A Functional Description of the Remote Unmanned Work System (RUWS)

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A FUNCTIONAL DESCRIPTION OF THE REMOTE UNMANNED WORK SYSTEM (RUWS)

REPORT NO. 155-3

PREPARED FOR:

CODE 65301
OCEAN SYSTEMS DIVISION
OCEAN TECHNOLOGY DEPARTMENT
NAVAL UNDERSEA CENTER
HAWAII LABORATORY

OCTOBER 1972

INTEGRATED SCIENCES CORPORATION
Santa Monica, California

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ABSTRACT

This report presents a functional description of the Remote Unmanned Work System (RUWS) in its current state of development. A system functional overview along with descriptions of the major subsystems and man/machine interfaces is included.

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

ACR	Acoustic Command and Release
ALD	Auxiliary Lift Device
ARS	Auxiliary Rescue Ship
DOT	Deep Ocean Transponder
HCTV	Head Coupled Television
HVPS	High Voltage Power Supply
I/O	Input/Output
LRTS	Long Range Tracking System
MCB	Motion Compensation Boom
NNSS	Navy Navigation Satellite System
NUC	Naval Undersea Center
PCT	Primary Cable Termination
PPS	Power Processing System
RCTS	RUWS Cable Telemetry System
RUWS	Remote Unmanned Work System
SPPS	Signal and Power Processing System
TDM	Time Division Multiplexer
VSS	Vehicle Search Sonar

LIST OF FIGURES

LIST OF TABLES

TABLE OF SOURCE MATERIAL

PREFACE

This report attempts a description of the RUWS system while it is being designed and developed by a technical staff of NUC engineers and civilian contractors. As such, it can best be understood as a "still photograph" of a continuing and dynamic sequence of events and decisions which, unfortunately, will date its contents from the moment of publishing.* Nevertheless it does reflect the magnitude of effort expended to date by the NUC RUWS development team, and presents in one document a functional description of the system. Its compilation at this time is relevant for two reasons. First, the system has undergone sufficient design trade-off analyses to allow a detailed definition of a system configuration which can be used for subsystem hardware procurement and test planning. Therefore, no major perturbations in the adopted system configuration are expected. Second, this document will serve as a vehicle for communicating the basic functional aspects of the adopted system configuration to the broad spectrum of RUWS technical personnel and contractors working in their individual areas. As such, the report may contribute to the continued cohesion of the program effort.

Most of the material in this report was obtained from various RUWS preliminary subsystem specifications, memoranda, working drawings, etc. which usually form the system documentation during the development phase. These documents are listed in the Bibliography and are keyed to the report sections in the Table of Source Material. Further clarification and updating of source materials was made possible by visits with Mr. Dan Hightower, RUWS Program Manager, and RUWS project personnel at the NUC Hawaii and NUC San Diego Laboratories. Individual conferences were held with the subsystem project engineers. These conferences were valuable to the author's understanding the complex details of the various subsystems. They were doubly valuable in allowing a friendly exchange of ideas. The substance of these ideas are presented under separate cover and will outline the ISC suggestions and recommendations for the RUWS program (Ref. 27). The cooperation received from each of the project team members during a busy work schedule was greatly appreciated.

1.0 INTRODUCTION

This report is a functional description of the Remote Unmanned Work System (RUWS). Under the direction of the Naval Ordnance Systems Command, the responsibility for design, fabrication, and operational testing of RUWS has been assigned to the Naval Undersea Center (NUC). RUWS is an integrated, remotely controlled, air transportable system capable of doing work at ocean depths down to 20,000 feet. The system is designed to be deployed from a surface ship of opportunity. Figure 1-1 shows the system in a deployed configuration.

The RUWS surface components consist of the manned Control and Navigation Vans, power generators and Cable Handling equipment. These are the support and control elements for the submerged components which consist of the Primary Cable Termination (PCT) and the Vehicle. During deployment, the PCT and Vehicle are coupled in a docked configuration and lowered at the end of a single primary cable which is used both as a strength member and as a data/power link. When the PCT and Vehicle reach operating depth, the Vehicle is undocked and is remotely controlled through a secondary cable by which it is tethered to the PCT. The Vehicle can maneuver, perform manipulation tasks, and is equipped with sonar and television.

RUWS is designed to perform a variety of underwater missions such as bottom survey, search, and object recovery. Sufficient flexibility is included in the initial system configuration to allow future expansion of submersible functions through the use of built-in spare communication channels and power capability. The sections that follow describe RUWS on a subsystem functional level.

1.1 SYSTEM REQUIREMENTS

The following have been established as system requirements for RUWS:

- A work capability, suitable for use at 20,000 foot depths, will be provided through remotely-operated manipulators and on-board sensors

- The system will be air transportable

- The system will be capable of operating from a surface ship of opportunity, specifically the wide beam Auxiliary Rescue Ship (ARS)

1.2 SYSTEM DESCRIPTION

This section provides a brief outline of the system components and their functions in satisfying the system requirements. The following are the major shipboard system equipments.

Control Van. The Control Van is located on the deck of the surface ship. It contains the RUWS electrical power distribution panels and the Control Console. On the Control Console are located the controls and displays used to remotely control the submerged elements of the system and monitor their performance.

Navigation Van. The Navigation Van is located on the deck of the surface ship. It contains the equipment to perform data processing, storage, and input/output (I/O) required for both ocean area and precise target area navigation.

Motor Generators. Two identical and interchangeable Motor Generators are used to supply the RUWS electrical and hydraulic power requirements. Both generators are located on the deck of the surface ship.

Motion Compensation Boom. The Motion Compensation Boom (MCB) will be located near the side of the surface ship. It contains a built-in traction winch and has an articulated boom to facilitate reach adjustments. It can be placed in either a stiff-boom mode to facilitate near-surface and on-board handling of the PCT and Vehicle units, or in a motion-compensation mode to minimize and uncouple the vertical motions of the surface ship from the primary cable and overboard units.

Cable Storage Reel. A level-wind reel is located on the deck of the surface ship and works in conjunction with the Motion Compensation Boom. The reel allows orderly payout and retrieval of approximately 24,000 feet of Primary Cable.

RUWS Surface Ship Transducers. An over-the-side sonar projector and adjacent hydrophone are used for target area support ship positioning with the Long Range Tracking System (LRTS), and operation of the RUWS Emergency System.

RUWS Antennas. RF antennas are provided for locating surfaced equipment under emergency conditions using Automatic Direction Finding equipment, and satellite navigation for precise target area location of the surface ship.

Shop and Equipment Vans. The use of additional vans for equipment storage and maintenance/repair shop facilities is being studied. Their inclusion in the RUWS hardware complement is not yet firm.

Vehicle and PCT Handling Dollies. Mobile dollies are provided to allow convenient movement of the PCT and Vehicle on the deck as required for check-out, repair, operational positioning, etc. These dollies will be provided with suitable tie-downs to prevent unintentional movement.

Other RUWS surface ship equipments include an intercom system connecting all manned RUWS stations and a bridge display system. The bridge display is used for transmitting ship maneuver data to the ship's helm during the underwater phase of the mission. Precise target area positioning of the surface ship and submerged elements requires deployment of three Deep Ocean Transponders (DOT). These transponders are placed on the ocean floor at the vertices of a triangle having nominal two-mile base legs and centered on the expected target location. Ranges measured from the tracked vehicles to these transponders are input to the LRTS.

Submerged elements include the Vehicle and the PCT. The PCT serves as the dock for the remotely operated Vehicle during deployment and recovery. Each is equipped with a transponder interrogator/receiver to allow positioning by the LRTS. The PCT is also used for storage of additional transponders and the Auxiliary Lift Device (ALD). In addition to a sonar altimeter and its own propulsion system, the PCT contains a major portion of the electronics for the Signal/Power Processing System. Finally, the PCT contains the Vehicle tether storage reel and winch which pays out and retrieves approximately 850 feet of cable forming the tether and power/data link between the PCT and Vehicle. In the event of docking difficulties, the Vehicle tether also acts as the strength member allowing the PCT and Vehicle to be recovered in the undocked configuration.

The Vehicle is the primary work and sensor system of RUWS. In addition to its own sonar altimeter and propulsion system, the Vehicle contains the electronics and power convertors to operate the work and sensor systems. The work system consists of the manipulator-grabber, drill, cable cutter, and visual sensors. The visual sensor package is made up of the Head Coupled Television (HCTV) and the still camera. Also located on the Vehicle are the Acoustic Command and Release (ACR) receiver and electronics, and the Vehicle Search Sonar (VSS).

1.3 SYSTEM OPERATION

This section contains a brief discussion of RUWS operation. A more detailed presentation of system operation is found in Ref. 26. The system is controlled and monitored from three major man/machine interfaces. These are located in the Control Van, Navigation Van, and on the Deck Handling equipment. Preliminary estimates indicate that a crew of seven is required for RUWS deployment from the surface ship. The actual size of the RUWS crew will depend on the amount of cross-training available and the length of the underwater mission. The seven-man crew consists of one man in the Navigation Van, one man operating the Motion Compensation

Boom, two men handling cable and operating the deck equipment, and three men in the Control Van. The Control Van crew consists of the Vehicle pilot, the PCT pilot, and the Mission Coordinator/Commander.

The operation of the RUWS equipments during a typical shipboard mission phase may be discussed in terms of four phases:

1. Transit to target area tasks

2. Pre-deployment tasks

3. In-water tasks

4. Post-deployment tasks

During the first phase, system operation will consist primarily of surface ship navigation via satellite navigation (NNSS) or Loran C, and system setup and preliminary checkout tasks. In this phase the Navigation and Control Vans will be set up and checked out. The deck equipment will also be exercised and the PCT and vehicle will be unpacked and prepared for pre-deployment checkout and assembly.

The pre-deployment tasks are performed after the ship arrives in the target vicinity. These tasks include deployment of the LRTS deep ocean transponders, on-deck assembly of the Vehicle and PCT, and running the system pre-deployment checks. The phase concludes with the system ready for the underwater mission phase and the support ship having taken station above the expected target location.

The in-water tasks begin after the PCT and Vehicle, in a docked configuration, have been lowered over the side into the water. During the descent phase, a number of PCT and Vehicle functions will be checked. The descent is stopped at the operational depth and the Vehicle is undocked from the PCT (Figure 1-2). The undocking is remotely controlled from the Control Console and is completed when the Vehicle is physically separated from the PCT. At this time the only connection between them is the Vehicle tether used for data and power transmission. After undocking, the search and maneuver tasks will be performed. The search and maneuver tasks may require simultaneous control of both PCT and Vehicle. As a minimum these tasks will require maneuvering of the Vehicle while scanning the bottom for the target with the VSS. The design of the Control Console allows one operator to "fly" the Vehicle while the other operates the VSS. When the target is found, the Vehicle will approach it and use elements of the Work System to perform the primary work of RUWS. The Work System is remotely controlled by the Vehicle pilot and includes a manipulator and grabber which are visible through the HCTV.

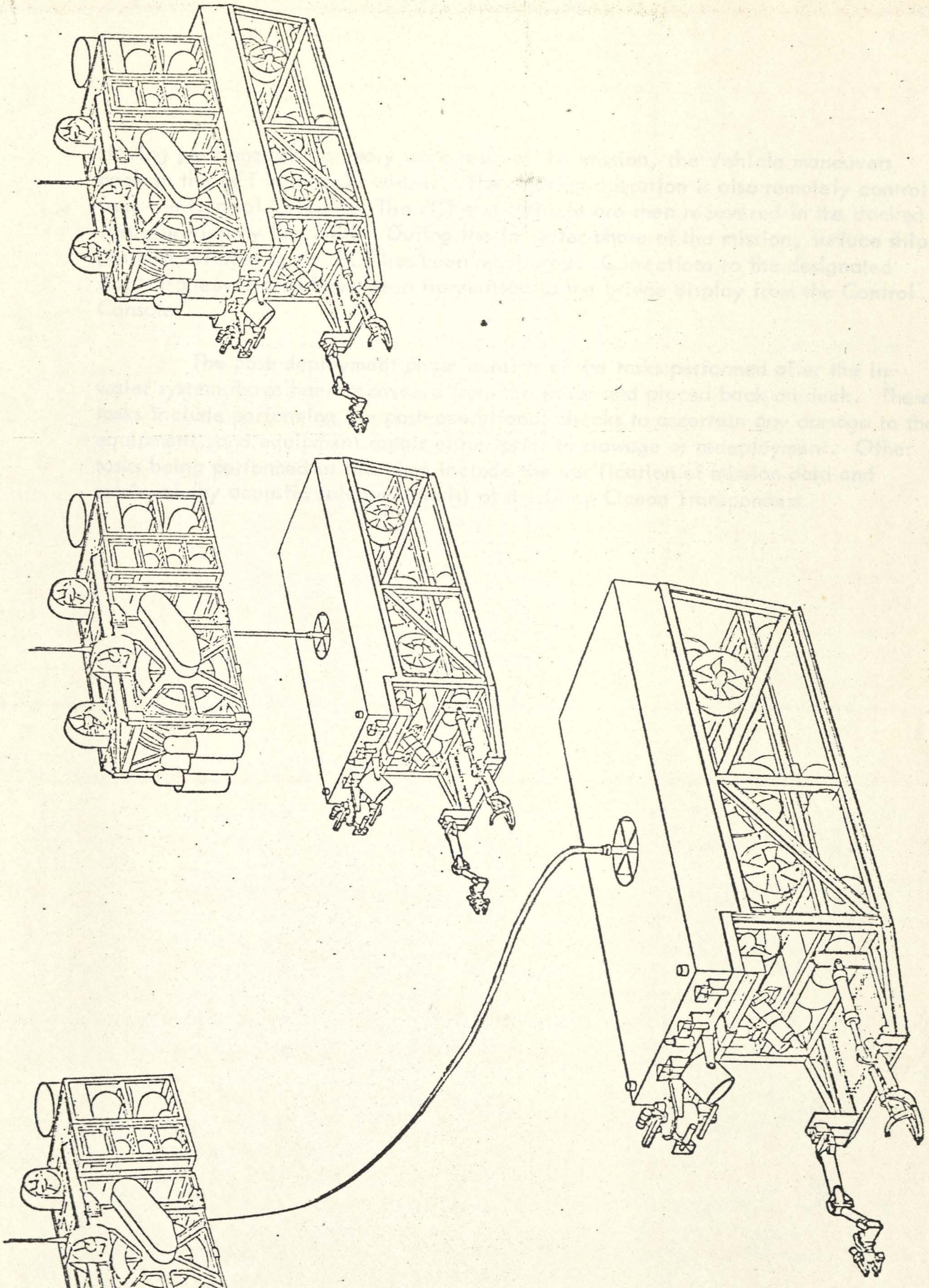


Figure 1-2. Deployment Sequence.

Having performed the primary work tasks of the mission, the Vehicle maneuvers back to the PCT and docks with it. The docking operation is also remotely controlled from the Control Console. The PCT and Vehicle are then recovered in the docked configuration by the MCB. During the in-water phase of the mission, surface ship position relative to the PCT has been monitored. Corrections to the designated ship's maneuver area have been transmitted to the bridge display from the Control Console.

The post-deployment phase consists of the tasks performed after the in-water systems have been recovered from the water and placed back on deck. These tasks include performing the post-operational checks to ascertain any damage to the equipment, and equipment repair either prior to stowage or redeployment. Other tasks being performed at this time include the verification of mission data and retrieval (by acoustic release signals) of the Deep Ocean Transponders.

2.0 RUWS TECHNICAL DESCRIPTION

This section presents a description of the overall system. The description will consist of a system functional overview, discussion of the major subsystems, descriptions of RUWS man/machine interfaces, and statement of RUWS support ship requirements.

The system functional overview will cover the basic capabilities of the system components and describe the system information flow and the data interfaces. The major subsystems of RUWS are defined along functional lines and are seen to be physically distributed throughout the deck and subsurface equipments. RUWS man/machine interfaces will be described for the Control and Navigation Vans, the Cable Handling equipment, and the Ship's bridge displays. Support ship requirements will be discussed in terms of the required characteristics of the ship of opportunity as related to its physical dimensions and maneuverability.

By design and functional necessity it is required that RUWS be a totally integrated system. Because it will be the first 20,000 foot underwater work system, it will be used for various projects which are designed to test a broad spectrum of advanced deep ocean technologies. For this reason, RUWS has been designed to allow expansion of intrasystem communications required by future system capabilities, and the ability, if required, to provide additional power at operating depth.

2.1 SYSTEM FUNCTIONAL OVERVIEW

This section describes the functions of each of the elements of the system. Figure 2-1 depicts the RUWS functional diagram and the major hardware interfaces.

