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HAWAII DEEP WATER CABLE PROGRAM

DRAFT

CABLE LAYING CONTROL AND DATA ACQUISITION SYSTEMS FINAL DESIGN REPORT

PREPARED FOR
HAWAIIAN DREDGING & CONSTRUCTION COMPANY

PREPARED BY
MAKAI OCEAN ENGINEERING INC.
AND
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SECTION 1

INTRODUCTION

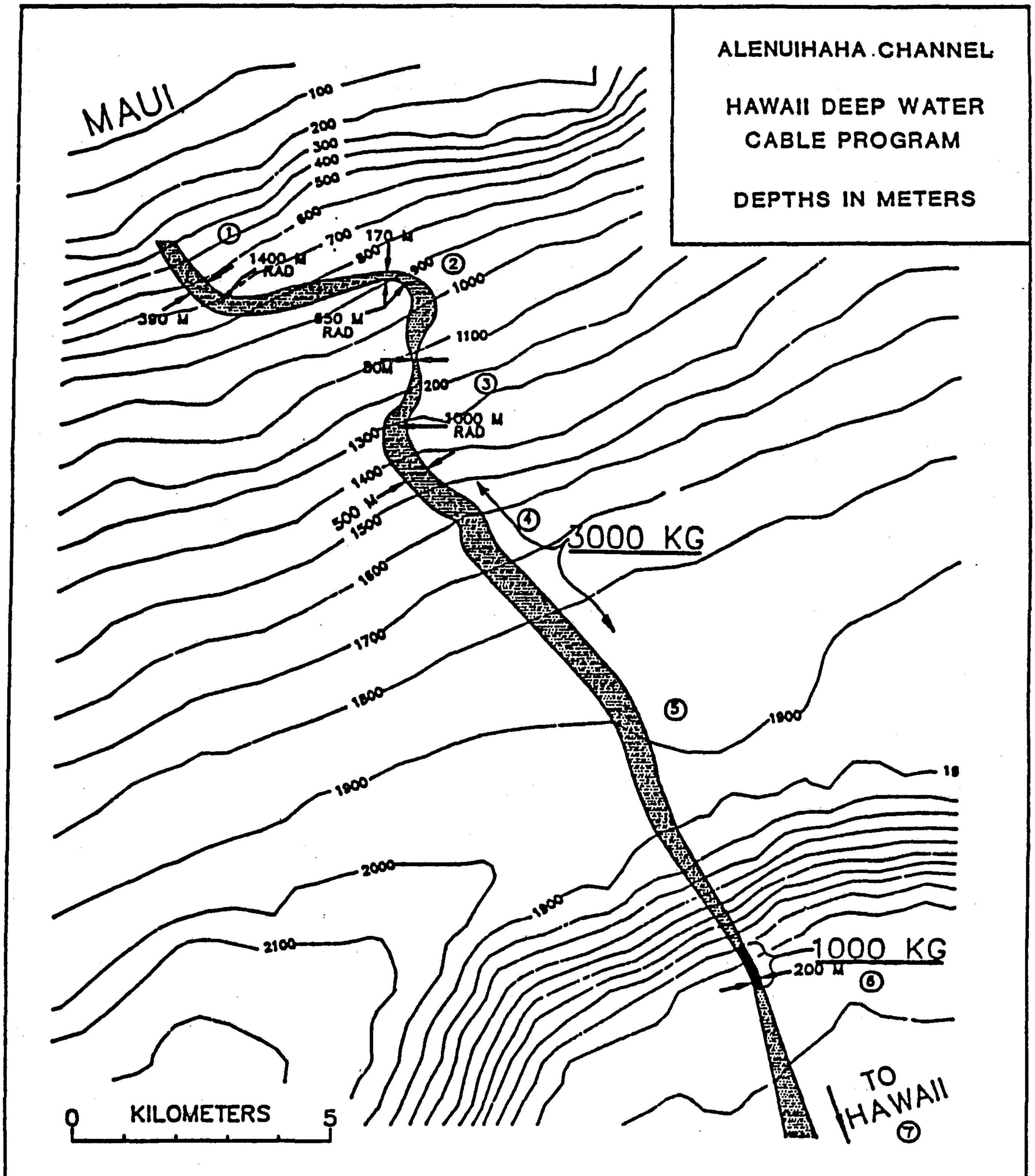
This report describes the Integrated Control System (ICS), the Data Acquisition System (DAS) and data collection systems presently being completed for the At-Sea Test phase of the Hawaii Deep Water Cable Program. Two previous reports on the control of the cable laying process are as follows: "Conceptual Design of Reduced Scale At-Sea Test" - January, 1987 and "Cable Laying Control and Data Acquisitions Systems, Preliminary Design Report" - September 15, 1987. These previous documents provided detailed description of the At-Sea Test and the performance ~~of~~ the cable laying control system. This report is primarily an update ~~on~~ the hardware and the physical description of the system.

The ~~Hawaii Deep Cable Program~~ (HDWC) has the objective of determining the feasibility of laying and operating a submarine power~~ed~~ cable between the islands of Hawaii and Oahu in the state of Hawaii. This program is sponsored by the United State~~d~~ Department of Energy. The Alenuihaha Channel, between the islands of Maui and Hawaii, is a major challenge for laying this power cable. The channel is 1,930 m deep and has a rough bottom terrain, necessitating a very narrow and winding cable path. The channel has been surveyed by the HDWC program; the selected cable route and necessary bottom cable tensions are illustrated in Figure 1. The narrowest portion of the cable route is 80 m wide on the Maui side of the channel and the restricted region on the southern side of the channel is both narrow and rough, requiring the cable to be layed at a relatively low tension. The tensions shown in Figure 1 are for the ~~final~~ power cable, PCC 116.

The At-Sea Test portion of the HDWC program will lay a test cable along portions of th~~is~~ Alenuihaha Channel route and determine whether the cable can be properly placed and tensioned on the bottom. As a secondary objective, the At-Sea Test will monitor the performance of the cable laying control system so that factors limiting the cable position and ~~cable~~ tension accuracy can be evaluated. The test will also ~~measure~~ the environmental conditions and the resulting ship motions and dynamic cable loads.

The final power system for the Hawaiian islands will require three cable to be layed across the Alenuihaha Channel. If all three cables are layed along the path identified, each of the cables must be layed to a ~~maximum~~ precision of ± 13 m in the 80 m wide narrowest portion of the path. The At-Sea Test, therefore, has a goal of precisely laying a single cable along this path with appropriate positioning ~~tolerances~~ and bottom tension tolerances.

Because of the very high accuracy required for positioning and tensioning, a computerized control system is being developed to precisely lay the cable. This control system, together with the



CABLE PATH

Figure 1

Data Acquisition Systems for achieving the secondary objectives of the At-Sea Test, is the subject of this report.

The equipment and systems described in this report are those required for the At-Sea Test. This equipment may be similar to the equipment necessary for the power cable lay, but the primary emphases in this report is on the upcoming At-Sea Test. One primary difference for the At-Sea Test is that the cable is a surrogate and is smaller and lighter. The weight and diameter have been matched, however, so that controlling the bottom position and tension will be equally as difficult for the surrogate as ~~with~~ for PCC-116.

SECTION 2

GENERAL OVERVIEW: CONTROL AND DATA ACQUISITION SYSTEMS

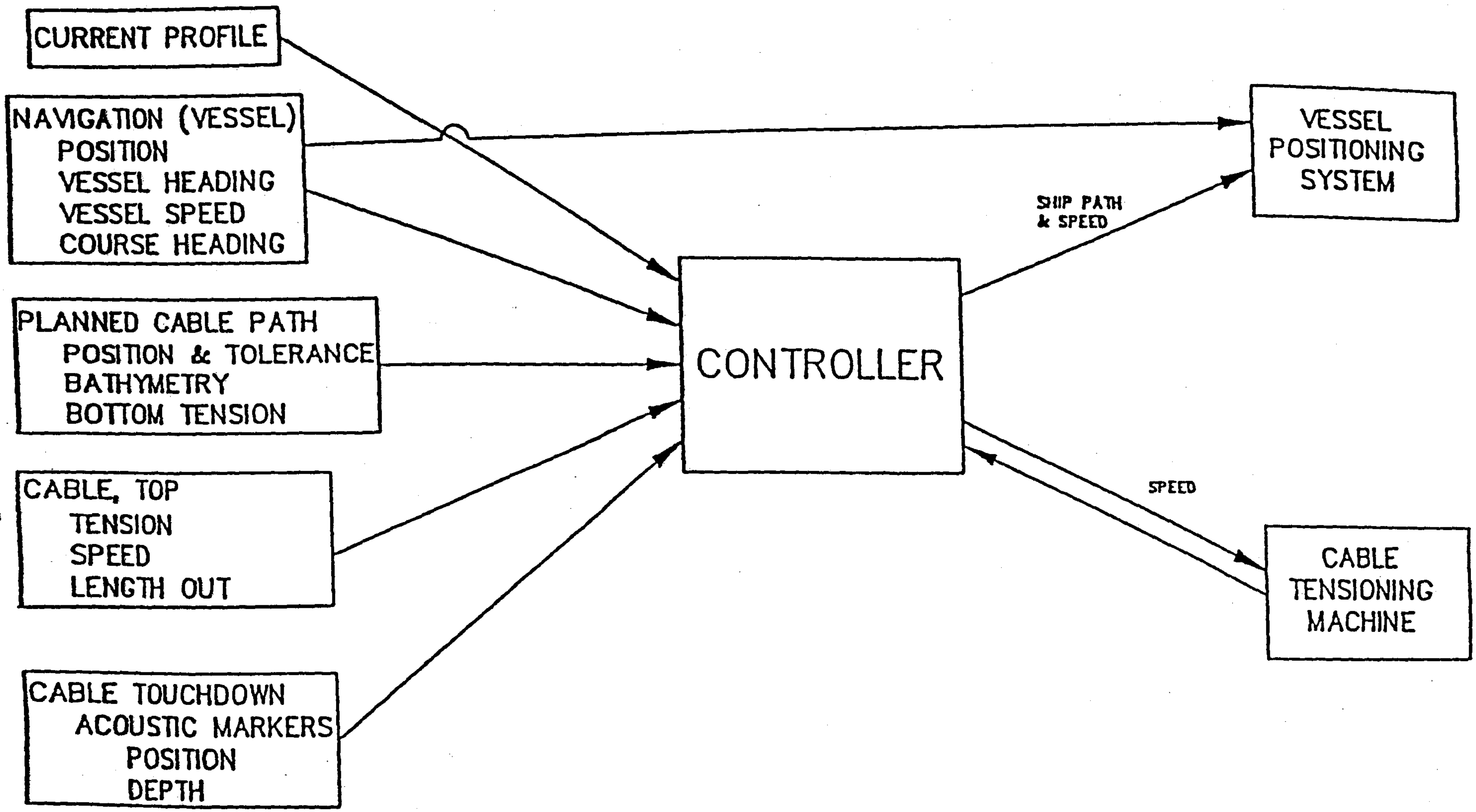
The overall control for the cable laying process is illustrated in Figure 2. The goal of the cable laying control system is to accurately place and properly tension the cable on the bottom, and the system output is instructions for the vessel to proceed along a particular course and instructions for the cable tensioner to pa~~id~~y out the cable at a specific speed. Corrections are constantly being made to these instructions provided to the tensioner and the vessel dynamic positioning system based on differences computed between the desired cable touchdown conditions and the actual touchdown conditions. In order to determine the actual touchdown conditions, the cable shape must be constantly computed based on ~~an~~ input information such as ship position, currents, cable transponders, etc. Much of the control loop concentrates on these computations.

In order to properly compute cable touchdown conditions and the cable bottom tensions, the controller requires accurate measurements of the information shown on the left of Figure 2. Under most circumstances, accurate knowledge of the current profile, vessel navigation, cable payout, the planned path including bathymetry, and the history of the cable lay is adequate to determine a sufficiently accurate touchdown point and tension. For cases of very high tension or position accuracies, transponders will be added to the cable to reduce the computation error.

The Data Acquisition system is provided on the cable vessel to achieve the two secondary goals of the At-Sea Test: recording the performance of the control system and recording the dynamics of the waves, ship and top cable tensions. These data will be used after the test to evaluate the performance of the control system and to perform an independent study o~~n~~f the dynamics of the suspended cable and ship.

The basic control loop for the integrated system is illustrated in Figure 3 and each of the blocks are described below:

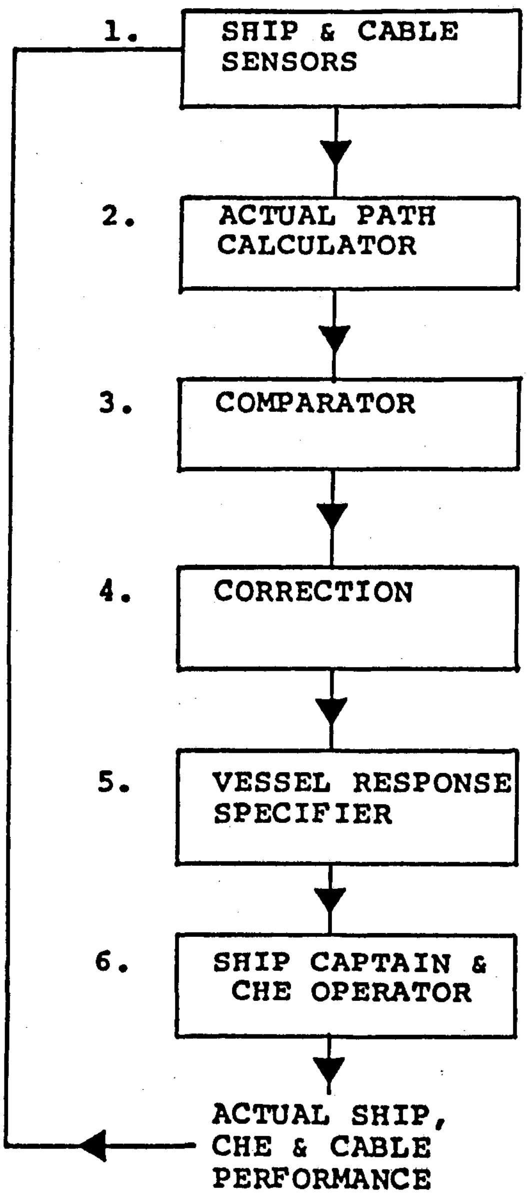
1. Ship and cable sensors provide the basic input information to the control computer (see Figure 2).
2. The Actual Path Calculator (APC) is a subroutine which, by iterative process, computes the actual cable touchdown point and bottom tension. It solves a mathematical model of the cable computing the position and the forces along the suspended cable length.
3. The comparator determines the difference between the actual touchdown values and the desired values.
4. The planned cable track on the bottom is corrected, if necessary, to bring the cable back to the desired path in the immediate future.
5. The Vessel Response Specifier (VRS) is a subroutine which computes the ship's course and speed and the cable



INPUTS/OUTPUTS TO INTEGRATED CONTROL SYSTEM

Figure 2

BASIC CONTROL SYSTEM LOOP



1. Ship navigation, speed, cable,& length, and tension, transponder positions, current profile.
2. Base on sensors, compute cable bottom location and tension
3. Compare computed value to desired values.
4. Adjust ~~C~~able path and tension requirements to meet desired values.
5. Calculate ship course and speed and CHE payout speed to get desired bottom cable path and tension.
6. Ship's crew operate vessel and payout cable.

