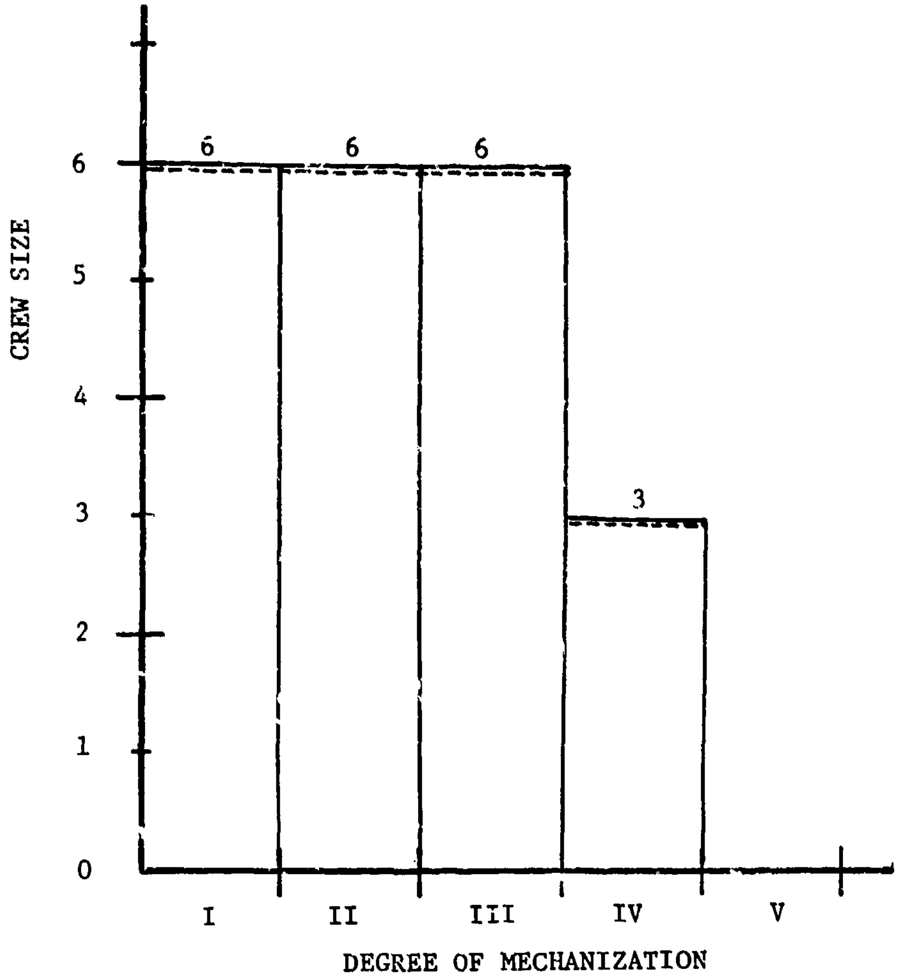
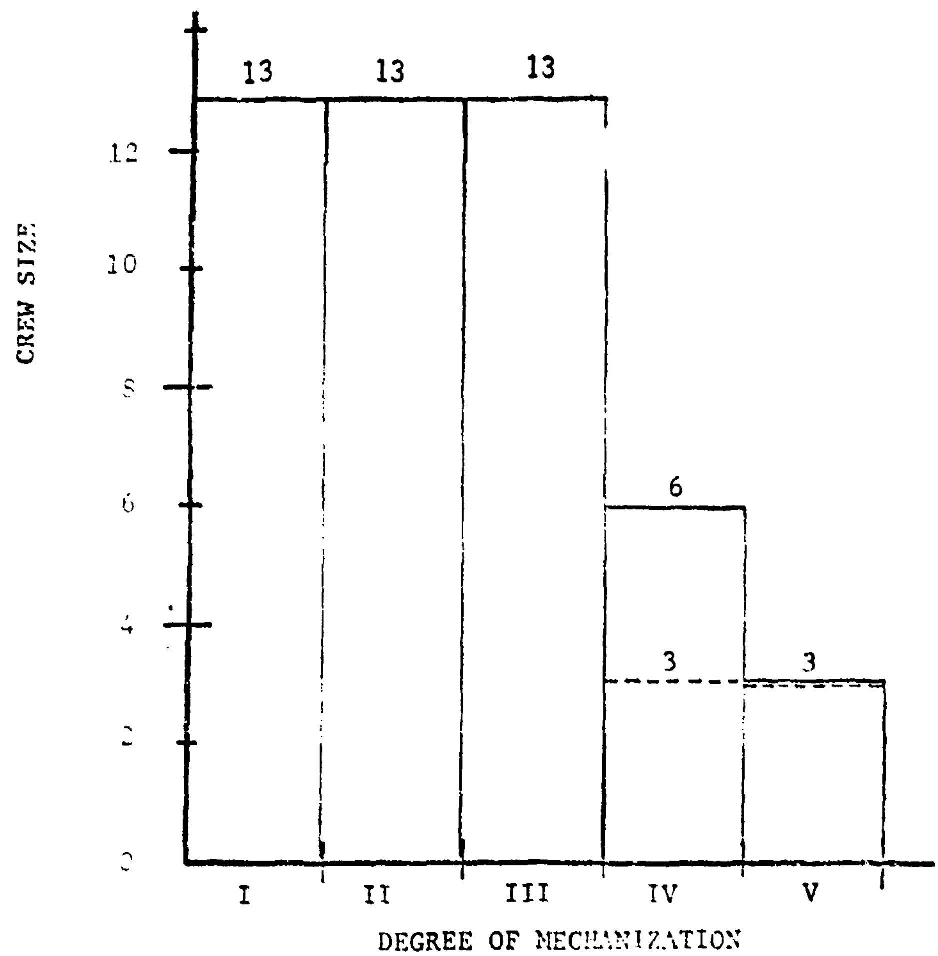