The Control Console is located in the Control Van. The Vehicle and PCT are controlled, monitored, and powered from additional equipment in the Control Van consisting of the high voltage power supplies, surface shipboard power distribution panels, a teleprinter for communication with the RUWS computer, and a graphic plotter which may be operated either in the Navigation or the Control Van. The hardware to perform broad ocean area and target area navigation is located in the Navigation Van. The DRC-44 computer is used for RUWS navigational computations and controlling the processor which drives navigation IMLAC displays located in the Control Van and on the surface ship bridge. The Navigation Van also contains teleprinters for computer I/O. Additional facilities are provided for tape storage of programs and mission data.

The Deck Handling equipments consist of the Primary Cable storage reel and the Motion Compensation Boom (MCB). The storage reel can store 24,000 feet of Primary Cable which is fed to the MCB. The MCB is used for lifting during the

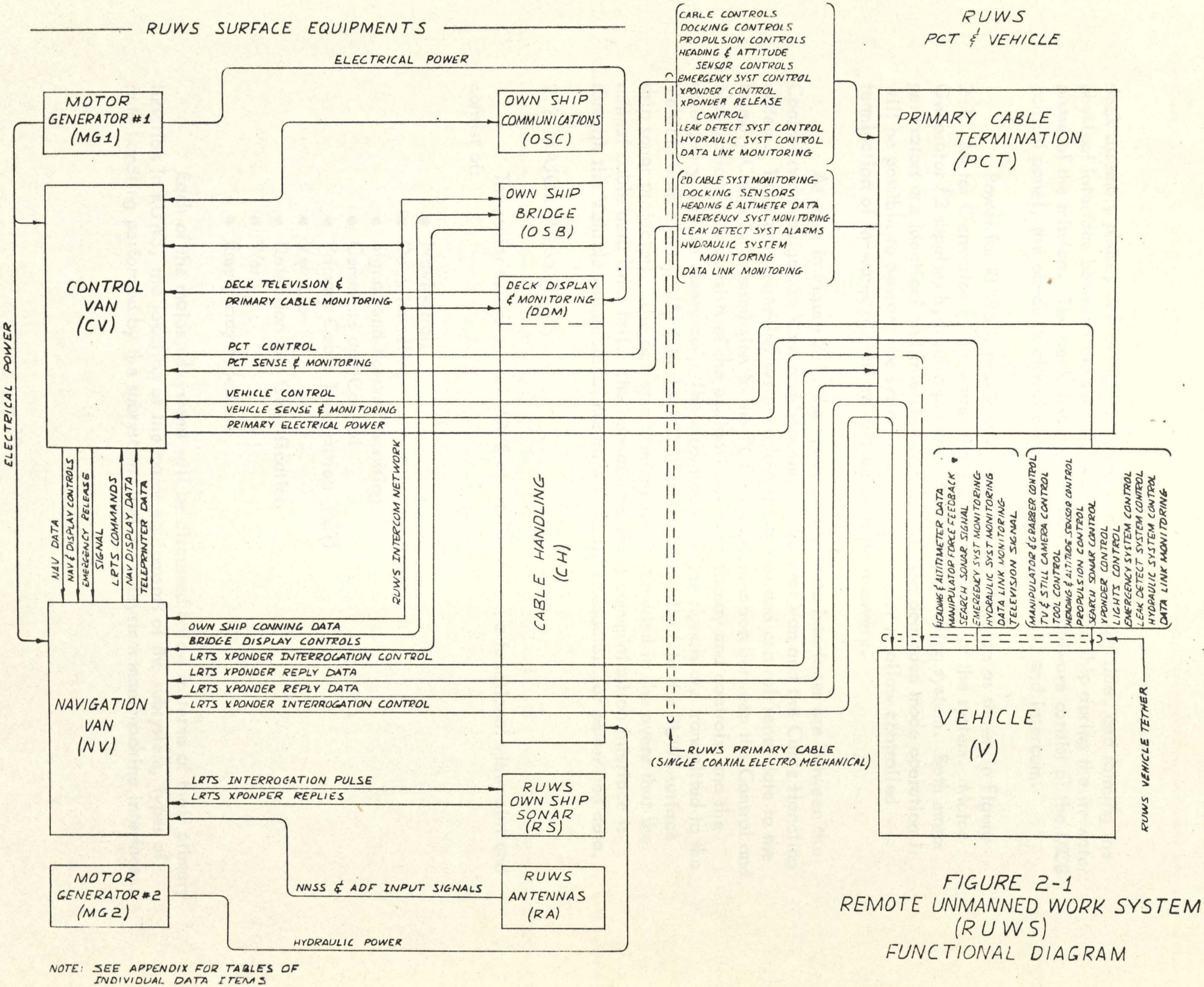


FIGURE 2-1
REMOTE UNMANNED WORK SYSTEM
(RUWS)
FUNCTIONAL DIAGRAM

deck assembly phase, deploying the mated package over the side, and forming the physical interface between the submerged elements and the ship during the in-water phase of the mission. The deck display and monitoring hardware consist of the MCB control panel, the on-deck closed circuit television system, and intercom.

Power for RUWS is provided by two motor generators as shown in Figure 2-1. Motor Generator #1 generates the electrical power for the system. Motor Generator #2 supplies hydraulic power to the Cable Handling system. Both motor generators are identical and interchangeable. During degraded mode operation it will be possible to operate the system from one generator to allow controlled termination of in-water operations and submersible recovery.

As seen in Figure 2-1, the major surface data interfaces are between the Control and Navigation Vans and between the Control Van and the Cable Handling system. The Cable Handling system relays the power and control/sense data to the Primary Cable for transmission to the PCT. Communication between the Control and Navigation Vans consists of the navigational data display and controls, and the emergency release commands. The emergency release signals are transmitted to the Vehicle both electrically (via the RCTS) and acoustically (via the RUWS surface ship sonar projector). The acoustic transmission is provided in the event that the normal cable data links fail. The normal subsurface communication interface is through the Vehicle tether which contains separate conductors for power and data.

2.2 MAJOR SUBSYSTEMS

The major subsystems of RUWS are defined from a functional viewpoint and consist of:

- Navigation
- Deck Handling
- Signal and Power Processing
- Command and Control
- Primary Cable Termination (PCT)
- Vehicle
- Detection and Classification
- Work
- Emergency Release

Each of the major subsystems will be discussed below in terms of their primary function in RUWS, the location of the major equipments of the subsystem, types of data handling performed by the subsystem, and the subsystem man/machine interfaces.

2.2.1 Navigation

The Navigation subsystem consists of individual equipments distributed throughout RUWS with the primary Navigation subsystem control performed from the Navigation Van. The Navigation man/machine interfaces are described in Section 2.3.2. Figure 2-2 contains the RUWS Navigation subsystem block diagram which depicts the location and functional relation of the major hardware components. The tracking capability of the Navigation subsystem is provided by the 3-D Sonar which forms the nucleus of the LRTS. The RUWS surface ship, PCT, and Vehicle are tracked by the LRTS. The primary functions of the subsystem consist of navigational computations, navigation display control, computer I/O, and RUWS ship-mounted sonar control. The Navigation subsystem also performs broad ocean area navigation via the Navigation Satellite System and has the ability to integrate the LRTS coordinates into the geodetic coordinate frame.

The Navigation subsystem provides software subroutines for the navigational satellite (NNSS), LRTS, display control, and system operation. Access to the computer is through the IMLAC CRT displays and three teleprinters -- two located in the Navigation Van and one located in the Control Van. The LRTS hardware consists of a 3-D sonar tracking system using an AN/SQQ-25 sonar which is tied into a DRC-44 computer. Target area navigation is performed by measuring ranges to the three deployed DOT's and computing the common intersection points of the resulting spheres. The intersection points for the three spheres are initially computed from either assumed or postulated positions of the transponders and updated as better data becomes available. The intersection ambiguity is resolved by introducing a fourth intersecting sphere centered on the surface ship, and by input of altimeter readings from the PCT and Vehicle. For surface ship tracking, the LRTS will use the 7 kHz interrogation pulses to the DOT transponders at selectable interrogation pulse repetition intervals. Each DOT will answer using its own characteristic frequency which is known to the signal processing equipments. Range resolution from the ship to each of the DOT's is within 10 feet for all environmental conditions. Range resolution obtained for the PCT and Vehicle is between 2.5 and 5 feet; altimeter resolutions are within 1 foot.

The DRC-44 is a 24 bit general purpose digital computer with a 12,288 word memory. Memory cycle time is 1.0 microsecond. An expanded software capability for the system includes assembler, symbolic editor, loader, I/O control, and on-line debugging. Input/output to the computer is possible through the single multiplex, block transfer, and direct memory access channels. The RUWS DRC-44 software will be written in assembly language.

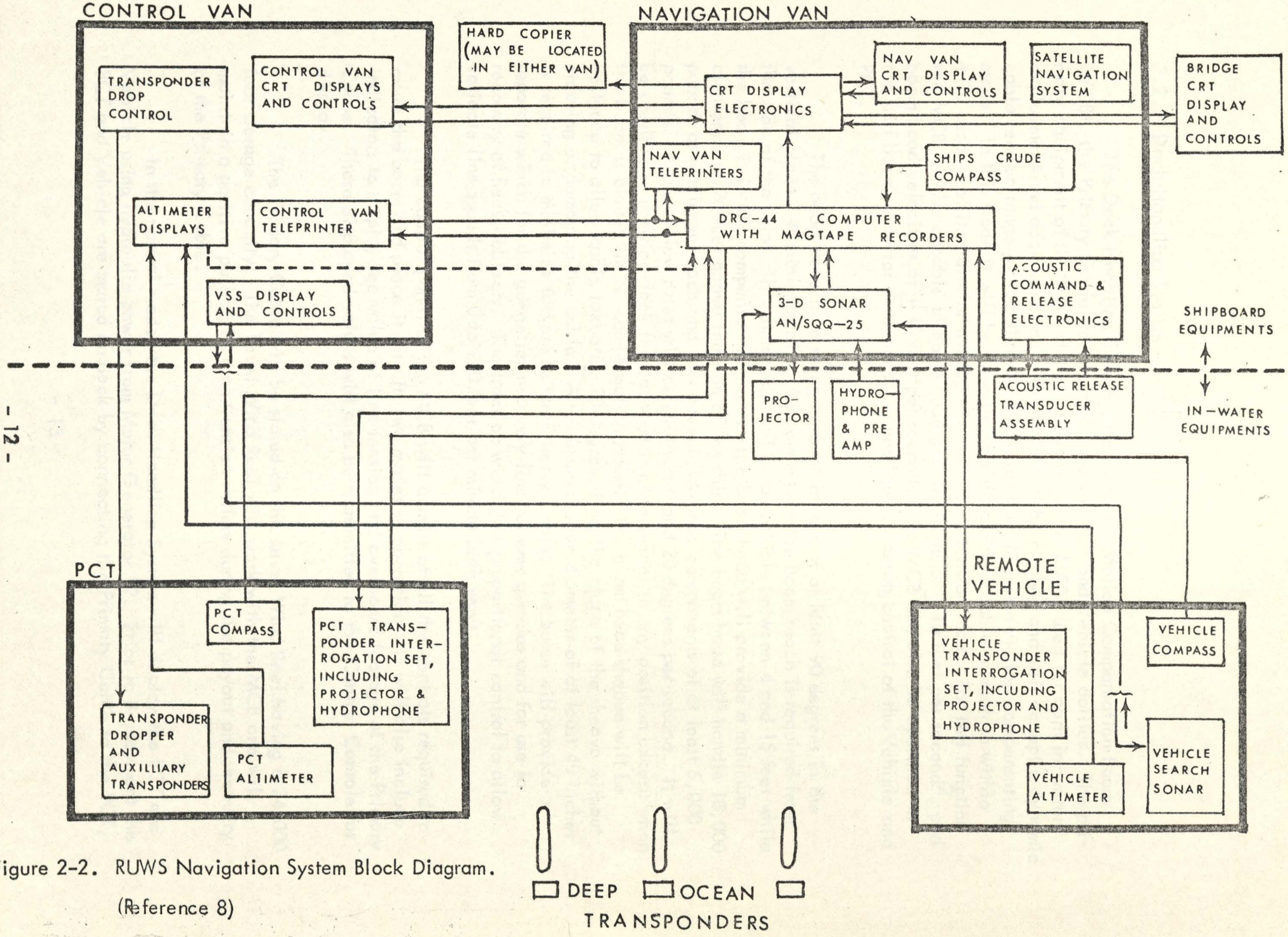


Figure 2-2. RUWS Navigation System Block Diagram.
(Reference 8)

2.2.2 Deck Handling System

The Deck Handling System consists of the Motion Compensation Boom (MCB), the Primary Cable storage reel, and the PCT and Vehicle dollies. The primary equipment of the Deck Handling System is the MCB, used for both in-water deployment and deck handling. The MCB will be manned and will accept a dynamic cable tension range of 1,000 to 15,000 pounds while in the motion compensating mode. In this mode it will be capable of maintaining a cable tension to within ± 10 percent of its static or average instantaneous tension load. For this function the MCB will be capable of boom head accelerations of ± 10 feet per second^2, and boom head velocities of ± 10 feet per second. The MCB can also be operated in the stiff boom mode for deck handling and shallow depth control of the Vehicle and PCT.

The boom head is to swing through an arc of at least 90 degrees in the vertical plane. A minimum of 15 feet over-the-side boom reach is required from the side of the ship. This dimension will be adjustable between 4 and 15 feet while the boom is in the compensation mode. The boom head will provide a minimum clearance of 20 feet above the side of the ship. The boom head will handle 18,000 pounds at maximum reach and will accept side load components of at least 6,000 pounds. Angular slew rates will be between 0 and 20 degrees per second. It will be possible to position-lock the boom (stiff boom mode) in any position except when the boom is placed in the compensation mode. The boom head sheave will be designed to allow cable takeoff ± 20 degrees from the plane of the sheave without creasing or damaging the cable. A minimum sheave diameter of at least 48 inches is required to minimize fatigue to the Primary Cable. The boom will provide a separate winch for the go-getter recovery line for emergencies and for use in recovery of heavy objects. The traction winch has proportional control to allow variable line speeds from 0 to 200 feet per minute both ways.

The control panel of the MCB will consist of all the controls required to move the boom and place it into its two modes of operation. It will also include indicators to display the value of line tension and overboard footage of the Primary Cable. These displayed values will also be transmitted to the Control Console for display.

The Primary Cable will be stored on the Level Wind Reel having a 24,000 foot storage capacity. The Level Wind Reel will work with the MCB and will maintain a positive pull on its drag/tension rollers during the payout and recovery of the Primary Cable.

In the normal mode, the Deck Handling System will deploy the PCT and Vehicle using hydraulic power from Motor Generator #2. Prior to deployment the PCT and Vehicle are mated on deck by connecting the Primary Cable to the PCT, stacking it on top of the Vehicle, and making the Vehicle tether connections. After completion of the pre-operational checks the mated units are lifted over the side. When they reach the (approximate) depth of 100 feet the MCB will be placed in the motion compensating mode. At operational depth it is planned to reduce cable wear around the 48 inch diameter sheave by using a device such as a pneumatic collar which will be placed on the Primary Cable. In this configuration, the collar will be connected to the boom head and will unload the Primary Cable on the storage reel side. This will prevent excessive cable wear in the vicinity of the boom head where the cable is repeatedly payed out and taken up in the motion compensating mode. The deployment of the Vehicle will be controlled and monitored by the Control Van personnel using the RUWS shipboard intercom and deck-mounted CCTV.

2.2.3 Signal and Power Processing System (SPPS)

The SPPS contains the cables and the electronic equipment for transmission of power and data between the Vehicle and the RUWS surface subsystems. Primary power is received from Motor Generator #1 as shown in Figure 2-1. The major elements of the SPPS are the Power Processing System (PPS), the Time Division Multiplexer (TDM), and the RCTS. The TDM contains the electronics to actually perform the interleaving of digital data. The resulting sequence of digital word blocks are then frequency-multiplexed and transmitted by the RCTS. At their destination the multiplexed signals are detected, separated, and demodulated. Power is transmitted one way by the PPS -- from the surface equipments to the PCT and Vehicle. Data is transmitted two ways -- from the bottom units to the surface, and from the surface to the bottom units. Figure 2-3 presents a simplified SPPS block diagram showing the directions of the power and data transmissions along the RUWS cables.

The RCTS also detects the emergency functions: loss of TDM control signals, loss of power when submerged, and presence of salt water leaks in critical pressure-proof enclosures. Detection of any of these malfunctions will cause the RCTS to automatically transmit emergency enable signals to the related emergency equipments. In the event that the TDM is not operable, emergency signals may be acousitcally transmitted through the water. To prevent mis-sensing an emergency condition, transients caused by electric motor start-ups and excessive power line voltage drops are compensated for by power from the momentary power batteries aboard the PCT and Vehicle.