Figure 3

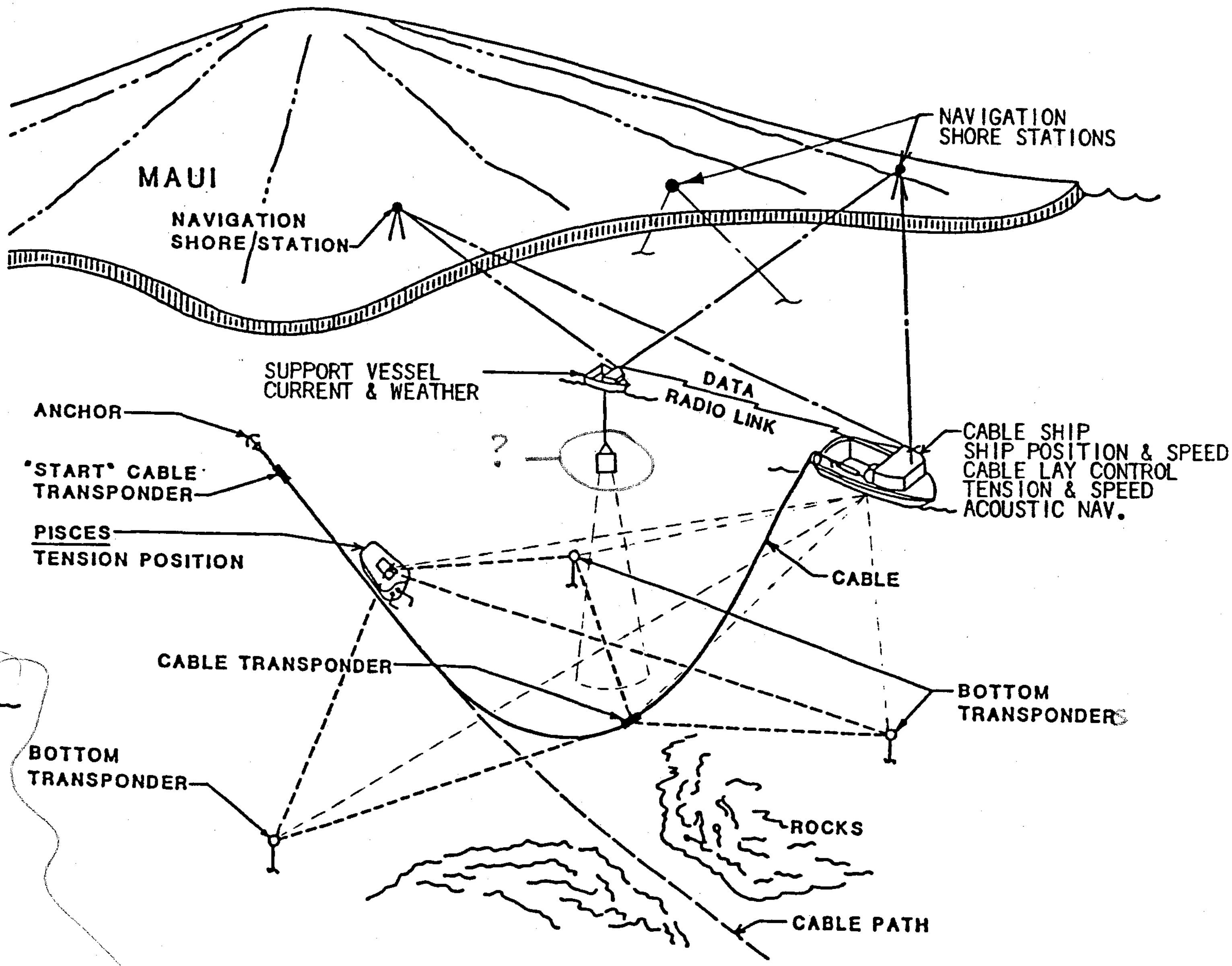
payout speed in order to achieve the desired cable path and tension specified in Step 4, above. This subroutine provides instructions directly to the vessel and cable handling equipment crew.

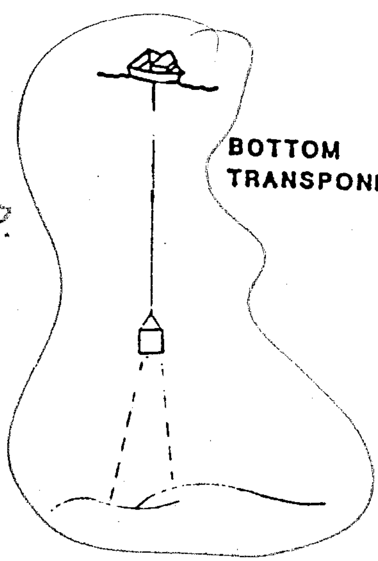
6. The ship's captain and cable handling equipment operator received the instructions from the Vessel Response Specifier. The ship and the cable handling equipment respond to their directions and the ship and cable sensors monitor the performance. Hence the control loop returns to Step 1.

The At-Sea Test for the HDWC Program will involve repeatedly laying a surrogate cable across the more difficult regions of the Alenuihaha Channel. The major components of this At-Sea Test are illustrated in Figure 4. Two primary vessels will be used: the cable ship and a support vessel. The primary function of the cable ship is to lay the cable and on that vessel will be the Integrated Control System, the Data Acquisition System and the acoustic navigation. The support vessel will be used primary to operate an acoustic doppler current profiler. These current data are transmitted via radio between the two ships.

As the cable is being layed, two different navigational systems will be used. A surface electronic range range navigation system will guide both the cable ship and the support vessel on the surface. Underwater, a long-base acoustic navigation system will be used to primary follow transponders attached to the cable suspension but ~~and~~ to also occasionally follow a manned submersible checking the layed cable.

The PISCES V submersible will check the location of the finally layed cable (through the long-based navigation system), visually look for suspensions or other improper bottom cable configurations and measure tensions in the bottom layed cable. The PISCES V is not an active part of the cable laying process but rather a final check on the success/failure of the cable laying operation. Data from the PISCES V will not be fed back into the control system during the cable lay.





what is this ?

Figure 4 Ships and Components of the HDWC At-Sea Test

SECTION 3

SPECIFIC HARDWARE AND SYSTEMS

3.1 SYSTEM BLOCK DIAGRAM

Figure 5 is a block diagram of all the major components making up the cable laying control system. These components are being provided by three different suppliers:

1. Coflexip & Services, Inc. is providing the cable laying ship Flexservice 3, which includes the dynamic positioning systems (DP), cable handling equipment (CHE), a ship computer and two ship positioning systems (Syledis and Microfix).

2. Edward K Noda & Associates is providing and operating the Data Acquisition System and supplying through subcontractors the underwater acoustic navigation and the current profiling system.

3. Makai Ocean Engineering, Inc. is providing and operating the Integrated Control System and providing the feedback to the ship's positioning and cable payout systems.

The DP system receives ship position data from two electronic navigation systems, the Syledis and the Microfix and based on instructions from the ICS, controls the positioning of the ship. The Cable Handling Equipment (CHE) controls the cable speed and provides feedback data on the cable speed, length and tension to the ship's computer. This computer then transmits the cable data as well as the ship's position data to the Integrated Control System and the Data Acquisition System.

The ICS uses the ship position and CHE data together with transponder and current data from the DAS and computes instructions to the ship's systems. These instructions are displayed on CRTs both at the dynamic positioning console and the CHE console. Based on these instructions, the ship dynamic positioning system automatically and precisely controls the ship's thrusters to keep the ship on a desired course and speed and the Cable Handling Equipment pays out cable from the ship at the requested speed. The DAS records control system performance, ship data, current data, transponder position data as well as ship motion and wave data.

3.2 SHIP NAVIGATION

Two independent range-range electronic navigation system are being provided by Coflexip on the Flexservice 3. The Syledis is a short to medium range radio-positioning system with a range capability to 400 Km (216 nautical miles). The brochure described accuracy is 1 meter within line of sight, which will be the range of operations for the HDWC At-Sea Tests. The Syledis is connected directly into the Kongsberg dynamic positioning system.

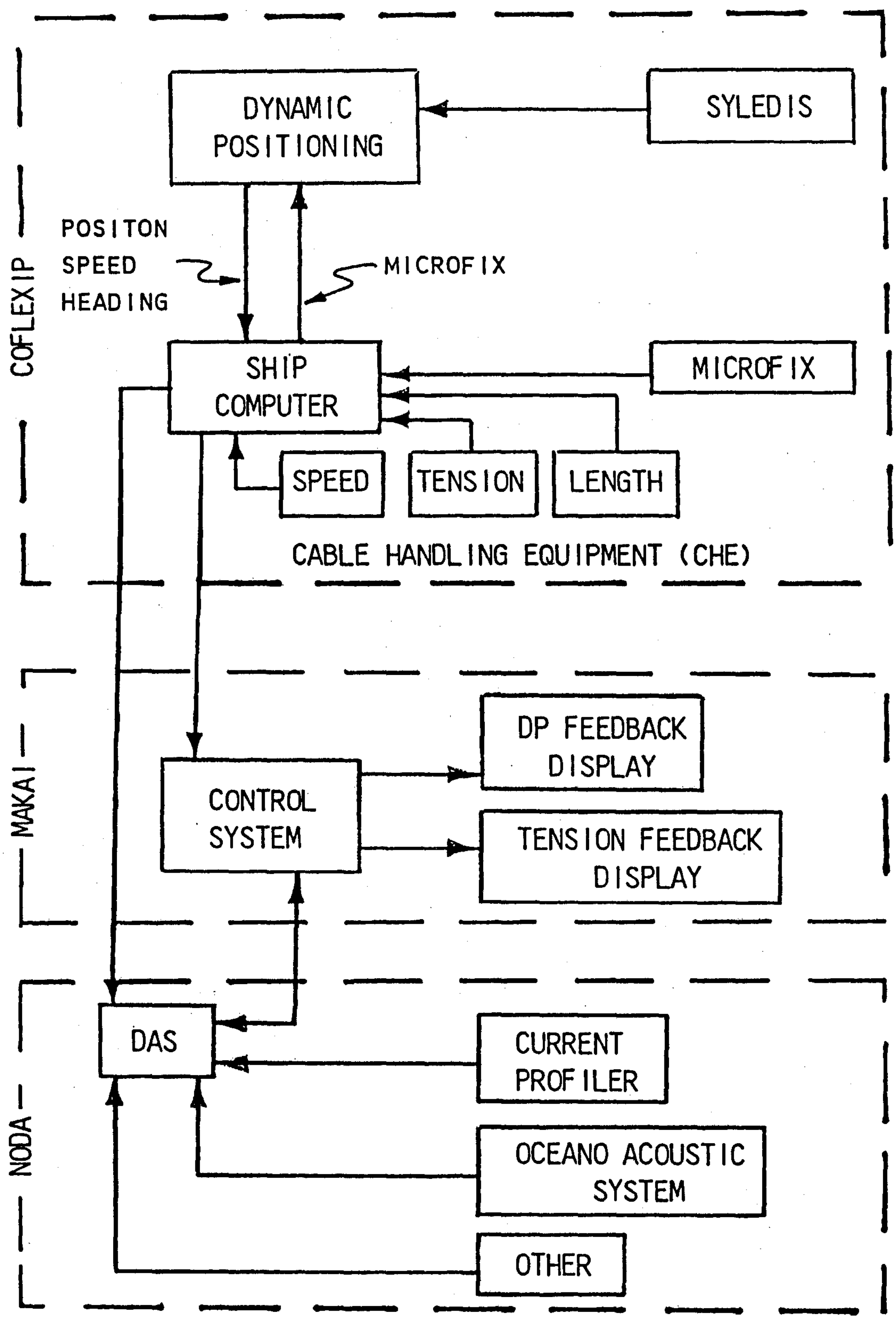


Figure 5 Block Diagram of the HDWC Ship/Control/DAS Systems

The second independent system is a Microfix system manufactured by Racal Positioning Systems Limited, England. Microfix is a short range positioning system using microwave technology to achieve an accuracy of $\pm$ 1 meter with a maximum range of 80 Km within line of sight. The Microfix is connected directly into the ship's computer. The ship's computer calculates the x,y position for the receiving antenna on the ship and provides this to the Kongsberg DP.

The DP uses both navigation systems to calculate the correct ship's position. It performs a coordinate transfer operation based on a reference position which is the aft end of the overboarding sheave (the cable surface position). During the coordinate transfer, the dynamic positioning system corrects for the vessel heading and roll.

The navigational grid for the At-Sea Test will be the Transverse Mercator System from the U.S. Coast and Geodetic Survey, Hawaii state grid, zone II. This is the same navigational grid used by the two previous HDWC surveys of the Alenuihaha channel and was used to establish the cable path. Two shore stations on Maui were used as reference locations for these previous surveys and these two stations, plus a third, will be established for the At-Sea Test. The third shore station provides a means of checking the electronic position and comparing the Syledis and Microfix. The dynamic positioning system computes the best position for the vessel based on both navigational systems.

There is redundancy in the ship navigational system. Two separate systems are being used and each of these systems uses three shore stations. Two shore stations only could be used by either of these systems to determine ship position (without an error check).

The two shore stations used in the past in the Alenuihaha channel have provided excellent coverage on both Maui and Kohala sides of the channel. The angles between these two extreme stations are nearly optimal being almost orthogonal to each other and the required ranges are well within the maximum working range of both the Microfix and the Syledis. A third will be surveyed in and be located between the previous two stations

3.3 SHIP DYNAMIC POSITIONING

The Kongsberg Albatross dynamic positioning (DP) system is a computerized system which enables the vessel to automatically control course, heading and speed. The instructions to this computerized system are provided by the Integrated Control System. These instructions are displayed on a CRT adjacent to the DP operator on the bridge of the Flexservice 3. On the CRT will be displayed the following information:

1. The next desired x, y ship position.
2. The next desired ship speed, in meters/second.
3. The desired ship heading.

4. A countdown signal to validate the new positions, speed and heading.
5. A timing signal (beep) to the operator to validate the new data.

Only one set of instructions can be stored in the DP at any given time. These instructions will be provided to the DP operator at least 15 seconds prior to the validation time.

The DP operator can validate only one input instruction at a time. He will first enter in the next x,y ship position and validate it at the countdown signal provided by the Integrated Control System. He will immediately follow this input with a revised ship speed, validate that information, and then follow with a new ship heading, if required. The DP system will (at the validation of the new coordinates) proceed to the new coordinate point at the previous ship speed. Once the ship speed is entered and validated (approximately 10 seconds later), the DP will adjust the ship speed as necessary. The ship reference position for the DP is the cable water entry point at the stern of the overboard sheave. The DP system keeps that reference point along the desired course and at the desired speed to an accuracy of ± 5 m in rough seas and within ± 3 m in the seas expected for the At-Sea Test.

The DP system operates on one set of instructions at a time; it cannot store a sequence of instructions. It therefore moves in a straight line at a specified speed toward the next x, y way point. If the ship reaches the way point, the DP systems stops the vessel. This is not a desired response for the cable laying operation and therefore a way point beyond the next desired position will be provided by the ICS to the DP. New instructions will be provided in a timely manner to prevent the ship from overshooting the desired course.

The ICS instructions to the DP will be given normally every 5 minutes but sometimes these intervals may be decreased to two or three minute updates. At a nominal ship speed of 10 meters/minute, 5 minute instruction updates (50 m) are sufficiently frequent to maneuver the vessel along even an irregular course.

The ship heading is not a primary concern of the HDWC control system. The primary concern is course and speed of the ship's reference point. The vessel heading would generally remain fixed throughout the entire cable lay and be directed to minimize vessel motions and keeping the cable properly aligned in the sheave. The heading may be changed for the following reasons:

1. To keep the cable properly aligned in the stern sheave.
2. To minimize large cable dynamic tensions.
3. To initiate cable dynamic tensions during specific periods of the At-Sea Test.
4. To reduce ship roll for personnel comfort.

Changing the ship heading has a detrimental effect on the DP ability to accurately control the speed and course of the ship's reference point. To maintain accuracy in the position keeping, the heading should be gradually changed by one degree at a time. Since there are no anticipated critical conditions under which the ship's heading needs to be quickly altered, a slow change in ship heading is compatible with the control system.

The dynamic positioning system on the Flexservice 3 has 100% redundancy. There is redundancy in computer systems, thrusters and generators. It is used in the North Sea for support of diving operations and certification requires a high degree of redundancy and reliability.

