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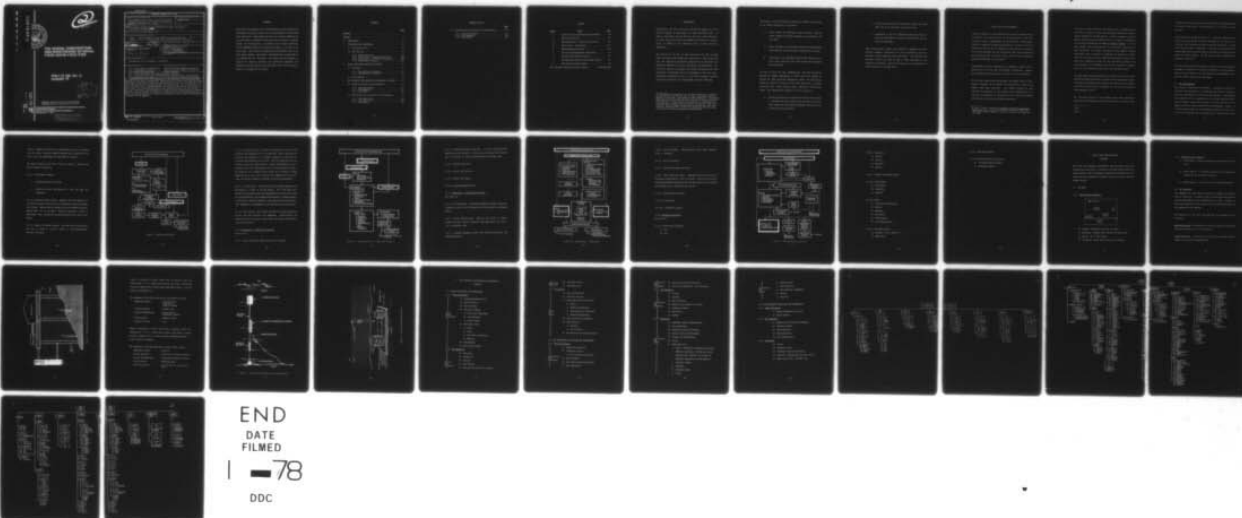
ROCKWELL INTERNATIONAL ANAHEIM CALIF MARINE SYSTEMS DIV F/G 13/13  
THE DESIGN, CONSTRUCTION AND MAINTENANCE OF NAVAL FIXED OCEAN F--ETC(U)  
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# THE DESIGN, CONSTRUCTION AND MAINTENANCE OF NAVAL FIXED OCEAN FACILITIES

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WASHINGTON, D.C. 20374

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Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Ocean Engineering and Construction Project Office Chesapeake Division, Naval Facilities Engineering Command, Washington, D.C. 20374		2a. REPORT SECURITY CLASSIFICATION <b>UNCLASSIFIED</b>	
		2b. GROUP	
3. REPORT TITLE <b>6</b> "The Design, Construction and Maintenance of Naval Fixed Ocean Facilities." Volume 1, [redacted]			
4. DESCRIPTIVE NOTES (Type of report and inclusive dates)			
5. AUTHOR(S) (First name, middle initial, last name) Volume 1. Marine Systems Division, Rockwell International Corp. <i>Smakham, Calif</i> Volumes 2, 3, 4, & 5 Ocean Systems Group, Lockheed Missiles & Space Co.			
6. REPORT DATE <b>11</b> Aug 1977		7a. TOTAL NO. OF PAGES Vol 1 - 30	7b. NO. OF REFS 1
8. CONTRACT OR GRANT NO. <b>15</b> N62477-75-C-0183 <i>new</i>		9a. ORIGINATOR'S REPORT NUMBER(S) <b>19</b> FP6-1-77(20, Vol-1)	
c. <b>10</b> W. D. / Knopf		<b>18</b> CHES/NAVFAC	
d.		9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	
10. DISTRIBUTION STATEMENT Distribution of this document is unlimited			
11. SUPPLEMENTARY NOTES Vol. 2 Ocean Facilities Engineering Vol. 3 Environmental Aspects of Ocean Facilities Engineering Vol. 4 Fixed Ocean Facilities Suspended Cable Structures Vol. 5 Fixed Ocean Facilities Bottom Mounted Surface Structures Work Breakdown Structure Charts from Volumes 2, 3, 4, & 5 are inserted in back of this volume.		12. SPONSORING MILITARY ACTIVITY Naval Facilities Engineering Command, Ocean Facilities Program, Criteria and Methods Program	
13. Abstract: Ocean Facilities Engineering is the application of ocean engineering knowledge to the design, construction, and maintenance of naval Fixed Ocean Facilities. Fixed Ocean Facilities are structures supported by the ocean floor or attached to the ocean floor by means of a mooring system. The structure may: (1) penetrate the air-water interface, (2) be suspended between the surface and bottom, or (3) rest on the ocean floor. The scientific disciplines and technology areas of the three phases (design, construction, and maintenance) of Ocean Facilities Engineering are introduced. The ocean facility engineer is required to integrate practical and operational knowledge with advanced scientific concepts and technology to meet current requirements and to prepare for the future.  ↑  + A 017 838			

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## ABSTRACT

Ocean Facilities Engineering is the application of ocean engineering knowledge to the design, construction, and maintenance of naval Fixed Ocean Facilities. Fixed Ocean Facilities are structures supported by the ocean floor or attached to the ocean floor by means of a mooring system. The structure may: (1) penetrate the air-water interface, (2) be suspended between the surface and bottom, or (3) rest on the ocean floor. The scientific disciplines and technology areas of the three phases (design, construction, and maintenance) of Ocean Facilities Engineering are introduced. The ocean facility engineer is required to integrate practical and operational knowledge with advanced scientific concepts and technology to meet current requirements and to prepare for the future.

CONTENTS

	<u>Page</u>
FOREWORD . . . . .	i
ABSTRACT . . . . .	ii
1. INTRODUCTION . . . . .	1-1
2. OCEAN FACILITIES ENGINEERING . . . . .	2-1
2.1 OFE Relationships . . . . .	2-3
2.2 OFE Functions . . . . .	2-5
2.2.1 Design Functions . . . . .	2-5
2.2.2 Construction - Preparation Functions . . . . .	2-8
2.2.3 Construction - Installation Functions . . . . .	2-10
2.2.4 Maintenance Functions . . . . .	2-12
3. NAVAL FIXED OCEAN FACILITIES (OUTLINE) . . . . .	3-1
3.1 FOF Types . . . . .	3-1
3.1.1 FOF Structure Categories . . . . .	3-1
3.1.2 FOF Emplacement Categories . . . . .	3-2
3.2 FOF Components . . . . .	3-2
4. OFE SCIENTIFIC DISCIPLINES AND TECHNOLOGIES (LISTING) . . . . .	4-1
4.1 Design Disciplines and Technologies . . . . .	4-1
4.1.1 Ocean Environment . . . . .	4-1
4.1.2 FOF Components . . . . .	4-1
4.1.3 FOF System . . . . .	4-2
4.2 OFE Construction Disciplines and Technologies . . . . .	4-2
4.2.1 Ocean Environment . . . . .	4-2
4.2.2 FOF Components . . . . .	4-3
4.2.3 FOF System . . . . .	4-3

CONTENTS (Cont'd)

	<u>Page</u>
4.3 OFE Maintenance Disciplines and Technologies . . .	4-4
4.3.1 Ocean Environment . . . . .	4-4
4.3.2 FOF Components . . . . .	4-4
4.3.3 FOF System . . . . .	4-4

FIGURES

<u>Figure</u>	<u>Title</u>	<u>Page</u>
1	Ocean Facilities Engineering Relationships . . .	2-4
2	OFE Design Functions . . . . .	2-7
3a	OFE Construction - Preparation Functions . . .	2-9
3b	Construction - Installation . . . . .	2-11
4	OFE Maintenance Functions . . . . .	2-13
5	FOF Structure/Emplacement Combinations . . . .	3-3
6	FOF Type S1/E3 Mooring Platform . . . . .	3-5
7	FOF Type S2/E1 Acoustic Array Sensor System . .	3-7
8	FOF Type S3/E2 Sensor System . . . . .	3-8
	Work Breakdown Structures Graphic Displays . . . . .	Back Envelope

## 1. INTRODUCTION

Historically, the Naval Facilities Engineering Command has given technical support to shore-based U.S. naval operating forces. In 1968, by instruction from the Office of the Chief of Naval Material, the Naval Facilities Engineering Command was assigned the responsibility of supporting naval operating forces in ocean facilities engineering.

This decision by the Navy to take construction out into the deep ocean\* was based on the recognition of two factors. One, the Navy saw that a new engineering discipline, recognized by the educational and industrial communities as ocean engineering, was developing. Two, the Navy's 200-year involvement with defense technology made them interested in encouraging the full development of this new, multi-disciplinary engineering field, a field which combines classical engineering disciplines with oceanography and ocean technology.

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\*At the beginning of World War II, the Navy formed several construction battalions to do the work that civilian contractors could not perform in a war zone. The Navymen in these battalions -- the Seabees, whose name was derived from the first initials of the term construction battalion -- gained their first experience in underwater construction when they built advance bases in the Pacific. Their work consisted mainly of demolition and salvage projects and coral reef blasting. When World War II ended, the underwater skill continued to be used on bridge and waterfront structure work.

Specifically, the Naval Facilities Engineering Command was chartered as the Command responsible for providing:

- Fixed surface and subsurface ocean structures, floating cranes, amphibious pontoon equipment, fleet moorings, and lift docks.
- Tools, equipment, and techniques required for construction and maintenance of fixed surface and subsurface structures.
- Architectural and engineering design and construction of naval shore facilities and fixed surface and subsurface ocean structures.

In order to carry out this responsibility, the Naval Facilities Engineering Command implemented an Ocean Facilities Program to develop the ocean facilities engineering, design, and construction capability required to provide fixed ocean facilities at minimum life-cycle cost, using military and/or contractual construction forces. The organizational components of this program are:

- a. The Ocean Engineering and Construction Project Office (FPO-1), Chesapeake Division, Naval Facilities Engineering Command, tasked with the technical management and execution of the Ocean Facilities Program.

- b. Two Naval Construction Force Underwater Construction Teams (UCTs) who do the underwater construction work.
  
- c. A department at the Civil Engineering Laboratory that provides the development of necessary ocean facility and construction technology.

These organizational elements were combined to implement the Naval Material Command's instruction that ocean engineering support be provided to naval operating forces (the Fleet). This required that extensive research and study be made in ocean engineering, a new engineering discipline, untried and untested in its application to naval operations in the deep ocean.

## 2. OCEAN FACILITIES ENGINEERING

"Ocean engineering is a new multidiscipline branch of technology that is based on the classical areas of engineering and on the newer scientific fields of oceanography and related fields. A new breed of engineer is beginning to emerge who typically is trained in one of the classical fields but who has expanded his interests and the scope of his working knowledge into the disciplines that have traditionally been associated with the ocean, such as marine biology, underwater geology and chemistry of the oceans."<sup>1</sup>

Oceanography and ocean engineering are recognized fields, and the application of this new base of knowledge is broadening. However, many fundamental questions about the oceans are still unanswered.

For the naval ocean facilities engineer, the present state of knowledge is adequate for the design and construction of some of the simpler fixed ocean facilities. For complex systems with long lifetimes and emplaced at great depths, much advancement will be required to understand the interactions of the ocean's environment with materials, structures, and ocean engineering.

