CABLE VESSEL SUBSYSTEM

FEASIBILITY CRITERIA

March 1986

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HAWAII DEEP WATER CABLE PROGRAM

PHASE II

CABLE VESSEL SUBSYSTEM

FEASIBILITY CRITERIA

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CABLE VESSEL SUBSYSTEM

1.0 PURPOSE AND SCOPE

The Cable Vessel Subsystem (CVSS) is a major hardware element to be used on the baseline commercial cable system. The cable system will link the geothermal resources on the island of Hawaii to the Oahu electrical grid system.

The present CVSS Feasibility Criteria document defines the functions of the CVSS, establishes performance requirements, and specifies the feasibility criteria by which the subsystem hardware and performance will be evaluated.

2.0 DEFINITIONS AND BACKGROUND

The baseline commercial cable system is composed of several subsystems: the Cable, Cable Vessel, Cable Handling Equipment, and a Shoreside Facilities Subsystem.

The Hawaii Deep Water Cable (HDWC) Program focuses on determining the feasibility of the commercial cable system. Until the actual commercial system is designed, a baseline system is defined as representing the best current understanding of the cable systems features, and equipment requirements. To determine the feasibility of implementing the commercial cable system, the HDWC Program is developing laboratory and at-sea test programs for use in determining this feasibility. The HDWC System hardware (i.e. cable, vessel and handling equipment) will be representative of the baseline commercial system only to the extent required for determining the specific feasibility issues.

2.0 DEFINITIONS AND BACKGROUND (continued)

The CVSS Feasibility Criteria is related to the System Feasibility Criteria document that establishes the overall standards and requirements to be used in judging feasibility of a commercial cable system. This top-level system document is the basis for developing the present CVSS Feasibility Criteria. The CVSS Feasibility Criteria in turn will be used to develop both selection criteria and test plans for the HDWC hardware and operations.

Specific CVSS components are summarized in Table 1. It should be noted that although component listings are the same for both the HDWC and commercial system, the individual components will differ. The important point is that the HDWC CVSS components be adequate to provide for an at-sea test that meets the minimum at-sea test requirements. The test requirements are related primarily to the determination of feasibility of accurately laying a submarine cable with the proper tensions. These requirements are further defined in the document titled "Summary of HDWC Program Minimum At-Sea Test Requirements" (August 1985).

There are CVSS components of the baseline commercial cable system that have no analogous components in the HDWC system. These include Embedding Equipment, Cable Locating Equipment and Disembedment Equipment. Feasibility

verification of these components will therefore not take place by laboratory or at sea testing during the HDWC program. Instead, analytical and design studies will be performed to address these elements to the level required.

TABLE I

CVSS COMPONENTS

BASELINE COMMERCIAL SYSTEM	HDWC SYSTEM
Hull and Deck	Hull and Deck
Propulsion and Maneuvering	Propulsion and Maneuvering
Navigation and Control	Navigation and Control
Submersible and Support Equipment	Submersible and Support Equipment
Operations Support Facilities	Operations Support Facilities
Port Facilities	Port Facilities
Embedding Equipment	
Cable Locating Equipment	
Disembedment Equipment	

4.0 CVSS FUNCTIONAL REQUIREMENTS

The CVSS functions are shown in the flow logic diagrams in Figures 1 and 2. Figure 1 shows the CVSS functional requirements during initial deployment of the cable, while Figure 2 gives the maintenance and repair requirements. The flow indicates the sequence of functional operations that the CVSS must perform. The unique CVSS operations are indicated by a common number; letter suffixes identify similar functional operations performed at other times in the logical flow sequence. The unique CVSS functional requirements are described below.

1. Provide hull and spaces for cable subsystem and CHSS equipment - The cable vessel must provide deck space and structural support to transport the cable, mount the cable handling equipment and deploy the cable; crew accomodations and other spaces are required for operating the vessel and performing deployment, retrieval, and repair operations.

2. Transfer cable subsystem components and/or CHSS components to local port facility - A possible function of the cable vessel if cost effective; the local port facility will serve as a mobilization/ demobilization site for the integrated HDWC System; vessel outfitting may take place at alternative facilities as required.