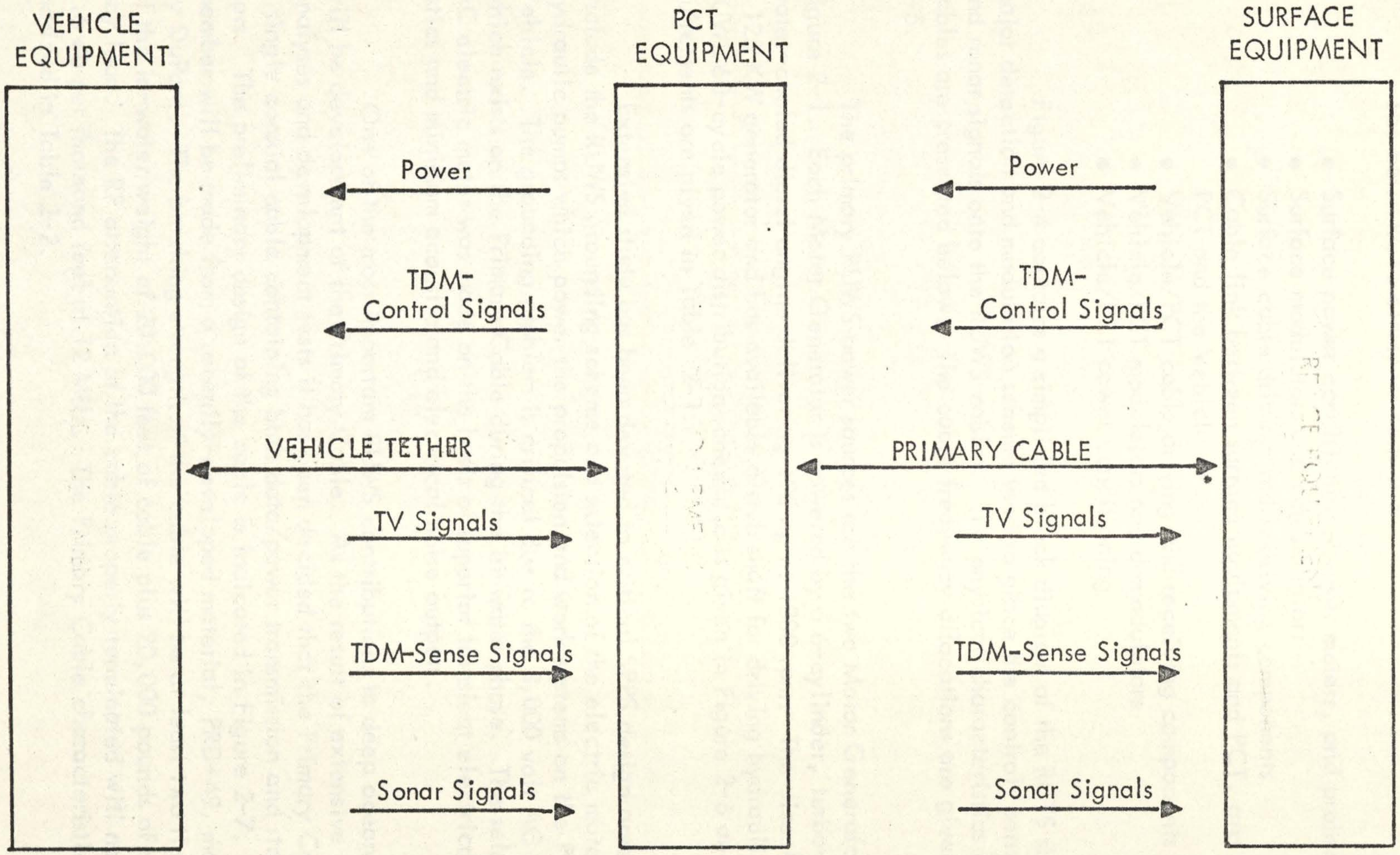


Figure 2-3. Simplified SPPS Block Diagram. (Reference: 15)

The basic RCTS elements consist of:

- Surface power conditioning, power meters, and protective devices
- Surface modulators and demodulators
- Surface cable driving and receiving components
- Cable link between surface equipments and PCT, and between the PCT and the Vehicle
- Vehicle/PCT cable driving and receiving components
- Vehicle/PCT modulators and demodulators
- Vehicle/PCT power conditioning

Figure 2-4 contains a simplified block diagram of the RCTS showing the major detection and modulation scheme used to place the control, sense, television, and sonar signals onto the RUWS cables. The physical characteristics of the the cables are presented below. The cable frequency allocations are given in Figure 2-5.

The primary RUWS power sources are the two Motor Generators shown in Figure 2-1. Each Motor Generator is powered by a 6-cylinder, turbo-charged, water-cooled diesel engine delivering 195 hp at 1800 rpm. The diesel engine drives a 125 KW generator and has available a stub shaft for driving hydraulic pumps. The RUWS 60-cycle power distribution schematic is given in Figure 2-6 and power requirements are given in Table 2-1.

Extensive study has been devoted to critical SPPS design areas. These include the RUWS grounding scheme and selection of the electric motors for driving hydraulic pumps which power the propulsion and work systems on the PCT and Vehicle. The grounding problem is critical due to the 3,000 volt AC potential which exists on the Primary Cable during the in-water phase. The selection of an AC electric motor was made on the basis of superior transient electrical characteristics and minimum acoustic and electrical noise outputs.

One of the most important RUWS contributions to deep ocean technology will be development of the Primary Cable. As the result of extensive trade-off analyses and development tests it has been decided that the Primary Cable will be a single coaxial cable containing both data/power transmission and strength members. The preliminary design of the cable is indicated in Figure 2-7. The strength member will be made from a recently-developed material, PRD-49, manufactured by DuPont. The breaking strength of the cable will be at least two times the sum of the in-water weight of 20,000 feet of cable plus 20,000 pounds of submersible pay load. The RF attenuation of the cable properly terminated will not exceed 2.6 db per thousand feet at 12 MHz. The Primary Cable characteristics are summarized in Table 2-2.

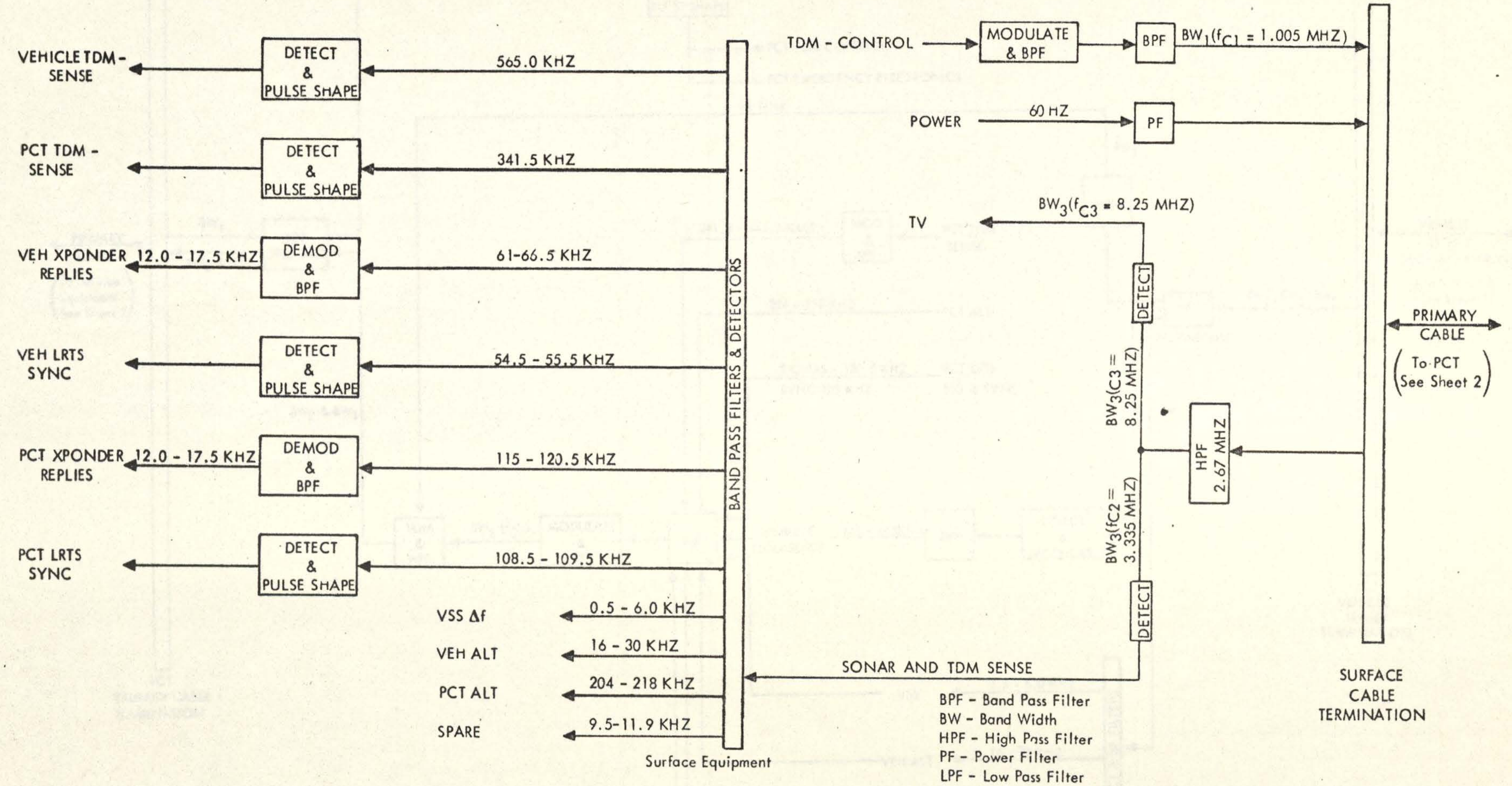


Figure 2-4. Simplified Block Diagram of RCTS. (Sheet 1 of 3)
(Reference: 15)

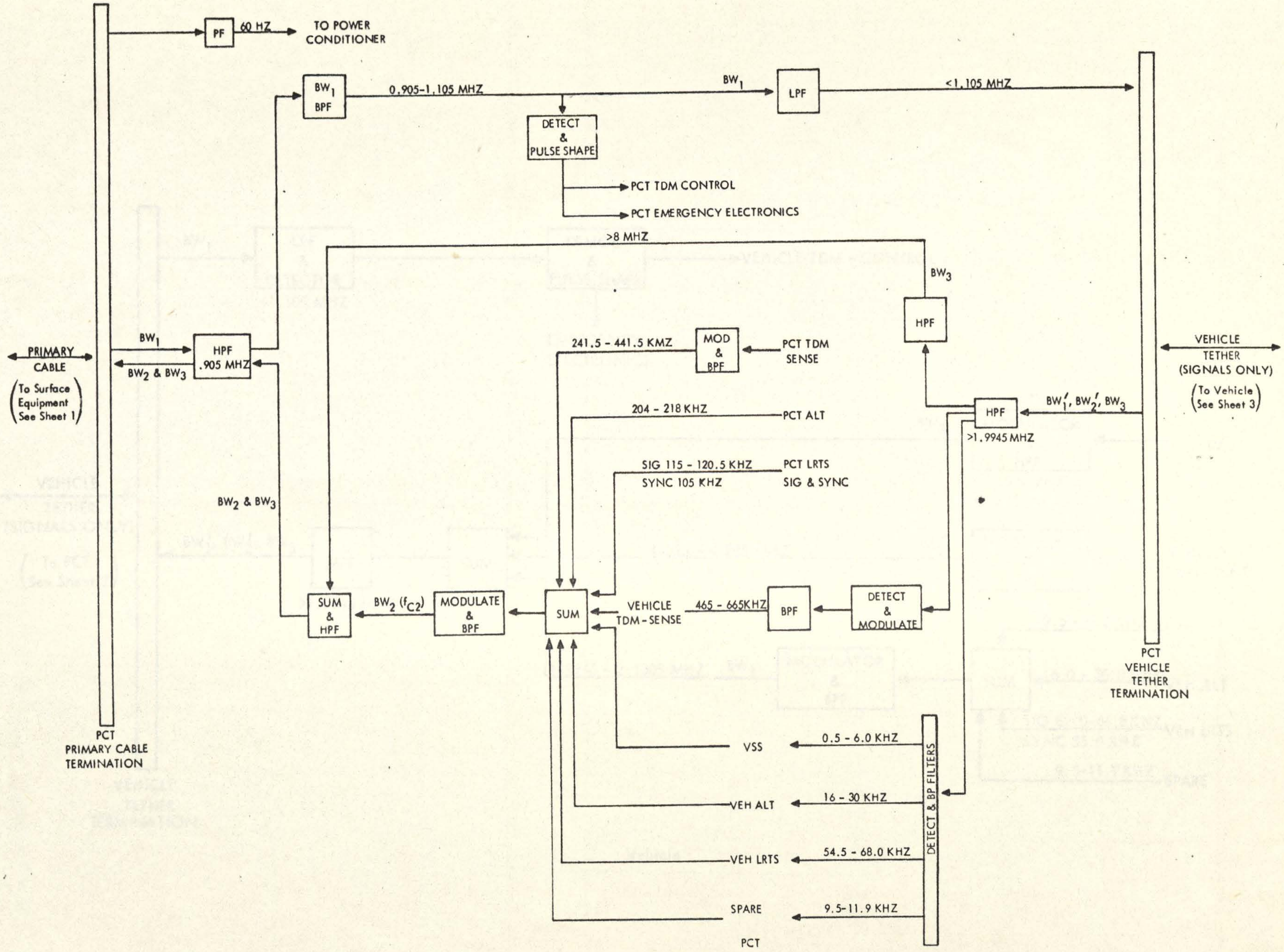


Figure 2-4. Simplified Block Diagram of RCTS. (Sheet 2 of 3)
(Reference: 15)

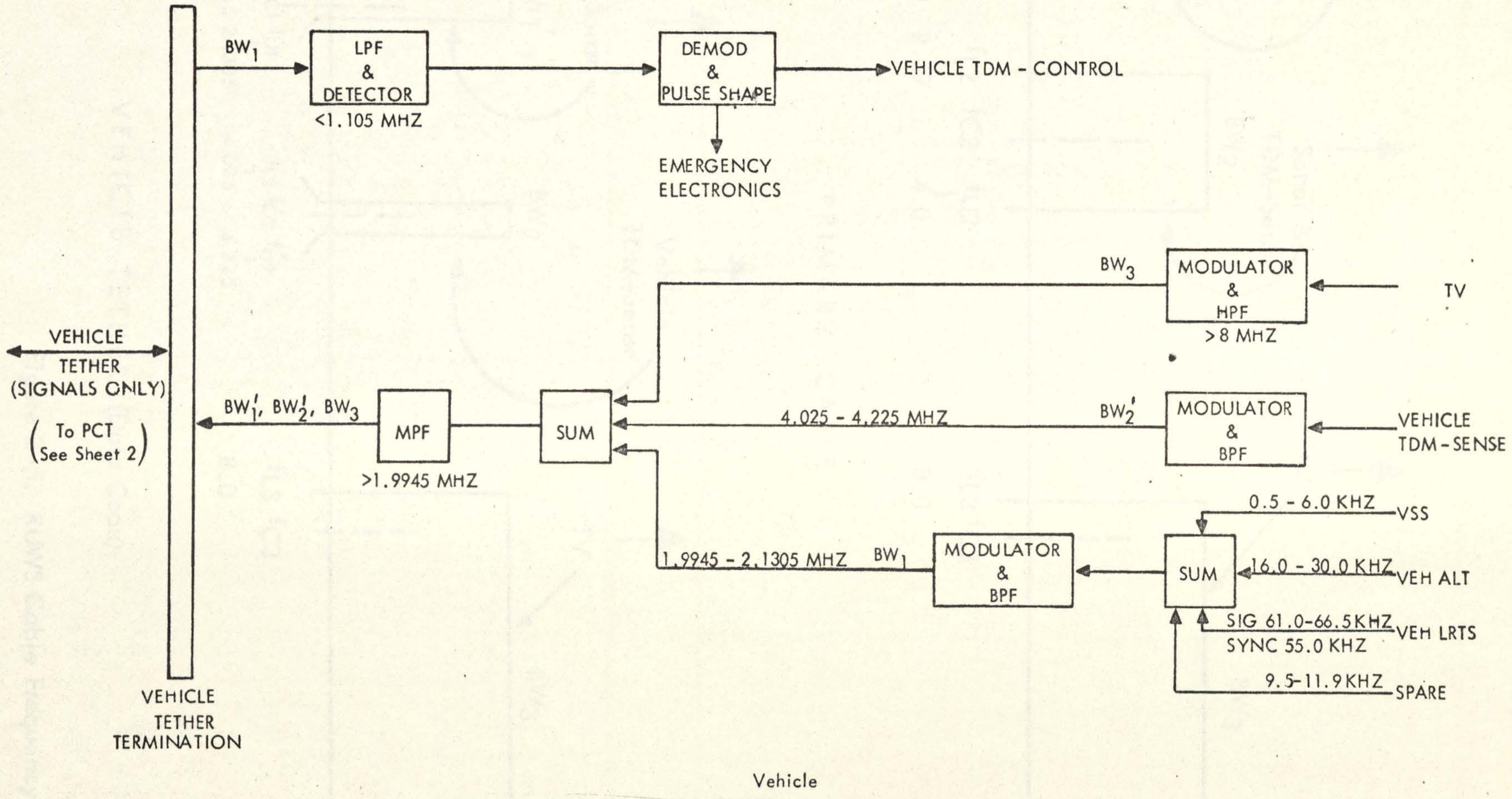


Figure 2-4. Simplified Block Diagram of RCTS. (Sheet 3 of 3)
(Reference: 15)