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<sup>1</sup>By John J. Myers in foreword of Handbook of Ocean and Underwater Engineering, Myers, Holm and McAllister, McGraw Hill 1969, Copyright North American Rockwell, Library of Congress Catalogue Card #67-27280.

"The ocean is often believed by the engineer who is inexperienced in its ways to be always a violent, hostile medium needing major technological advances for its exploitation. In fact, although not a benign medium, particularly during storms, much of the ocean is conquerable with existing engineering knowledge if properly applied -- but the ocean demands good engineering and is particularly unforgiving of poor engineering. For example, pressures at ocean depths, although exceedingly high by atmospheric standards, are handled by existing materials; corrosion, while an important environmental result, can be kept within acceptable bounds for many engineering purposes with known materials and techniques; and fouling, although a nuisance, does not limit underwater activities in any substantial way."<sup>2</sup>

The ocean facilities engineer must work closely with the technical and operational people experienced in actual work-at-sea problems (UCTs). "Such experienced people will frequently see possibilities to cooperate with the ocean and its environment in a way that will ease the ocean engineers' task."<sup>3</sup>

The following sections of this document define more specifically Ocean Facilities Engineering and Naval fixed ocean facilities. Engi-

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<sup>2</sup> Ibid.

<sup>3</sup> Ibid.

neering functions and interacting technology areas encompassed during the design, construction, and maintenance of a facility are also outlined.

Ocean Facilities Engineering (OFE) is a systematic application of existing engineering and scientific knowledge to the design, construction, and maintenance of naval fixed ocean facilities. A fixed ocean facility (FOF) is basically a structure with related utility systems supported by the ocean floor or attached to the ocean floor by means of a mooring system. The FOF types and their components are discussed in section 3.

The three major phases of OFE (design, construction, and maintenance) encompass a multitude of scientific disciplines and technologies. Areas of prime concern for all OFE functions are performance, reliability, safety, economy, and timeliness.

#### 2.1 OFE RELATIONSHIPS

OFE requires a broad base of knowledge -- engineering, scientific, practical, and operational -- to determine the technical feasibility and cost effectiveness of the various FOF concepts. The knowledge base, combined with the capabilities of the Naval Facilities Engineering Command, enable the OFE group to provide facilities which support the Navy's mission effectively and economically. Figure 1 is a block diagram showing the relationship of OFE and its major functions to the knowledge base and capabilities of the Naval Facilities

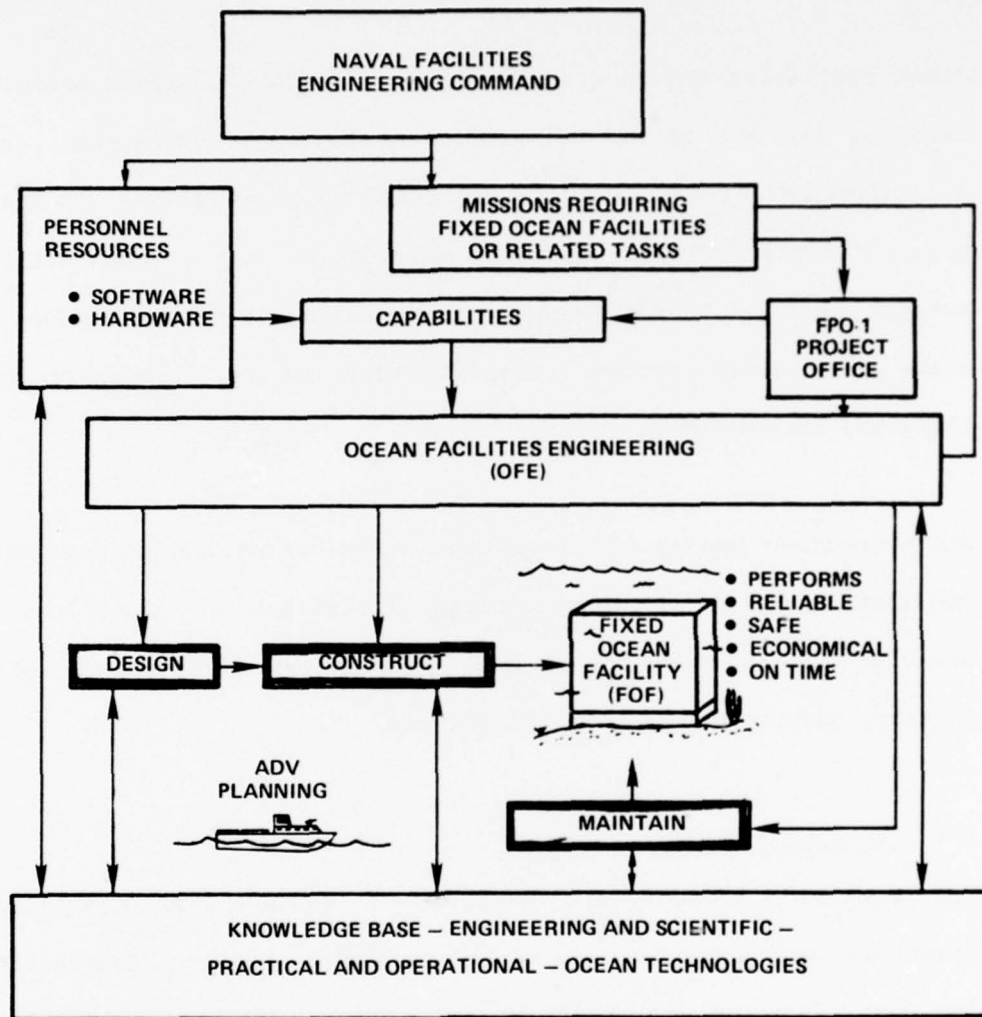


Figure 1. Ocean Facilities Engineering Relationships

Engineering Command. Note that there is a two-way flow of information from the knowledge base to the OFE, Design, Construct, Maintain, and Personnel-Resources blocks. In order to expand the knowledge, advance technically, and solve the problems within the field of OFE, this two-way flow of information must be a continuous process.

The OFE methodology starts at the top of Figure 1 with the Navy providing the mission and the supporting personnel, software, and hardware resources. The missions go through the Ocean Engineering and Construction Project Office (FPO-1) for planning, priority evaluations, and routing to the proper phase of OFE. With the capabilities and mission in hand, OFE performs the specific tasks required. The tasks may involve all phases of OFE or they may apply only to a specific function within a phase.

## 2.2 OFE FUNCTIONS

OFE is responsible for the various technical functions related to the design, construction, and maintenance of naval FOF. A breakdown summary of the major functions is presented here in chronological order of performance.

### 2.2.1 Design Functions

The design phase of OFE is primarily responsible for selecting the most effective and efficient site and facility, in order to satisfy the mission requirements. To insure minimum life cycle costs of the

facility, maximum reliability and maintainability must be designed into the system. Thorough trade-off analyses must be performed so as not to sacrifice performance and timeliness for economy.

The design process of the FOF, as shown in Figure 2, includes the basic functions listed here.

#### 2.2.1.1 Requirements Analysis.

- a. Establish design life of FOF.
- b. Establish mission requirements for site, FOF type, and components.

2.2.1.2 Conceptual Design Studies. Depending upon the complexity of the mission, several iterations may be required to create the conceptual designs. State-of-the-art capability versus research and development needs will be reviewed. Trade-off analyses in areas of performance, cost, reliability and maintainability will then be conducted.

2.2.1.3 Selection of Design Concept. The selection of the FOF type and site is based on criteria related to cost-effectiveness, schedule, and safety.

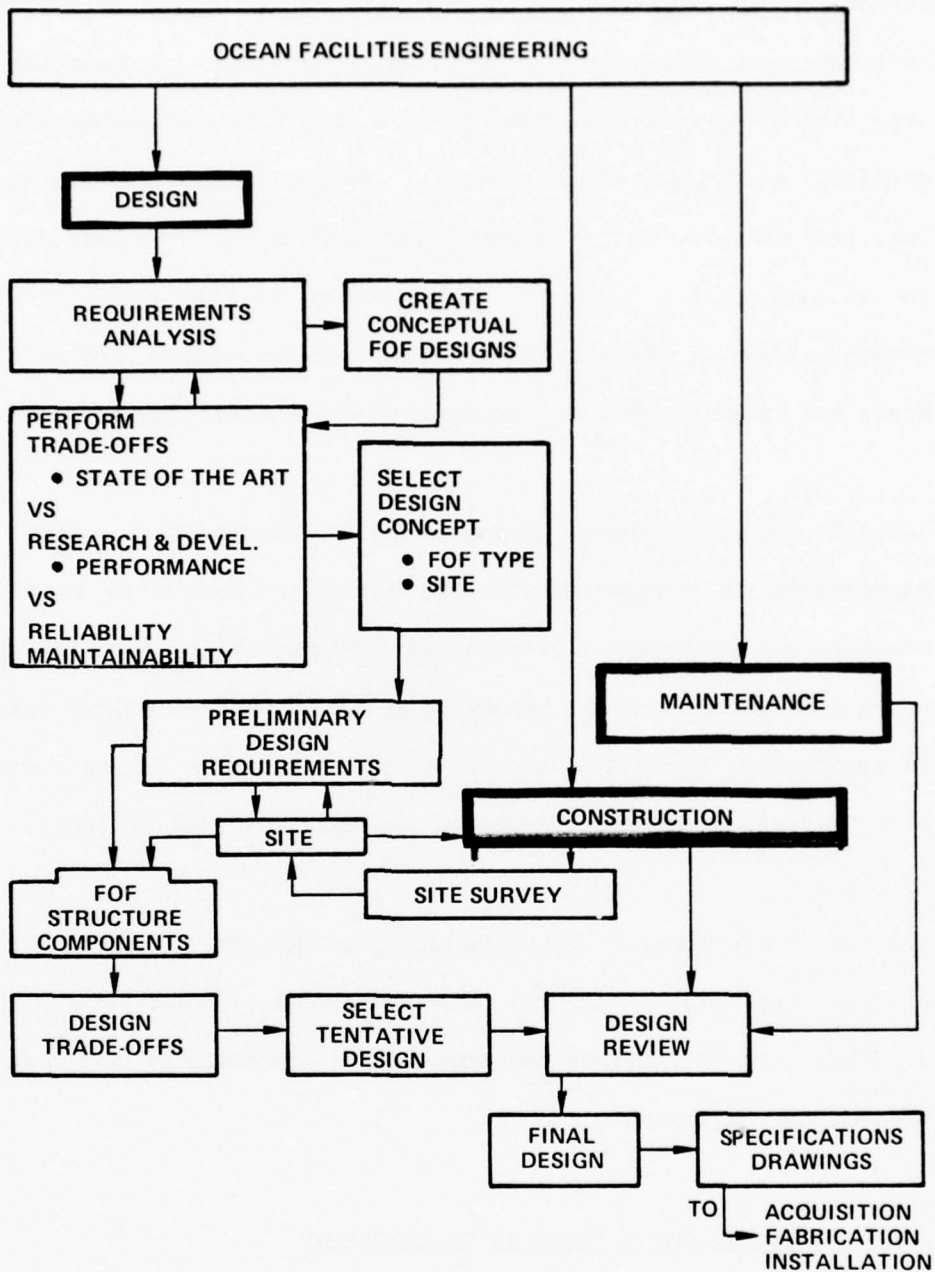


Figure 2. OFE Design Functions

2.2.1.4 Preliminary Design. Specific requirements for the site, FOF structure, and components will be established. Before designing the structure and components, it is usually necessary to have the construction group conduct a site survey. The site characteristics are critical to facility design factors. Design trade-offs will be at a detailed level, with performance and cost being important factors. The selection of a tentative final design will be based on design compatibility of the site's structure and components and will consider the factors necessary to satisfy the mission requirements.