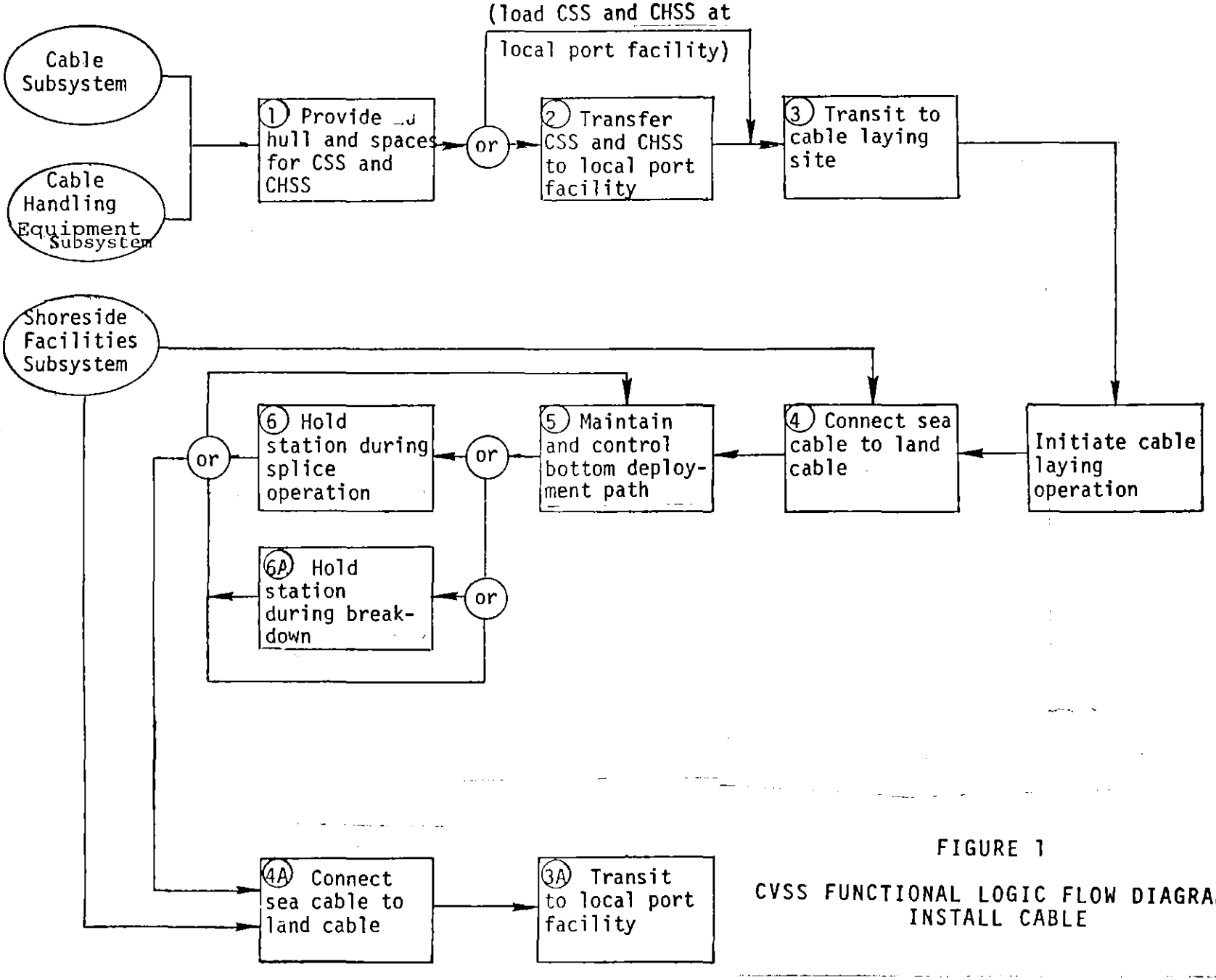

FIGURE 1

CVSS FUNCTIONAL LOGIC FLOW DIAGRAM: INSTALL CABLE

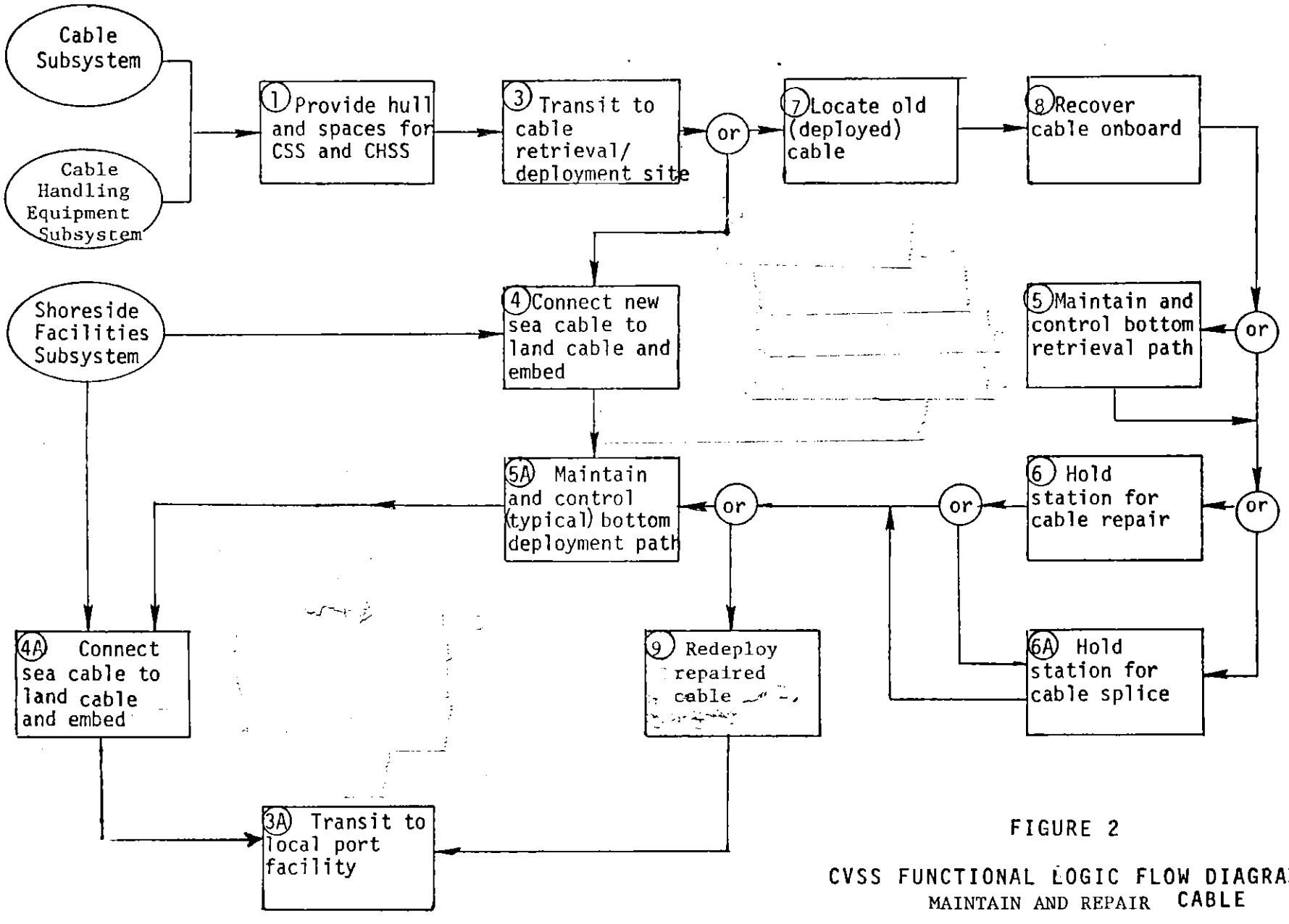

FIGURE 2

CVSS FUNCTIONAL LOGIC FLOW DIAGRAM:
MAINTAIN AND REPAIR CABLE

4.0 CVSS FUNCTIONAL REQUIREMENTS (continued)

3. Transit between port facility and cable deployment/retrieval site - The cable vessel must transit to the operational site with all personnel and equipment; the vessel configuration with and without the cable must be seaworthy.