Critical control data are provided by the dynamic positioning system to the Integrated Control System. The following critical data are provided:

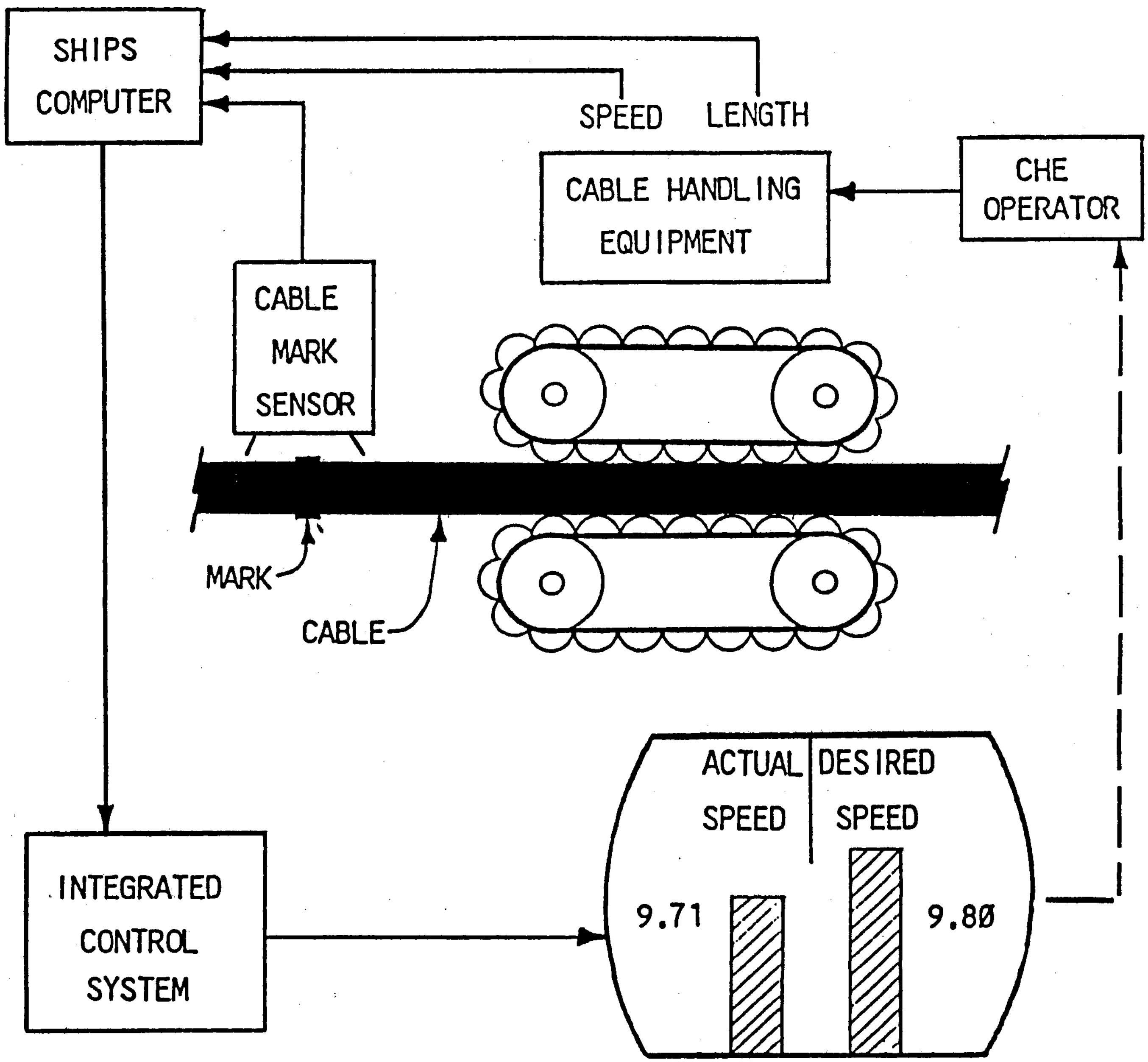
1. Position of the ship's reference point (X,Y).
2. Ship heading.
3. Time of data.
4. The current instructions to the DP.
5. Time since the last adequate position fix from the electronic navigation system.

The last two values provide accuracy checks to the Integrated Control System. Since the instructions to the DP are manually entered by the DP operator, the ICS will immediately check these instructions to be sure that they are the values desired. If not, the ICS will beep at the operator and tell him to correct the instructions. The time since the last adequate electronic ship navigation position tells the ICS whether the electronics navigation is working. If not, the control system operator may direct the cable laying operation to stop.

3.4 CABLE SPEED CONTROL

The cable handling equipment (CHE) is a linear tensioner which pays the cable out at a constant speed. Two 30 ton tensioners will be provided by Coflexip which are linked together hydraulically and operated manually by the CHE operator. The desired cable speed is provided to the CHE operator on a CRT display.

The two linear tension machines are large electrical, hydraulic and mechanical systems primarily used for laying flexible pipeline. The speed control of these machines is not as precise as required by the ICS. The ICS will therefore provide an active feedback to the CHE operator such that the cable speed is kept within the tolerances desired. Information from the linear tensioners on speed and length together with an independent length sensor mark check are provided via the ship's computer to the Integrated Control System which in turn instructs the CHE operator to adjust the speed accordingly. See Figure 6.



CHE SPEED CONTROL

Figure 6

The linear tensioners are outfitted with integral speed and length sensors which are directly coupled to the tensioner's tracks. Because there is slippage of the cable, depending on tension, through the tensioner, the track speed and track length is several percent different than the cable speed and length. To avoid this problem, the cable will be marked with a durable, high contrast mark every 100 meters to a length accuracy of $\pm$ 0.1%. An optical sensor provided by Coflexip will detect this mark and send a signal to the ship's computer. The CHE speed and length sensor measurements together with the time of the most recent cable mark detection are transmitted from the ship's computer to the ICS at a frequency of once per second.

The ICS computes the actual speed and cable length paid out based on the information from the ship's computer. The marks on the cable are used as the absolute reference and are spaced at 100 meters along the cable (approximately 10 minutes of cable laying). The length measurement sensor (track length) from the cable handling equipment is used to interpolate between the marks and a scaling factor between the CHE length sensor and the actual cable length is determined on a cable mark by mark basis. The discrepancy between the CHE length sensor and the actual length of the cable is a function of top cable tension and this tension changes very little from one 100-meters segment to the next.

The actual cable speed and the desired cable speed are displayed on a CRT graphics display to the CHE operator. His task is to adjust the speed controls on the cable handling equipment such that the actual and desired speeds are matched. The Integrated Control System monitors its progress and adjusts the desired speed to compensate if the actual speed is not correct. The cable paid out is the absolute reference used in these computations.

3.5 DATA ACQUISITION SYSTEM

3.5.1 DAS OVERVIEW

The primary purpose of the Data Acquisition System (DAS) is to support the following requirements of the At-Sea Test:

Acquire data from instrumentation devices and systems and distribute data to the Control System and other subsystems in nearly real time.

Record performance of the Control System.

Record the position, heading and dynamics of the cable ship and of the cable itself, undersea currents and wave heights. Cable data includes payout parameters at the ship tensioner and data from positional transducers on the cable near and at the ocean bottom.

The DAS will be prepared to deliver to the ICS, on demand, a limited history of measured data and cable model parameters to facilitate the rapid restart of the ICS cable model. These data will be supplied by the DAS for a time window specified by the ICS. It is possible to do this because cable model parameters were supplied to the DAS by the ICS in the previous operational interval for archival recording.

The DAS also will provide quickly generated reports and charts to support analysis of sensor and subsystem data during the course of the At-Sea Tests. Special reports and tests will be available to assist the operations staff in the calibration and maintenance of the various instrumentation and in troubleshooting the equipment

The connections of the DAS to other systems is shown in Figure 7. The DAS obtains data from the ship's computer, the ICS and from direct connection to physical sensors mounted on two separate ships, the Cable Vessel (C/V) and the Support Vessel (S/V).

The Geodetic/Surface Navigation System, the Dynamic Positioning (DP) System and the Shipboard Cable Handling Equipment (CHE) are all connected to the ship's computer and channel all of their data through this computer. The DAS does not connect directly to these three systems, but acquires all data regarding their operation through the ship's computer.

The DAS obtains some data directly from sensors in raw, unprocessed form. The DAS will process these data for storage in their more useful normalized forms. The ICS will receive wave height, stern accelerometer (heave, pitch & roll) and undersea current profile information via the DAS only, obtained by direct connection between the DAS and the measuring devices or their support processors.

The Wave Height Monitoring System (Waverider) is a self-contained device which will be deployed at sea and will be periodically recovered and relocated to keep it close to the cable laying activity. It is housed in a floating buoy which also contains a data transmitter which links it by radio to a receiver on the C/V.

An Acoustic Positioning (AP) & Navigation Computer and its associated Hydrophone are located on the C/V and are used to track the fixed and mobile transponders which are used to determine cable position relative to the sea floor. This system also tracks the position of the Underwater Manned Submersible, Pisces V.

An Acoustic Doppler Current Profile System (ADCP) Computer and its associated transducer are located on the Support

DAS CONNECTION

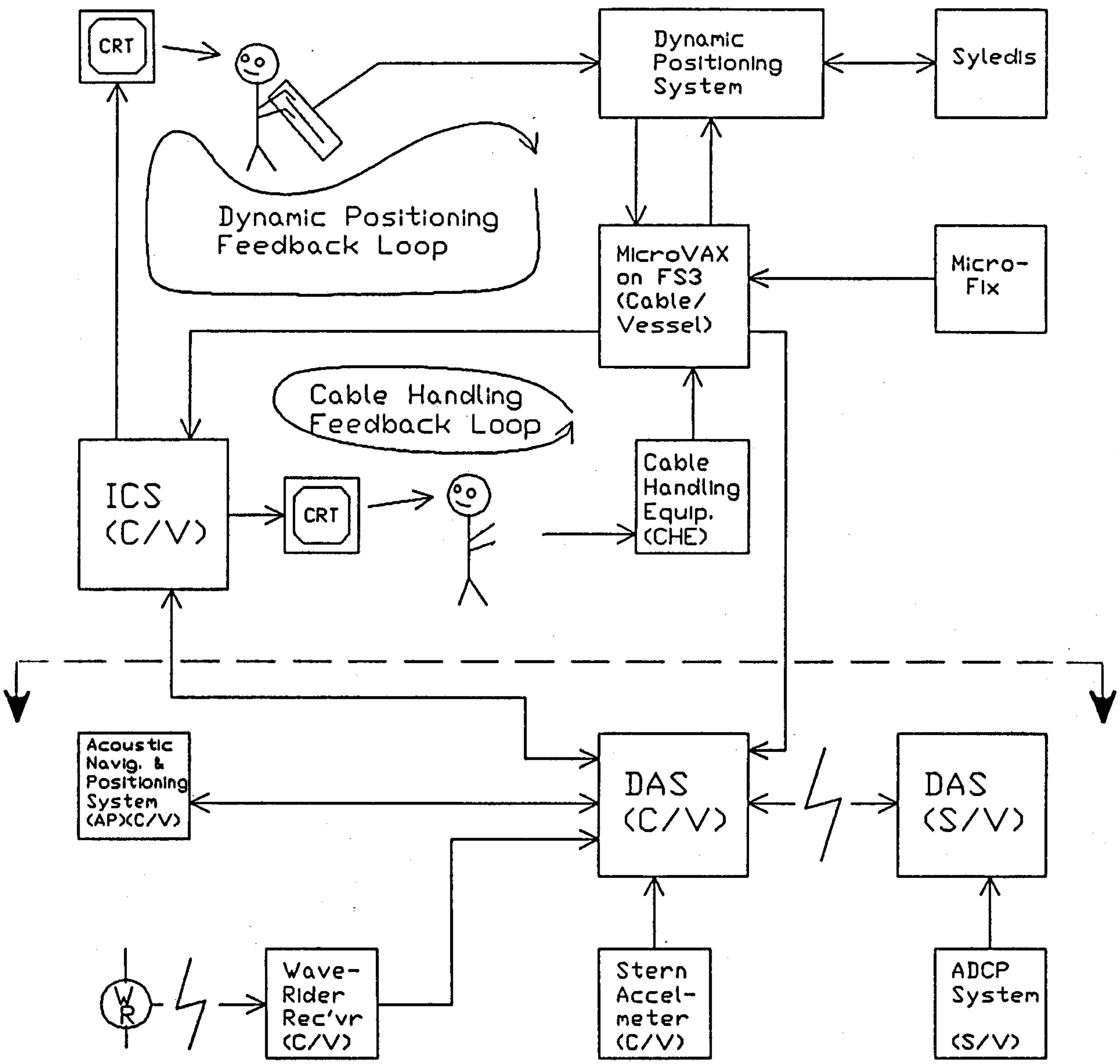


Figure 7

Vessel (S/V). The ADCP supplies a measure of underwater current velocities in a vertical water column in the vicinity of the cable touchdown point on the ocean floor.

The two vessels and DAS related equipment are illustrated in Figure 8 for the At-Sea Test. The major reason for employing the second support vessel is to carry the Acoustic Doppler Current Profile (ADCP) transducer(s) and their specialized processor. The ADCP transducer need to be located close to the ocean floor and close to the cable touchdown point. There is a high risk of tangling the ADCP cable with the actual cable being layed if the ADCP is towed from the C/V. Locating the ADCP on the support vessel also provides some isolation from the mechanical vibration of the heavy machinery on the C/V and from the Acoustic Positioning System hydrophone which is used to track the many fixed and mobile positional transponders.

The DAS C/V computer and the principal DAS Operator's position are located in an air conditioned van housing on the C/V with the ICS (see section 3.7). The principal DAS operator's position is in close proximity to the ICS operator's position so that the two operators are in earshot and immediate view of each other to facilitate communications.

The principal DAS operator is responsible for monitoring and maintaining overall DAS performance, including monitoring the data streams from the sensors and computers to which it is connected on the C/V. A secondary operator's position is located on the S/V. The main responsibility of this operator is to monitor the operation of the Acoustic Doppler Current Profile (ADCP) system.

3.5.2 DAS CABLE VESSEL EQUIPMENT

A block diagram of the DAS computer, instrumentation and support equipment which are located on the Cable Vessel is shown in Figure 9. Each distinct subsystem or component is identified by a number displayed in a box in the subsystem's symbol on the diagram. These numbers will appear in this section of this report surrounded by square brackets (i.e. [1]).

A. C/V DAS Processor [1]

The C/V DAS processor is the primary computer of the DAS system. It is an IBM PC at or 100% compatible computer with an 80287 math coprocessor and is located in the same room as the ICS. The principal DAS operator and the ICS operator will be in talking range and in sight of each other during test operations.

B. Disk Storage (C/V) [1a - 1c]

The C/V DAS processor is equipped with one (1) 360 KB 5-1/4" disk drive [1b], one (1) 1.2 MB 5-1/4" disk drive [1a] and one (1) 100 MB hard disk [1c].