2.2.1.5 Design Review. Construction and maintenance experts will participate in review of the FOF design. The review board will evaluate the projected life-cycle performance of the facility, point out any deficiencies, and recommend effectiveness or economy changes. In particular, potential hazards to safe operation during construction, operation, or maintenance of the facility will be identified.

2.2.1.6 Final Design. This function provides for system integration of the site, FOF structure, and components. Specifications and drawings will be provided for acquisition, fabrication and installation of the facility.

## 2.2.2 Construction - Preparation Functions

See Figure 3a.

2.2.2.1 Review FOF Plans, Specifications, and Drawings.

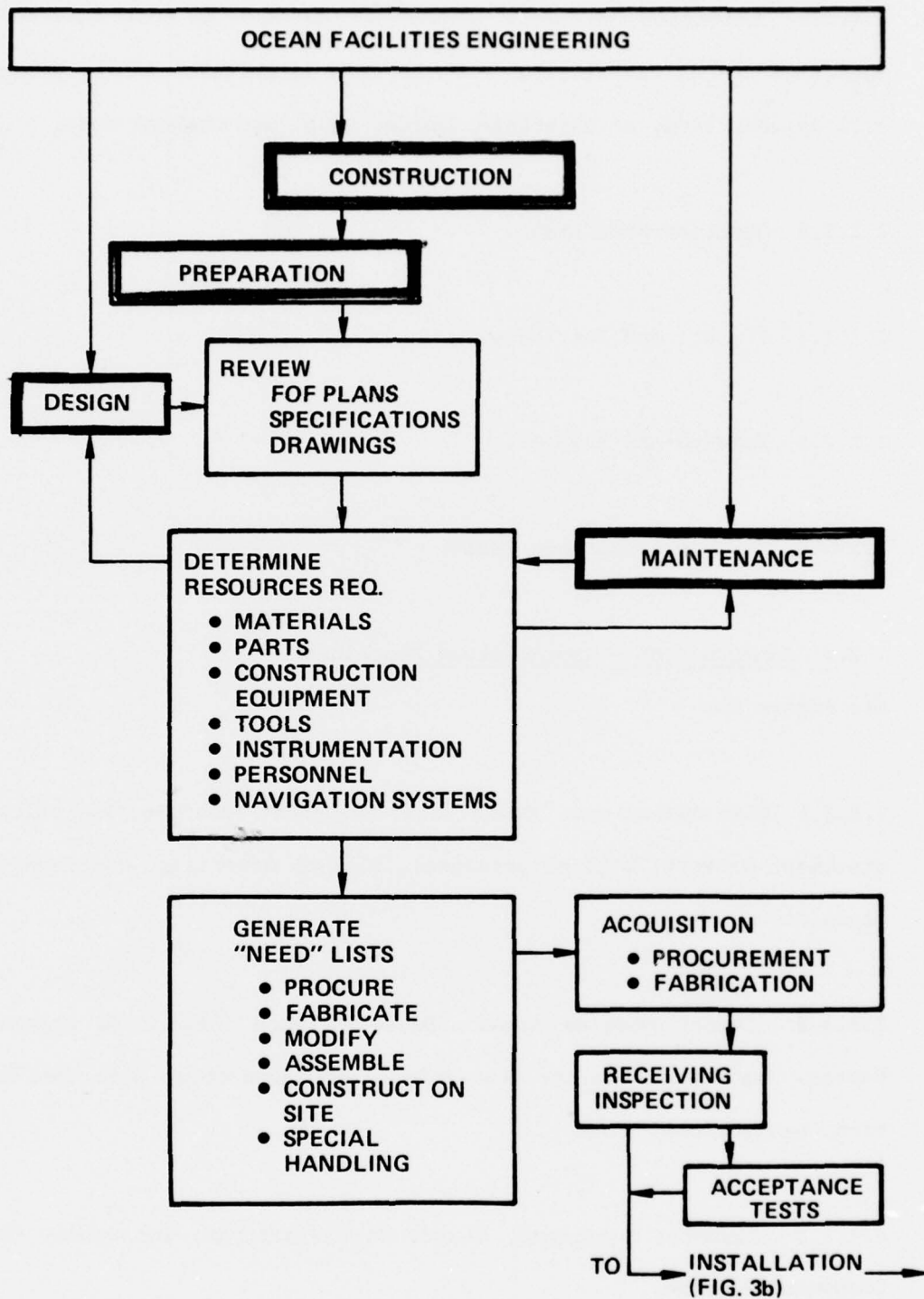


Figure 3a. OFE Construction - Preparation Functions

2.2.2.2 Determine Resources Required. It may be that materials specified are not available, in which case maintenance and/or design will be consulted, an alternate decided upon, and changes made.

2.2.2.3 Generate Need Lists.

2.2.2.4 Procure and Fabricate.

2.2.2.5 Receive and Inspect.

2.2.2.6 Perform Acceptance Tests.

### 2.2.3 Construction - Installation Functions

See Figure 3b.

2.2.3.1 Plan Operations. Operational sequence, schedule, logistics, statement of work, bill of personnel, bill of materials, contingency plans.

2.2.3.2 Select Staging Area. Based on such factors as channel depths, sea state, shelter available, land approaches, port facilities, navigational aids.

2.2.3.3 Assemble Equipment, Ships, Work Platforms, Personnel, FOF Components/System.

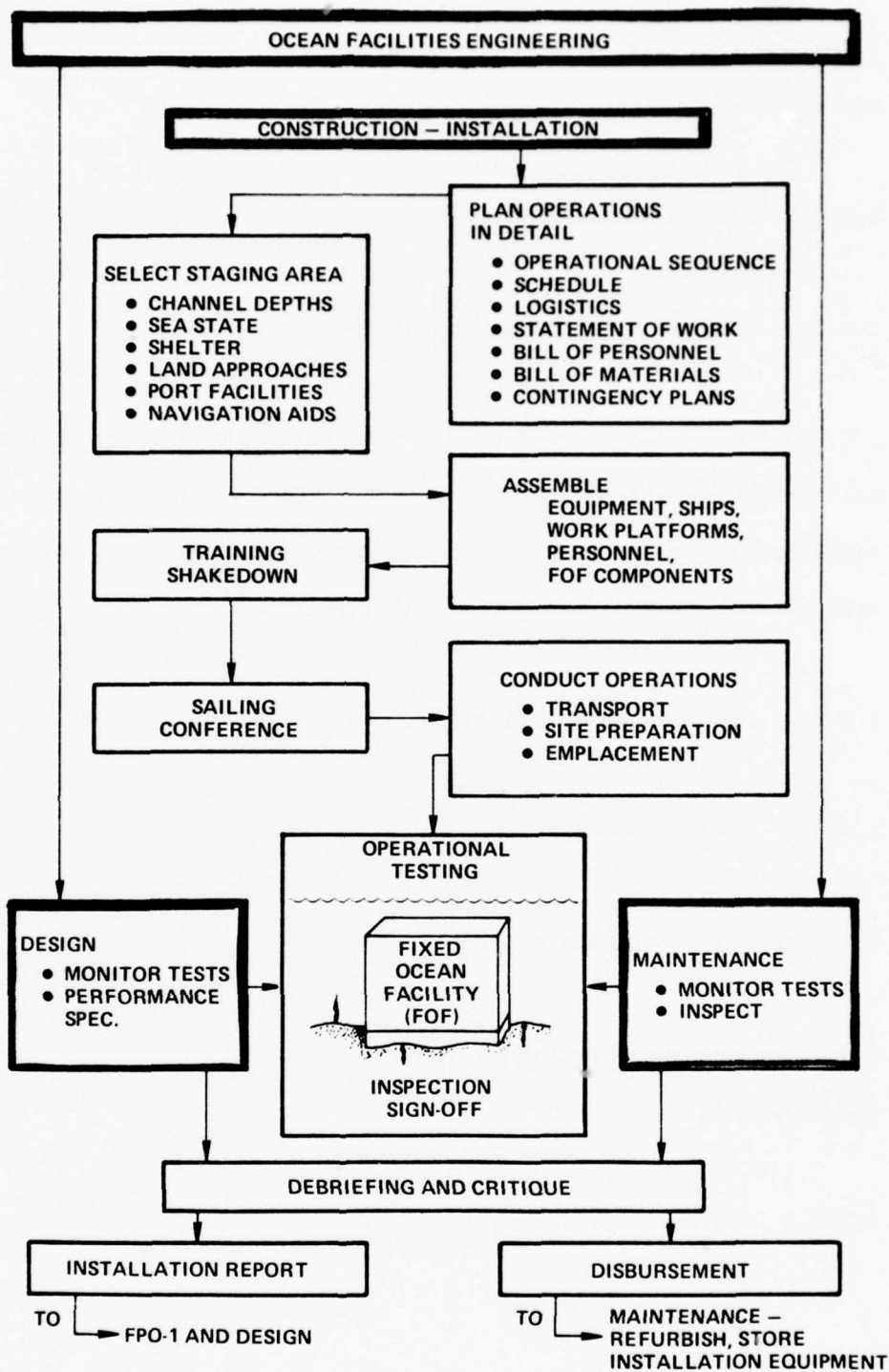


Figure 3b. Construction - Installation

2.2.3.4 Train Personnel. Assign specific work tasks, shakedown cruise if necessary.

2.2.3.5 Sailing Conference.

2.2.3.6 Perform Emplacement Operations.

2.2.3.7 Make Operational Tests. Representatives from design and maintenance should monitor tests if possible. Design has previously submitted performance specifications and test procedures; maintenance will perform initial inspection and sign off.

2.2.3.8 Debriefing and Critique.

2.2.3.9 Disbursement.

2.2.3.10. Installation Report.

2.2.4 Maintenance Functions.

See Figure 4.