4. Connect sea cable to land cable - As yet undefined technique supported by the CVSS will connect the cable with the shore electrical grid station. Embedding will likely be required at the landing site and in any locations where the cables might be subject to hazards. Special cable floatation and dredging/backfill equipment are considered to be part of the CVSS since they will operate directly in the ocean environment.

5. Maintain and control cable deployment and retrieval paths - The cable vessel must be capable of maintaining and controlling velocity and position over a defined bottom pathway during both cable deployment and retrieval.

6. Hold station during cable repair/splice or operational breakdown - The cable vessel must maintain station while performing on-board cable repair/splice or during CVSS or CHSS operational breakdowns; the cable length to the ocean bottom must be supported and maintained in appropriate position during station hold.

4.0 CVSS FUNCTIONAL REQUIREMENTS (continued)

7. Locate deployed cable - The CVSS must be capable of locating the deployed cable for system maintenance and repair operations.
8. Recover cable on-board - Special CVSS bottom recovery equipment is needed to bring cable to surface and aboard vessel for repair/splice as required during operational phase.
9. Re-deploy repaired cable - As yet undefined maneuver may be required to re-deploy the repaired cable.

It should be recognized that there will be differences between the CVSS functional requirements of the HDWC and baseline commercial systems. For example, the deck space and structural support requirements for the HDWC Program will be small compared to those of the commercial system. Also, cable embedding will not be a requirement of the HDWC Program CVSS.

The relationship between CVSS components and performance functions is shown in Table 2.

5.0 CVSS FEASIBILITY CRITERIA

A set of feasibility criteria have been formulated for the CVSS based on the design factor considerations specified for the baseline commercial cable system concept and presented in the System Feasibility Criteria. These criteria are categorized as:

- functional performance criteria
- environmental criteria
- reliability and availability criteria

TABLE 2

RELATIONSHIP BETWEEN
CVSS FUNCTIONAL REQUIREMENTS
AND CVSS HARDWARE

Functional Requirements	Hull and Deck	Propulsion and Manuevering	Navigation and Control	Embedding Equipment	Submersible and Support Equipment	Cable Locating Equipment	Operational Support Facility	Port Facilities	Disembedment Equipment
1 - Provide Hull and Spaces	X						X		
2 - Transport CSS/CHSS to Local Port Facility	X	X	X				X	X	
3 - Transit between Port and Operations Site	X	X	X				X	X	
4 - Connect Cable to Land End	X	X	X	X			X		
5 - Maintain and Control Deployment/Retrieval Path	X	X	X		X		X		
6 - Hold Station during Repair/Splice/Breakdown	X	X	X				X		
7 - Locate Deployed Cable	X	X	X		X	X	X		
8 - Recover Deployed Cable	X	X	X		X		X		X
9 - Re-deploy Repaired Cable	X	X	X	X			X		

5.0 CVSS FEASIBILITY CRITERIA (continued)

- o repairability and maintainability criteria
- o design and construction criteria
- o personnel and system equipment criteria
- o legal and institutional criteria
- o economic criteria
- o interface criteria

The CVSS Feasibility Criteria are described below. Verification procedures during the HDWC Program are presented in Section 6.

5.1 FUNCTIONAL PERFORMANCE CRITERIA

A listing of performance criteria is presented in Table 3 corresponding to the CVSS functional requirements presented in Section 4. These functional criteria define the commercial CVSS hardware peformance during all aspects of initial cable deployment and maintenance and repair operations.

The vessel activities during maintenance and repair operations will be similar to that during initial cable deployment with three possible exceptions: (1) long new cable lengths may not be required, (2) special maneuvering during cable recovery and re-deployment may be necessary, and (3) special equipment may be required to raise a cable for repair, particulary if the cable has become embedded. Alternative vessels may be defined based on subsequent design/cost analyses of these different requirements.

TABLE 3. CVSS Functional Performance Criteria

Function	Feasibility Criteria	Performance Requirement or Constraint
1 - Provide hull and spaces	1.1 Adequate deck space and structurally designed for cable, cable accessory equipment (i.e., pressurizing, monitoring) and cable handling equipment	Original cable: 50-100km (max) Repair cable: TBD Cable handling equipment: TBD Cable accessory equipment: TBD
	1.2 Facility for cable splice/repair-environmentally controlled room/building	10m x 35m building ("low tension" deck site)
	1.3 Accommodations for at-sea personnel	Cable ops: 15 people temp./ no overnight Ship crew: as required for operation
	1.4 Spaces for submersible and other special hardware	TBD
2 - Transport cable subsystem and CHSS to local port facilities (optional)	2.1 East Coast to Honolulu transport (typical) of cable subsystem and/or CHSS hardware for outfitting	Load = ? Transit time = 3 months (max)
	2.2 Local port(s) to serve as mobilization/demobilization site and deployment/retrieval staging	Potential ports: O Honolulu O Kawaihae Harbor O Hilo O Kahului
3 - Transit between port facility and cable deployment/retrieval site	3.1 Transit to/from site in adequate time for cable operations	Cruising speed = 8-10 kts Distance = 400 km (max) 12 foot seas
	3.2 Provide stable vessel configuration with and without cable	Cable weight = 4000 ton (100 km length) Cruising speed = 10-15 kts 8 foot seas
4 - Connect sea cable to land cable	4.1 Dredge trench in near-shore zone affected by waves and bury cable as required	Trench: from landing site; bury 2-4m deep Trenching must not damage neighboring cables
	4.2 Deploy cable in trench backfill, and provide with protective cover as required	