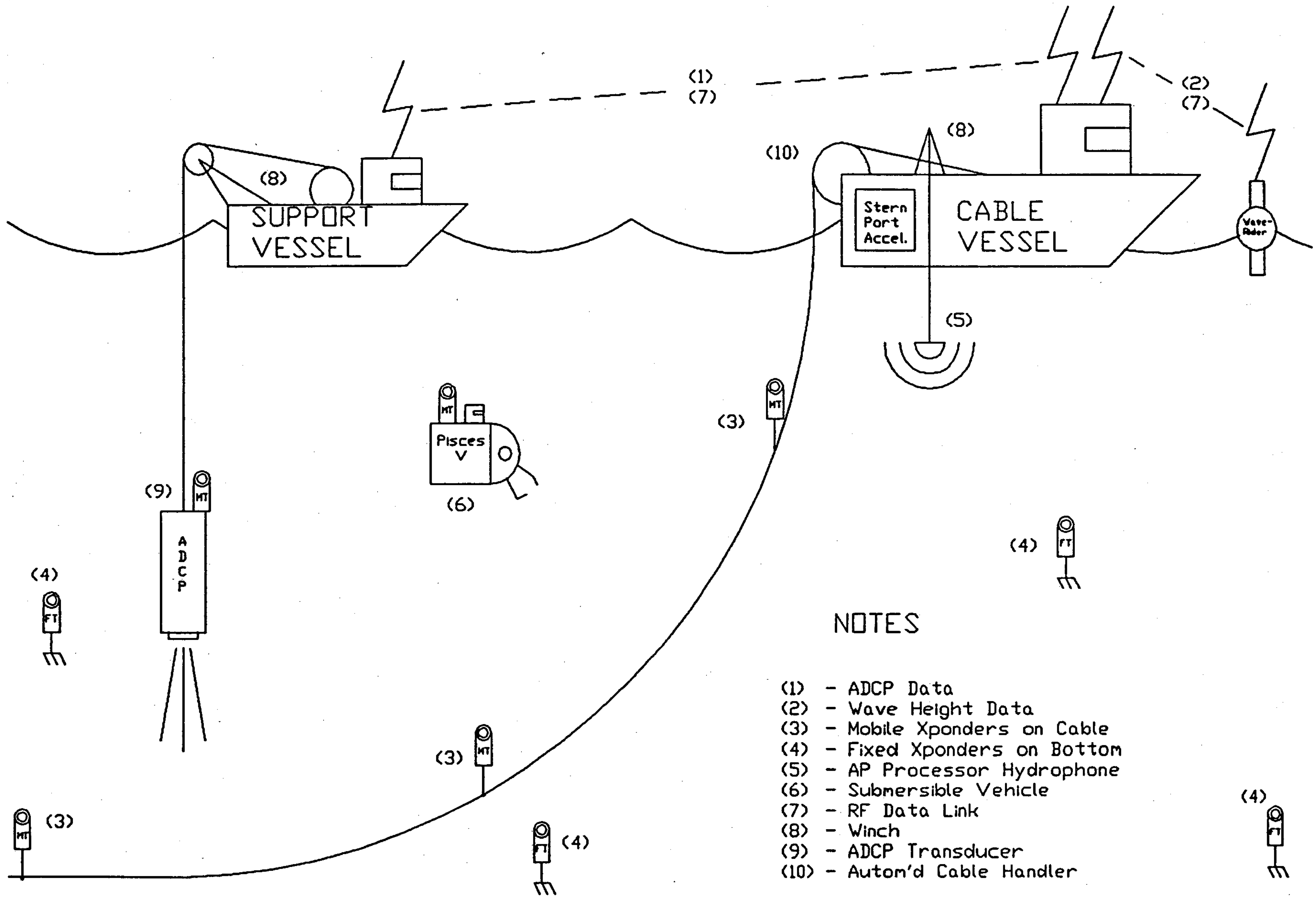


Figure 8 DAS System Components for the At-Sea Test

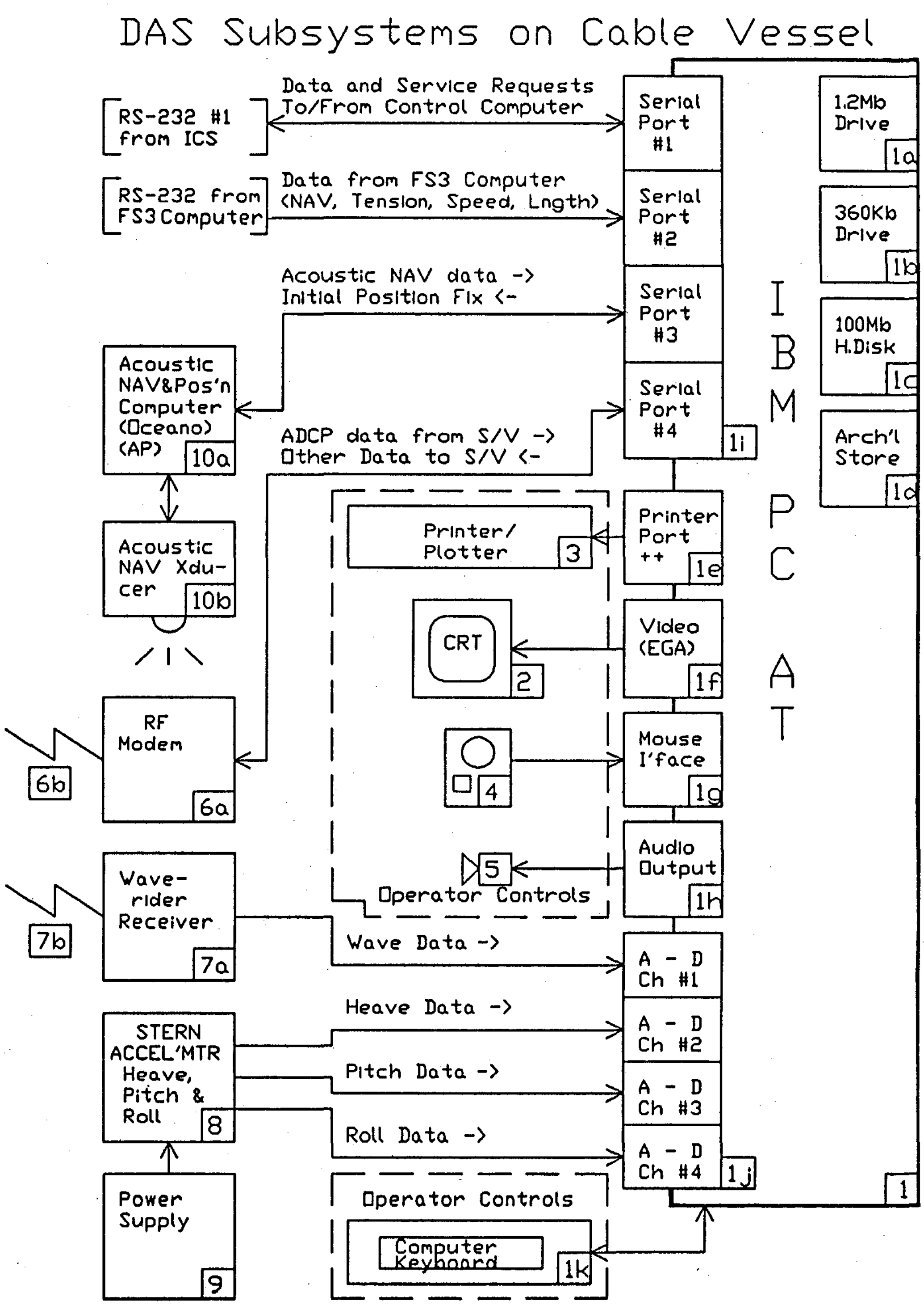

DAS Subsystems on Cable Vessel
RS-232 #1 from ICS
Data and Service Requests To/From Control Computer
RS-232 from FS3 Computer
Data from FS3 Computer (NAV, Tension, Speed, Lngth)
Acoustic NAV data ->
Initial Position Fix <-
Acoustic NAV&Pos'n Computer (Oceano) (AP) 10a
ADCP data from S/V ->
Other Data to S/V <-
Acoustic NAV Xducer 10b
RF Modem 6a
6b
Wave-rider Receiver 7a
7b
STERN ACCEL'MTR Heave, Pitch & Roll 8
Power Supply 9
Printer/ Plotter 3
CRT 2
4
5
Operator Controls
Wave Data ->
Heave Data ->
Pitch Data ->
Roll Data ->
Operator Controls
Computer Keyboard 1k
Serial Port #1
Serial Port #2
Serial Port #3
Serial Port #4 1i
Printer Port ++ 1e
Video (EGA) 1f
Mouse I'face 1g
Audio Output 1h
A - D Ch #1
A - D Ch #2
A - D Ch #3
A - D Ch #4 1j
IBM PC AT
1.2Mb Drive 1a
360Kb Drive 1b
100Mb H.Disk 1c
Arch'l Store 1d
1

Figure 9

The 360 KB drive and the 1.2 MB drive are the standard configuration usually found on a PC AT. They are used for storage and transportation of programs and data and for interchange of programs and data with other PCs during system software development.

The 100 MB hard disk is the principal bulk storage device used to accumulate experimental data during normal operation of the DAS. It is also the location of all C/V DAS system operating software and auxiliary support software.

C. Archival Storage (C/V) [1d]

An Archival Storage Device [1c] is provided as a means of storing historical database data when the 100 MB hard disk drive starts to reach the limits of its capacity. The collection of historical database data on the archival storage device is called the archival database.

It is anticipated that due to the large amount of data being collected that an archive operation might be necessary every eight or ten hours during the course of an experimental test-lay and certainly will be required at the conclusion of each experiment.

The data placed in Archival Storage represents one of the principal products of the At-Sea Test. The Archival Storage device must be reliable and must be able to retrieve the digital data accurately and precisely after extended storage time and after repeated prior read operations.

The Archival Storage Device must be rugged, and must use removable recording media. Tape Streamers, CD devices (Write Once Read Many) and so-called Bernoulli drives use removable media and offer large storage capacity. Devices in each of these categories have been evaluated. A Tape Streamer is the final selection.

D. Serial Data Channels (C/V) [1i]

The C/V DAS processor is equipped with four (4) RS-232C serial ports [1i] on one board. Ports #1 & #2 connect the DAS to the Control System computer and to the ship's computer on the Cable Vessel, respectively. Further discussion on these two ports immediately follows. Port #3 connects the DAS to the Acoustic Positioning computer which is used to track undersea positional transponders (item K, following). Port #4 is connected to an RF Modem which establishes a radio data link to the DAS computer on the Service Vessel (S/V). (item G, following)

DAS to ICS data link: The HDWC Control System (ICS) Computer maintains a mathematical model of the shape and dynamics of the cable being layed and this model is updated with each computation. The ICS computer generates instructions to the DP operator and the CHE operator. The ICS periodically delivers to the DAS for logging into the historical database a large packet of data which contains a snapshot of the various internal parameters which the ICS uses to represent the cable (model parameters) and to control the Cable Vessel. The ICS computer also can request the DAS to retrieve and report these data for recent reporting periods. This would occur, for example, in the case of a restart after an interruption in the operation of the ICS's programs.

Ship's Computer to DAS data link: The DAS has the responsibility of logging a history of all of the information which the ICS computer receives from the Dynamic Positioning System, the Geodetic/Surface Navigation System and the Cable Handling Equipment. DAS receives an exact copy of all of the information which the ICS Computer receives in a parallel connection to the ship's computer. (Figure 7).

E. Analog Data Input Channels (C/V) [1j]

The C/V DAS processor also is equipped with a high speed analog-to-digital (A-D) converter [1j] which is used to accept analog inputs (voltage levels) from the Waverider receiver [7] and the stern mounted accelerometer [8]. The A-D converter will support at least four (4) differential input channels. The A-D converter produces digital representations of the voltages available at the multiplexed input channel, one channel at a time, for use by the C/V DAS processor. These digital values are checked for reasonability and are converted into useful form (wave height, heave, pitch and roll) by input compensation and transformation functions tailored to the characteristics (linear or nonlinear) of the respective sensor instrumentation. The normalized values are then stored in the historical database. The A-D converter selected for this application employs the successive approximation conversion technique which is much faster than the alternative integration method.

F. Operator's Console - (C/V) [1k] [2] [3] [4] [5]

The DAS operator's console located on the C/V is the primary operating position for the DAS. It is located in the same air conditioned room on the Cable Vessel (C/V) as the ICS operator, the ICS computer, the DAS computer and the support equipment for both systems. The DAS support equipment includes the Waverider Receiver, the RF Modem Transmitter/Receiver and the Acoustic Positioning Navigation Processor.

The C/V DAS operator's normal position will be seated at the C/V DAS computer controls. From time to time, as required, the operator will need to observe indicators and meters on the support equipment and change parameters using the controls provided on the equipment. The operator will be able to enable optional audio output and alert signals from the console if he wishes to do so.

The operator's consoles on the C/V and the S/V are equipped with the same compliment of equipment:

[1j] - The KEYBOARD is a standard AT-keyboard which is normally supplied with the IBM PC-AT computer.

[2] - The CRT or monitor is a standard EGA compatible high resolution color monitor with a swivel base to allow a comfortable and easily adjustable viewing angle. Rubber feet on the swivel base have been specified to prevent unexpected sliding in the at-sea environment. A glare-reducing screen filter has been specified for long term user comfort.

[3] - The PRINTER/PLOTTER is a laser-electrostatic printer which is capable of producing a text report or a monochrome graphic image (such as a graph or transponder plan-position map).

[4] - A TRACKBALL has been specified to support graphics interactions. The trackball has the advantage that the package which contains it remains stationary on a working surface, much like a keyboard - an advantage at sea. All X-Y input is accomplished by the operator moving his hand over the ball portion of the control. It also has buttons like a mouse.

[5] - An AUDIO OUTPUT device has been specified to allow the computer to signal the operator (for example, to announce a subsystem malfunction) with a distinctive sound, a melodic series of tones, or even a computer-constructed phrase in English. It will also be possible to verbalize selected parameter names and digital information such as decimal numbers for those circumstances where the operator is unable to provide full undivided attention to the CRT screen. An amplifier with a volume control and a small loudspeaker are provided.

G. RF Modem (C/V) [6a] [6b]

An RF (Radio Frequency) Modem [6] (Modulator/Demodulator) is a specialized hardware module which facilitates the transmission of digital information from a computer or digital device at one location to a computer or digital device at another location using radio transmission rather than a hardwire connection. One (1) RF Modem is required at each end of such a radio data link; each unit functions alternately as a transmitter or receiver depending upon the direction of data flow at any given time. The modems employed at each end of the C/V-S/V DAS Data Link are identical.

Unlike conventional modems used with telephone networks or leased lines, RF Modems incur considerable time overhead under ordinary operating circumstances. This is due to the requirement to verify that data have been received correctly after each transmission, since a radio link is subject to noise, fadeout and weather conditions. For this reason an RF Modem rated at a particular data transmission rate (Baud Rate) cannot be expected to maintain that rate continuously, but only for the duration of each data packet or block transmission. After each transmission, the RF Modem at the receiving end of the channel calculates a check sum of the data in the packet just received and compares this number to a check sum which was generated at the transmitting end and attached to the packet. If the check sums match then the transmission is accepted as valid; if not then a re-transmit request is sent to the originating device and the same packet is re-transmitted until a check sum match occurs. Under ordinary circumstances the average data communication rate between devices using such modems may be substantially less than the instantaneous rate quoted in the device specification.

Radio frequency bandwidth restrictions limit the maximum instantaneous data transmission rate to 9600 Baud. As a practical matter the overall data transmission rate will be approximately 60% - 90% of the maximum instantaneous rate due to the error checking protocol. The RF Modem selected for this application has the maximum rate (9600 Baud) available.

RF Modems have limited range, usually line-of-sight. Communication over distances as great as 1-2 miles should be reliable and trouble free. The antenna(s) used for the RF Modem require a mounting position that is well away from the ocean surface. The antenna(s) should be selected to assure uniform signal distribution in all directions horizontally around the vessel, while limiting the amount of power directed vertically. A vertical dipole or loaded whip will probably meet the requirement.

The actual Modem selected for this application is the RDS 9600 manufactured by Repco. It appears to be the highest speed RF Modem that it available and employs some of the more recent developments in error correction. Power requirements are 120 VAC (60 Hz), which is the standard power supply voltage used throughout the DAS equipment configuration.

It will be necessary to obtain a license or channel assignment from the FCC or subsidiary organization to operate the modem equipment. The authorizing agent might also specify the type of antenna that we are allowed to use in view of the power output (2 watts) of the modem transmitter. The modem selected is already FCC type approved.

H. Wave Height Monitoring Subsystem [7a] [7b]

The Wave Height Monitoring Systems consists of a Waverider fl buoy with transmitter and a companion WAREP MARK II-F receiver.