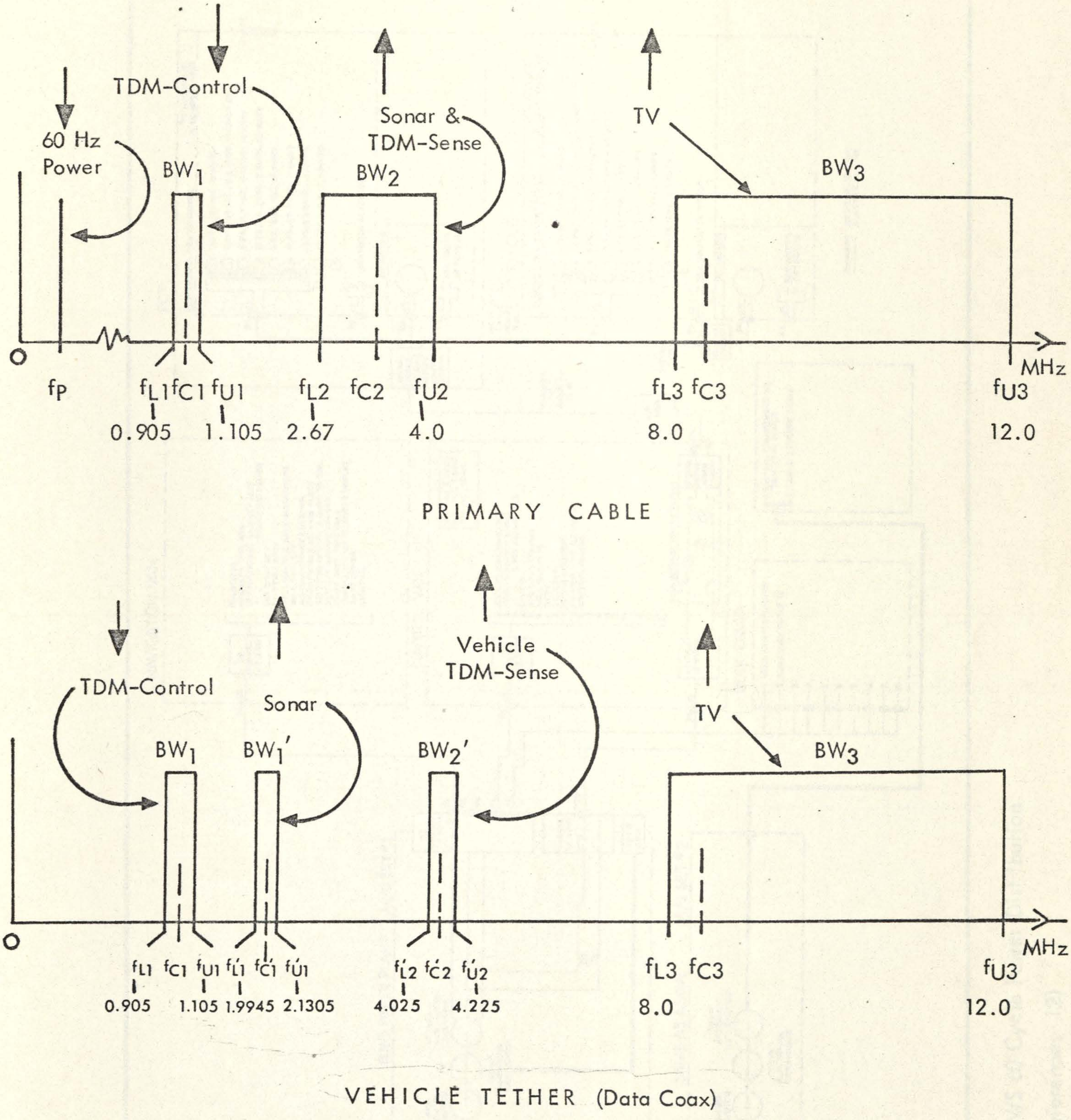


Figure 2-5. RUWS Cable Frequency Allocations.

(Reference: 15)

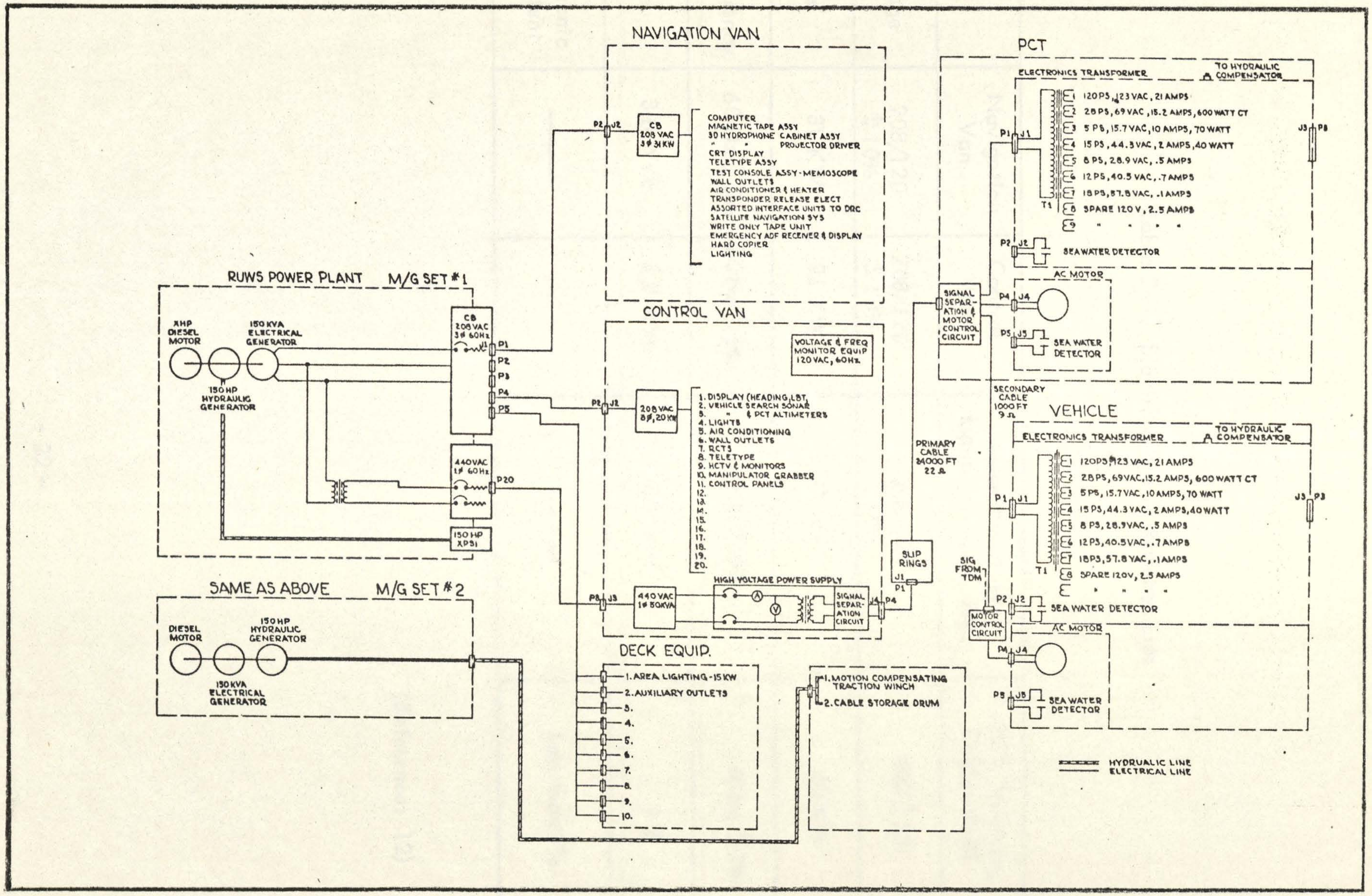


Figure 2-6. RUWS 60 Cycle Power Distribution.

(Reference: 12)

Table 2-1. Electrical Power Requirements

	Navigation Van	Control Van	Deck Handling Equip. - Lights, etc.	PCT, Vehicle, Cable, HVPS
Voltage	208/120 ± 10%	208/120 ± 10%	208/120 ± 10%	400 ± 2%
Watts	31 KW	21 KW	15 KW	50 KW
Frequency	60 Hz ± 5%	60 Hz ± 5%	60 Hz ± 5%	60 Hz ± 2%
Phase	3 Ø WYE	3 Ø WYE	3 Ø WYE	1 Ø
Harmonic Content	———	———	———	Less than 2%

(Reference: 12)

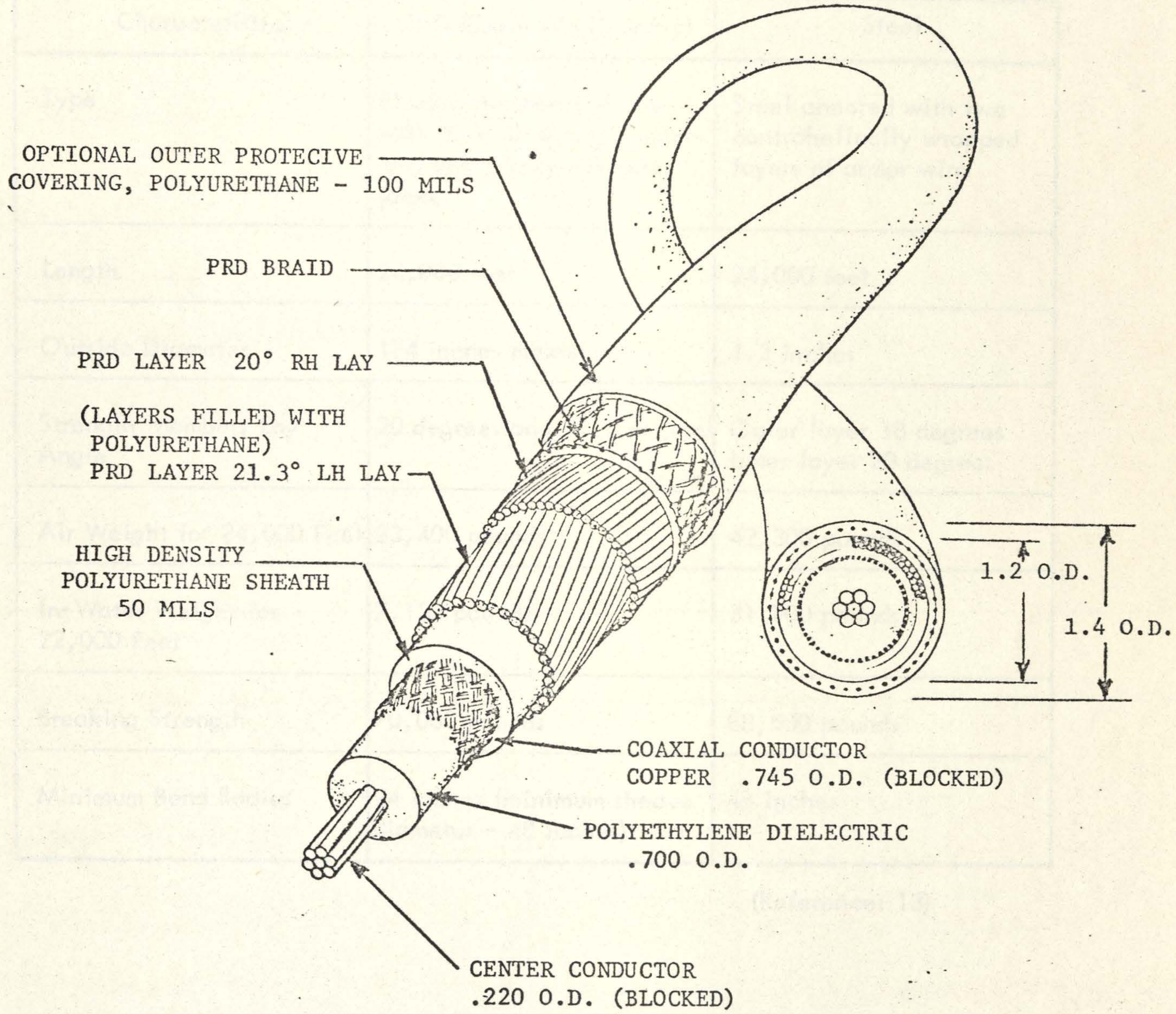


Figure 2-7. RUWS Primary Cable (PRD Prototype). (Reference : 3)

Table 2-2. Primary Cable Characteristics (Preliminary Estimates)

Characteristic	PRD Cable (Preliminary)	Steel
Type	Electro-mechanical coax with PDR-49 strength members and a polyurethane jacket	Steel armored with two contrahelically wrapped layers of armor wire
Length	24,000 feet	24,000 feet
Outside Diameter	1.4 inches maximum	1.2 inches
Strength Members Lay Angle	20 degrees and 21.3 degrees	Outer layer 18 degrees Inner layer 20 degrees
Air Weight for 24,000 Feet	23,400 pounds	42,300 pounds
In-Water Weight for 22,000 Feet	7,130 pounds	31,700 pounds
Breaking Strength	70,000 pounds	88,500 pounds
Minimum Bend Radius	24 inches (minimum sheave diameter - 48 inches)	48 inches

(Reference: 13)

The slightly bouyant Vehicle tether is the data link between the PCT and the Vehicle. It is 850 feet long and is stored on a level wind reel integral to the PCT. The tether contains two power cables and one coaxial high frequency cable for data. Figure 2-8 gives details of the cable design. The Vehicle tether will be sufficiently strong to allow recovery of the Vehicle in the undocked configuration.

2.2.4 <u>Command and Control</u>

The major RUWS Command and Control functions will be performed in the air-transportable Control Van (see Figure 2-9). The Control Van measures 8 feet wide, 8-1/2 feet high, 14 feet long, and weighs a maximum of 6,000 pounds. It is air-transportable by C-141 aircraft and will be deck-mounted during the at-sea phase of the RUWS operation. The Control Van electronics are powered by 208 volt, 60 Hz, 1.2 KW, 3 phase power. Individual control groups are included for the following equipments and subsystems:

- Vehicle maneuver
- PCT maneuver
- Manipulator
- Grabber
- Still Camera
- Vehicle Lights
- Head Coupled Television
- Work System Tools
- Vehicle Sonar

Displays will be included for system status, navigation, television monitoring and RUWS emergency system control/status.

The Control Van layout given in Figure 2-9 shows the seating configuration for the PCT and Vehicle pilots. The Vehicle Pilot will sit in the right seat and the PCT Pilot in the left seat. The RUWS High Voltage Power Supply is physically located in the Control Van but is not associated with the Control Van power distribution system. The High Voltage Supply supplies electrical power to the PCT and Vehicle.