TABLE 3 (continued)

Function	Feasibility Criteria	Performance Requirement or Constraint
5 - Maintain and control bottom deployment and retrieval paths	5.1 Lay/retrieve cable at required speeds to allow deployment witin weather window	Deployment: 1m/sec max Retrieval: 0.5m/sec max Weather window: 3 days Water depth: 7000 ft max
	5.2 Vessel stability adequate for at-sea deployment/ retrieval operations	8 ft seas 35 kt winds 4 ft swells 3 kt currents
	5.3 Maintain predetermined bottom path for deployment and retrieval	Path accuracy: ±500m max Underwater obstacle/hazard avoidance. Maximum slope: 30 degrees
	5.4 Maintain bottom tension on cable during deployment	Bottom tension: 5000 kg ±2500 kg Sea bottom conditions unstable
6 - Hold station during cable repair/splice or operational breakdown	6.1 Maintain vessel with cable deployed in fixed position and orientation	Station radius = 200m 100m depth 500m 100m depth Direction = ±20° Duration = 21 days
	6.2 Vessel stability adequate for at-sea station-hold	8 ft seas 35 kt winds 4 ft swells 3 kt currents
7 - Locate old (deployed) cable	7.1 Detect bottom cable position	Depth range: 0-2100m Location accuracy: ±3m Cover depth: 0-100m
8 - Recover cable onboard	8.1 Uncover length of cable	Depth range: 0-2100m Cover depth: 3m-100m
	8.2 Attach recovery line to cable (?)	Operation must not damage neighboring cables
	8.3 Bring cable to surface	
9 - Redeploy cable	9.1 Perform special manuever for cable redeployment (?)	Redeploy without kinking or coiling

5.2 ENVIRONMENTAL CRITERIA

The vessel at-sea cable deployment and repair operations shall be compatible with the following environmental criteria:

- Three-day weather window for deep, unsheltered channel waters.
- Maximum 8-foot seas, 35-knot winds, 4-foot swells, and 3-knot currents (see Table 4 and Figure 3 for more details).
- Maximum 2100m cable deployment depth
- Maximum bottom slope of 30 degrees

A map of the prospective cable route between Maui and Hawaii, the longest deep water span, is shown in Figure 4. Directions of the expected current, wind, sea and swell are indicated. The distance between islands is about 56 km.

5.3 RELIABILITY AND AVAILABILITY CRITERIA

The CVSS and all associated hardware components shall be designed for reliable operation in the marine environment. Preliminary requirements are as follows:

- Marine breakdowns (causing less than 2-hour delay in cable laying/retrieval operations) shall have less than 5 percent probability of occurrence over any 12-hour work day.
- Major breakdowns (causing less than 5-day delay in cable laying/retrieval operations) shall have less than 3 percent probability of occurrence during any given 3-day period.

TABLE 4

ENVIRONMENTAL DESIGN CONDITIONS

Location	-	Alenuihaha Channel (between Maui and Hawaii)
Depth	-	2000m (maximum)
Wind	-	35 knots
Sea Waves	-	Significant Wave Height H_s = 8 ft Significant Wave Period T_s = 6 sec
Swell Waves	-	H = 4 ft Swell Wave Period T = 13 sec Direction: from 147°-236°T
Currents	-	

Depth (feet)	Current (knots)
0	2.94
50	2.80
100	2.68
150	2.58
200	2.51
250	2.44
300	2.39
400	2.32
650	2.22
800	1.97
1000	1.65
1200	1.34
1300	1.20