The Waverider is a buoy which follows the movement of the water surface. It measures waves by measuring the vertical acceleration of the buoy. The acceleration is integrated twice to obtain vertical displacement. The vertical displacement is transmitted to the receiver on an FM sub-carrier which in turn is AM modulated onto an RF carrier in the 27 MHz band. The Waverider Receiver receives and demodulates the 27 MHz carrier, detects the FM sub-carrier and delivers an analog voltage output. The output signal is passed through a low pass butterworth filter before being presented as output to the user.

I. Stern Accelerometer Subsystem [8]

The Stern Accelerometer Subsystem is composed of the following items enclosed in a watertight package suitable for mounting in a location exposed to the weather:

Vertical Stabilized Accelerometer (Humphrey Model # SA09-0101-1)

Companion Power Supply/Inverter for the Vertical Stabilized Accelerometer (Humphrey Model # PS27-0101-1)

The Humphrey Model SA09-0101-1 is a small precision vertical gyroscope with a sensitive servo-type accelerometer mounted on its inner gimbal. It provides three (3) outputs: a vertical acceleration vector whose magnitude is interpreted as heave, and pitch & roll angles in reference to the vertical. Inner and outer gimbal pickoffs are precision wire-wound potentiometers which provide pitch and roll outputs.

J. Accelerometer Power Supply [9]

The power supply for the above accelerometer is a 27.5 VDC nominal, 1.8 Amperes supply also providing regulated, noise free, power at $\pm$ 15 volts, 10 ma and $\pm$ 5 volts, 10 ma.

K. Acoustic Positioning & Navigation System [10]

The acoustic positioning and navigation system will be provided by Oceano Instruments, U.S.A., Inc., Seattle, Washington. The system will be a long baseline acoustic system operating in the low frequency range (8-16 kHz) with a nominal maximum range of about 10 Km. A bottom-fixed series of transponders will be deployed at each of the cable lay test sites in a predetermined grid layout, and utilizing the surface positioning data, the exact locations of these transponders will be determined (calibrated) in the USCGS Hawaii coordinate system, zone 2. Once the bottom mounted transponders have been calibrated, then the position of a mobile transponder can be determined relative to the base coordinate system independent of the surface navigation system.

At present a maximum of 6 mobile transponders will be tracked simultaneously consisting of a transponder on the submersible Pisces V, a transponder on the acoustic doppler current profiler suspended from the S/V, and 4 (max.) transponders attached to the test cable as it is being laid. In this configuration, and considering maximum ranges, the update rate for each successive position reading will be about 110 seconds. Each of the transponders has a unique enable and disable code. Thus, when the services of a particular transponder are not required, this unit can be deactivated (disabled), allowing another transponder to be enabled and tracked.

For planning purposes 8 bottom mounted transponders will be scheduled at each of the test lay sites plus two additional transponders placed by the Pisces V to mark specific locations. Twenty-four transponders will be attached to the cable and one each for the Pisces V and ADCP. With spare units the total number of transponders comes to about 54.

At present, the location of the central processing system for the acoustic navigation system is aboard the C/V. This arrangement will minimize the necessity for RF data telemetry but the question of acoustic noise interference from the Flexservice 3 operations during DP maneuvering remains unanswered. Measurements of the acoustic noise generated by the Flexservice 3 under normal DP operations are presently scheduled during a previous Flexservice 3 job. This data will then dictate whether the acoustic navigation system is to be operated from the C/V or the S/V.

3.5.3 DAS SUPPORT VESSEL EQUIPMENT

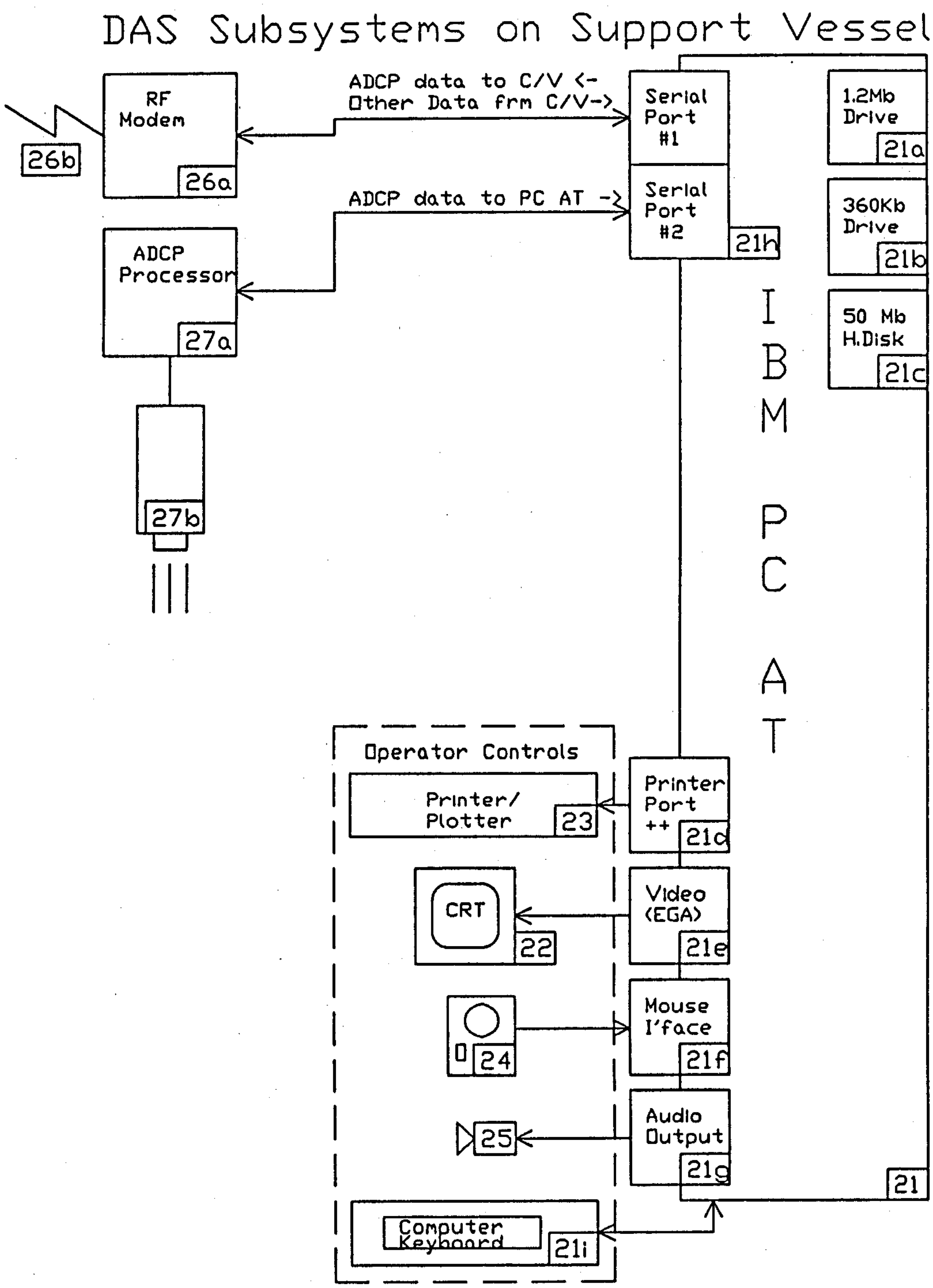
A block diagram of the DAS equipment on the Support Vessel (S/V) is shown in Figure 10. Each distinct subsystem or component is identified by a number displayed in a box in the subsystem's symbol on the diagram. These numbers will appear in this section of this report surrounded by square brackets (i.e. [21]).

A. S/V DAS Processor [21]

The principal task of the DAS processor on the S/V is to accept Acoustic Doppler Current Profile (ADCP) data from the ADCP processor [27] and to format it for transmission to the DAS processor on the C/V. The S/V DAS processor will supply the operator at the S/V console with special reports and support functions to assist with the setup, operation and checkout of the communications link with the ADCP subsystem. The S/V DAS processor [21] is an IBM PC AT or 100% compatible computer.

B. Disk Storage (S/V) [21a] [21b] [21c]

The S/V DAS processor is equipped with one (1) 360 KB 5-1/4" disk drive [21b], one (1) 1.2 MB 5-1/4" disk drive [21a]



DAS Subsystems on Support Vessel
RF Modem
26a
26b
ADCP data to C/V <-
Other Data frm C/V->
ADCP data to PC AT ->
Serial Port #1
Serial Port #2
21h
ADCP Processor
27a
27b
1.2Mb Drive
21a
360Kb Drive
21b
50 Mb H.Disk
21c
I B M P C A T
Operator Controls
Printer/ Plotter
23
Printer Port ++
21d
CRT
22
Video (EGA)
21e
24
Mouse I'face
21f
25
Audio Output
21g
21
Computer Keyboard
21i

Figure 10

and one (1) 50 MB hard disk [21c]. The 360 KB drive and the 1.2 MB drive are the standard configuration usually found on a PC AT. They are used for storage of programs and data and for interchange of programs and data with other PCs. The 50 MB hard disk is used to store all S/V DAS system operating software and auxiliary support software.

C. Serial Data Channels (S/V) [21h]

The S/V DAS processor is equipped with four (4) RS-232C serial ports [21h] on one board. Port #1 is connected to an RF Modem which provides bi-directional digital communication with the DAS processor on the C/V (see section E, following). Port #2 is connected to the Acoustic Doppler Current Profile processor (see section F, following). Ports #3 & #4 are not used.

D. Operator's Console - (S/V) [21i] [22] [23] [24] [25]

The DAS Operator's console on the Support Vessel is a secondary operating position. The primary operating position for the DAS is on the C/V. The S/V DAS operator's position is located in an air-conditioned room with a chair and sufficient table space to accommodate the S/V DAS computer, accessories, computer operator controls and support equipment for the Acoustic Doppler Current Profile (ADCP) System and the RF Modem transmitter/receiver.

The S/V DAS operator can enable an optional audio output warning and alert system if he wishes to do so.

The DAS operator controls on the S/V are identical to those located at the console of the DAS computer on the C/V. For this reason, please refer to section 3.5.2 for a list and a detailed description of the devices provided.

E. RF Modem (S/V) [26]

The RF Modem [26] employed at the Support Vessel end of the C/V-S/V DAS RF Data Link is identical to the RF Modem used on the Cable Vessel. Please refer to section 3.5 2-G for more detailed information.

F. Acoustic Doppler Current Profiling System [27]

Deep current data are necessary input to the ICS. To satisfy this need, an acoustic doppler current profiling (ADCP) system was selected where a direct reading 75 kHz system would be towed by the support vessel and suspended by an electro-mechanical cable with 9 conductors. The ADCP would be housed in a tow body which would provide some vertical stability and would be towed such that the acoustic signal would reach the ocean bottom. Depending on water conditions, ranges off the bottom could vary between 500-750 meters and possibly greater. The ADCP has a bottom-tracking mode, where the measured relative velocities can be made absolute since the bottom is at zero velocity. In the event that bottom-tracking is lost, an acoustic transponder will also be attached to the towed ADCP. The velocity vector of the ADCP would be subtracted from the ADCP measured velocities to obtain absolute velocities.

The ADCP system takes a data sample at approximately one second intervals. The 750 m vertical water column is divided into 32 contiguous vertical column segments, or bins. Each measurement or 'ping' produces two velocity values (u,v) for each of 32 bins.

The ADCP processor averages approximately 100 readings before delivering output data to the DAS (S/V) computer. Each output packet (which occurs approximately every 100 seconds consists of a U velocity, a V velocity, signal strength, standard deviation and 2 additional measures of data quality for each of the 32 bins.

Present analysis indicates that it is not necessary to directly measure the current velocities in the upper part of the water column not sensed by the ADCP. The cable vessel control system can calculate an "equivalent" current for this upper region which would be satisfactory for the future calculation of the cable shape. As a standby option, a single current meter suspended from a cable can provide information in the upper part of the water column.

The ADCP current profile data will be interfaced to a DAS computer onboard the S/V for general data storage. In addition, these data will be transmitted via an RF modem to the C/V for real-time input into the ICS.

G. <u>Support Vessel Navigation</u>

The support vessel (S/V) will also require a surface navigation system. It is envisioned that either a Syledis and/or Microfix system will be utilized on the S/V. The same C/V shore transponder stations would be used.

3.5.4 DAS HARDWARE DUPLICATION

Overall system reliability has been enhanced by providing alternate paths for critical or potentially congested data channels. Duplicate DAS system components will be available as spares on both vessels.

The ICS Computer will ordinarily receive information from the ship's computer over its own dedicated RS-232C high speed communications link. An alternative backup path exists through the DAS. See Figure 7.

Spare parts and duplicate spare system components for the critical equipment whose failure at sea would introduce a significant delay in the progress of the At-Sea Test will be inventoried on the C/V and on the S/V. The spares inventory on each vessel will be based upon the vessel's installed equipment list.

3.6 INTEGRATED CONTROL SYSTEM COMPUTER

3.6.1 SOFTWARE AND HARDWARE SCHEMATIC.

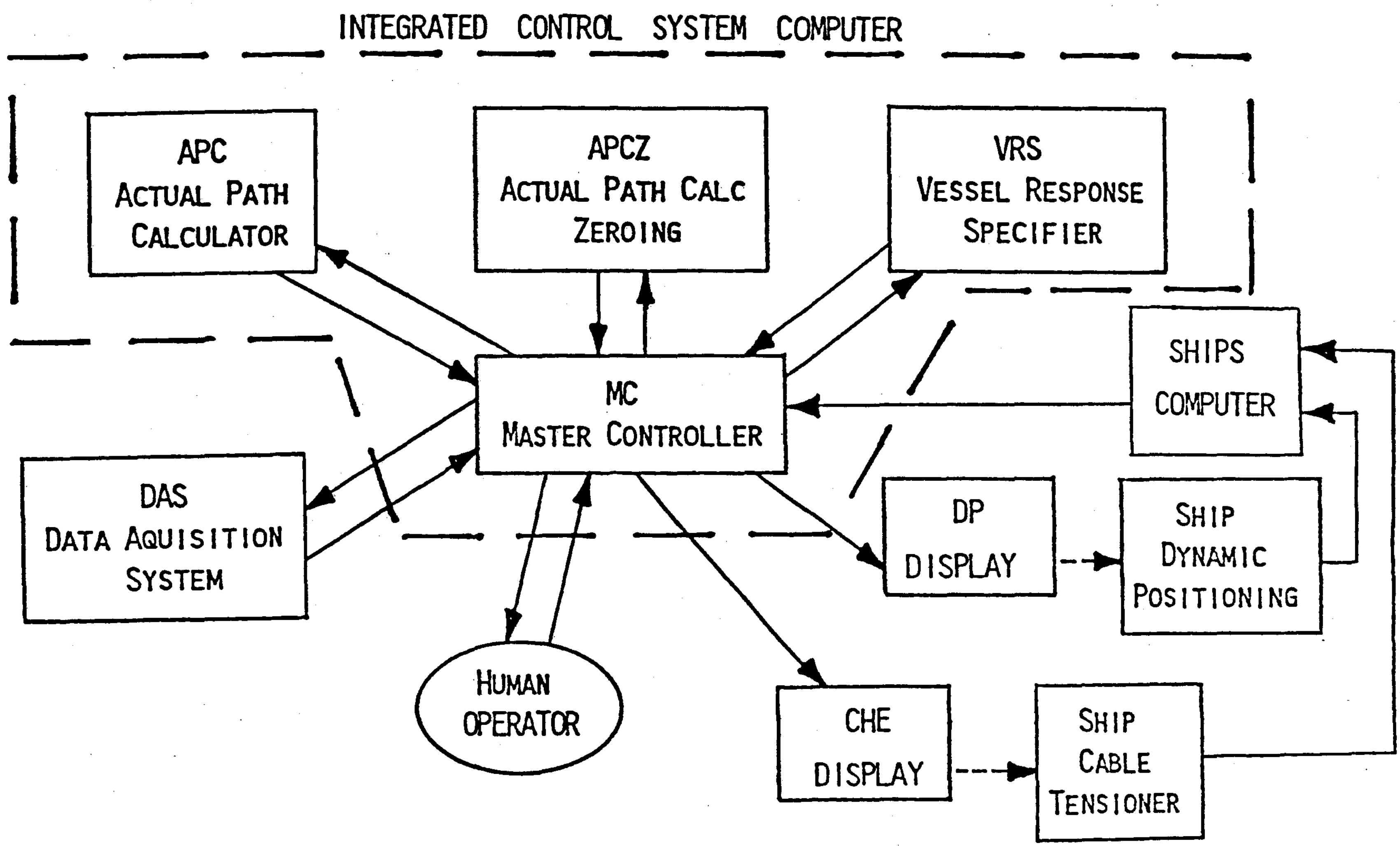
Figure 11 illustrates the hardware and program interconnection for the Integrated Control System. The ICS computer receives information from the Data Acquisition System, the ship's computer and the control system human operator. Output information to control the cable lay goes to the Dynamic Positioning display and the Cable Handling Equipment display. Additional historical data go to the Data Acquisition System.