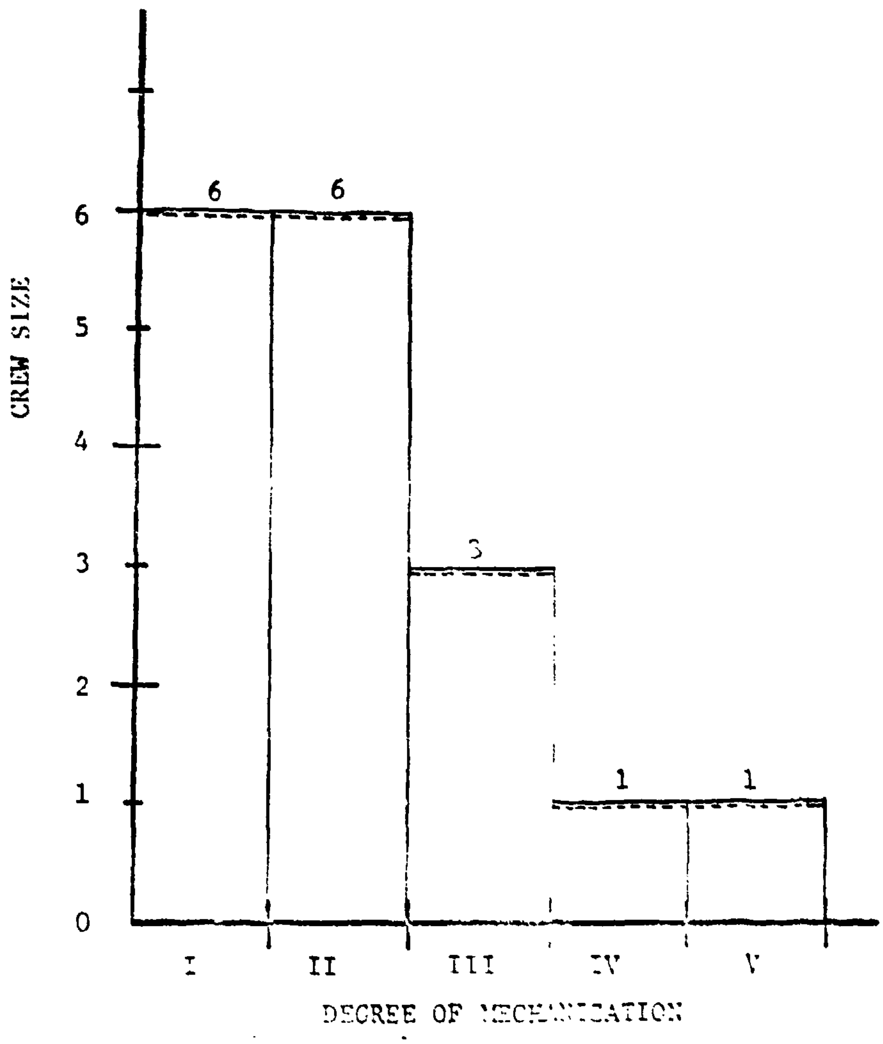