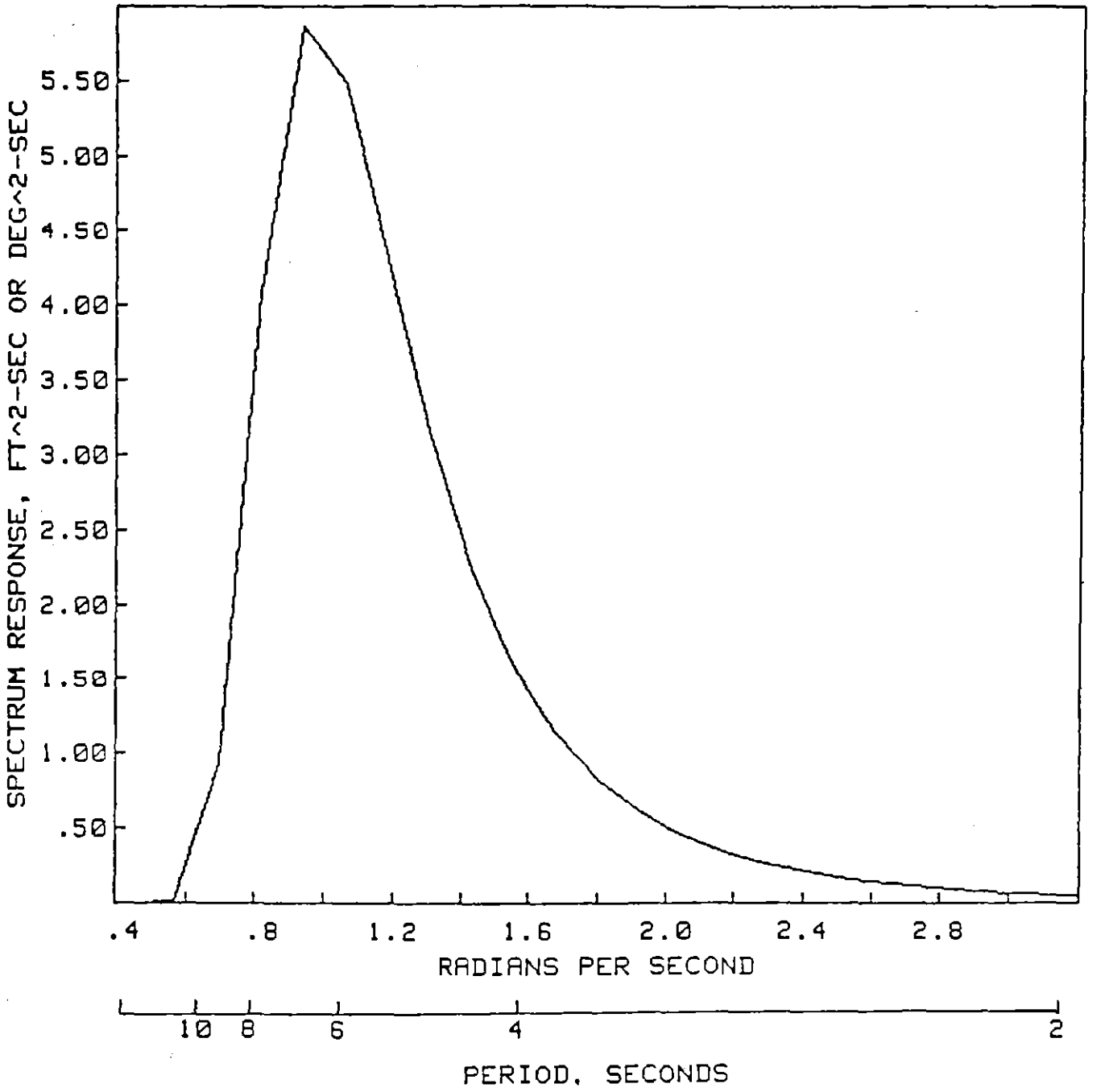

FIGURE 3

SEA SPECTRUM FOR 8-FOOT SIGNIFICANT SEAS

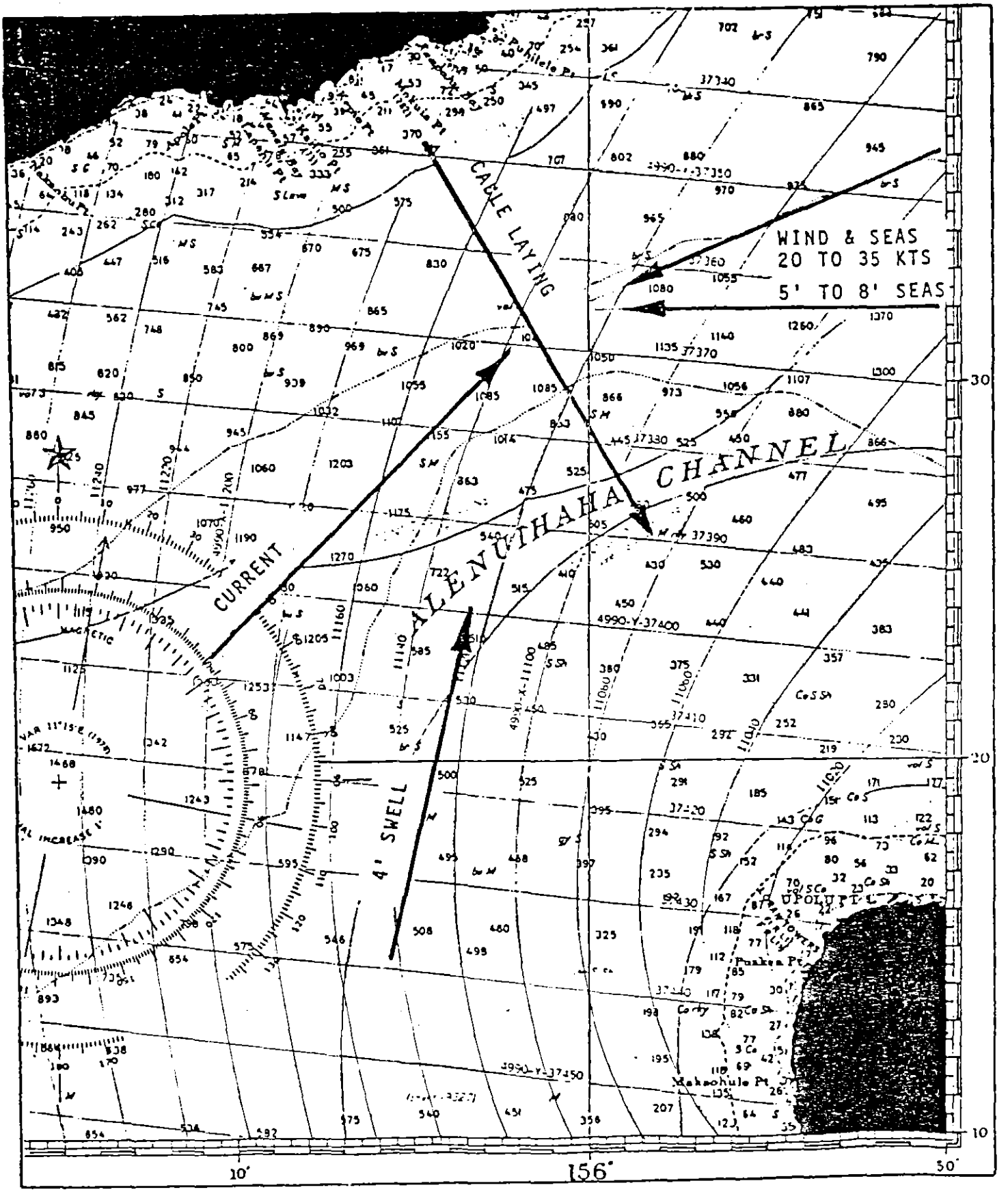

FIGURE 4

MAP OF ALENUIHAHA CHANNEL SHOWING PROSPECTIVE CABLE PATH AND DIRECTION OF ENVIRONMENTAL FORCES

5.3 RELIABILITY AND AVAILABILITY CRITERIA (continued)

The CVSS shall be designed such that a breakdown or component failure shall cause no damage to the cable or injury to any person during installation, operation, maintenance or repair. In particular, the system shall be designed to fail-safe with regard to the vessel, cable, and all personnel.