Within the ICS computer is operating, sometimes in parallel, multiple programs. The central program is the master controller, MC, which coordinates all data transfer and timing of the operation of various control programs. These programs are further detailed in the following sections.

3.6.2 GENERAL DESCRIPTION OF ICS PROGRAMS

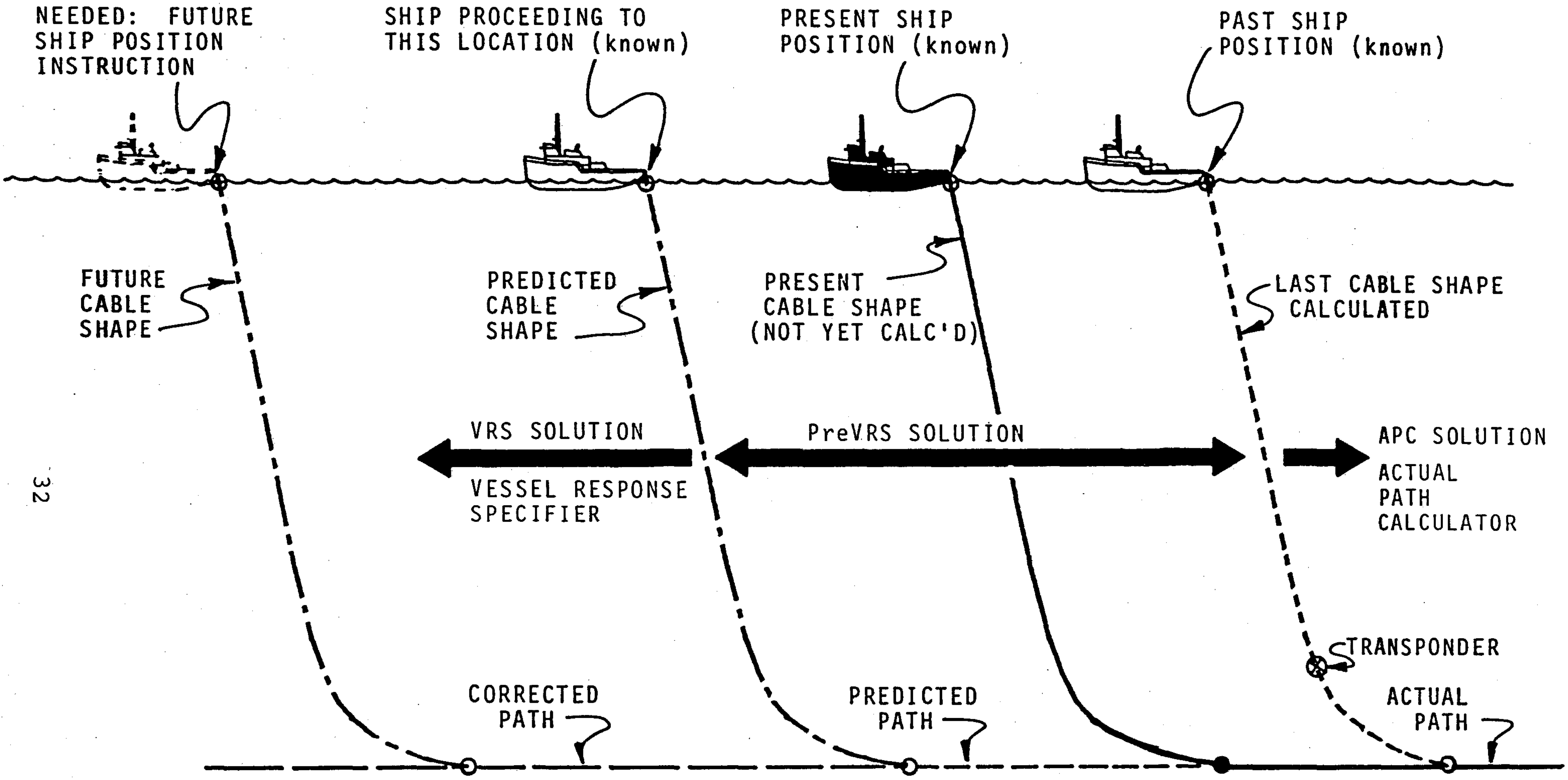
Figure 12 pictorially represents the application areas for various software programs within the integrated systems. The control system operates by computing as accurately as possible the shape and tensions in the suspended cable below the cable laying vessel. By solving for the shape and loads, the touchdown point and touchdown tensions can be accurately computed. In Figure 12 the vessel is laying the cable from right to left and illustrated are several snapshots in time of the cable laying process. The dark boat illustrates the ship and cable at the present time. The shape below the ship at that time has not yet been calculated because of delays in transponder and current data being transferred to the control system and because there is a finite length of time required to do the calculation. To the far right in Figure 12 is a ship and cable position which occurred in the immediate past for which a solution exists in present time. These solutions are calculated with the Actual Path Calculator, APC, which is the primary program used to calculate where the cable has been layed. This program uses measured data on the ship position and speed, cable payout length and speed, current profiles, transponder data and knowledge of the previous cable solutions.

To the left of the present time ship and cable shape in Figure 12 are several ship positions into the future. These future positions need to be known in order to direct the captain of the ship and the cable handling equipment operator to respond as desired. It is therefore necessary to compute cable shapes into the future. This is done with a separate program called the Vessel Response Specifier (VRS). The VRS solution is broken into two sub categories. While the computation is taking place, the captain of the vessel and the cable equipment operator are following previously



HARDWARE/PROGRAM INTERCONNECTION

Figure 11



CONTROL PROGRAMS

Figure 12

issued instructions. The ICS, therefore, knows where the vessel will be and what the cable payout length will be for the immediate future. With the ship operating under these previously specified instructions, the cable shape and response can be calculated by the PreVRS program. This program operates on a current profile forecast generated by the latest APC cable solution and observed trends in the measured current profiles.

The primary purpose of the VRS is to provide the next incremental instructions to the DP operator and the CHE operator. Therefore, the VRS solution needs to go beyond the previous instruction point. These solutions are based on current forecasts and knowing the desired cable path and tension on the bottom.

Coordinating these primary programs within the ICS is the master controller, MC, as illustrated in Figure 11. This program orchestrates the whole process. It is the control system clock, the main decision maker, and the only interface to the human operator. It also controls the input and output information to and from the ICS. The automatic functions of the MC are as follows:

1. Control the flow of all data between the various systems such as the ship's computer, DAS, and the various programs running within the control system.
2. Provide the timing and sequencing of program operation within the control system.
3. Provide a schedule for the overall cable lay and remind the operator of upcoming events.
4. Transmit historical data to the DAS.

The functions provided by the MC in conjunction with the human operator are as follows:

5. Check all data coming from various sources before it is transmitted to the next sequential step.
6. Select which program is to be run to compute cable shapes.
7. Provides a detailed status report to the operator including specifics on the cable laying performance, data checks, program timing and the overall "health" of running programs.
8. Stop the cable laying upon a simple command by the operator.

Under operator (human) command, the MC allows the following:

9. Allow the operator to correct and modify data, as necessary.
10. Allow the operator to recover a cable laying sequence in case of a computer failure or other contingency.
11. Allow the operator to change parameters within individual programs.

12. Allow the operator to be fully in command of the control system, keeping him fully informed and allowing him to override automatic processes.

The following programs are operated by the MC within the integrated system:

APC - Actual Path Calculator. This program calculates the actual cable shape, tensions and touchdown point knowing a fixed point on the cable (either the ship's location or a transponder location), the previous solution, the current profile, and the bottom terrain.

APCT - Actual Path Calculator with Transponders. This program is identical to the APC but makes use of the multiple transponders on the cable and generates a best fit solution with redundant data available.

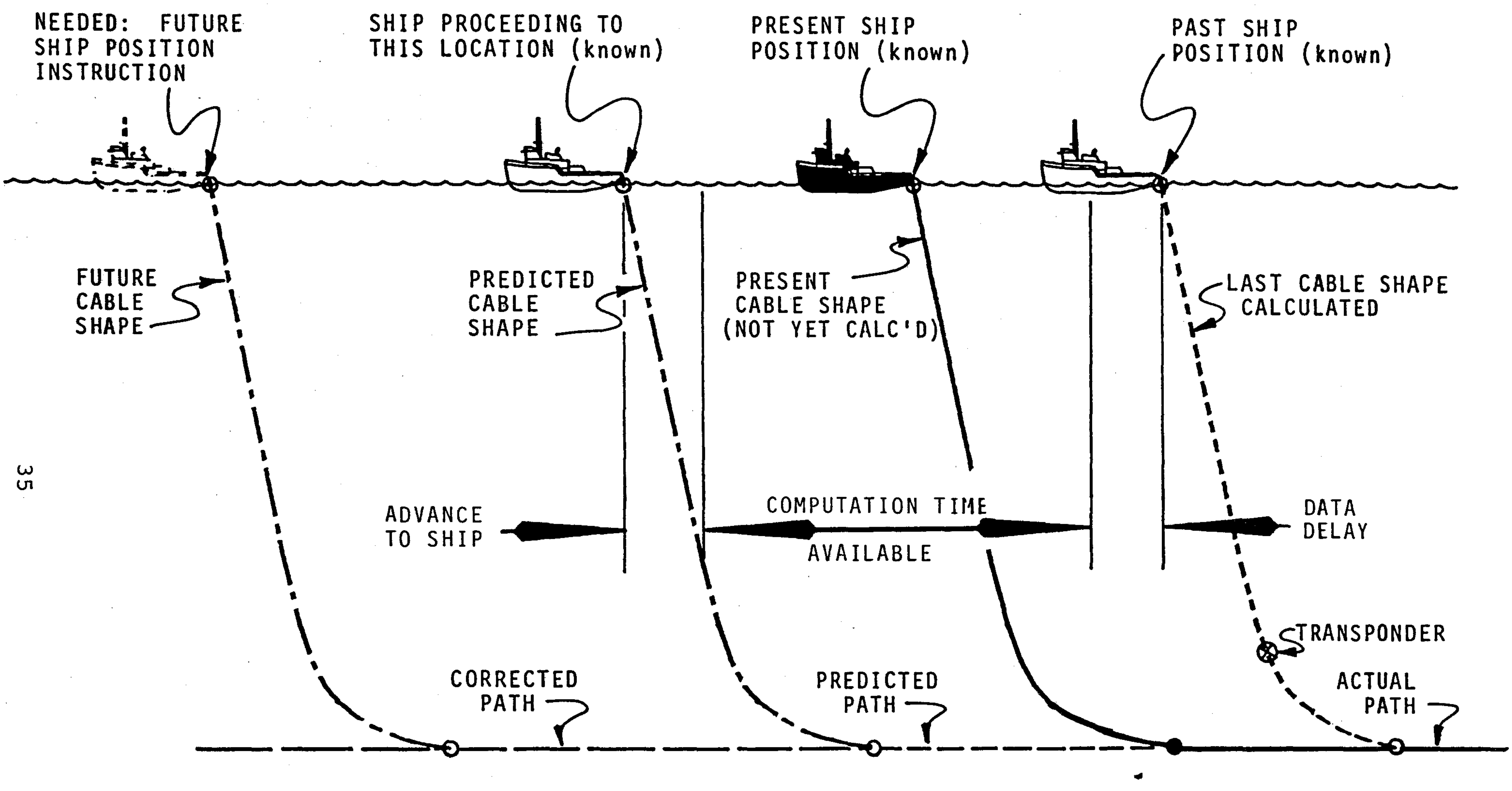
APCZ - Actual Path Calculator, Zeroing. This program uses one or more transponders on the cable, with one transponder fairly close to the bottom, and computes the cable shape while ignoring the cable history and previous cable touchdown position. While laying the cable there may be an accumulated error in cable length laying on the bottom and the computed touchdown position may drift as a result of this accumulated error. The APCZ allows this accumulated error to be zeroed out.

CD - Drag Coefficient Computation. This program uses multiple transponder locations, ship location and speed and current profile data to compute the average drag coefficient on a freely suspended cable. The cable will be suspended early in the At-Sea Test to measure the drag coefficient on the actual cable and under representative velocity conditions.

CR - Cable Recovery. This program generates and prints an entire cable recovery scenario for the Flexservice 3 which is independent of bottom current. During recovery, the bottom cable tensions will be elevated such that the cable shape is minimally affected by the current. By this method, the cable recovery process can proceed without the guidance of the control system.

3.6.3 CONTROL SYSTEM TIMING

The ultimate output for the control system is instructions to the ship and the cable handling equipment and these instructions must be timely and provided at regular intervals. In order to make these "deadlines" for instructions for the ship, the control system must complete a series of APC, preVRS and VRS calculations. Figure 13 illustrates the time available for performing these computations. As in the previous figure, the ship and cable configurations are illustrated for past, present and future positions. The ship is presently proceeding upon instructions that



TIME AVAILABLE FOR COMPUTATIONS

Figure 13

have already been provided to the captain and the CHE operator. Before the ship reaches the next way point, a new set of instructions must be provided to the vessel. Furthermore, these instructions must be provided in advance to the ship in order that the operators can properly enter the data. To the far right in Figure 13 is a past cable shape for which measured data are available only after a finite data delay. After that delay, computation may begin on running the APC, the preVRS and the VRS in order to determine the desired ship position illustrated at the far left of Figure 13. The computation time which is available is schematically shown.

Figure 14 graphically illustrates the computational time steps and processing time for each of the major ICS programs. The horizontal scale is time and the units are 5 minute ship/CHE instruction update periods. A new set of instructions is provided to the ship every 5 minutes and all the computations that are shown on this graph must be repeated for every update period. The time period from -1 to 0 on the x axes corresponds to the period where the latest instructions to the vessel are valid. At some finite time before time zero on the x axes, new instructions must be provided to the ship. The time period from 0 to 1 is the time period for which instructions are being calculated. In other words, the ship is proceeding to point 0 and will require another set of instructions before reaching 0.

The upper portion of the graph in Figure 14 shows the four major computer components of the control system. Each of the four components is represented by a horizontal line and the steps at the top of the line represents the ship time steps for which computations are being made. The steps below the horizontal line are the times during which the programs are actually run. For example, the Actual Path Calculator (APC) computes the actual cable shape up through point A indicated on the graph and this computation is actually completed by this program at point B. The preVRS then computes where the cable should go as long as the ship closely follows the instructions that have been provided to it. It calculates the cable position and touchdown from point A to time 0. This is a particularly fast program since it does not involve transponders. Once the preVRS's program is complete, the VRS program computes the desired ship position and cable payout speed for time 0 to 1. This computation is completed at point C with enough time for the MC to transfer the data to the ship in advance of its need at time 0. Directing the three major cable shape programs is the Master Controller, the MC, and its time involvement in transferring data and coordinating the various programs is illustrated along its time curve.