Figure A-III-3 Auxiliary Subsystem Crew Sensitivity


13
13
13
6
3
3
CREW SIZE
12
10
8
6
4
2
0
I
II
III
IV
V
DEGREE OF MECHANIZATION

[illegible]



CREW SIZE
6
5
4
3
2
1
0
6
6
3
1
1
I
II
III
IV
V
DEGREE OF MECHANIZATION

Figure A-III-[illegible] [illegible]

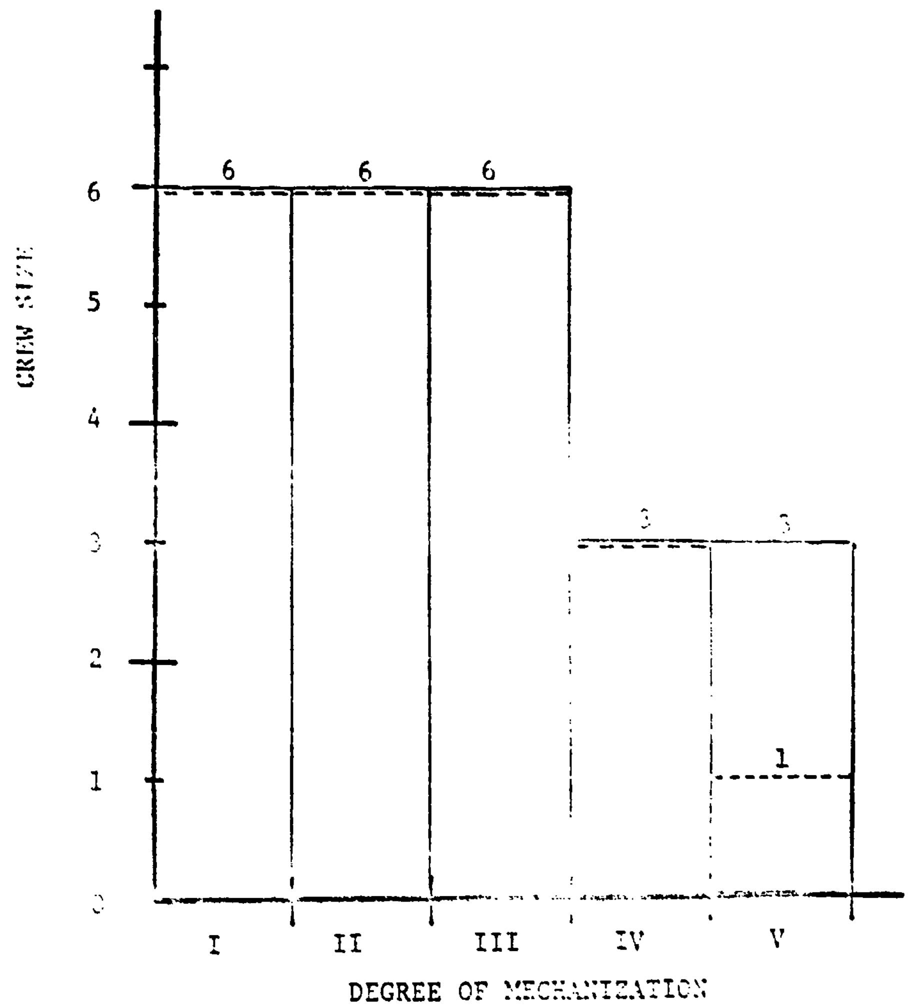


Figure A-III-2 Crew and [illegible]