2.2.4.1 Monitoring Performance.

- (1) FOF
- (2) Site

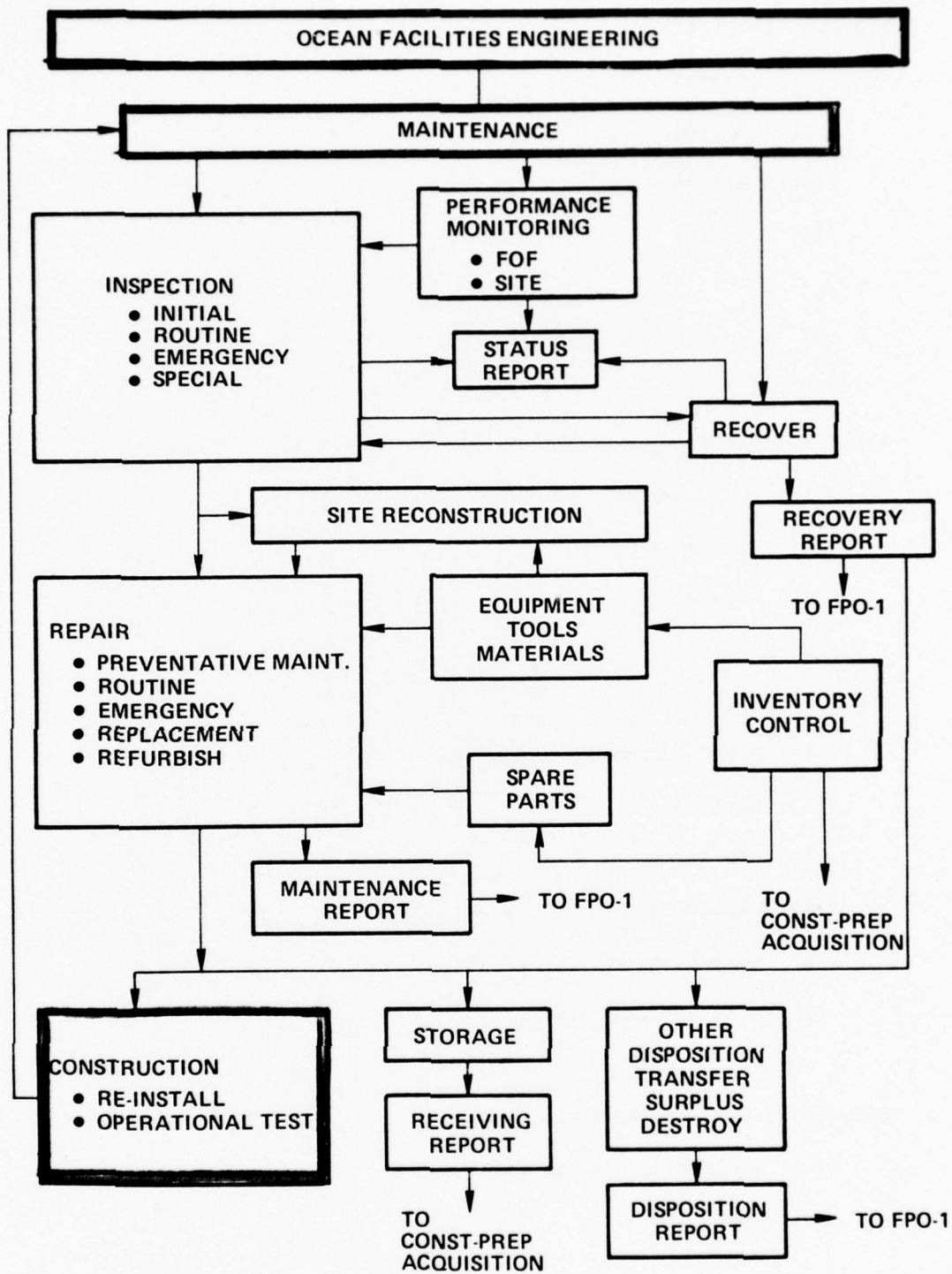


Figure 4. OFE Maintenance Functions

2.2.4.2 Inspection.

- (1) Initial
- (2) Routine
- (3) Emergency
- (4) Special

2.2.4.3 Recovery and Special Report.

2.2.4.4 Status Report.

- (1) Performance
- (2) Inspection
- (3) Recovery

2.2.4.5 Repair.

- (1) Preventative Maintenance
- (2) Routine
- (3) Emergency
- (4) Replacement
- (5) Refurbishment
- (6) Site Reconstruction

2.2.4.6 Inventory Control.

- (1) Equipment, Tools, Materials
- (2) Spare Parts

2.2.4.7 Maintenance Report.

2.2.4.8 Storage and Other Disposition.

(1) In-storage Receiving Report

(2) Disposition Report

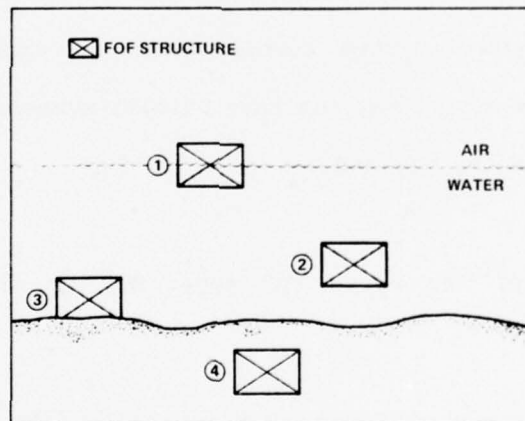
### 3. NAVAL FIXED OCEAN FACILITIES

#### (OUTLINE)

Naval FOFs are underwater installations and structures either supported by the ocean floor or attached to the ocean floor by means of a mooring system. They are designed, constructed, and maintained by the Naval Facilities Engineering Command to perform the Navy's national defense mission.

#### 3.1 FOF TYPES

##### 3.1.1 FOF Structure Categories



- (1) Surface - Penetrates air-water interface.
- (2) Subsurface - Between water surface and ocean floor.
- (3) Bottom - On the ocean floor.
- (4) Sub-Bottom - Those which penetrate the seafloor.

### 3.1.2 FOF Emplacement Categories

- (1) Bottom Moored - Buoyant suspension systems anchored to the floor.
- (2) Bottom Resting - In contact with bottom but without any foundation, may or may not be moored.
- (3) Bottom Mounted - Pile, mat, rock or concrete foundation.

### 3.2 FOF COMPONENTS

The components of fixed ocean facilities are related to the basic types of facilities. In general, there are seven basic FOF types of structure/emplacement system combinations, as shown in Figure 5. These basic types may or may not have utility systems associated with them depending on the payload.

The components of the basic FOF types may be classified as the following:

Emplacement System - that portion of a FOF which supports the primary structure and holds it in a fixed position;

Primary Structure - that portion of a FOF which provides physical support to the payload accommodations;

STRUCTURE EMPLACEMENT	SURFACE S(1)	SUBSURFACE S(2)	BOTTOM S(3)	SUB-BOTTOM S(4)
BOTTOM MOORED E(1)	FOF S1/E1	FOF S2/E1 (EXAMPLE 2)	FOF S3/E2 (EXAMPLE 3)	FOF S4/E3
BOTTOM RESTING E(2)	FOF S1/E3 (EXAMPLE 1)	FOF S2/E3	FOF S3/E3	
BOTTOM MOUNTED E(3)				

Figure 5. FOF Structure/Emplacement Combinations

Payload Accommodations - that portion of a FOF which encloses and/or attaches the payload to the primary structure;

Utility System - that which provides power, water, fuel or waste disposal facilities to the payload;

Protective System - that portion of a FOF which provides protection against damage to or deterioration of the facility.

The examples of FOF types presented in Figure 5 illustrate surface S(1), subsurface S(2), bottom S(3), and subbottom S(4) structure categories, combined with emplacement systems that are bottom moored E(1), bottom resting E(2), and bottom mounted E(3).

Figure 6 is representative of a mooring platform. It is a fixed ocean facility, type S1/E3, a surface structure combined with a bottom mounted emplacement system.

The components of FOF type S1/E3 may be classified as follows:

Emplacement System	- Bearing piles
Primary Structure	- Concrete deck
Payload Accommodations	- Deck facility
Utility System	- Generator & power cable
Protective System	- Fender

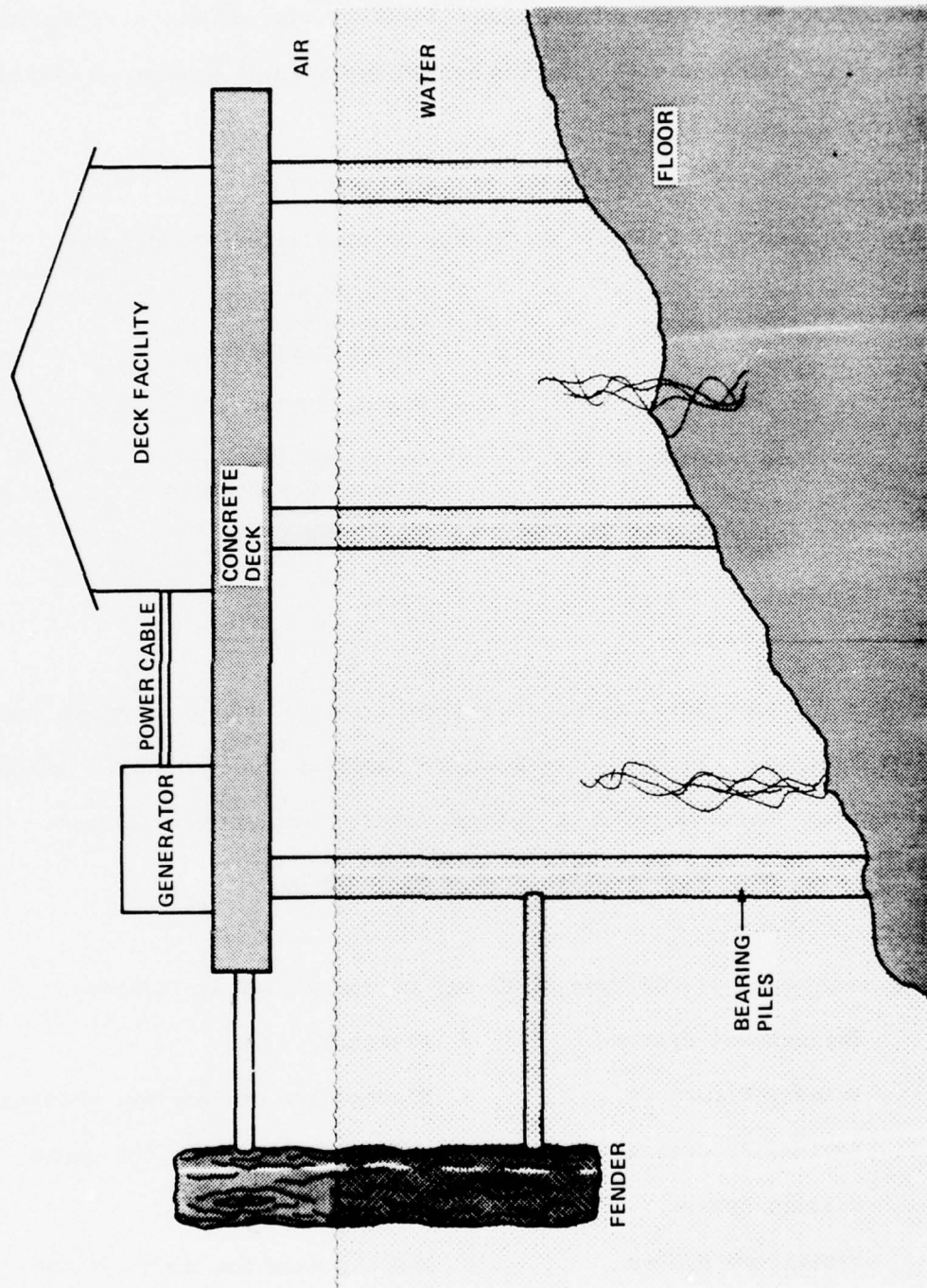


Figure 6. FOF Type S1/E3 Mooring Platform

Figure 7 represents a sensor system from an acoustic array test installation. It is a fixed ocean facility type S2/E1, a subsurface structure combined with a bottom moored emplacement system. A utility system is attached to it.

The components of FOF Type S2/E1 may be classified as follows:

- |                        |   |
|------------------------|---|
| Emplacement System     | - Subsurface buoy<br>Clump anchor<br>Acoustic release |
| Primary Structure      | - Braided nylon                                       |
| Payload Accommodations | - Sensor housing<br>Transponder housing               |
| Utility System         | - Submarine cable                                     |
| Protective System      | - Paint   |

Figure 8 represents a sensor system from an acoustic array test installation. It is a fixed ocean facility type S3/E2, a bottom structure combined with a bottom resting emplacement system. A utility system is attached.