The CVSS shall be available for repair operations within a minimum practical mobilization time throughout the 40-year life of the commercial cable system. A preliminary requirment for this minimum time period is 30 days. Worst-case CVSS failure shall require suspension of operations for a period not to exceed 15 days (preliminary requirement) unless catastrophic damage to hull, propulsion or other critical safety-related components.

5.4 REPAIRABILITY AND MAINTAINABILITY CRITERIA

The CVSS and all associated hardware components shall be repairable or replaceable except for catastrophic occurrences. Minor breakdowns during laying/retrieval operations (i.e., 5 percent occurrence probability for 12-hour period) must be repairable within 2 hours. Major breakdowns during laying/-retrieval operations (i.e., 3 percent occurrence probability for 3-day period) shall be repairable and/or components shall be replaceable within 5 days, either at a local Hawaiian facility or at sea.

The CVSS shall be maintained during the life of the cable system so that all systems are operational and available within a 30-day period (preliminary estimate) for cable repair.

5.5 DESIGN AND MANUFACTURE CRITERIA

All CVSS component designs and selected materials shall be available and proven to the greatest extent possible. New designs shall be fully laboratory and field tested to the maximum extent practical.

All CVSS component designs shall be manufacturable and/or available to meet the scheduling demands of installation and repair operations over the 40-year system design life.

5.6 PERSONNEL AND SUPPORT EQUIPMENT CRITERIA

Personnel and support equipment with the necessary capabilities to operate, maintain, and repair all CVSS system components shall be available as required in Sections 5.3 and 5.4.

All personnel involved with operation, maintenance and repair of CVSS components shall be throughly trained and provided appropriate state-of-the-art tools and equipment.

5.7 LEGAL AND INSTITUTIONAL CRITERIA

CVSS design and operation shall conform to all applicable legal requirements and shall meet all applicable safety code requirements for operation, maintenance and repair.

The impacts of the CVSS on the environment, if any, during operation, maintenance and repair shall meet all federal, state, and local environmental protection regulations.

5.8 ECONOMIC CRITERIA

CVSS cost shall be minimized to the extent that the total system capital and operational costs are minimized, while satisfying all technical feasibility criteria. Life cycle costing shall be used with appropriate discounting of operational versus capital cost items.

The CVSS capital and operational costs shall be low enough and appropriately proportioned such that the commercial system is financially viable.

The CVSS technical risk shall be of an acceptable magnitude to secure the financing required for system implementation and operation.

5.9 INTERFACE CRITERIA

All CVSS components shall be designed, modified, procured and/or installed in such a manner as to be compatible with each other, with other subsystems and with the environment.

The CVSS interfaces are identified by the N^2 chart in Figure 5. The nature of the interfaces are described in Table 6 according to the following categories:

- static and dynamic loading
- hydrodynamic loading
- space and structural support
- thermodynamics and heat transfer
- mechanical connection
- sensor data
- control signal

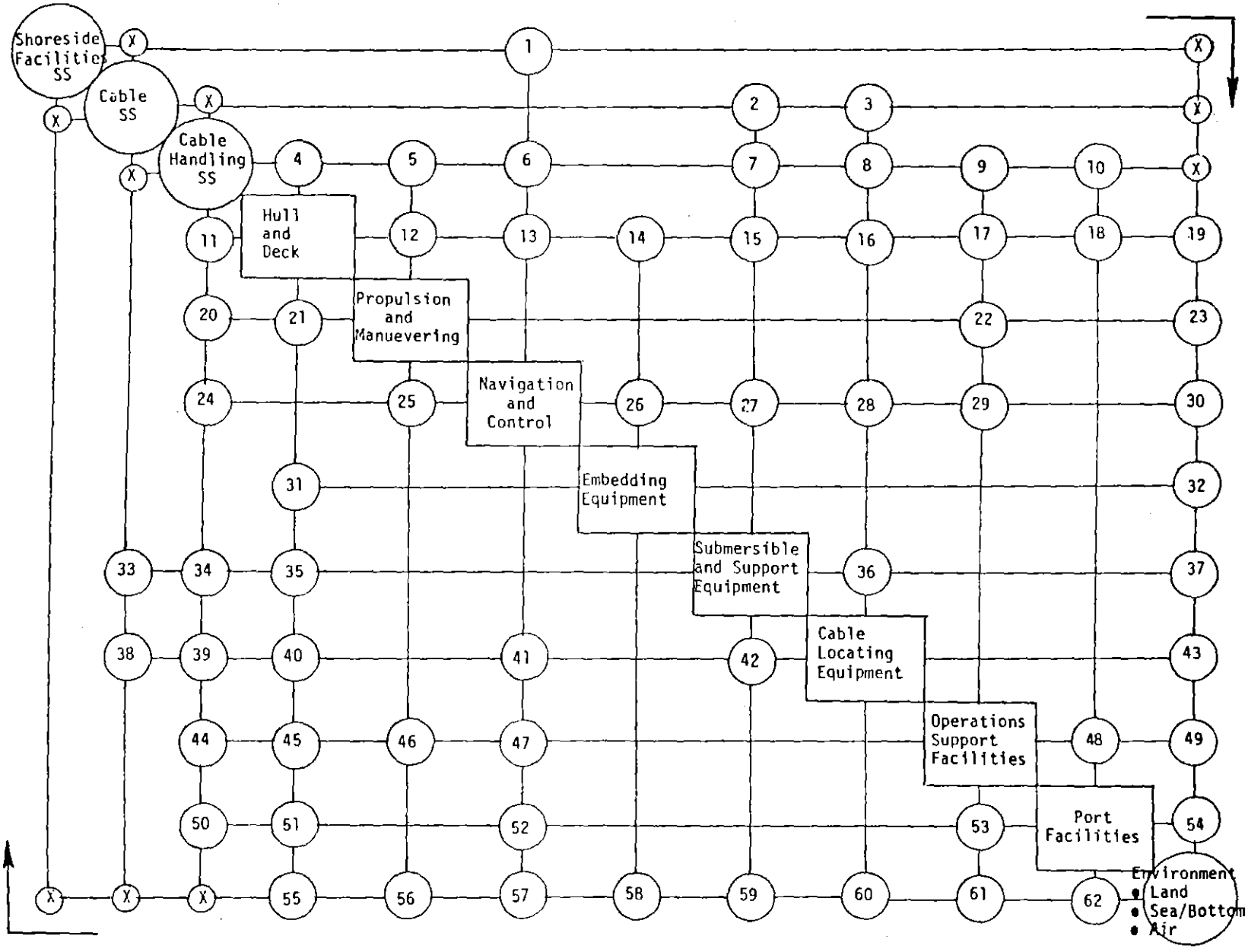

FIGURE 5.