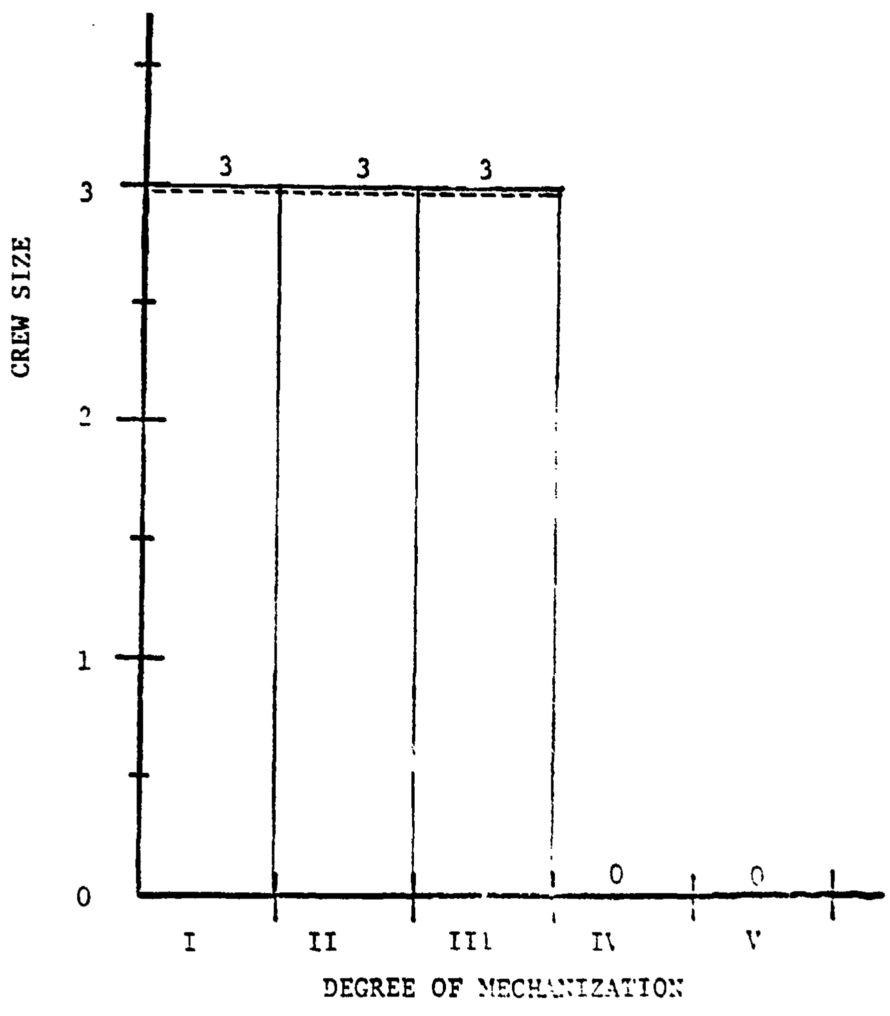


Figure A-III-[illegible] Defensive Weapon System Crew Sensitivity

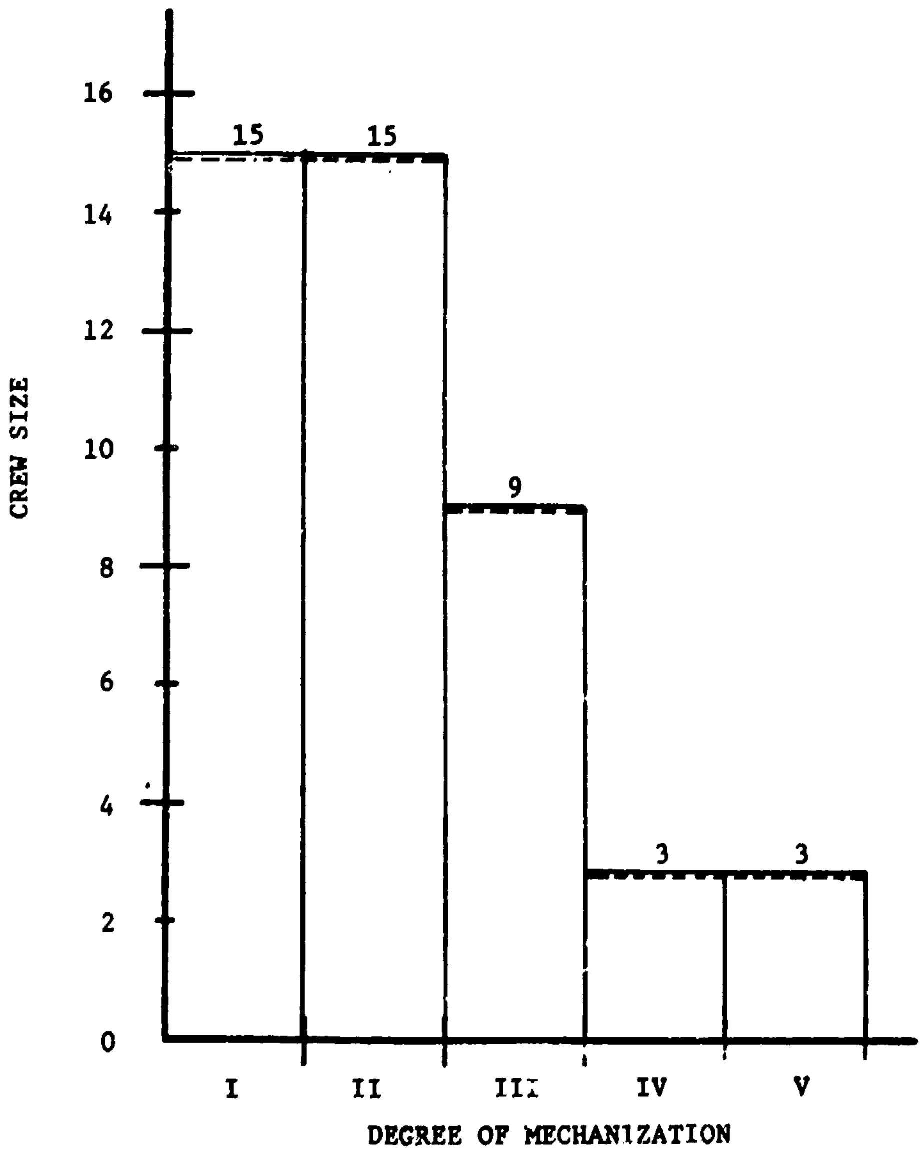