The components of FOF Type S3/E2 may be classified as follows:

- |                        |                                     |
|------------------------|-------------------------------------|
| Emplacement System     | - Platform                          |
| Primary Structure      | - Electronics cylindrical housing   |
| Payload Accommodations | - Cylindrical housing for sensor    |
| Utility System         | - Submarine cable                   |
| Protective System      | - Rip rap mats for scour protection |

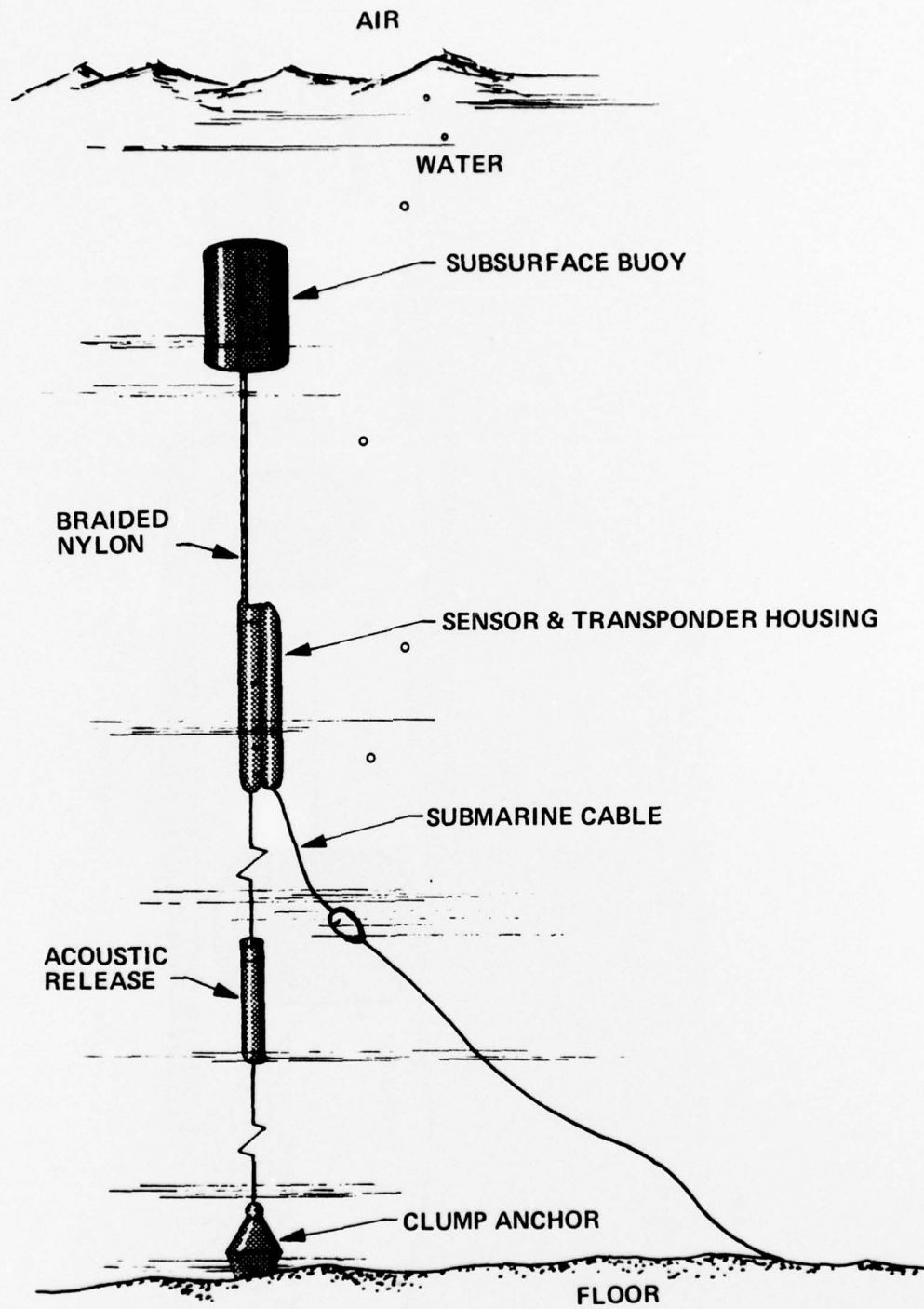


Figure 7. FOF Type S2/E1 Acoustic Array Sensor System

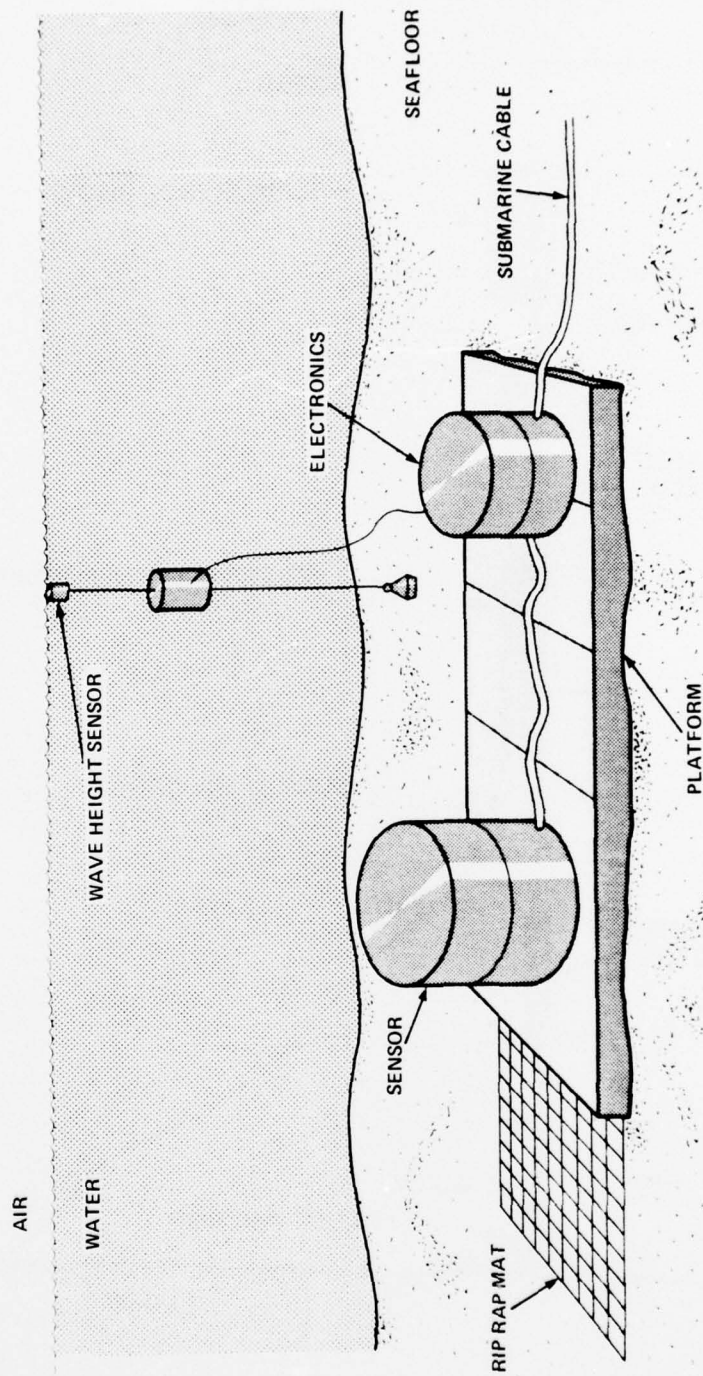


Figure 8. FOF Type S3/E2 Sensor System

#### 4. OFE SCIENTIFIC DISCIPLINES AND TECHNOLOGIES

(LISTING)

##### 4.1 DESIGN DISCIPLINES AND TECHNOLOGIES

###### 4.1.1 Ocean Environment

- |                                |  |                              |
|--------------------------------|--|------------------------------|
| Design<br>Ocean<br>Environment |  | (1) Oceanography/Meteorology |
|                                |  | (2) Ocean Chemistry          |
|                                |  | (3) Marine Biology           |
|                                |  | (4) Underwater Geology       |
|                                |  | a) Ocean Floor Topography    |
|                                |  | b) Soil Mechanics            |
|                                |  | c) Seismic Zones             |
|                                |  | (5) Underwater Fields        |
|                                |  | a) Sound                     |
|                                |  | b) Light                     |
|                                |  | c) Radio Wave Transmission   |
|                                |  | d) Magnetic                  |
|                                |  | (6) Hydrodynamics            |
|                                |  | (7) Wind and Wave Loads      |

###### 4.1.2 FOF Components

- |                             |  |                                       |
|-----------------------------|--|---------------------------------------|
| Design<br>FOF<br>Components |  | (1) Structures                        |
|                             |  | (2) Foundations                       |
|                             |  | (3) Moorings                          |
|                             |  | (4) Power Sources                     |
|                             |  | (5) Materials and Protective Coatings |

- |
- Design FOF Components (6) Underwater Cables
- (7) Instrumentation

4.1.3 FOF System

- Design FOF System
- (1) Test and Evaluation
- (2) Resources and Cost
- (3) Ocean Operations and Logistics
  - a) Safety
  - b) Anchoring Techniques
  - c) Lowering/Lifting Techniques
  - d) Handling/Transporting
- (4) Ocean Construction Equipment
- (5) Specifications
  - a) Drawings
  - b) Parts Control
- (6) Documentation (Information System)

4.2 OFE CONSTRUCTION DISCIPLINES AND TECHNOLOGIES

4.2.1 Ocean Environment

- Construction Ocean Environment
- (1) Geophysical Surveying
- (2) Underwater Geology
  - a) Soil bearing load capacity
- (3) Marine Hazards
- (4) Soil Sampling and Stabilization
- (5) Rock Exploration

- Construction (6) Wave Tide and Storm Forecasting
- Ocean Environment (7) Survey Instrumentation - Data Processing

4.2.2 FOF Components

- (1) Pilings
- (2) Moorings
- (3) Marine Concrete
- Construction FOF Components (4) Materials and Protective Coatings
- (5) Underwater Cables
- (6) Fabrication
- (7) Anchors

4.2.3 FOF System

- (1) Underwater Tools and Manipulators
- (2) Drilling Systems
- (3) Underwater Cutting and Welding
- (4) Rigging, Tackle and Techniques
- (5) Winches and Deck Machinery
- Construction FOF System (6) Diving
- (7) Ocean Operations
  - a) Safety - Underwater, shipboard, small boat, offshore structures, firefighting, weight handling gear, handling and stowage of dangerous substances, electro magnetic radiation hazards
  - b) Anchoring
  - c) Lowering/Lifting
  - d) Towing

Construction  
FOF  
System

- e) Communications
- f) Ship Chartering
- g) Ship Handling & Seamanship
- h) Staging
- i) Logistics