CVSS N^2 INTERFACE DEFINITION DIAGRAM

5.9 INTERFACE CRITERIA (continued)

- o physical contact and/or reconfiguration
- o pollutants
- o electrical connection
- o water/fuel flow

The classifications in Table 5 are preliminary and will be resolved and quantified as the component designs are resolved.

6.0 VERIFICATION OF CVSS FEASIBILITY CRITERIA

The CVSS feasibility criteria will be verified during the HDWC Program. Verficiation procedures are listed in Table 6 for each of the criteria. Verification will result from the at-sea tests which, for the CVSS, involves a cable lay vessel capable of transporting, laying and retrieving a surrogate test cable which meets the minimum at-sea test requirements (Summary of HDWC Program Minimum At-Sea Test Requirements, August 1985); extrapolation of the at-sea test results to the full-scale commercial CVSS; and HDWC design studies of the commercial system and analyses of other systems performing related functions will provide further verification.

TABLE 5

CVSS INTERFACE DESCRIPTIONS

Interfaces	Static/Dynamic Loading	Hydro Loading	Space and Structural Support	Thermo/Heat Transfer	Mechanical Connection	Physical Contact/Reconfig.	Electrical Connection	Water/Fuel Flow	Sensor Data	Control Signal	Pollutants
(1) SF/SS - Navigation and Control									X		
(2) C/SS - Submersible and Support Equipment	X										
(3) - Cable Locating Equipment						X			X		
(4) CH/SS - Hull and Deck	X			X	X	X					
(5) - Propulsion and Manuevering										X	
(6) - Navigation and Control										X	
(7) - Submersible and Support Equipment										X	
(8) - Cable Locating Equipment										X	
(9) - Operational Support Facility							X				
(10) - Port Facilities	X					X					
(11) Hull and Deck - CH/SS	X		X		X	X					
(12) - Propulsion and Manuevering	X		X		X	X					
(13) - Navigation and Control	X		X		X	X					
(14) - Embedding Equipment	X		X			X					
(15) - Submersible and Support Equipment	X		X			X					
(16) - Cable Locating Equipment	X		X			X					
(17) - Operational Support Facility	X		X		X	X					
(18) - Port Facilities	X				X	X					
(19) - Environment						X					X
(20) Propulsion and Maneuvering - CH/SS									X		
(21) - Hull and Deck	X			X	X	X					
(22) - Operational Support Facility							X				
(23) - Environment				X		X					X
(24) Navigation and Control - CH/SS									X		
(25) - Propulsion and Manuevering									X		
(26) - Embedding Equipment									X		
(27) - Submersible Support Equipment									X		
(28) - Cable Location Equipment									X		
(29) - Operational Support Facility							X				
(30) - Environment						X					

TABLE 5 (Continued)

Interfaces	Static/Dynamic Loading	Hydro Loading	Space and Structural Suppor	Thermo/Heat Transfer	Mechanical Connection	Physical Contact/Reconfig.	Electrical Connection	Water/Fuel Flow	Sensor Data	Control Signal	Pollutants
1) Embedding Equipment - Hull and Deck	X					X					
32) - Environment						X					X
3) Submersible and Support Equipment - C/SS	X				X	X					
34) - CH/SS									X		
5) - Hull and Deck	X					X					
36) - Cable	X				X	X	X			X	
7) - Environment						X					X
38) Cable Location Equipment - C/SS					X	X					
39) - CH/SS									X		
0) - Hull and Deck	X					X					
41) - Navigation and Control									X		
2) - Submersible and Support Equipment			X			X	X		X		
43) - Environment						X					X
4) Operational Support Facility - CH/SS							X				
45) - Hull and Deck	X			X	X	X					
6) - Propulsion and Maneuvering							X				
47) - Navigation and Control							X				
48) - Port Facilities	X				X	X	X	X			X
9) - Environment											X
50) Port Facilities - CH/SS			X			X					
1) - Hull and Deck	X		X		X	X					
52) - Navigation and Control										X	
3) - Operational Support Facility					X	X	X	X			
54) - Environment						X					X
55) Environment - Hull and Deck		X				X					
56) - Propulsion and Manuevering		X		X		X					
57) - Navigation and Control		X				X					
58) - Embedding Equipment		X				X					
59) - Submersible and Support Equipment		X				X					
60) - Cable Location Equipment		X				X					
61) - Operational Support Facility		X				X					
62) - Port Facilities		X				X					

TABLE 6

CVSS VERIFICATION PROCEDURES

Feasibility Criteria	HDWC At-Sea Test Program	Baseline Commercial System Design Studies	Other Data and/or Special Analysis
A. Functional Performance Criteria			
1.1 Adequate deck space and structurally designed for cable and cable handling equipment		O layout and design of all commercial system hardware O validate vessel/cable dynamics model and perform simulations of commercial system	
1.2 Facility for cable splice/ repair-environmentally controlled room/building		Layout and design of all repair facilities and equipment	
1.3 Accommodations for at-sea personnel		Layout and design of habitability spaces	
1.4 Spaces for submersible and other special hardware		Layout/design studies for all other equipment: cable trenching and cable locating equipment	
2.1 East Coast to Honolulu transport (typical) for outfitting of CVSS and/or CHSS hardware	Transport requirement not yet defined for CVSS	Tradeoff studies of cost/additional design requirements for transport function	
2.2 Local port(s) to serve as mobilization/demobilization site and deployment/retrieval staging	Selection and use of available port facility requiring all major accommodations	Additional requirements evaluated for cable system operations, including maintenance and repair	