Figure A-III-8 Strategic Weapons Subsystem Crew Sensitivity

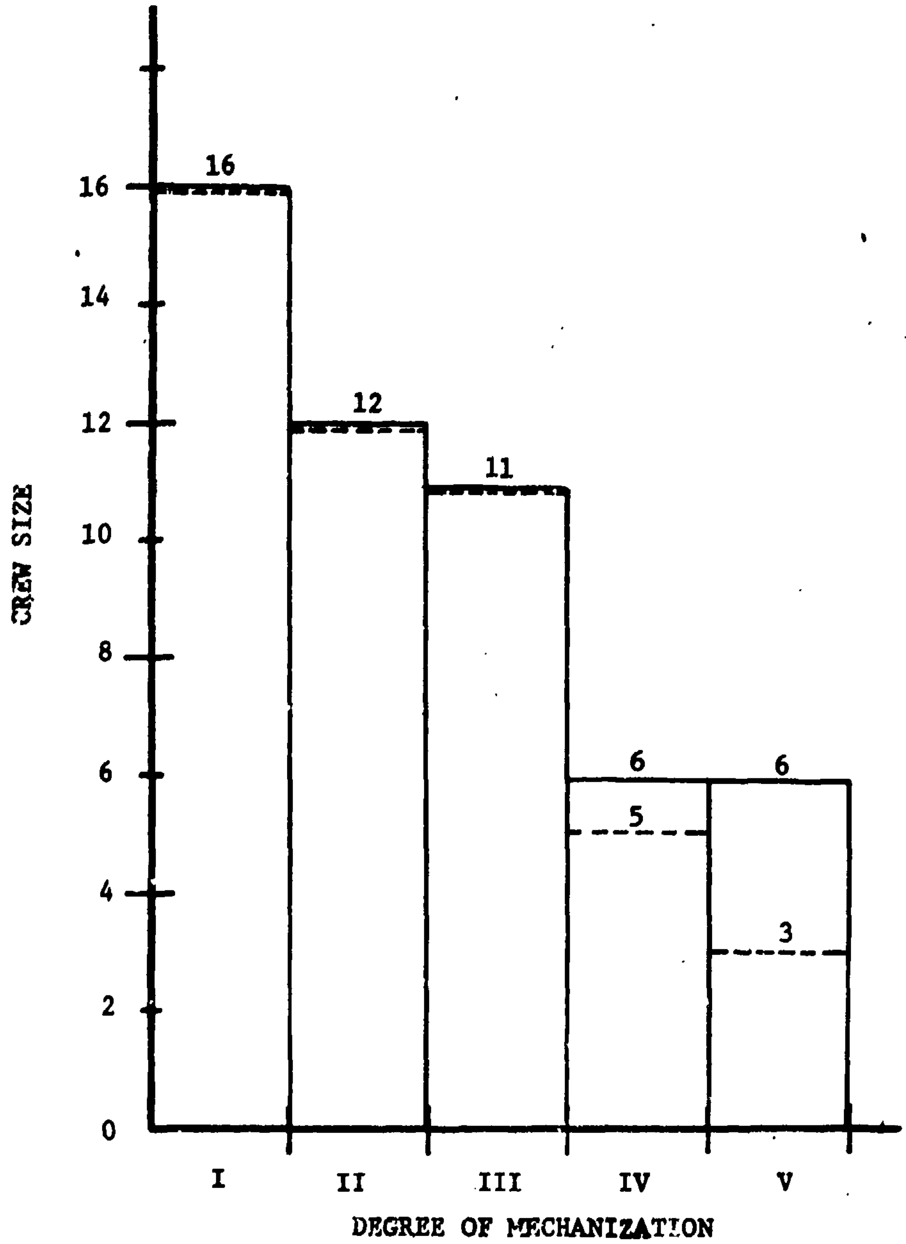