#### 4.3 OFE MAINTENANCE DISCIPLINES AND TECHNOLOGIES

##### 4.3.1 Ocean Environment

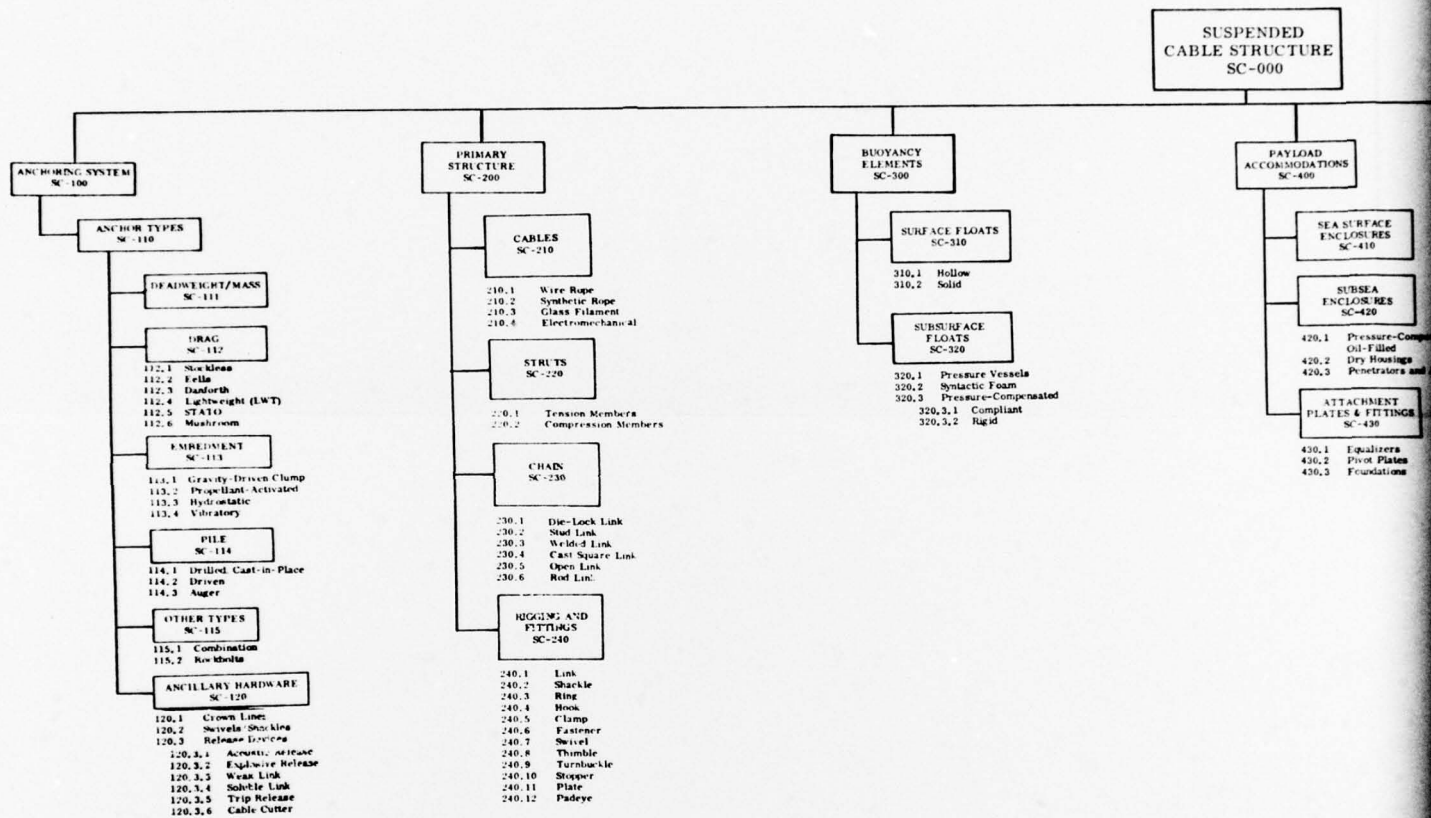
- (1) Meteorology/Weather Forecasts
- (2) Marine Hazards

##### 4.3.2 FOF Components

- (1) Mechanical and Electrical Equipment
- (2) Underwater Cables
- (3) Marine Concrete
- (4) Repair Materials
- (5) Soil Stabilization

##### 4.3.3 FOF System

- (1) Diving
- (2) Underwater Tools
- (3) Underwater Cutting and Welding
- (4) Logistics - Maintenance and Repair Crews
- (5) Repair Facilities - Drydocks, etc.



SUSPENDED  
CABLE STRUCTURE  
SC-000

PAYLOAD  
ACCOMMODATIONS  
SC-400

SEA SURFACE  
ENCLOSURES  
SC-410

SUBSEA  
ENCLOSURES  
SC-420

- 420.1 Pressure-Compensated, Oil-Filled
- 420.2 Dry Housing
- 420.3 Penetrators and Access

ATTACHMENT  
PLATES & FITTINGS  
SC-430

- 430.1 Equalizers
- 430.2 Pivot Plates
- 430.3 Foundations

PROTECTIVE  
SYSTEMS  
SC-500

MECHANICAL  
(FENDERS)  
SC-510

- 510.1 Pneumatic Fenders
- 510.2 Rope Fenders
- 510.3 Rubber Fenders
- 510.4 Standoff Boom

COATINGS  
SC-520

- 520.1 Paints and Tars
- 520.2 Cable Jacketing
- 520.2.1 Plastics
- 520.2.2 Rubber
- 520.3 Antifouling Paints

CATHODIC  
PROTECTION  
SC-530

- 530.1 Sacrificial Anodes
- 530.2 Impressed Current

ELECTRICAL  
POWER SYSTEMS  
SC-600

POWER  
SOURCES  
SC-610

- 610.1 Battery
- 610.1.1 Primary Batteries
- 610.1.2 Secondary Batteries
- 610.2 Fuel Cell
- 610.3 Nuclear
- 610.4 Thermoelectric Generators
- 610.5 Shore Power

CONTROLS  
SC-620

- 620.1 Pumps
- 620.2 Circuit Breakers
- 620.3 Regulators
- 620.4 Switching Gear
- 620.5 Rectifiers
- 620.6 Converters
- 620.7 Inverters
- 620.8 Transformers

POWER  
DISTRIBUTION  
SC-630

- 630.1 Electrical Cables
- 630.2 Junction Boxes
- 630.3 Connectors
- 630.4 Electrical Penetrators
- 630.5 Slip Rings

NAVIGATION, WARNING,  
AND COMMUNICATION  
SYSTEMS  
SC-700

ACOUSTIC  
SC-710

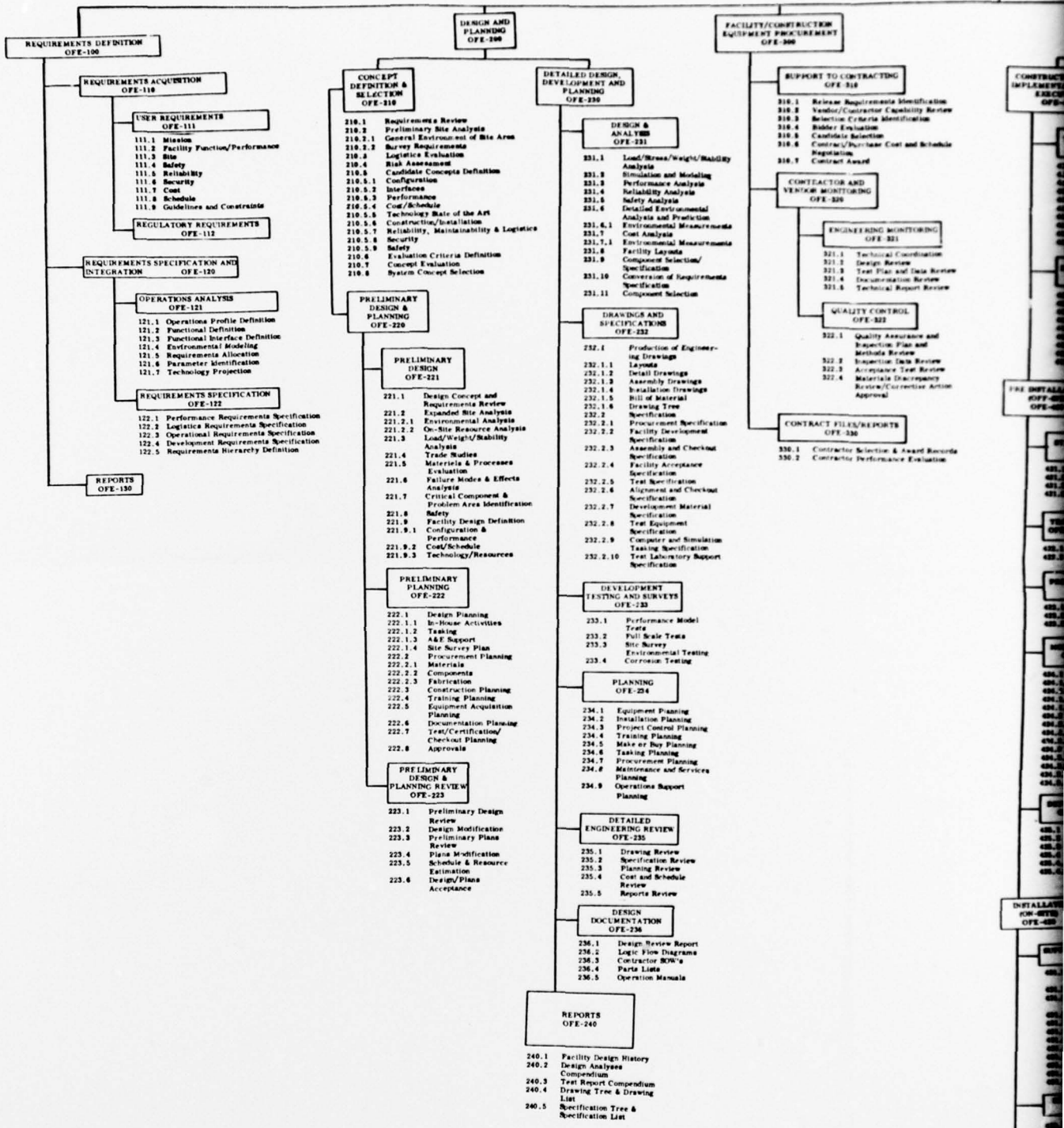
- 710.1 Bells, Horns, Whistles
- 710.2 Transponders
- 710.3 Pingers
- 710.4 Reflectors