Individual breakdown of the control/display placement is given in Figure 2-10. This figure shows the location of the major control and display groupings on the Control Console. The PCT Pilot station will contain the following major display/control components:

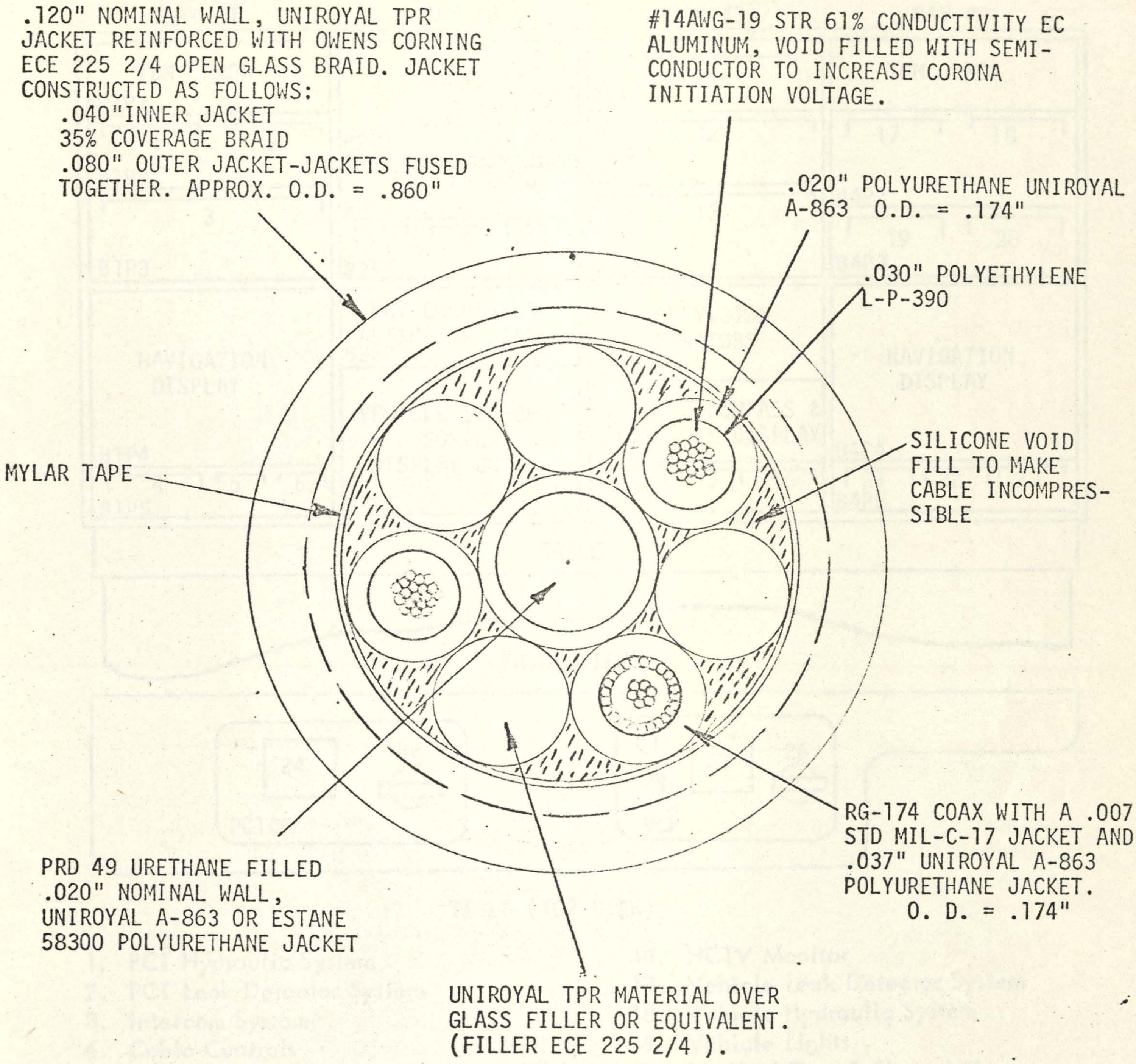
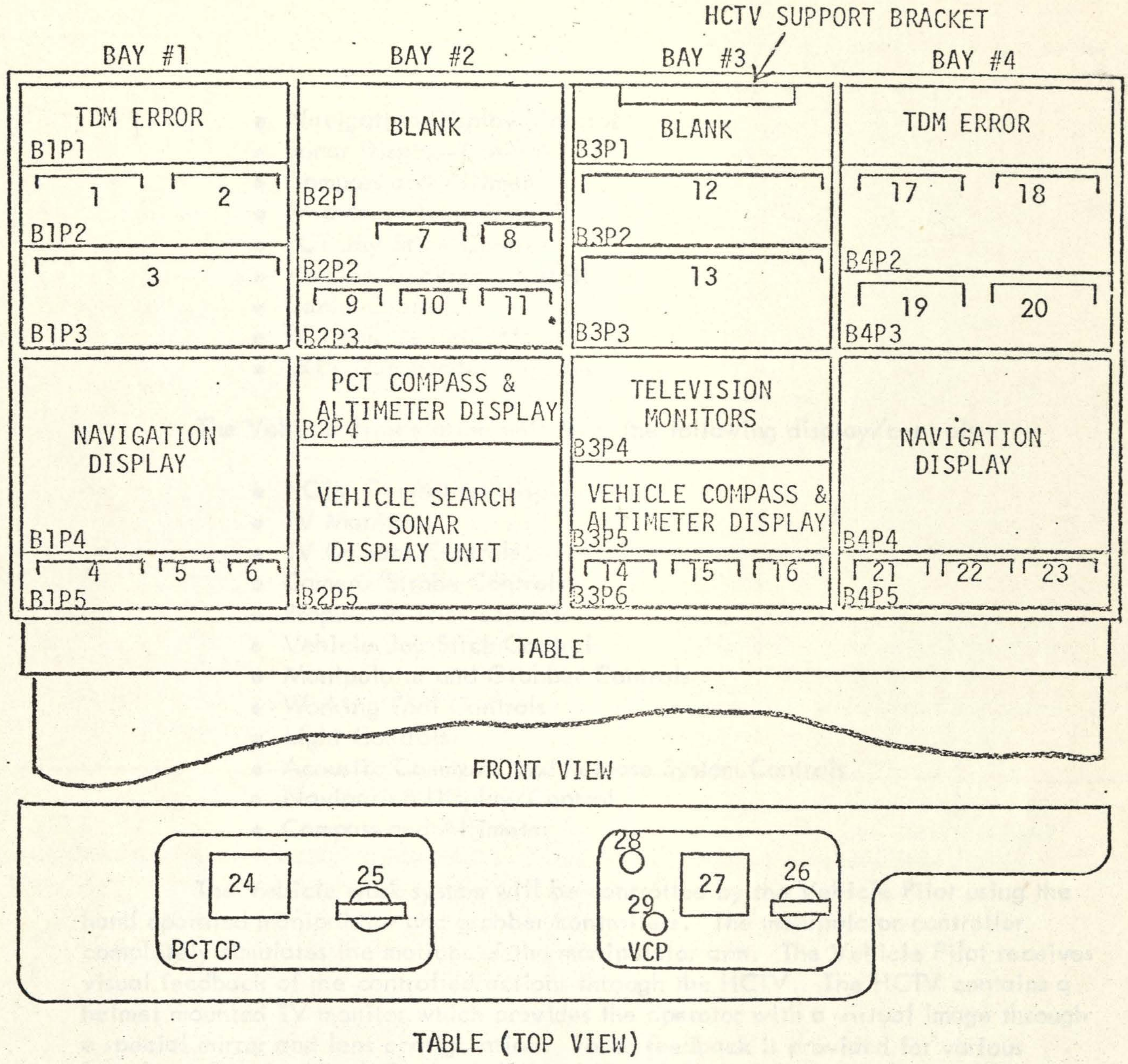


Figure 2-8. Prototype Vehicle Tether.
(Reference: 3)



1. PCT Hydraulic System
2. PCT Leak Detector System
3. Intercom System
4. Cable Controls
5. Docking Controls
6. PCT/Vehicle Power Switches
7. PCT Alarm System
8. Vehicle Alarm System
9. LRTS Extender Control
10. PCT S.R. Transponder Release Switch
11. Transponder Interrogator Switch
12. Acoustic Command and Release System
13. Intercom System
14. Television Camera Controls
15. Camera Gimbal Controls
16. HCTV Monitor
17. Vehicle Leak Detector System
18. Vehicle Hydraulic System
19. Vehicle Lights
20. Standard Time & Elapsed Time
21. Still Camera Controls
22. Tool Controller
23. Manipulator Controller
24. PCT Trim Controls
25. PCT Controller (Joystick)
26. Vehicle Controller (Joystick)
27. Vehicle Trim Controls
28. TV Camera Controller
29. Grabber Controller

Figure 2-10. RUWS Control Console Control/Display Groupings (Reference: 23)

- Navigation Display/Control
- Sonar Display/Control
- Compass and Altimeter
- Propulsion Trim Controls
- PCT Joy Stick Control
- Vehicle Docking Controls
- Cable Controls
- PCT and Vehicle Alarm
- LRTS Transponder Controls

The Vehicle Pilot station will have the following display/controls:

- HCTV Controller/Display
- TV Monitors
- TV Camera Controls
- Camera/Strobe Controls
- Propulsion Trim Controls
- Vehicle Joy Stick Control
- Manipulator and Grabber Controls
- Working Tool Controls
- Light Controls
- Acoustic Command and Release System Controls
- Navigation Display/Control
- Compass and Altimeter

The Vehicle work system will be controlled by the Vehicle Pilot using the hand operated manipulator and grabber controllers. The manipulator controller completely simulates the motions of the manipulator arm. The Vehicle Pilot receives visual feedback of the controlled actions through the HCTV. The HCTV contains a helmet mounted TV monitor which provides the operator with a virtual image through a special mirror and lens configuration. Force feedback is provided for various functions of the manipulator controller. A description of the Work System is given in Section 2.2.8.

Both stations will have status displays for the respective hydraulic and leak detector systems.

2.2.5 Primary Cable Termination (PCT)

The PCT is a controllable "terminal box" at the end of the Primary Cable. It has a rectangular box-shaped structure having an approximate air weight of 4,000 pounds and measuring 48 inches high, 48 inches wide, and 102 inches long. The PCT components are grouped as follows: structure, propulsion, Vehicle tether handling and storage, electrical pressure housings and equipments, and equipment mounts. The pressure housings consist of the:

- Signal Separation and Power Amplifier Case
- Motor Control and Compass Case
- SPPS Case
- Emergency Receiver-Transponder Case
- LRTS Altimeter Case

The fluid-filled, pressure-compensated cases consist of the:

- Power Transformer Case
- Hydraulic Pump and 15 hp Single Phase Electric Motor
- Main Junction Box

Each of the pressure proof and pressure compensated cases contains a leak detector to sense presence of salt water.

PCT propulsion is provided by hydraulically powered thrusters which allow translation and rotation in the horizontal plane. The propulsion system is used for station keeping during local search and extended lateral translation from one search area to another. Maximum water-relative velocity is approximately 1/2 knot.

PCT navigational hardware consists of the LRTS transponder-interrogator, altimeter, and compass. The PCT also provides remotely controlled storage mounts for the ALD and three transponders. These transponders will be used for either object location or to augment the DOT net as needed. The Emergency System components located on the PCT consist of a cable cutter for severing the Primary Cable and the docking release mechanism for the Vehicle.

2.2.6 Vehicle

The Vehicle is the primary submersible platform used to perform the RUWS underwater mission. It is a 4,200 pound (air weight) rectangular box-shaped submersible, measuring 54 inches wide, 60 inches high, and 132 inches long (see Figure 1-1). The Vehicle is connected to the PCT by the slightly buoyant 850 foot long Vehicle tether which forms the data and power transmission interface with the PCT. Propulsion is provided by five 2-1/2 h.p., 18 inch diameter, reversible hydraulic thrusters which allow complete rotational and translational motion in the horizontal plane and translation in the vertical plane. Synactic foam is used to make the Vehicle slightly positively buoyant. This requires slight continuous use of the vertical thruster to stay down. Sufficient thrust is provided by the electro-hydraulic propulsion system to achieve a water-relative speed of two knots. The Vehicle receives TDM control and emergency signals from the surface. Vehicle TDM sense signals are transmitted to the surface along with frequency-multiplexed signals containing TV, VSS, altimeter, and LRTS information. The modulation and demodulation of the signals are performed by the RCTS circuitry located aboard the Vehicle.

The major functions of the Vehicle are detection and classification, using the VSS and HCTV sensors, and the performance of work through employing the manipulator, grabber, and special tools. The Detection and Classification Subsystem will be described in greater detail in Section 2.2.7. The Work Subsystem will be described in Section 2.2.8.

The Vehicle major equipments consist of:

- Still Camera and Strobe Light
- Transponder Interrogator and Altimeter Transducers
- Quartz and Thallium Iodide Lights
- VSS Training Mechanism and Transducers
- Emergency Receiver-Transponder Transducer
- TV Cameras and Pan and Tilt
- Manipulator
- Grabber
- Drill
- Cable Cutter
- Pressure Cases for:
    - SPPS
    - Motor Control (also contains compass)
    - VSS Motor Control
    - LRTS-Altimeter
    - VSS Transmit and Receive
    - Emergency Receiver-Transponder
- Fluid-Filled Pressure Compensated Cases for:
    - Motor Pump
    - Transformer
    - Main Junction Box

The Still Camera and Strobe Light are used to make a permanent high quality visual record of bottom objects. The HCTV, using the iodide lights for illumination, is able to transmit a real time picture of what the Vehicle TV camera "sees". During the mission this TV picture may be permanently stored on video tape. The VSS signal containing the acoustic survey and search data is transmitted via the RCTS to the VSS CRT display. It is also possible to record the VSS signal for permanent storage and later analysis.

The RUWS Emergency Subsystem is acoustically activated from the support ship in the event it is physically impossible to control the Vehicle, or when the data link between the Vehicle and the surface is broken. The Emergency Subsystem will initiate a series of sequenced actions aboard the PCT and Vehicle allowing the Vehicle to float to the surface.

2.2.7 Detection and Classification Subsystem

The RUWS Detection and Classification Subsystem is located on the Vehicle and consists of the VSS and the HCTV. The VSS is a CTFM sonar employed in a sector scanning mode which looks at a 120 degree sector forward of the Vehicle. Its highest scan rate of 26 degrees per second will give a data update of once every 4.6 seconds. The sonar will have the capability of detecting a -20 db target at about 1,000 feet. The VSS may also be used in the passive mode and has a listening capability in the 8 to 46 kHz range. The horizontal VSS beam is 1.3 degrees wide in active receive and 7.7 degrees wide in passive receive at 36 kHz. Beam height is from 15.5 degrees above to 25.5 degrees below the horizontal. Maximum active range for the normal higher-frequency mode of operation is 1,000 feet. For the lower-frequency mode the maximum range is 1,000 yards. VSS direction is controlled from the surface with the sonar normally employed in the back and forth sweep mode. It is possible to manually reverse the scan of the VSS at any time. Table 2-3 gives additional normal high-frequency mode VSS characteristics.

In this discussion the HCTV is considered part of the Detection and Classification Subsystem. However, due to its controllability and the similarity of its control technology to that of the manipulator/grabber systems, it is also considered as part of the Work Subsystem when RUWS is performing manipulative tasks at operational depth. As an equipment of the Detection and Classification System, the HCTV is used for visually scanning the ocean bottom during survey and search missions. The HCTV cameras are connected to a servo control pan and tilt system whose pointing direction is derived either from the Vehicle operator's head via the HCTV helmet or manually by use of the console controller. Two cameras are mounted close together and can be switched from one to the other to provide simulated depth perception. The HCTV optics have been so designed that the operator wearing the helmet is at the center of perspective for the viewed image. An alternate display is provided for the Vehicle TV camera on the Control Console along with the manual controls for directing camera position. Lighting for the Television camera is provided by Vehicle mounted quartz and thallium iodide lights which have separate on/off controls.

2.2.8 Work Subsystem

The RUWS Work Subsystem is located on the Vehicle and consists of three functional groupings of equipments. These are:

Table 2-3. VSS Characteristics (Normal High-Frequency Mode).

Frequency	
Echo-ranging (active):	Frequency sweep from 225 kHz to 199 kHz, recycling at 199 kHz.
Listening (passive):	Tunable from 8 kHz to 46 kHz.
Range Scales and Coverage	
125 ft scale:	25 to 125 feet
250 ft scale:	50 to 250 feet
500 ft scale:	100 to 500 feet
1000 ft scale:	200 to 1000 feet
Range Resolution	
125, 250, 500 and 1000 feet range scales	1.25, 2.5., 5.0 and 10.0 ft., respectively
Azimuthal Resolution	
Echo-ranging:	1.3°, all range scales
Listening:	Approximately 30.8° at 9 kHz, 7.7° at 36 kHz to 6.0° at 46 kHz.
Sector Scan	
Automatic:	± 60° from reference centerline
Manual:	Manual reversal command can be given at any time while scanning
Sector Scan Rate	
Echo-ranging:	26°/sec on all range scales except the 1000 ft scale where the rate is 10.5°/sec.
Listening:	6°/sec.

(Continued)

(Reference: 14)

Table 2-3. (Continued)

Transducer Beam Patterns (at 3 db-down points re axis)	
Hydrophone (horizontal):	1.3° at 212 kHz
Hydrophone (vertical):	41° at 212 kHz, beam axis tilted down 5°.
Projector (horizontal):	Two 3.8° beams (212 kHz) with each beam axis located 4° on each side of projector centerline (only one beam operates at a time depending on scan direction).
Projector (vertical):	Greater than 23° but less than 35°, beam axis tilted down 5°.
System Receiving Sensitivity (minimum detectable signal)	
Echo-ranging:	Better than +60 db re 1 μPa (-40 db re 1 μbar).
Listening:	Design goal of better than +70 db re 1 μPa (-30 db re 1 μbar).
Target Detection	+4 db signal-to-noise ratio (acoustic) for -20 db target at 1000 ft range on sand bottom at 15,000 ft depth and an altitude of 10 ft.
Outputs	
Audio:	Speaker and/or headset
Visual:	PPI display on 10 inch CRT with P7 phosphor.
Major Controls	
Sonar Range:	Selects 125, 250, 500 and 1000 ft scales
Passive/Active:	Selects passive or active mode
Passive Tune:	Tunes for pinger frequency
Scan:	Selects scan ON or REVERSE
Operating Depth	20,000 feet.