Figure A-III-9 Habitability Subsystem Crew Sensitivity

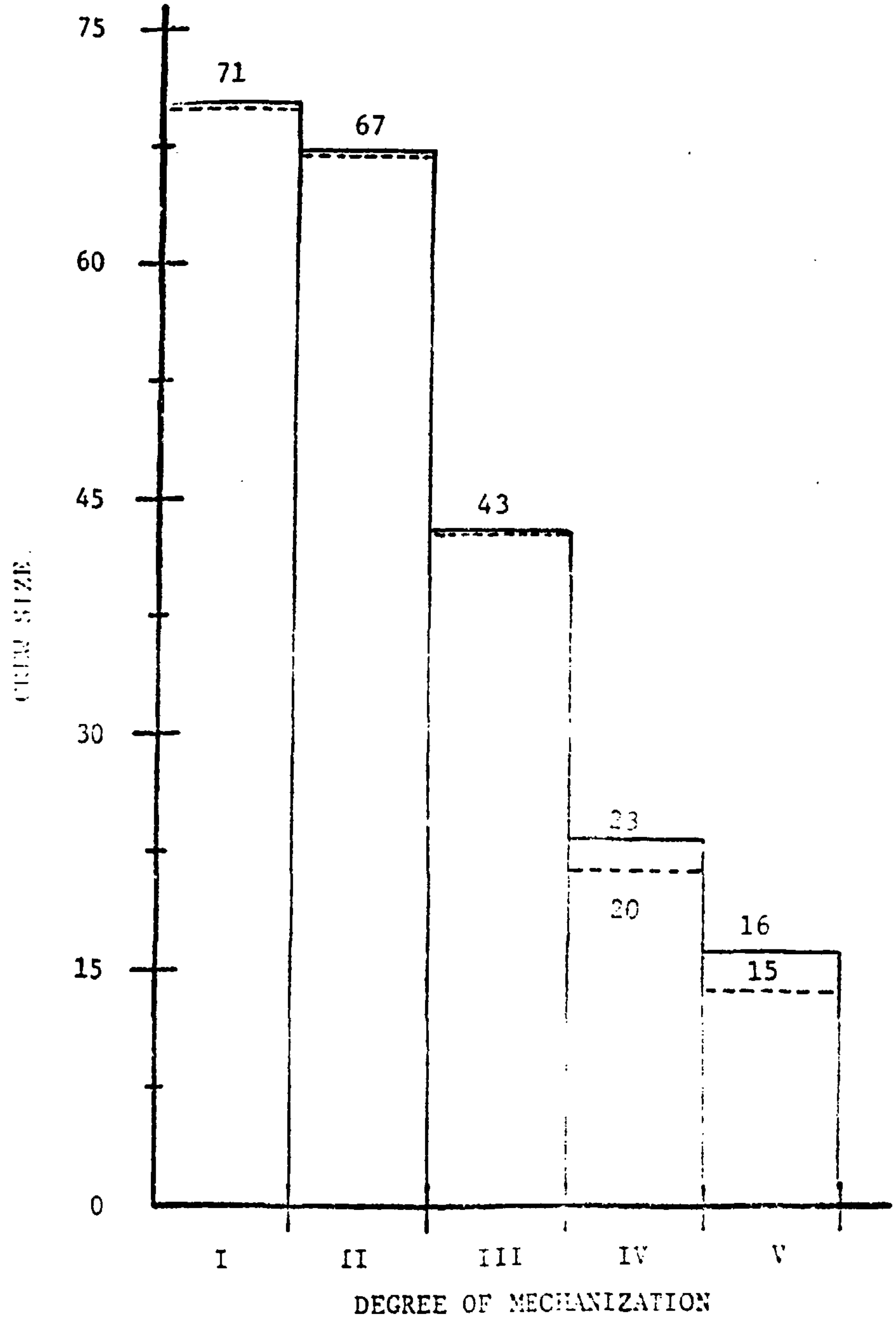


Figure A-III-1? Damage Control [illegible]