VISUAL  
SC-720

- 720.1 Lights
- 720.2 Reflectors
- 720.3 Marker Buoys

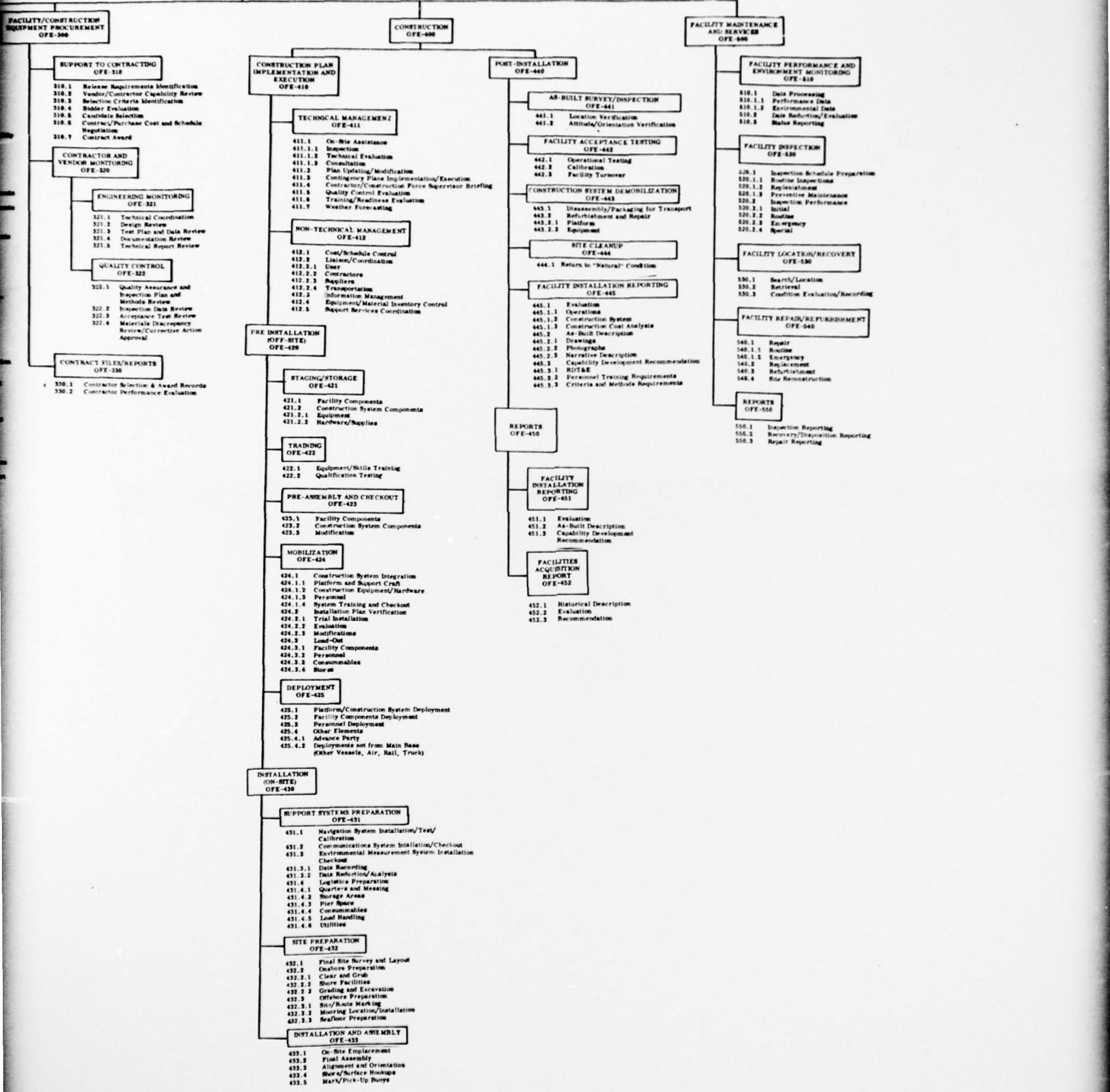
ELECTROMAGNETIC  
SC-730

- 730.1 Telecommunications
- 730.2 Signal Conditioners
- 730.3 Isular Reflectors



OCEAN FACILITIES ENGINEERING OFE-000

2



ATMOSPHERIC ENVIRONMENT EV-100

PHYSICAL PROPERTIES EV-101

- 101.1 Temperature Variation
- 101.2 Humidity
- 101.3 Composition
- 101.4 Pressure Variation

WINDS EV-102

- 102.1 Speed
  - 102.1.1 Sustained
  - 102.1.2 Gusts
- 102.2 Direction
  - 102.2.1 Prevailing
  - 102.2.2 Other Directions
- 102.3 Duration and Fetch
- 102.4 Percent Frequency
- 102.5 Recurrence Interval
- 102.6 Forces
- 102.7 Chill Factor

PRECIPITATION EV-103

- 103.1 Types
- 103.2 Quantities
- 103.3 Duration
- 103.4 Percent Frequency
- 103.5 Recurrence Interval

VISIBILITY EV-104

- 104.1 Distance
- 104.2 Restrictions
  - 104.2.1 Fog or Haze
  - 104.2.2 Precipitation
  - 104.2.3 Clouds
  - 104.2.4 Duration
  - 104.2.5 Percent Frequency
  - 104.2.6 Recurrence Interval

METEOROLOGICAL PHENOMENA EV-105

- 105.1 Hurricanes
- 105.2 Waterspouts/Cyclones
- 105.3 Thunderstorms
- 105.4 Lightning
- 105.5 Design Storm Conditions
  - 105.5.1 Peak Gusts
  - 105.5.2 Duration
  - 105.5.3 Recurrence Interval

OCEAN ENVIRONMENT EV-200

PHYSICAL/CHEMICAL PROPERTIES EV-201

- 201.1 Chemical
  - 201.1.1 Salinity
  - 201.1.2 Trace Elements
- 201.2 Optical
  - 201.2.1 Turbidity
  - 201.2.2 Extinction
  - 201.2.3 Refraction
  - 201.2.4 Reflection
  - 201.2.5 Solar Radiation
- 201.3 Electromagnetic
  - 201.3.1 Conductivity
- 201.4 Mechanical
  - 201.4.1 Viscosity
  - 201.4.2 Compressibility
  - 201.4.3 Surface Tension
  - 201.4.4 Density and Pressure
- 201.5 Acoustic
  - 201.5.1 Sound Velocity
  - 201.5.2 Sound Absorption
  - 201.5.3 Sound Refraction/Reflection
  - 201.5.4 Sound Scattering/Distortion
  - 201.5.5 Sound Pressure
  - 201.5.6 Ambient Noise
- 201.6 Thermodynamic
  - 201.6.1 Seasonal Variations
  - 201.6.2 Depth Variations
  - 201.6.3 Water Temperature
  - 201.6.4 Thermoclines

CURRENTS EV-202

- 202.1 Types
  - 202.1.1 Tidal
  - 202.1.2 Inertial
  - 202.1.3 Baroclinic vs. Barotropic
  - 202.1.4 Wind Driven
- 202.2 Stratification
  - 202.2.1 Surface Forces
  - 202.2.2 Mid-Depth Forces
  - 202.2.3 Bottom Forces
  - 202.2.4 Current Drag
- 202.3 Direction
- 202.4 Speed
- 202.5 Turbulence
- 202.6 Coherence
- 202.7 Variation
  - 202.7.1 Seasonal
  - 202.7.2 Fluctuations
  - 202.7.3 Decay
- 202.8 Spectrum
- 202.9 Vortex Shedding

INTERNAL WAVES EV-203

- 203.1 Deep Interface
- 203.2 Shallow Interface

BIOLOGICAL ASPECTS EV-204

- 204.1 Effects of Marine Biota
  - 204.1.1 Fouling
  - 204.1.2 Fishbite
  - 204.1.3 Boring
  - 204.1.4 Biodeterioration
- 204.2 Variation
  - 204.2.1 Seasonal
  - 204.2.2 Daily
  - 204.2.3 Depth

CORROSION ASPECTS EV-205

- 205.1 Types

SEAFLOOR ENVIRONMENT EV-300

BOTTOM TOPOGRAPHY EV-301

- 301.1 Surface Geology
- 301.2 Surface Bathymetry
- 301.3 Lateral Geology
- 301.4 Topography

SUBBOTTOM GEOLOGY EV-302

- 302.1 Composition
  - 302.2 Stratification
  - 302.3 Spatial Correlation
  - 302.4 Rock Properties
  - 302.5 Discontinuities
    - 302.5.1 Fractures
    - 302.5.1.1 Frequency
    - 302.5.1.2 Orientation
    - 302.5.1.3 Permeability
    - 302.5.1.4 Bedding
  - 302.5.2 Orientation
  - 302.5.3 Extent

GEOMORPHOLOGY EV-303

- 303.1 Origin/Classification
- 303.2 Active Geomorphology During Past

GEOTECHNICAL ASPECTS EV-304

- 304.1 Soil
  - 304.1.1 Classification
  - 304.1.2 Composition
    - CaCO<sub>3</sub>
    - Shear Strength
  - 304.1.3 Sensitivity
  - 304.1.4 Bulk Unit Weight
  - 304.1.6 Consolidation
  - 304.1.7 Atterberg Limits
  - 304.1.8 Water Content
  - 304.1.9 Porosity
  - 304.1.10 Void Ratio
  - 304.1.11 Specific Gravity
  - 304.1.12 Permeability
  - 304.1.13 Viscosity
  - 304.1.14 Characteristic Values
  - 304.1.15 Dynamic Values
  - 304.1.16 Adhesion
  - 304.1.17 Friction
- 304.2 Rock
  - 304.2.1 Shear Strength
    - 304.2.1.1 Compressive Strength
    - 304.2.1.2 Disruptive Strength
  - 304.2.2 Compressive Strength
  - 304.2.3 Deformation Modulus
  - 304.2.3.1 Shear Modulus
  - 304.2.3.2 Poisson's Ratio
  - 304.2.4 Seepage Permeability
  - 304.2.5 Density
  - 304.2.6 Water Content

GEOPHYSICAL ASPECTS EV-305

- 305.1 Gravimetric
- 305.2 Magnetic
- 305.3 Conductivity
- 305.4 Acoustic

SEISMIC ASPECTS EV-306

BIOLOGICAL ASPECTS EV-307

SEAFLOOR/BIOME INTERACTIONS EV-308

- 308.1 Foundation
  - 308.1.1 Immediate
  - 308.1.2 Long-Term
  - 308.1.3 Differential
- 308.2 Foundation
  - 308.2.1 Bearing Capacity
  - 308.2.2 Rotational
  - 308.2.3 Lateral
  - 308.2.4 Uplift
  - 308.2.5 Breakout

SEA/SEAFLOOR INTERACTIONS EV-309

- 309.1 Scouring
- 309.2 Accretion
- 309.3 Turbidity

**SEAFLOOR ENVIRONMENT  
EV-300**

**BOTTOM TOPOGRAPHY  
EV-301**

- 301.1 Surface Gradient
- 301.2 Surface Roughness
- 301.3 Lateral Continuity/Variation
- 301.4 Topographic Effects

**SUBBOTTOM GEOLOGIC STRUCTURE  
EV-302**

- 302.1 Composition
- 302.2 Stratification
- 302.3 Spatial Continuity/Variation
- 302.4 Rock Protrusion
- 302.5 Discontinuities
  - 302.5.1 Fractures
    - 302.5.1.1 Faults
    - 302.5.1.2 Joints
    - 302.5.1.3 Fissures
    - 3.2.5.1.4 Bedding Planes
  - 302.5.2 Orientation
  - 302.5.3 Extent

**GEOMORPHOLOGY  
EV-303**

- 303.1 Origin/Courses of Geologic Formations
- 303.2 Active Geomorphology During Facility Life

**GEOTECHNICAL PROPERTIES  
EV-304**

- 304.1 Soil
  - 304.1.1 Classification
  - 304.1.2 Composition/Mineralogy/  
CaCO<sub>3</sub>
  - 304.1.3 Shear Strength (Sediment,  
Soil)
  - 304.1.4 Sensitivity
  - 304.1.5 Bulk Unit Weight
  - 304.1.6 Consolidation
  - 304.1.7 Atterberg Limits
  - 304.1.8 Water Content
  - 304.1.9 Porosity
  - 304.1.10 Void Ratio
  - 304.1.11 Specific Gravity
  - 304.1.12 Permeability
  - 304.1.13 Viscoelastic/Creep  
Characteristics
  - 304.1.14 Dynamic Characteristics
  - 304.1.15 Adhesion
  - 304.1.16 Friction
  - 304.1.17 Wave Induced Liquefaction
- 304.2 Rock
  - 304.2.1 Shear Strength (Rock)
    - 304.2.1.1 Competent Rock
    - 304.2.1.2 Discontinuity
  - 304.2.2 Compressive Strength
  - 304.2.3 Deformation Characteristics
    - 304.2.3.1 Stress/Strain
    - 304.2.3.2 Poisson's Ratio
  - 304.2.4 Seepage Characteristics/  
Permeability
  - 304.2.5 Density
  - 304.2.6 Water Content