TABLE 6 (continued)

Feasibility Criteria	HDWC At-Sea Test Program	Baseline Commercial System Design Studies	Other Data and/or Special Analysis
A. Functional Performance Criteria (continued)			
3.1 Transit to/from site in adequate time for cable operations	Transit to/from actual site with hardware and personnel	Dynamic studies of commercial system with validated vessel/cable model	
3.2 Provide stable vessel configuration with and without cable for transit	O Dynamic performance of test vessel in same environment O Extrapolation of results to full-scale commercial vessel	Dynamic studies of commercial system with validated vessel/cable model	
4.1 Dredge trench in nearshore zone effected by waves and bury cable			Similar trenching operations performed/ state-of-the-art techniques
4.2 Deploy cable in trench, backfill, and provide with protective cover as required			Similar trenching operations performed/ state-of-the-art techniques
5.1 Lay/retrieve cable at required speeds to allow deployment within weather window	Surrogate cable lay/retrieval test for various sea state conditions - a range of cable vessel speeds and cable payout rates - different minimum bottom tensions - cable laying up-slopes vs. down-slopes	Validation of vessel/cable dynamics model and simulation of other environments/commercial systems	Shallow water cable lay experience from other projects
5.2 Vessel stability adequate for at-sea deployment/retrieval operations	O Surrogate cable lay/retrieval test for various sea state conditions - a range of cable vessel speeds and cable payout rates - different minimum bottom tensions - cable laying up-slopes vs. down-slopes O Extrapolation of results to full-scale commercial vessel	Validation of vessel/cable dynamics model and simulation of other environments/commercial systems	Shallow water cable lay experience from other projects

TABLE 6 (continued)

Feasibility Criteria	HDWC At-Sea Test Program	Baseline Commercial System Design Studies	Other Data and/or Special Analysis
A. Functional Performance Criteria (continued)			
5.3 Maintain predetermined bottom path for deployment and retrieval	Surrogate cable lay/retrieval test for various sea state conditions - a range of cable vessel speeds and cable payout rates - different minimum bottom tensions - cable laying up-slopes vs. down-slopes	Validation of vessel/cable dynamics model and simulation of other environments/commercial systems	Shallow water cable lay experience from other projects
5.4 Maintain bottom tension on cable during deployment	Surrogate cable lay/retrieval test for various sea state conditions - a range of cable vessel speeds and cable payout rates - different minimum bottom tensions - cable laying up slopes vs. down-slopes	Validation of vessel/cable dynamics model and simulation of other environments/commercial systems	Shallow water cable lay experience from other projects
6.1 Maintain vessel with cable deployed in fixed position and orientation	Test of hold procedure	Validation of vessel/cable dynamics model and simulation of other environments/commercial systems	Shallow water cable-hold experience from other projects
6.2 Vessel stability adequate for at-sea station hold	Test of hold procedure	Validation of vessel/cable dynamics model and simulation of other environments/commercial systems	Shallow water cable-hold experience from other projects
7.1 Detect bottom cable position		Analysis of requirements, tradeoff studies and design of feasible system and operational procedures	Application of current state-of-the-art techniques
8.1 Attach recover line to cable (?)		Analysis of requirements, tradeoff studies and design of feasible system and operational procedures	TBD

TABLE 6 (continued)

Feasibility Criteria	HDWC At-Sea Test Program	Baseline Commercial System Design Studies	Other Data and/or Special Analysis
A. Functional Performance Criteria (continued)			
8.2 Bring cable to surface (?)		Analysis of requirements, trade-off studies and design of feasible system and operational procedures	TBD
9.1 Perform special maneuver for cable re-deployment (?)	Surrogate cable retrieval operations performed along steepest slope	Analysis of alternative maneuvers and cost/feasibility tradeoffs for associated hardware	
B. Environmental Criteria	Evaluate environmental impact	Tradeoff studies of route alternatives	Literature review of environmental data; route surveys; in situ measurement program
C. Reliability and Availability Criteria	At-sea experience to project/highlight potential problems and mitigation measures	Critical components failure analysis and operational planning studies	Review and evaluation of applicable vessel reliability data for similar cable laying/repair operations
D. Repairability and Maintainability Criteria	At-sea experience to project/highlight potential problems and mitigation measures	Development of repair and maintenance procedures based on cost tradeoffs	Review and evaluation of applicable vessel repair/maintenance procedures
E. Design and Manufacturing Criteria			Review and evaluation of other potential vessel hardware availability and performance capabilities

TABLE 6 (continued)

Feasibility Criteria	HDWC At-Sea Test Program	Baseline Commercial System Design Studies	Other Data and/or Special Analysis
F. Personnel and Support Equipment Criteria	At-sea experience with similar personnel contingent and support equipment	Evaluation and definition of personnel training program and support equipment requirements	Review and evaluation of other applicable personnel training programs and support equipment availability
G. Legal and Institutional Criteria	At-sea experience to highlight potential safety and environmental impact problems	Safety studies of component failures and operational procedures	Review and evaluation of all applicable safety regulations and licensing/ permitting requirements; analyses of environmental impacts and definitions of mitigation measures
H. Economic Criteria	Costs for vessel and operation, and cost extrapolation to the full-scale commercial process	Develop cost model of vessel hardware alternatives and associated performance features for realibility analyses of failure, repair scenarios and associated costs for input to system level tradeoffs	Collection of applicable cost data for similar vessel and equipment operations
I. Interface Criteria	Operational analysis of test results to define problems and potential mitigation	Interface analyses and specifications development	