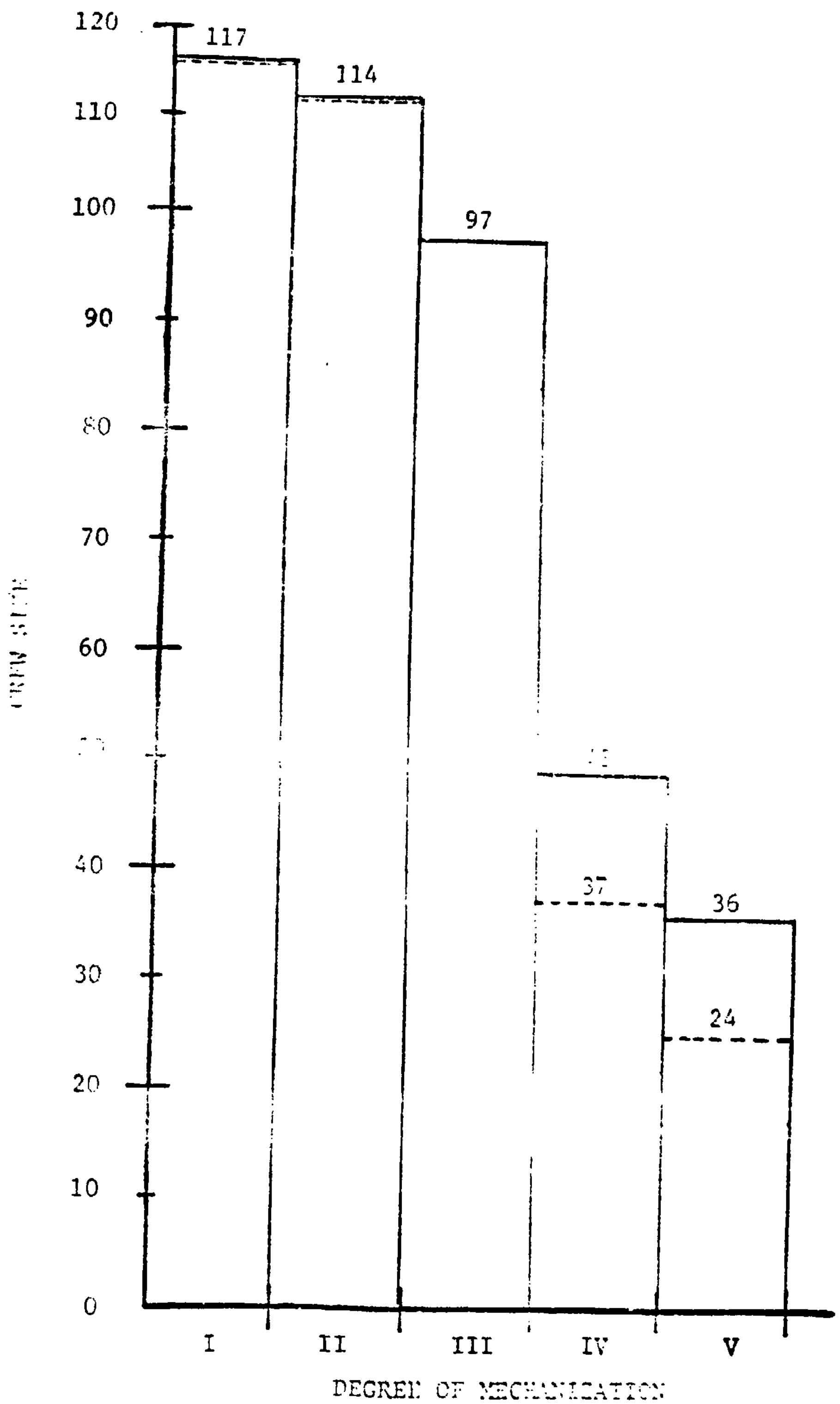


Figure A-III-[illegible] Total Ship Crew Sensitivity