(Reference: 14)

- Remote manipulator group consisting of a dexterous remotely controlled master-slave manipulator and a less dexterous rate-controlled grabber to serve as a holding arm

- Sensor group consisting of the HCTV, still camera, and strobe

- The tool group consisting of variable speed drill and cable cutter

The manipulator, tools and the HCTV pan and tilt platform are hydraulically actuated.

The manipulator has seven degrees of freedom allowing motion of the shoulder in both azimuth and elevation, motion of the elbow in azimuth, and motion of the wrist in yaw, pitch, roll and grip. Force feedback is provided for the shoulder, grip, and elbow functions. The manipulator is controlled through the manipulator controller which is operated by the right hand of the Vehicle Pilot. The grabber is operated from Control Console table by either the Vehicle or PCT Pilot. The grabber functions as an anchor to the object to be worked on, and is used for the retrieval and carrying of heavier objects. The manipulator is capable of carrying a 25 pound load at full extension.

The Work Subsystem will also operate the ALD by which objects weighing up to 200 pounds are retrieved. The ALD, stored on the PCT and carried by the Vehicle, consists of a lift bag attachment mechanism and a gas generator with manual controls that are operated by the manipulator. The ALD is controlled by an on/off valve which allows hydrazine to decompose into nitrogen, hydrogen, and ammonia. The ALD valves are opened by the manipulator until sufficient buoyancy has been obtained for the device and load to either become neutrally buoyant to allow translation at operating depth, or to ascend to the ocean surface. The individual specifications for the RUWS Work Subsystem are contained in Table 2-4.

2.2.9 Emergency Subsystem

The RUWS Emergency Subsystem consists of the ACR equipment whose primary function is to allow recovery of the positively buoyant Vehicle in the event of an emergency. The ACR equipments are mounted on the PCT and the Vehicle. The PCT-located equipment will release the Vehicle in the docked configuration and will sever the Primary Cable at the PCT. The ACR equipment consists of emergency receivers and transponders, transducer assemblies, pressure switches and interconnecting cables. The emergency receiver-transponder electronics equipment set is shown in Figure 2-11. The ACR will receive and discern between ten commands. Two of the command codes are designated as the emergency commands to the Vehicle and the PCT. The remaining commands will be used as separate release commands to the Deep Ocean Transponders. A single coded command to the PCT shall cause the PCT

Table 2-4. RUWS Work System Description.

Manipulator

Lift capability at full extension	25 lb
Shoulder azimuth range	+135° - 90°
Elbow yaw range	+ 0° -150°
Shoulder elevation range	+ 45°
Wrist yaw range	∓140°
Wrist pitch range	∓ 30° -110°
Wrist roll range	±135°
Grip opening	0-4 in
Grip force	0-35 lb
Weight in air	62 lb
Weight in water	45 lb
Hydraulic pressure	1000 ±10 psi
Hydraulic flow rate	4 gpm
Control - Master-slave position control on all functions with force control on elbow, shoulder elevation, and shoulder azimuth; and pseudo-force control on grip.	
Acceleration	0-.5 g at full load
Positional response	90% of command/sec
Overshoot	15% max
Force feedback ratio	0 to 1/10:1
Positional deadband	1/2 in.max at full extension
Angular deadband (wrist)	5° max
Force deadband	5 lb
Angular velocity (wrist)	0-1 rad/sec
Positional velocity	0-2 ft/sec
Droop under max. load	2 in.max
Oscillation	.02 in.max*

*Due to hydraulic pressure fluctuations.

(Continued)

Table 2-4. (Continued).

Grabber	
Load capability	200 lb
Elevation range	- 20° + 90°
Wrist pitch range	+ 5° - 95°
Wrist roll range	±170°
Grip opening	0-8 in
Grip force	400 lb
Weight in air	71.3 lb
Weight in water	63 lb
Control - On-off joystick	
Hydraulic pressure	1000 psi ± 100
Hydraulic flow rate	.5 gpm
Tools (Drill)	
Weight in air	15 lb
Capability	1/2 in. hole in steel
Hydraulic pressure	1000 psi
Hydraulic flow rate	1 gpm
Weight in water	7 lb
(Cable Cutter)	
Weight in air	28 lbs
Capability	1/2 in. wire rope
Hydraulic pressure	1000 psi
Hydraulic flow rate	.2 gpm

(Reference: 10)

emergency receiver to deliver the necessary electrical power for cutting the Primary Cable at the PCT and operating the docking release control. A different single coded command shall be transmitted to the Vehicle which will cause the tether to be severed at the Vehicle.

The ACR equipment will also be able to receive electrical commands from the RCTS in the event that the cables are still intact when the emergency occurs. The individual electrical commands will result in the same actions as described above.

The secondary function of the ACR emergency receiver-transponder is to provide a means of locating either the PCT or Vehicle after receipt of a coded command. This is performed by acoustically interrogating the emergency receiver and transponder. The reply signals are individually identifiable as having originated from either the Vehicle or the PCT. As shown in Figure 2-11, the emergency receiver-transponder consists of the transducer assembly, pressure switch, reply transmitter, receiver processor, enable and energizing circuits, battery and tester, battery charger, and leak detector.

All commands, power, and outputs are processed by the RCTS with the exception of the 'energize' output which is used to fire the cable guillotine squib. Power is supplied to the ACR from the SPPS 115 volt, 60 Hertz power circuit. Emergency power will be obtained from self-contained rechargeable batteries which will provide power to all submersible ACR circuitry and deliver the necessary energizing currents. The batteries can also be placed in a test condition by a command from the RCTS. This allows battery voltage measurements to be monitored on the Control Console. During normal operation the 115 volt, 60 Hertz power is available to the battery charger. During an emergency condition when the 115 volt, 60 Hertz power is not available, the emergency battery will supply power to operate the emergency equipment for periods up to 24 hours before receiving a coded command. The emergency receiver/transponder will also be activated by a hydrostatic pressure switch. The switch will activate the equipment at depths greater than 30 feet.

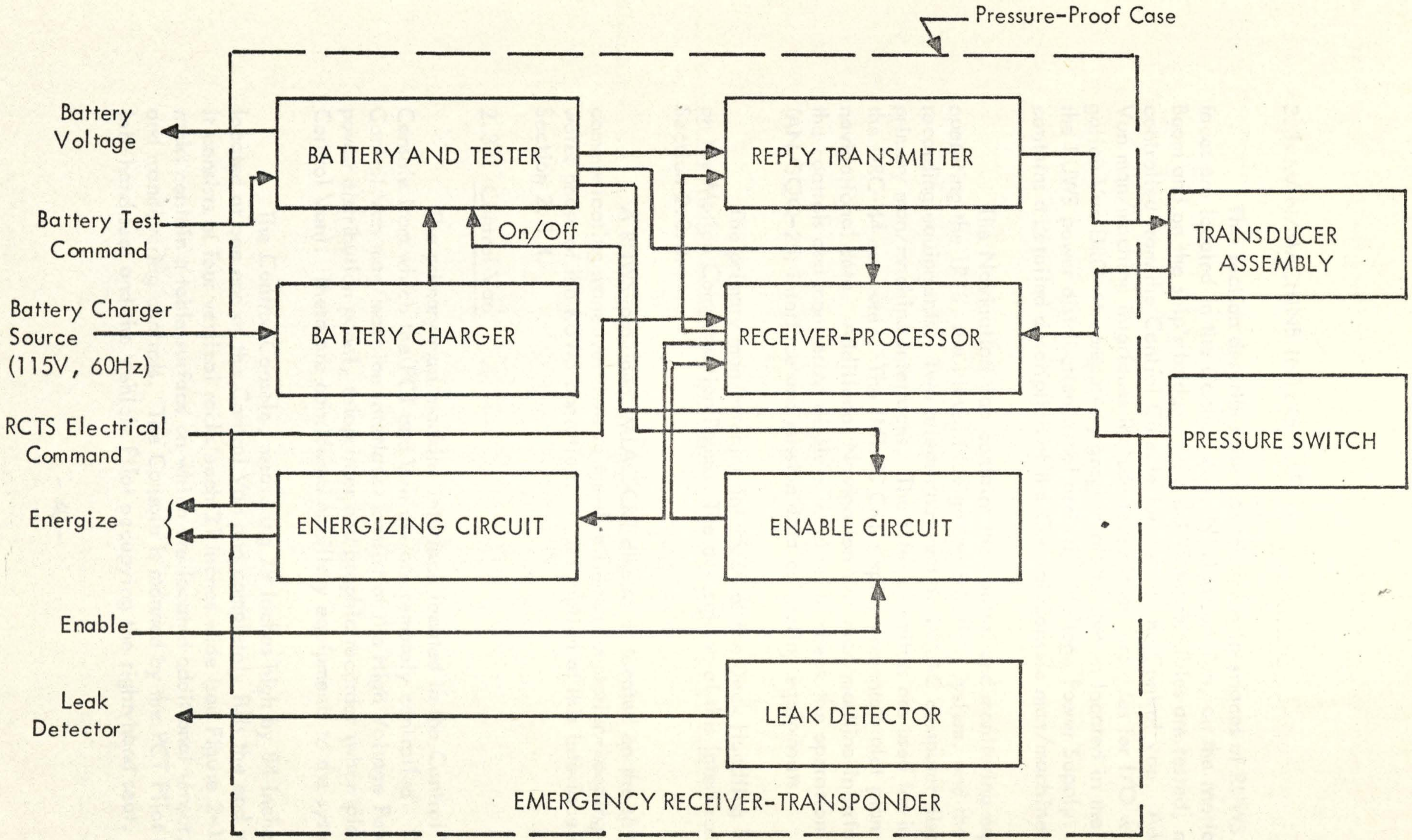


Figure 2-11. Block Diagram of Vehicle or PCT ACR Equipment.
(Reference: 19)

2.3 MAN/MACHINE INTERFACES

This section describes the man/machine interfaces of RUWS. These interfaces are located in the Control Van, Navigation Van, on the Motion Compensation Boom and on the ship's bridge. The RUWS submersibles are tested, monitored and controlled from the Control Console located in the Control Van. Additional Control Van man/machine interfaces include teleprinter (provides for I/O with the Navigation Van DRC-44 computer), graphic plotter (when located in the Control Van), and the RUWS power distribution panel and High Voltage Power Supply. Section 2.3.1 contains a detailed description of the Control Console man/machine interfaces.

The Navigation Van contains the control and monitoring equipment for operating the LRTS, the Naval Navigation Satellite System, and the mission data recording equipments. Two teleprinters and an IMLAC computer display form the primary man/machine interfaces. The teletypewriters are used for input-output to the DRC-44 computer. The IMLAC CRT display presents a plot plan of the RUWS navigational data. Additional Navigation Van man/machine interfaces consist of the controls and monitoring displays required to check the operation of the sonar (AN/SQQ-25) interface and mission data collecting equipments.

The primary man/machine interface of the Deck Handling System is located on the Motion Compensation Boom. The description of this interface is presented in Section 2.3.3.

A RUWS-provided IMLAC CRT display is located on the ship's bridge for communicating maneuver data to the ship's helm for station-keeping during the in-water phase of the RUWS operation. A description of this interface is contained in Section 2.3.4.

2.3.1 Control Van

The primary man/machine interface located in the Control Van is the Control Console from which the PCT and Vehicle are remotely controlled. The remaining Control Van man/machine interfaces consist of the High Voltage Power Supply panel, power distribution panel, teleprinter and graphic recorder (when placed in the Control Van). These are considered ancillary equipments to the system.

The Control Console, measuring 79 inches high by 84 inches wide, is located at one end of the Control Van and completely fills the end wall space. It consists of four vertical racks each 21 inches wide (see Figure 2-10). The four racks contain a table surface on which are located additional sensor, Work System, and maneuvering controls. The Console is manned by the PCT Pilot occupying the left-hand seat and the Vehicle Pilot occupying the right-hand seat. Consequently, the left two racks contain the controls and displays primarily used by the PCT Pilot during the underwater operation phase. The right two racks are similarly dedicated to controls and displays primarily used by the Vehicle Pilot. The Vehicle Pilot also wears the HCTV helmet which is mechanically linked to the top of Bay #3 for pick-off of operator's head direction pointing vector. The remaining man/machine interface not located on the Control Console is the manipulator controller. The manipulator controller is a hinged mechanical lever system which simulates seven functions of the human arm and hand. These are shoulder elevation and azimuth, elbow azimuth, wrist roll, pitch, yaw and grip. Refer to Figure 2-10 for the following overview description of the Control Console display and control groupings.

The top section of Bay #1 contains two control panels. Panel B1P2 contains the PCT hydraulic and leak detector systems. Panel B1P3 contains the intercom system consisting of a Talk-a-Phone having access to a maximum of 12 stations. The lower section of Bay #1 is divided into two panels. The top portion contains the navigation CRT display and control panel and the lower portion contains the PCT/ Vehicle power and control switches. The top section of Bay #2 contains the PCT and Vehicle alarm system indicators which may be combined as shown in Figure 2-16. Panel B2P3 contains the controls for positioning the transducer, releasing the PCT-stored transponders, and the power switch for the PCT and Vehicle LRTS electronics. The lower section of Bay #2 consists of two control and display panels. The top panel contains the PCT compass and altimeter control/display group. The lower panel contains the Vehicle Search Sonar display/control group.

The top section of Bay #3 contains the HCTV support bracket and two control/display panels. At the top is panel B3P2 containing the Acoustic Command Release System controls. Panel B3P3 contains an intercom unit similar to that contained in panel B1P3. The lower section of Bay #3 is divided into three panels. The top panel consists of two identical television monitors and their related controls. These monitors are used for displaying the Vehicle-transmitted television picture and/ or closed circuit TV picture for monitoring deck activities during deployment and recovery. The middle panel contains the Vehicle navigation sensor displays and controls identical to those described in the above paragraph for the PCT. Panel B3P6 is located at the bottom of this section and contains the Vehicle TV camera, TV camera gimbal, and HCTV monitor controls.

The top section of Bay #4 contains Panels B4P2 and B4P3. Panel B4P2, located at the top, contains the Vehicle leak detector system and the Vehicle hydraulic system indicators. Panel B4P3 contains the Vehicle light controls and the elapsed time indicator. The lower section of Bay #4 is divided into two panels. The top panel contains a duplicate of the RUWS Navigation System display which was described for the bottom section of Bay #1. The only difference in this display from that described above is the reduction in the number of control pushbuttons. Panel B4P5 forms the lower portion of this rack section and contains the still camera and tool controls, and the force feedback and servo controls for the manipulator controller.

The Control Console table contains two sets of controls used by the pilots. In front of the PCT Pilot are located the PCT control joystick and trim controls. The Vehicle Pilot's table control group contains the Vehicle control joystick and trim controls, the manual television camera controller, and the grabber controller.

The following paragraphs contain detailed descriptions of each control/display/indicator and their function in operating RUWS. The references indicate the location on the console of the control or indicator: for example, (1-5-7) refers to the 7th control (or indicator) on Panel 5 in Bay 1.

Panel B1P5 (see Figure 2-12)

The right-hand control group consists of the PCT cable controls. (1-5-1) and (1-5-2) are analog meters displaying the Primary Cable length out and the Vehicle tether length out, respectively. (1-5-3) is a control for operating the Vehicle tether winch.

The center group contains the PCT docking controls. (1-5-4) is a Vehicle docking two-position switch indicating HOLD and RELEASE conditions. (1-5-5) is the ALD docking control inidcating HOLD and RELEASE conditions. (1-5-6) is a Vehicle status two state display indicating LAUNCHED and IN PLACE. This displays the status of the Vehicle/PCT configuration. (1-5-7) is a PCT docking light control. It is a two position switch reading ON/OFF.

On the right side of the panel is located the PCT/Vehicle power switch. It reads EMERGENCY OFF and is used to cut all power to the submersible units.

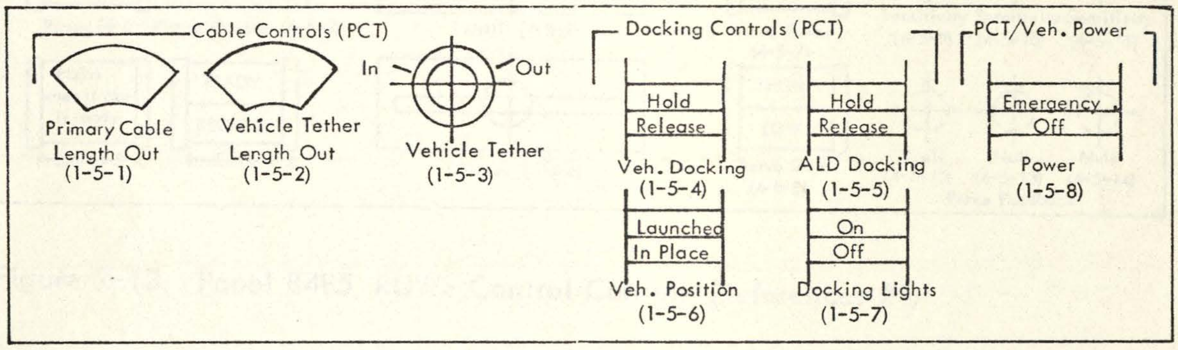


Figure 2-12. Panel B1P5 RUWS Control Console (Reference: 23)

Panel B4P5 (see Figure 2-13)

The still camera and strobe light controls are on the left side of the panel. (4-5-1) is a two-position ON/OFF power switch. (4-5-2) is a frame counter consisting of 4 decimal digit read-out with an integral reset button. (4-5-3) indicates the strobe light conditions READY and RECHARGE. (4-5-4) is the frame control which is operated in a push-to-take mode.