**GEOPHYSICAL PROPERTIES  
EV-305**

- 305.1 Gravitational Anomalies
- 305.2 Magnetic Anomalies
- 305.3 Conductivity/Resistivity
- 305.4 Acoustic

**SEISMIC ACTIVITY  
EV-306**

**BIOLOGICAL ASPECTS/BURROWING  
EV-307**

**SEAFLOOR/FOUNDATION  
INTERACTIONS EV-308**

- 308.1 Foundation Settlement Parameters
  - 308.1.1 Immediate Settlement
  - 308.1.2 Long-Term Settlement
  - 308.1.3 Differential Settlement
- 308.2 Foundation Failure Parameters
  - 308.2.1 Bearing Capacity Instability
  - 308.2.2 Rotational Instability
  - 308.2.3 Lateral Instability
  - 308.2.4 Uplift
  - 308.2.5 Breakout

**SEA/SEAFLOOR INTERFACE  
EV-309**

- 309.1 Scouring
- 309.2 Accretion
- 309.3 Turbidity Currents

**AIR-SEA-LAND INTERFACE  
EV-400**

**SURFACE WAVES (DEEP WATER)  
EV-401**

- 401.1 Types
  - 401.1.1 Sea
    - 401.1.1.1 Gravity Waves
    - 401.1.1.2 Capillary Waves
  - 401.1.2 Swell
  - 401.1.3 Fetch
- 401.2 Speed
  - 401.2.1 Composite
  - 401.2.2 Particle Velocity
  - 401.2.3 Particle Dispersion
- 401.3 Direction
- 401.4 Dispersion
- 401.5 Mass Transport/Inertia
- 401.6 Characteristics
  - 401.6.1 Height
  - 401.6.2 Period Length
  - 401.6.3 Spectrum
- 401.7 Spray
- 401.8 Breaking Height
- 401.9 Wave Loading Analysis
  - 401.9.1 Static Analysis
    - 401.9.1.1 Wave Forces and Moments
    - 401.9.1.2 Subsurface Pressure
    - 401.9.1.3 Hydrodynamic Drag and  
Inertia Coefficients
  - 401.9.2 Dynamic Analysis
- 401.10 Wave Prediction Methods  
for Design of FOPS
- 401.10.1 SMD Method

**WAVES (SHALLOW RESTRICTED WATERS)  
EV-402**

- 402.1 Breakers/Surf

**SEA ICE  
EV-403**

- 403.1 Types
  - 403.1.1 Drift
  - 403.1.2 Icebergs
  - 403.1.3 Pack
  - 403.1.4 Ice Islands
- 403.2 Statistics of Occurrence
- 403.3 Speed
- 403.4 Direction
- 403.5 Composition
  - 403.5.1 Salinity
  - 403.5.2 Density
  - 403.5.3 Structure
- 403.6 Formation
- 403.7 Ice
- 403.8 Ice Forces

**LITTORAL TRANSPORT  
EV-404**

**EROSION  
EV-405**

**RIVER DISCHARGE  
EV-406**

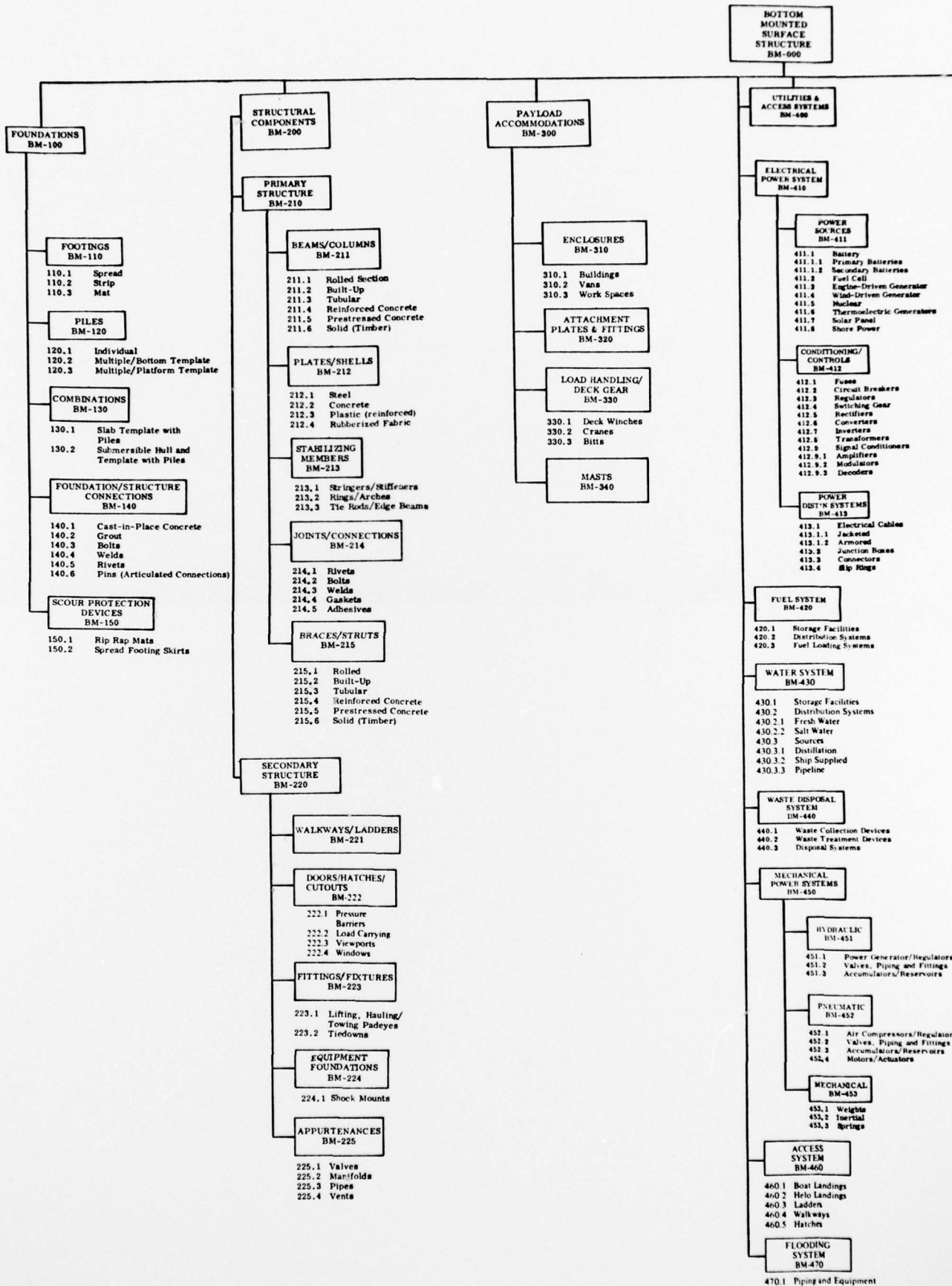
**SEA LEVEL VARIATION  
EV-407**

- 407.1 Storm Surges
- 407.2 Tides
- 407.3 Tsunami
- 407.4 Seiches
- 407.5 Wave Setup

**SHORE CHARACTERISTICS  
EV-408**

- 408.1 Beach Topography
- 408.2 Beach Geology

2



**BOTTOM MOUNTED SURFACE STRUCTURE BM-000**

**UTILITIES & ACCESS SYSTEMS BM-400**

**ELECTRICAL POWER SYSTEM BM-410**

**POWER SOURCES BM-411**

- 411.1 Battery
  - 411.1.1 Primary Batteries
  - 411.1.2 Secondary Batteries
- 411.2 Fuel Cell
- 411.3 Engine-Driven Generator
- 411.4 Wind-Driven Generator
- 411.5 Nuclear
- 411.6 Thermoelectric Generators
- 411.7 Solar Panel
- 411.8 Shore Power

**CONDITIONING/CONTROLS BM-412**

- 412.1 Fuses
- 412.2 Circuit Breakers
- 412.3 Regulators
- 412.4 Switching Gear
- 412.5 Rectifiers
- 412.6 Converters
- 412.7 Inverters
- 412.8 Transformers
- 412.9 Signal Conditioners
- 412.9.1 Amplifiers
- 412.9.2 Modulators
- 412.9.3 Decoders

**POWER DISTRIBUTION SYSTEMS BM-413**

- 413.1 Electrical Cables
  - 413.1.1 Jacketed
  - 413.1.2 Armored
- 413.2 Junction Boxes
- 413.3 Connectors
- 413.4 Slip Rings

**FUEL SYSTEM BM-420**

- 420.1 Storage Facilities
- 420.2 Distribution Systems
- 420.3 Fuel Loading Systems

**WATER SYSTEM BM-430**

- 430.1 Storage Facilities
- 430.2 Distribution Systems
  - 430.2.1 Fresh Water
  - 430.2.2 Salt Water
- 430.3 Sources
  - 430.3.1 Distillation
  - 430.3.2 Ship Supplied
  - 430.3.3 Pipeline

**WASTE DISPOSAL SYSTEM BM-440**

- 440.1 Waste Collection Devices
- 440.2 Waste Treatment Devices
- 440.3 Disposal Systems

**MECHANICAL POWER SYSTEMS BM-450**

**HYDRAULIC BM-451**

- 451.1 Power Generator/Regulators
- 451.2 Valves, Piping and Fittings
- 451.3 Accumulators/Reservoirs

**PNEUMATIC BM-452**

- 452.1 Air Compressors/Regulators
- 452.2 Valves, Piping and Fittings
- 452.3 Accumulators/Reservoirs
- 452.4 Motors/Actuators

**MECHANICAL BM-453**

- 453.1 Weights
- 453.2 Torsion
- 453.3 Springs

**ACCESS SYSTEM BM-460**

- 460.1 Boat Landings
- 460.2 Helo Landings
- 460.3 Ladders
- 460.4 Walkways
- 460.5 Hatches

**FLOODING SYSTEM BM-470**

- 470.1 Piping and Equipment

**SAFETY SYSTEMS BM-500**

**FIRE FIGHTING EQUIPMENT BM-510**

- 510.1 Detection Devices
- 510.2 Alarm System
- 510.3 Extinguishers

**PERSONNEL SAFETY EQUIPMENT BM-520**

- 520.1 Fallings
- 520.2 Screens
- 520.3 Escape Apparatus
- 520.4 Protective Clothing
- 520.5 Safety Harnesses
- 520.6 Remote Shutdowns
- 520.7 Emergency Signals
- 520.8 Lightning Arrestors
- 520.9 First Aid Kits

**NAVIGATION, WARNING, AND COMMUNICATION SYSTEMS BM-600**

**ACOUSTIC BM-610**

- 610.1 Bells/Horns/Whistles
- 610.2 Transponders
- 610.3 Pingers
- 610.4 Reflectors

**VISUAL BM-620**

- 620.1 Lights
- 620.2 Reflectors

**ELECTROMAGNETIC BM-630**

- 630.1 Telecommunications
- 630.2 Signal Conditioners
- 630.3 Radar Reflectors

**PROTECTIVE SYSTEMS BM-700**

**MECHANICAL (FENDERS) BM-710**

- 710.1 Pneumatic Fenders
- 710.2 Rope Fenders
- 710.3 Crushable Elements
- 710.4 Stand-off Boom
- 710.5 Ship Fenders

**COATINGS BM-720**

- 720.1 Paints and Tar
- 720.2 Plastics and Rubber
- 720.3 Antifouling Paints

**CATHODIC PROTECTION BM-730**

- 730.1 Sacrificial Anodes
- 730.2 Impressed Current