The lower portion of Figure 14 illustrates the forecast need for currents with this particular control loop timing. The APC requires no current forecast since the computations are computed on the basis of actual measurements. The preVRS, however, has need of current profiles in advance of when the data are available and even into the future. As each time step in the preVRS and the VRS is

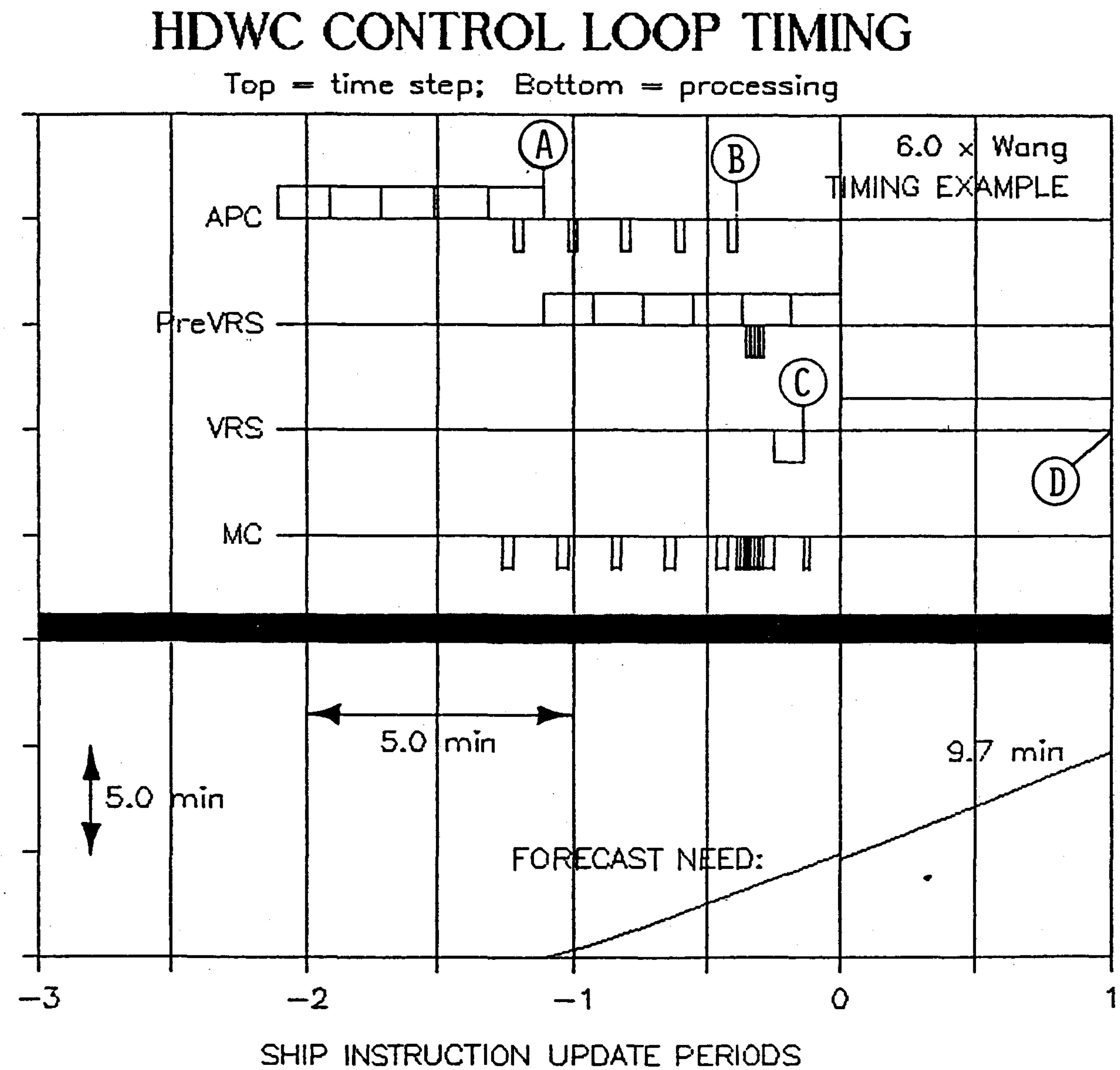

HDWC CONTROL LOOP TIMING
Top = time step; Bottom = processing
A
B
C
D
6.0 x Wang
TIMING EXAMPLE
APC
PreVRS
VRS
MC
5.0 min
5.0 min
9.7 min
FORECAST NEED:
-3
-2
-1
0
1
SHIP INSTRUCTION UPDATE PERIODS

Figure 14

computed, it reaches further into the future and the size of the forecast jump into the future increases. The curve at the bottom of Figure 14 illustrates that once the final VRS time step is completed, it has relied on a current forecast jump of 9.7 minutes.

The timing of the various programs, the selection of required computer speed and the allowable delays for data delivery have been and are continuing to be adjusted to minimize the time length of the current forecast required and also to minimize the time distance between points A and D. The greater the forecast projection into the future, the greater the probable errors for this current profile. Furthermore, the time distance A-D represents the physical delay time between commands to the vessel and feedback. A responsive control system needs to minimize this delay.

3.6.4 CONTROL SYSTEM HARDWARE AND OPERATING SYSTEM

The hardware and operating system has been selected in the final design of the ICS. The selected computer is a HP 9000 Series 800 Model 835CHX and peripherals shown in Figure 15. The HP uses a Unix-V standard operating system and supports a Fortran 77 compiler, the language in which the programs have been developed. The selection process is detailed in Appendix A.

The entire Integrated Control System (excluding the DAS) will reside on the HP computer. All the numerical models and control programs will run as processes on the HP. All the displays will be on peripherals of the HP. This will greatly simplify fabrication of the system, eliminating many problems of connection and communications protocol.

Shown in Figure 15 is the At-Sea Test configuration of the HP. There will be both primary and backup systems for the At-Sea Test, the backup provided under agreement with HP for the At-Sea Test time period only. The computers have identical System Processing Units (SPUs) with Local Area Network (LAN) and Multiplexer (MUX) hardware.

Connected to the SPU buss are the CHX and CH monitor subsystems. The CHX and CH are individual components that provide I/O control Monitor, Keyboard and Mouse. Also connected to the SPU buss are the 304 Mb disk drives and the Cartridge Tape drive.

The MUX can connect to up to 6 RS232 devices. On the primary system this will include 3 terminals, the Flexservice 3's VAX computer, the DAS and a printer. The terminals will display commands to the DP and CHE operators and information on the ICS activity. The LANs are used to connect the 2 system together providing a means of quickly updating either system. The LAN may also be used for connection to the DAS, if the MUX RS232 connection proves too slow.

The ICS operator will work on a single color graphics monitor in a windows environment. The windows environment will enable him

CS EQUIPMENT SCHEMATIC

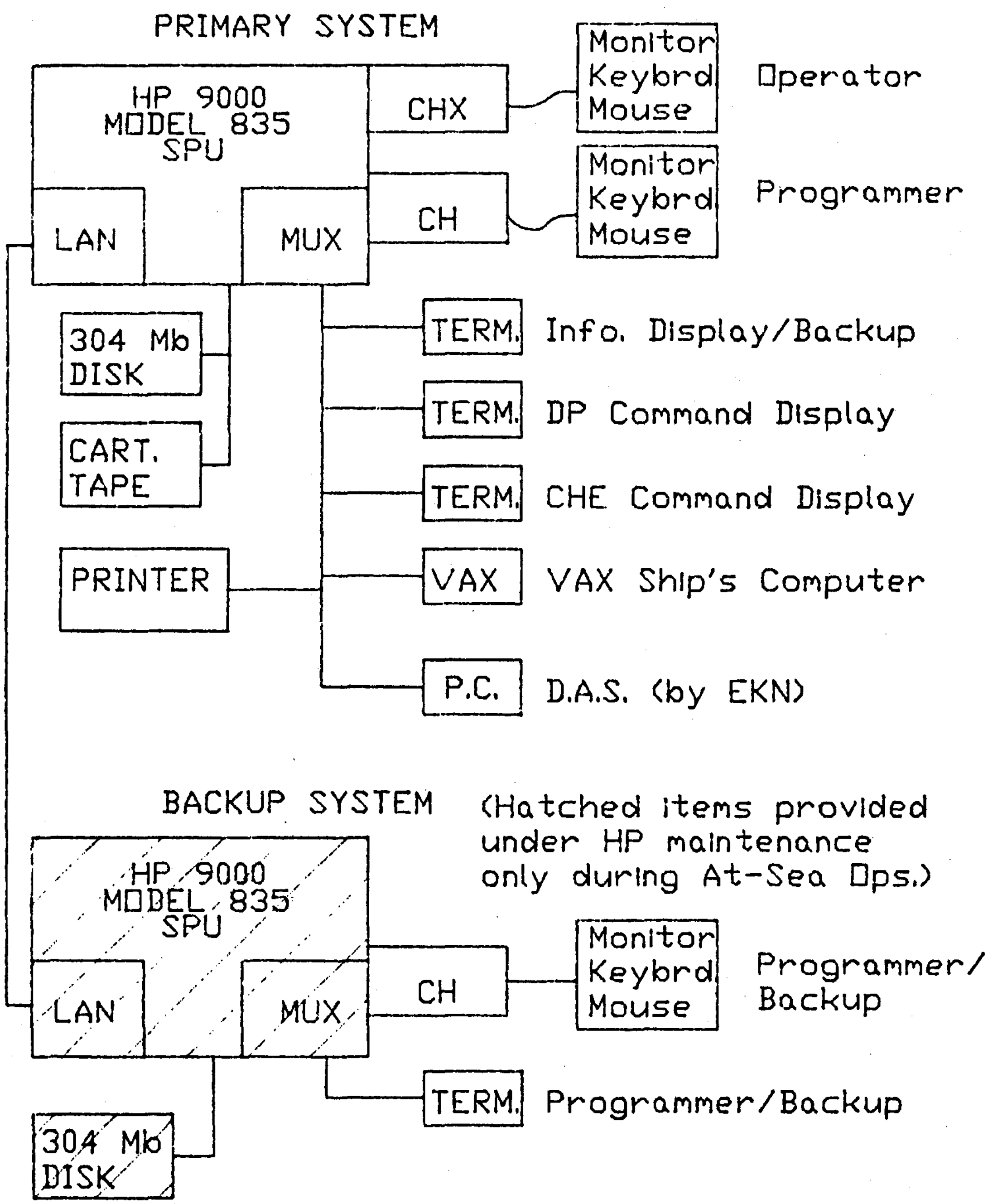


Figure 15

to quickly check all the processes and perform his operations from a single terminal. This will prevent the confusion of multiple keyboards and the need for multiple monitors.

In selecting the hardware and software for the computer system for the HDWC Integrated Control System the overriding criteria has been ability to preform the job. Ability of a computer system to preform includes computational speed, operational utility, programing functioning and vendor support. These four abilities are critical to the success of the HDWC program due to the complex control model involved and the limited development time remaining.

The HP 9000 Model 835CHX is the recommended system for the ICS. It has a capability in speed comfortably greater than our estimated requirements. HP provides excellent support, critical for the timely development of applications such at the CS. Finally the HP comparable cost is the lowest of the qualifying systems. The evaluation and selection process used to arrive at this decision is detailed in Appendix A. System details are also in Appendix A.

3.7 FLEXSERVICE 3 ACCOMMODATIONS

The ship to be used for the At-Sea Test is the Flexservice 3 supplied by Coflexip Services, Inc. The Flexservice 3 is a dynamically positioned flexible pipe and cable laying vessel with a dead weight of 3050 tons. Her overall length is 82 meters with a 19 meter beam. Further details of the capabilities of the Flexservice 3 can be found in the "HDWC Conceptual Design of Reduced Scaled At-Sea Test" prepared by Hawaiian Dredging and Construction, January, 1987.

3.7.1 DECK LAYOUT

Figure 16 contains plan and profile views of the work deck of the Flexservice 3 as outfitted for the HDWC At-Sea Test. The work deck is a large spacious wood planked area 52 meters long and approximately 18 meters wide. On both the starboard and port side of the work deck are wide cargo rails approximately 3.5 meters high. At the stern is a very large 100 ton A-frame.

The cable handling equipment for the At-Sea Test will be mounted on the starboard side of the work deck. The overboarding sheave, tensioners and storage reel are oriented as shown in Figure 16. The clear distance between the overboarding sheave and the aft tensioner will be approximately 10 meters; this space is important for attaching transponders to the overboarding cable. A level wind will be mounted just aft of the storage reel.

Down the center and along the port side of the work deck will be mounted cable reel support rails (approximately 0.5 meters high). These rails provide a support base for the movable reel drive systems that power the cable takeup reel. For the HDWC At-Sea Test program, however, the cable reel with the attached drive units will remain fixed in the locations shown.

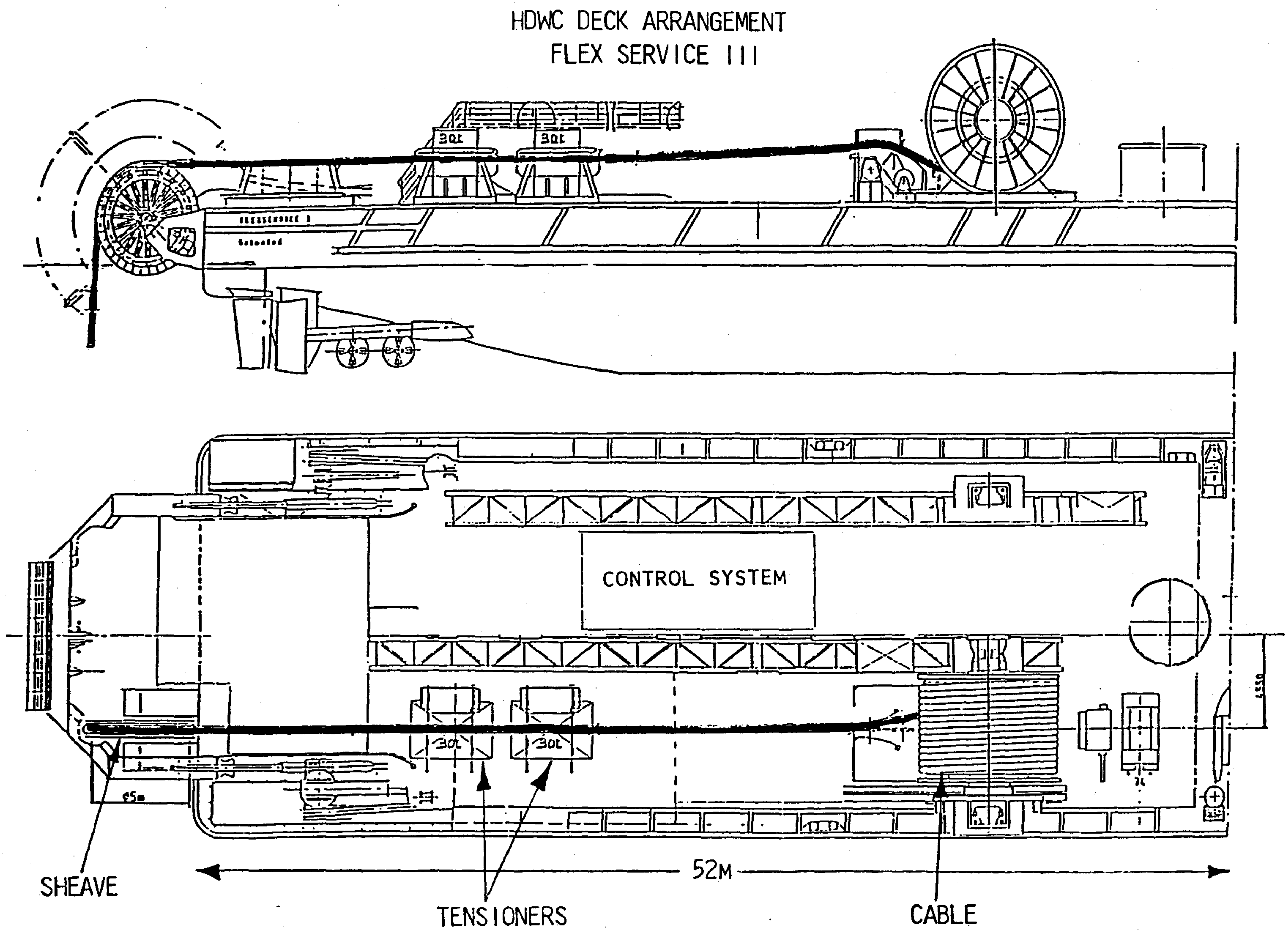


Figure 16 Flexservice 3 Deck Arrangement for the At-Sea Test

3.7.2 HDWC EQUIPMENT PLACEMENT

Figure 17 is a second illustration of the work deck of the Flexservice 3 but including the ICS/DAS equipment placement and cable routing. The control van will be centrally mounted on the port side of the work deck. In it will be housed the Integrated Control System, the Data Acquisition System, and the Acoustic Positioning System. The control van will be approximately 3 m by 7 m outfitted with windows on all sides and benches. The van will be air conditioned.