The center group contains two slide potentiometers controlling the drill (4-5-5) and the cable cutter (4-5-6). The right-hand group contains the manipulator controls. (4-5-7) is a two-position switch for servo power. Servo gain is selected as HIGH or LOW from (4-5-8). Potentiometers (4-5-9) through (4-5-14) control the force feedback to the indicated shoulder and elbow functions.

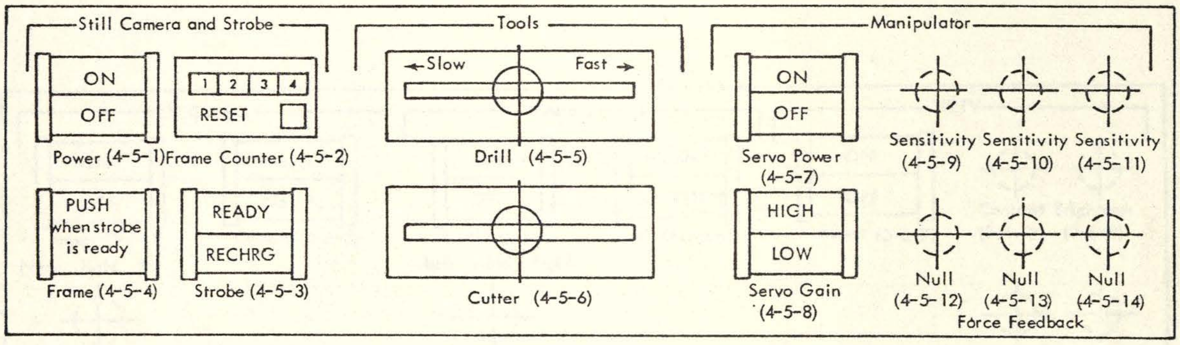


Figure 2-13. Panel B4P5 RUWS Control Console (Reference: 23)

Panel B3P6 (see Figure 2-14)

The Vehicle TV Camera controls are located on the left side of the panel and consist of (3-6-1), a back lighted power ON/OFF switch; (3-6-2), a two-position camera selector switch; (3-6-3), a three-way focus switch which servos the TV camera optics for NEAR, HOLD and FAR settings. The center group contains the TV camera gimbal controls.(3-6-4) is a two-position power ON/OFF switch. Camera direction control is selected as HELMET or JOYSTICK from (3-6-5). Traverse motion of the camera gimbal is controlled by the three-position switch (3-6-6).

The right-hand group on the panel consists of the Vehicle HCTV monitor controls. (3-6-7) is the two-position power switch. (3-6-8, 9, 10, and 11) are continuous potentiometer settings to control the TV monitor contrast, brightness, vertical and horizontal settings respectively.

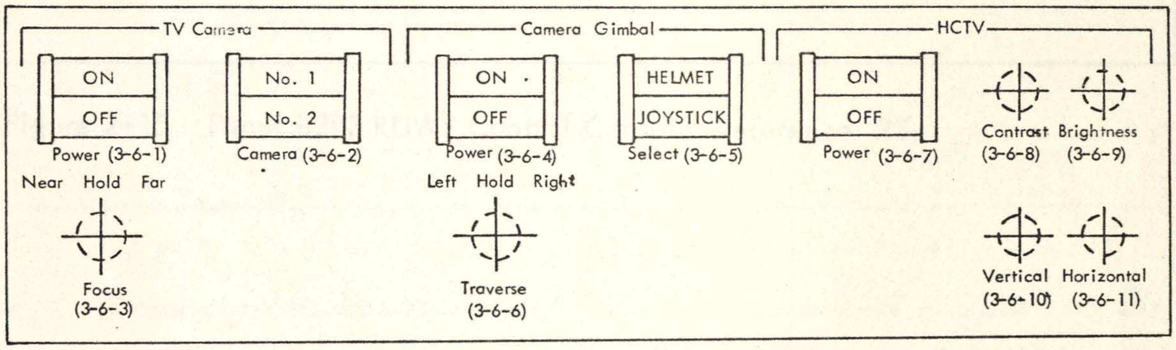


Figure 2-14. Panel B3P6 RUWS Control Console (Reference: 23)

Panel B2P3 (see Figure 2-15)

On the left is located a two-position switch (2-3-1) for raising and lowering of the Vehicle LRTS transducer. The middle group of two-position switches (2-3-2, 3, and 4) reads OPEN and CLOSE. They are used for releasing the PCT stored transponders. On the right is located the power switch (2-3-5) for the LRTS electronics located on the PCT and Vehicle.

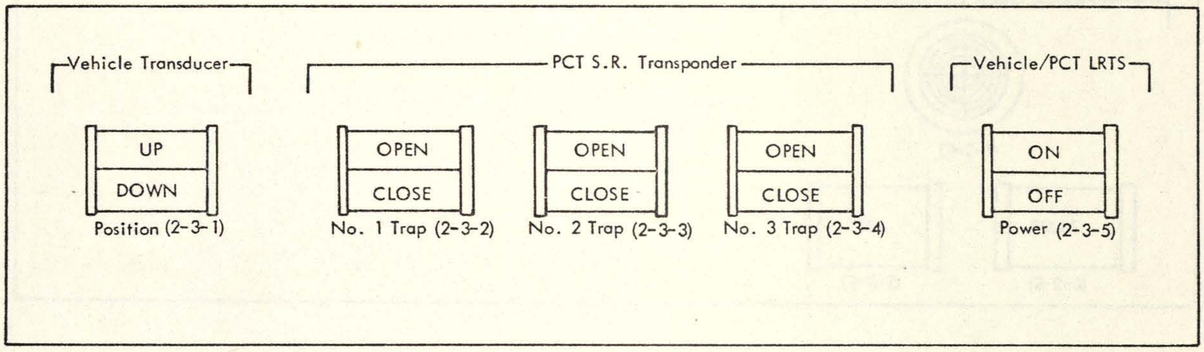


Figure 2-15. Panel B2P3 RUWS Control Console (Reference: 23)

Panel B2P2 (see Figure 2-16)

This panel contains the alarm system indicator and controls for the PCT and Vehicle. In the figure they are shown combined for both units. (2-2-1) is an aural alarm which activates to indicate an alarm condition. (2-2-2) is the alarm TEST switch, and (2-2-3) is the switch used to RESET the alarm.

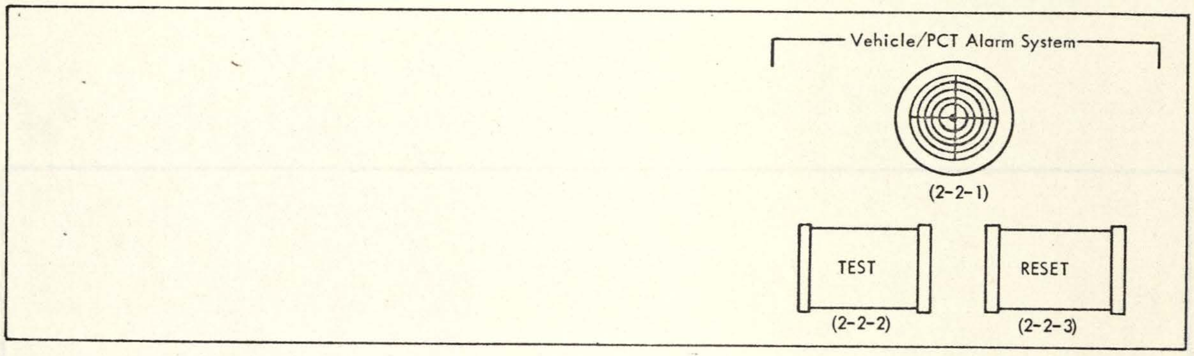


Figure 2-16. Panel B2P2 RUWS Control Console (Reference: 23)

Panel B3P2 (see Figure 2-17)

This panel will contain the Acoustic Command and Release System indicators and controls. They will consist of arming and activating switches for emergency retrieval of the Vehicle and normal retrieval of the Deep Ocean Transponders.

Figure 2-17. Panel B2P3 Acoustic Command and Release System. (Configuration not established)

Panel B4P3 (see Figure 2-18)

The left-hand group of switches control the Vehicle lights (4-3-1) and (4-3-2) and operate the thallium iodide lights. (4-3-3) operates the quartz iodide light. All three switches are two position, back lighted switches indicating ON/OFF status. Controls (4-3-4) through (4-3-6) are three spare two-position back lighted ON/OFF switches.

On the right is a standard clock and a resetable Elapsed Time meter.

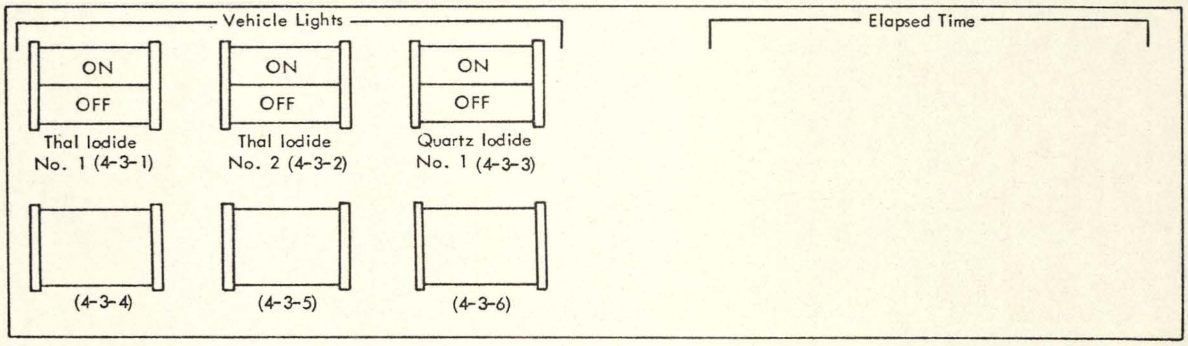


Figure 2-18. Panel B4P3 RUWS Control Console (Reference: 23)

Panels B1P3 and B3P3 (see Figure 2-19)

These are identical panels containing the 12-station Talk-a-Phone intercom units. One is used by the Vehicle Pilot and the other is used by the PCT Pilot.

Figure 2-19. Panels B1P3 and B3P3 Intercom Controls.
(Configuration not established)

Panel B1P2 (see Figure 2-20)

The left-hand group consists of the displays and controls for the PCT hydraulic system. (1-2-1) is a vertical positioned analog meter giving the pressure and temperature readings for the PCT hydraulic system. (1-2-2) is a two-position switch for controlling and displaying the ON/OFF status of the hydraulic pump motor. (1-2-3) is a two state indicator for the pump motor temperature reading OVER TEMP and NORMAL. A similar control display group for the Vehicle is located on Panel B4P2.

The right-hand control display group gives the status of the PCT leak detector system. Displays (1-2-4) through (1-2-10) are two state displays reading LEAK and NO LEAK conditions for the individual pressure compensated cases located on the PCT. These are:

(1-2-4)	Junction Box
(1-2-5)	Motor Control/Compass Case
(1-2-6)	Emergency Receiver Transponder Case
(1-2-7)	LRTS Altimeter Case
(1-2-8)	Electronics Transformer Case
(1-2-9)	Pump Motor Case
(1-2-10)	SPPS Case
(1-2-11)	PSF and Power Amplifier Case

(1-2-12) is the leak detector RESET.

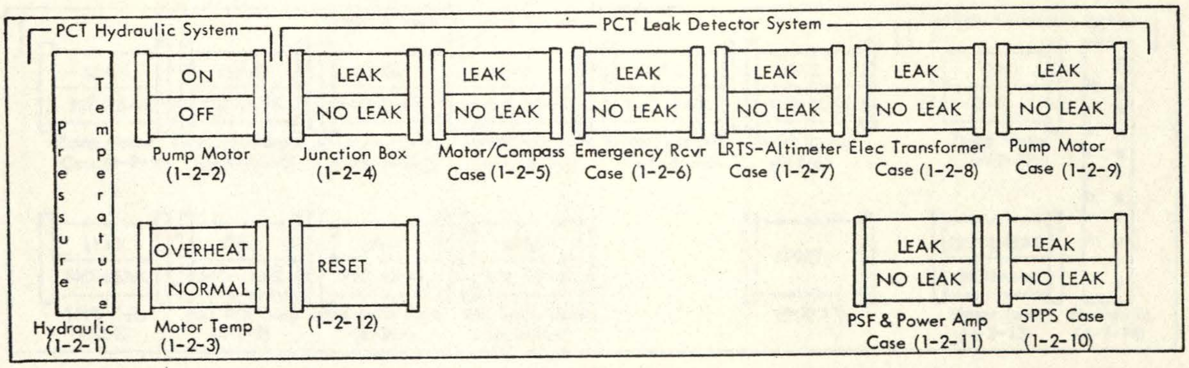


Figure 2-20. Panel B1P2 PCT Hydraulic Controls (Reference: 23)

Panel B4P2 (see Figure 2-21)

The left display group on this panel gives the LEAK/NO LEAK status from the Vehicle leak detector system. The two-state indicators (4-2-1) through (4-2-10) are designated as follows:

(4-2-1)	Pump Motor Case
(4-2-2)	Electronics Transformer Case
(4-2-3)	LRTS Altimeter Case
(4-2-4)	Emergency Receiver Transponder Case
(4-2-5)	Motor Control/Compass Case
(4-2-6)	Junction Box
(4-2-7)	SPPS Case
(4-2-8)	VSS T/R Case
(4-2-9)	VSS M/C Case
(4-2-10)	VSS Train Mechanism

(4-2-11) is a momentary pushbutton for detector RESET.

The right hand group contains the displays and controls for the Vehicle hydraulic system. (4-2-12) is a two-position back lighted switch for ON/OFF control of the pump motor. (4-2-13) is a two-state indicator reading OVERHEAT and NORMAL conditions for the hydraulic pump motor temperature. (4-2-14) is a vertical positioned display of TEMPERATURE and PRESSURE readings for the Vehicle hydraulic system.

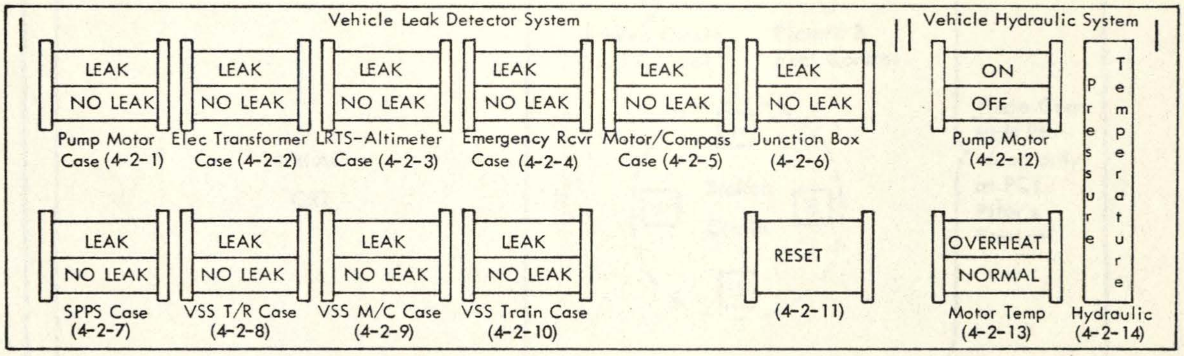


Figure 2-21. Panel B4P2 Vehicle Hydraulic Controls (Reference: 23)

Navigation Display Panel (see Figure 2-22)

As indicated in Figure 2-10, a navigational display panel is provided in two locations for use by the submersible pilots. Figure 2-22 shows the layout of the PCT Pilot's navigational display panel. The display controls consist of the IMLAC CRT toggle switches labeled BROKEN CIRCLE EXCLUSIVE CONTROL and PICTURE B EXCLUSIVE CONTROL which allows the PCT Pilot to perform the indicated functions so that only he may move the Broken Circle for surface ship maneuver control and modify the format of Picture B. Along the bottom left of the CRT are three momentary pushbuttons labeled ERASE, REDRAW, and HARD COPY. The ERASE and REDRAW buttons are used in conjunction with the teletype to command the computer to erase or redraw trajectory display symbols. Pushing the HARD COPY button produces a hard copy of the IMLAC CRT picture. To the right of these buttons are four momentary pushbuttons labeled N, E, W, S, indicating the four cardinal compass directions. Pressing these momentary pushbuttons causes the CRT display to shift one unit in the commanded direction. At the right bottom of the display panel are two momentary pushbuttons labeled MAG and DEMAG. These buttons are used for magnifying and demagnifying the Navigation CRT horizon plane geometry.

A similar display panel is provided in B2P4 for the Vehicle Pilot. The panel, as noted in Figure 2-22, is identical to the one described above with the exception of the toggle switches and broken circle controls.

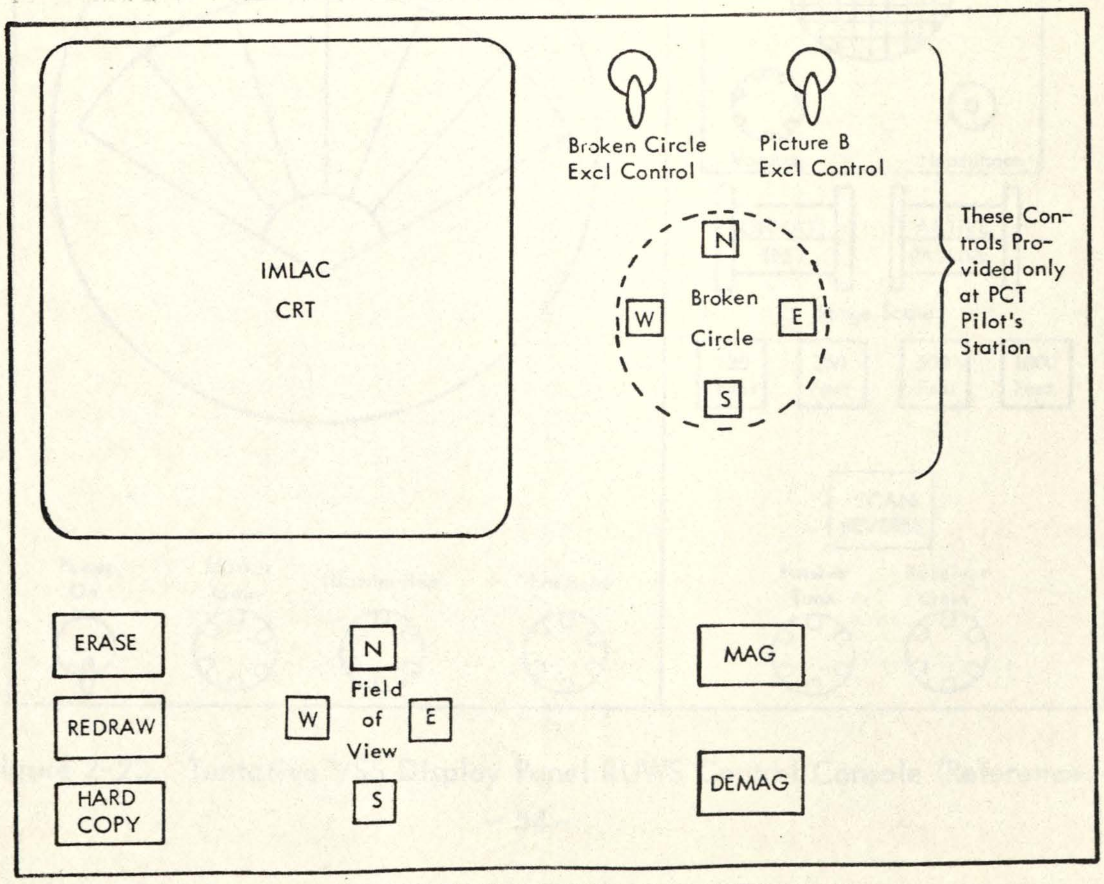


Figure 2-22. Navigation Display Panel RUWS Control Console (Reference: 8)

VSS Display (see Figure 2-23)

The Vehicle Search Sonar display shown in Figure 2-23 is a two section panel located at the bottom of Bay #2 and operated by the PCT Pilot. The left section contains the CRT and associated controls. The CRT sweep display is a 120 degree sector centered on the Vehicle bow. The top of the right hand portion contains the speaker and volume control. Below that are located the two two-position switches which allow selection of OPERATE/TEST condition and ACTIVE/PASSIVE sonar transmission modes. Below those are located four pushbuttons to allow selection of the sonar range scale. Next are two pushbuttons which control sonar scanning. These are labeled SCAN RATE and SCAN REVERSE. The control is a three-position pushbutton which selects and displays the 26 degrees per second, 10.5 degrees per second, and 6 degrees per second scan as allowed. When PASSIVE mode is selected the scan rate automatically shows the allowed 6 degrees per second. When the ACTIVE mode is selected the operator has the option of choosing either 26 degrees per second or 10.5 degrees per second. The bottom control on the right half of the panel is the PASSIVE TUNE knob which allows manual tuning of the VSS mixer injection frequency.

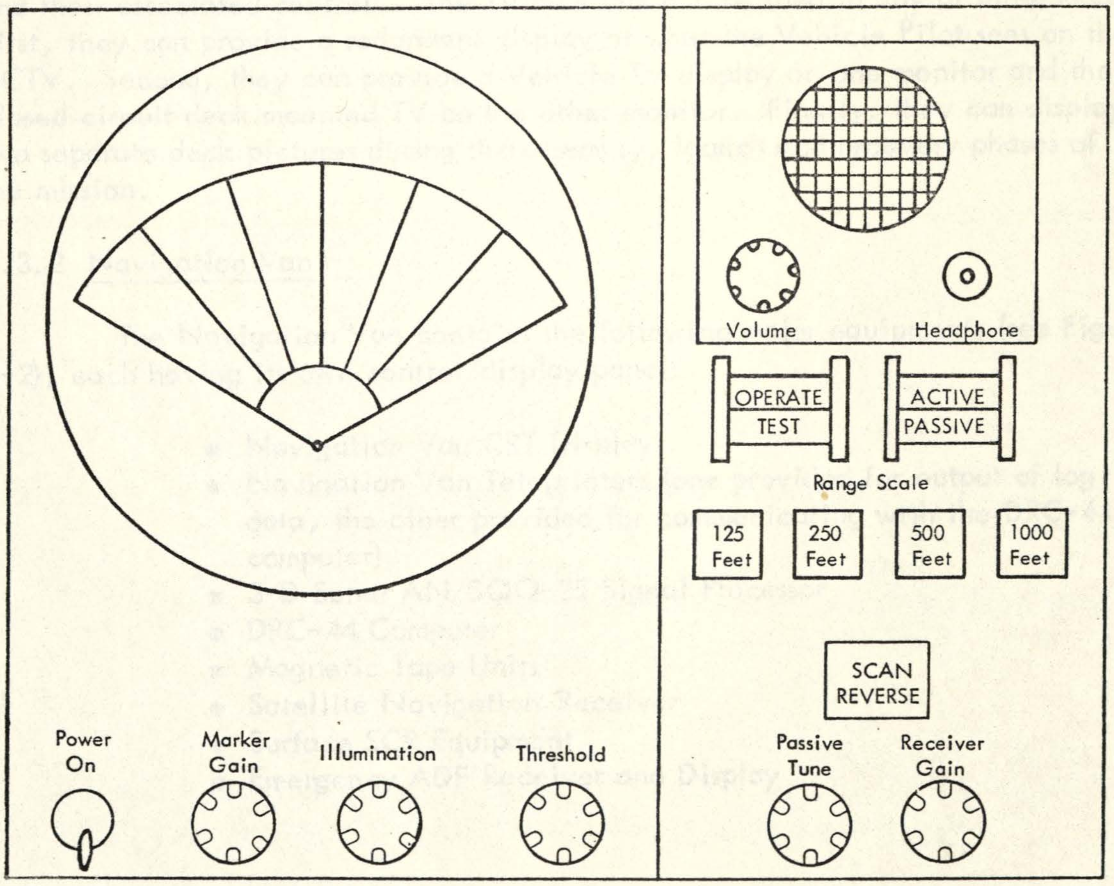


Figure 2-23. Tentative VSS Display Panel RUWS Control Console (Reference: 17)

PCT and Vehicle Navigation Sensor Displays

The PCT and Vehicle navigational sensor display panels are located on the lower portion of Bays #2 and #3 as indicated in Figure 2-10. Each is a two section display. One section contains the submersible compass heading display. The other section of the navigational display contains the submersible altimeter CRT and related controls. The altimeter readout is obtained from a small vertically oriented CRT display containing two scales -- 0 to 20 feet and 0 to 200 feet. The associated altimeter controls allow the turning on and off of the Vehicle altimeter and positioning an altimeter cursor at the desired depth. The operator can also select a mode which automatically monitors the transmitted altimeter depth from the RCTS and inputs it to the RUWS navigational computer. Both submersible displays are identical except for the low altitude warning light on the Vehicle display.

TV Monitors

On the top half of the lower portion of Bay #3 are located two TV monitors and their associated controls. The TV monitors can be used in any of three modes. First, they can provide a redundant display of what the Vehicle Pilot sees on the HCTV. Second, they can provide a Vehicle TV display on one monitor and the closed circuit deck mounted TV on the other monitor. Finally, they can display two separate deck pictures during the assembly, launch and recovery phases of the mission.

2.3.2 Navigation Van

The Navigation Van contains the following major equipments (see Figure 2-2), each having its own control/display panel:

- Navigation Van CRT Display
- Navigation Van Teleprinters (one provided for output of log data, the other provided for communicating with the DRC-44 computer)
- 3-D Sonar AN/SQQ-25 Signal Processor
- DRC-44 Computer
- Magnetic Tape Units
- Satellite Navigation Receiver
- Surface SCR Equipment
- Emergency ADF Receiver and Display

A detailed description of each of the man/machine interfaces for these equipments will not be given since most of them are standard equipments. The primary man/machine interfaces in the Navigation Van consist of the teleprinters and the IMLAC CRT display identical to those located on the ship's bridge and in the Control Van. The Navigation Van CRT display may be moved, if required, into the Control Van for use by the Mission Commander/Coordinator. A hard copier is also included with the RUWS equipments and may be located in either the Control or Navigation Vans.

2.3.3 Deck Handling

The primary man/machine interface of the Deck Handling Subsystem is located on the Motion Compensation Boom. Secondary man/machine interfaces are found on the two motor generators. Since each motor generator has only an electric start button, a fuel gauge, output frequency meter, and hydraulic temperature and pressure gauges, no detailed description of this interface will be included.

The MCB control panel contains all the controls and displays required for one-man operation of the boom during the raising, lowering and deck handling of the submersibles. The panel will have the following controls and indicators:

- Control for Primary Cable winch takeup and payout
- Boom raise/lower control
- Boom gooseneck raise/lower control (elevation)
- Boom traverse control
- Mode select switch (stiff boom/motion compensated)
- "Spring" adjustment air pressure tensiometer for motion compensated mode
- Primary Cable "length out" indicator
- PCT Altimeter repeater
- Boom hydraulic pressure and temperature gauges
- Motion compensation 'spring' gauges for monitoring pneumatic pressure, active cylinder pressure, reserve bottle pressure
- Go-getter winch control (in-out control and free wheel mode)
- Voltage-to-Ground drop indicator and aural/visual alarm
- RUWS intercom control

In the recovery phase of the mission when the Primary Cable is being reeled in, the deck mounted closed circuit television may be used for monitoring the level-wind state of the Primary Cable as it is taken back onto its storage reel.

2.3.4 Bridge Display

Located on the support ship bridge will be an IMLAC CRT display with controls similar to those found on the Vehicle Pilot's navigational display. The controls consist of picture selector, field-of-view controls and magnify and demagnify controls. Additional communication with the bridge is provided by placing one of the Talk-a-Phone RUWS intercom units near the CRT.

2.4 SUPPORT SHIP REQUIREMENTS

RUWS is designed for deployment from a variety of ocean going vessels. At-sea tests are being conducted to determine the effect on the system of ship handling. The results of these tests and equipment location studies will be used to establish available deck space, maneuverability, crew quartering, change in center of mass and buoyancy requirements for the RUWS support ship.

Due to the physical characteristics, number, and availability of the wide beam ARS, the decision was made to design the system to specifically interface with this vessel. The wide beam ARS is 213.5 feet long, 43 feet 11 inches wide, and has a 13 foot draft. It has twin screws for maneuverability and is able to maintain a sufficiently low speed for RUWS station keeping operations. The ship accommodates seven officers, four CPO's, and 93 crew members which allows sufficient berthing to quarter the RUWS personnel contingent. The ARS also has two 35 foot motor work boats and seven CO_2 inflatable life boats for support work in retrieving objects floated to the surface. Additional shipboard facilities include a salvage workshop, integral diesel engines with 610 KW generators, and adequate booms and deck cable handling equipments.

Three deck configurations of RUWS surface equipments were considered for the wide beam ARS. These positions were forward on the forecastle deck, off the fantail, and the quarterdeck forward of the plane of the propellers. The latter position was deemed optimal from the standpoint of maneuverability and RUWS equipment location. Shipboard modifications required to accommodate the system include removal of certain ARS deck equipment and shoring of the deck under the major equipments (primarily the Motion Compensation Boom).

BIBLIOGRAPHY

1. RUWS Program Plan, TN-623. NUC Hawaii Laboratory, October 1971.

2. Subsystem Descriptions for the Remote Unmanned Work System (RUWS). NUC Hawaii Laboratory, October 1971.

3. Cable Assembly Specification for RUWS Vehicle Tether Cable Assembly. NUC Hawaii Laboratory, January 1972.

4. Cable Test Specifications - RUWS Primary Cable. (Prepared by D.M. Rosencrantz), NUC Hawaii Laboratory, 17 December 1971.

5. IMLAC Display Computer PDS-I. IMLAC Corporation brochure and specifications.

6. Control Van Functions. (Received from D. Hightower), NUC Hawaii Laboratory, 16 February 1972.

7. Control Center Specifications. NUC Hawaii Laboratory, 18 January 1972.

8. RUWS Navigation System - Preliminary Specification. (Prepared by R. Wickenden), NUC Hawaii Laboratory, 27 January 1972.

9. Computer DRC-44. Dynamics Research Corporation brochure and specifications, Boston, Massachusetts.

10. RUWS Work System Specs. (Table 1.) (Received from J.Held), NUC San Diego, California.

11. RUWS Fixed Subsystems Specification. (Memorandum from R. Urich and J. Held), NUC San Diego, California, 8 January 1971.

12. Preliminary Design Specification - RUWS Power System. NUC Hawaii Laboratory, October 1971.

13. Deck Handling and Boom Equipment Requirements. (Letter to Dr. J.Q. Burns, OS&E Incorporated, from H. Chalmers), NUC Hawaii Laboratory, 13 January 1972.

14. Vehicle Search Sonar System Summary Sheets. (Letter to H.R. Tolkington from H.W. Volberg), NUC Hawaii Laboratory, 1 February 1972.

15. Preliminary RUWS Cable Telemetry System (RCTS) Specification. NUC Hawaii Laboratory.

16. Specification for Long Range Tracking Sonar (LRTS) and Altimeter Equipment for RUWS. (Prepared by H.W. Volberg), NUC Hawaii Laboratory, January 1972.

17. Specification for Vehicle Search Sonar (VSS) Equipment. (Prepared by H.W. Volberg), NUC Hawaii Laboratory, 17 December 1971.

18. RUWS Grounding Work Sheet. (Prepared by H.W. Volberg), NUC Hawaii Laboratory.

19. Specification for the Acoustic Command and Release Equipment for RUWS (Preliminary). (Prepared by H.W. Volberg), NUC Hawaii Laboratory, March 1972.

20. RUWS Electrical Power and Electronics System, Functional Diagram. (Received from D. Hightower), NUC Hawaii Laboratory.

21. Wide Beam ARS Blueprints. U.S. Navy Documents. (Received from H. Chalmers), NUC Hawaii Laboratory, February 1972.

22. Technique for Establishing Personnel Performance Standards (TEPPS) - Procedural Guide. (Prepared by R.L. Smith, R.A. Westland, and R.E. Blanchard), Integrated Sciences Corporation Report No. PTB-70-5, Vol. II, Santa Monica, California, December 1969.

23. RUWS Control Console Panel Layouts. NUC Hawaii Laboratory, 8 March 1972.

24. Wide Beam ARS Stiff Boom Load, As Is Inclining, Acoustic Noise, Ship Manuevering and Ship Motion Tests. (Memorandum to D. Murphy from H. Chalmers), NUC Hawaii Laboratory, 20 March 1972.

25. Conference Notes. Conferences held with RUWS Staff at NUC Hawaii Laboratory during 14-18 February and 3-7 April 1972.

26. An Operational Description of the Remote Unmanned Work System (RUWS). (Prepared by G.J. Rebane), Integrated Sciences Corporation, Santa Monica, California, October 1972.

27. Design and Planning Recommendations for the Remote Unmanned Work System (RUWS). (Prepared by G.J. Rebane), Integrated Sciences Corporation, Santa Monica, California, May 1972.