On the bridge, 5 levels above the work deck, is the ship's computer and the Dynamic Positioning System with the DP operator. The Microfix and Syledis Systems are also located on the bridge and these systems connect directly to their antennas several levels above the bridge.

Also located on the main deck is the CHE control center which is a small van approximately 2 meters by 3 meters which will be located in close proximity to the tensioners. The CHE operator monitors a control panel at this location.

An accelerometer package is located on the aft, starboard side of the main deck to record ship motions that most directly impact the cable dynamics.

The transducer for the Acoustic Position and Navigation System will most likely be located on the fore port side of the work deck to keep it well clear of the suspended cable and thrusters.

Figure 17 also illustrates the cable routing required to connect the various systems. Cables will be concentrated along the port cargo rail. This cargo rail has an elevated walkway with easy access along the work deck. The top of the cargo rail is well protected and Coflexip routinely uses this area for routing electrical cables. Cables will be routed to the bridge along the external port side hand rails and routed into the bridge through a modified porthole.

3.7.3 COMMUNICATIONS

The Flexservice 3 routinely uses radio communications between the deck crew, remote control vans, and the bridge. All the parties are on a common channel. A Motorolla system is used on board with a combination of hand-held and stationary units. Radio communication will be provided in the control room for the HDWC personnel to contact the DP and CHE operators as well as other ship personnel. Redundancy, radio protocol, and extra channels have not yet been defined.

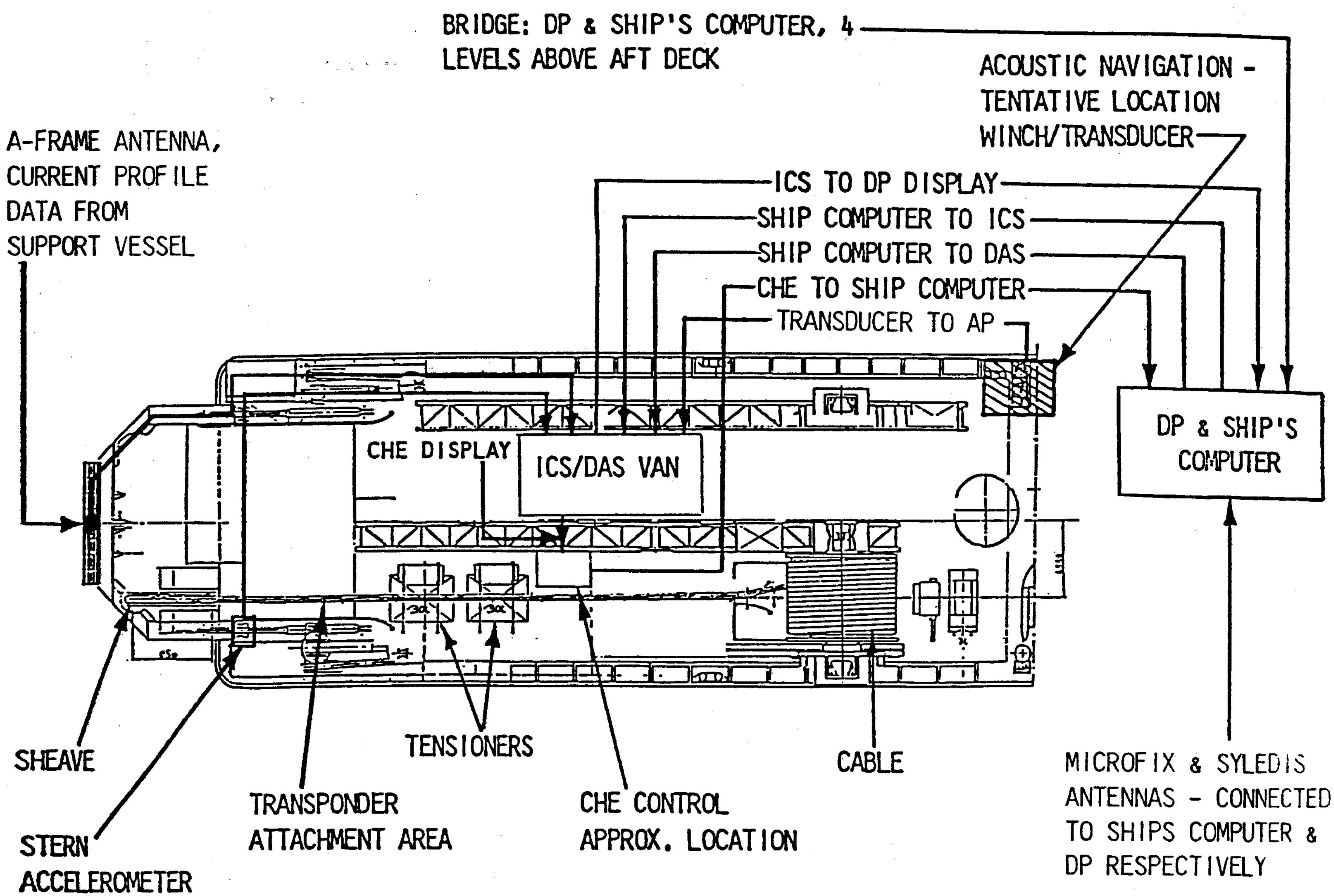


Figure 17 Control & DAS Positioning on the Flexservice 3

SECTION 4

DATA TRANSFER

This section discusses the data paths between subsystems and the type (analog or digital) and format of data which cross each interface. The number of items, frequency of occurrence, dynamic range and precision of each datum are discussed where possible. The following subsections each describe one of the numbered data paths which are shown in a diagram in Figure 18. The number which appears in brackets (e.g. '[1]') at the beginning of each subsection is the data path number used in the diagram.

4.1 SHIP'S COMPUTER --> ICS (C/V) COMPUTER [1]

This is a hard-wire RS-232C serial digital communications link. Communication is one way, there are no data transmitted across this interface from the ICS to the ship's computer.

The ship's computer transmits fixed length data packets or 'telegrams' to the ICS (C/V) computer which are 134 bytes long. The data format is Binary Coded Decimal (BCD). The transmission speed will be 4800 baud and transmission rate will be one telegram each second. The time for transferring one telegram will be 210 milliseconds.

The 'telegram' is as follows:

1. Start of record. Used for block synchronization. 1 byte
2. X - Position. Position of vessel north of reference point. 12 BCD numbers including sign. Least significant number 0.1 meter. Negative sign is the BCD 1101. Least significant number = LSN. 6 bytes
3. Y - Position. Position of vessel east of reference point. 12 BCD digits including sign. LSN is 0.1 meter. 6 bytes
4. H - Vessel's heading. Vessel's heading referenced to geographical north. Estimated value. 4 BCD digits. LSN 0.1 degrees. 2 bytes
5. C - "Current speed". Current speed (meter/sec). 4 BCD digits. LSN is 0.1 m/s. 2 bytes
6. HC - "Current direction". Current direction (degrees). 4 BCD digits. LSN is 0.1 degree. 2 bytes
7. W - Wind speed. Wind speed (meter/sec). 4 BCD digits. LSN is 0.1 degree. 2 bytes
8. HW - Wind direction. Wind direction (degrees). 4 BCD digits. LSN is 0.1 degree. 2 bytes
9. T - Time. Time: 6 BCD digits. Hours, minutes, seconds. 3 bytes
10. To. - Time since last acceptable positioning fix (seconds). 2 BCD digits. 1 byte
11 SX - Syledis range 1. 10 BCD digits. Raw data

Inter-System Data Flow

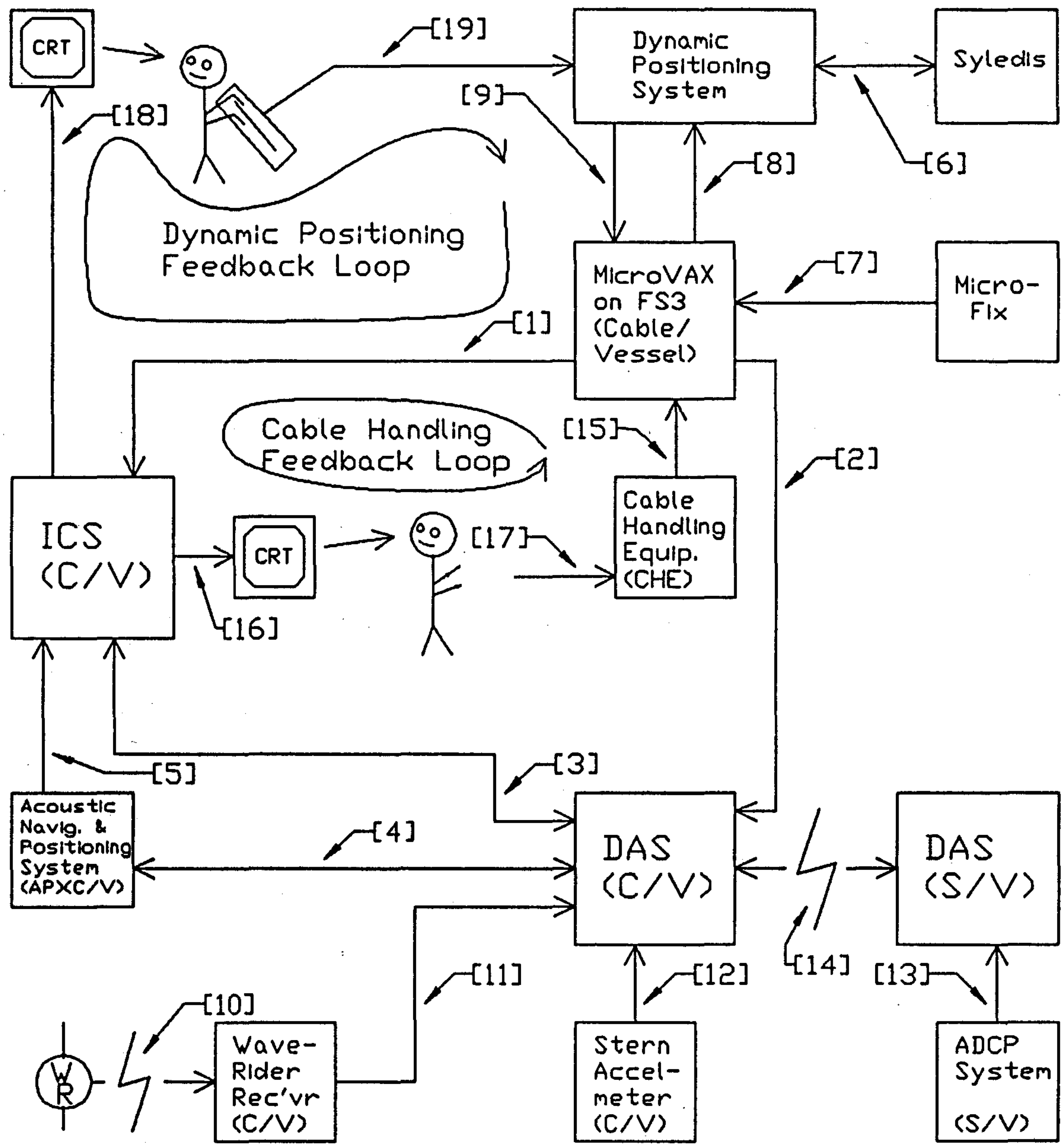


Figure 18

referenced to the antenna. LSN is 0.1 meter. First byte gives the beacon number. 5 bytes

12. SY - Syledis range 2. First byte gives the beacon number. 5 bytes
13. SZ - Syledis range 3. First byte gives the beacon number. 5 bytes
14. SDS - Standard deviation Syledis. 4 BCD digits. LSN is 0.1 meter. 2 bytes
15. SYLN MFIX SR - 3 position (North). Microfix position in UTM - coordinates (north). 12 BCD numbers including sign. Negative sign is 1101. Least significant digit is 0.1 meter. 6 bytes
16. SYLE MFIX SR - 3 position (East). Microfix position in UTM - coordinates (east). 12 BCD numbers including sign. Negative sign is 1101. Least significant digit is 0.1 meter. 6 bytes
17. ISDSR3 - Standard deviation for microfix. 4 BCD digits. 1 byte
18. X - Position of set point selected. Position north of set point. 12 BCD numbers including sign. Least significant number is 0.1 meter. Negative sign is the BCD 1101. Least significant number = LSN. 6 bytes
19. Y - Position of set point selected. Position east of set point. 12 BCD digits including sign. LSN is 0.1 meter. 6 bytes
20. V - Ship speed selected. Ship speed (meter/sec). 4 BCD digits. Units and LSN to be determined. 2 bytes
21. LgC - Length of cable. 8 BCD numbers including sign. Least significant number is 0.1 m. Negative sign is the BCD 1101. Length between -999999.9 m and +999999.9 m. 4 bytes
22. ToC - Top time detect. Top of cable last detect time. 6 BCD numbers hrs, min, sec. 3 bytes
23. SpC - Cable speed + or - += laying. Cable speed. 6 BCD numbers including sign. + is laying, - is retrieving. Units and LSN to be determined. 3 bytes
24. TeC - Cable tension. 4 BCD numbers. LSN = 0.1 ton tension between 000.0 t and 999.9 t. 2 bytes
25. Istop - End of record. The bit pattern is 1101 - 1100. The character is used as block synchronization. 1 byte

4.2 SHIP'S COMPUTER --->DAS (C/V) [2]

This is a hard-wire RS-232C serial digital communications link. The data transmission rate is 4800 Baud. The data format is Binary Coded Decimal (BCD).

The data which cross this interface from the ship's computer to the DAS (C/V) computer is exactly the same as described in item [#1] above. Data packets or 'telegrams' are transmitted by the Flexservice 3 computer at the rate of one (1) packet per second.

There are no data transmitted across this interface from the DAS Computer to the ship's computer.

4.3 ICS (C/V) <--> DAS (C/V) [3]

This is a hard-wire RS-232C serial digital communications link. The data transmission rate and format will match the transmission between the ship's computer and the ICS and the DAS.

The Data Acquisition System (DAS) uses this interface to forward the following information to the ICS:

- Acoustic Doppler Current Profile (ADCP) data
  - Time of profile
  - Z, u, v for multiple points along profile
  - accuracy indicators
  - Current forecast parameters (to be determined)
- Transponder positions
  - Transponder identification number
  - Time of transponder fix
  - X, Y, Z in meters
  - accuracy indicators.

This interface is also used by the ICS computer to transmit data from the cable model to be logged into the historical database. These data are organized into fixed length packets which are transmitted by the ICS at a 1 packet per ICS computation cycle. The computation cycle is presently 5 minutes. For each ICS cycle, the following data values will be transmitted:

From APC program (5 calc/period)	variables/calc	variables/period
Segment Variables	200	1000
Solution Variables	60	300
Program Variables	70	350
Interpolated Data Set	60	300
Contingency	97	495
TOTALS		2435

From VRS program (1 calc/period)	variables/calc	variables/period
Segment Variables	600	600
Solution Variables	180	180
Program Variables	210	210
Interpolated Data Set	180	180
Contingency	292	292
TOTALS		1462

From MC program (1 calc/period)	variables/calc	variables/period
Data Correction	240	240
Status	75	75
Contingency	63	63
TOTALS		4275

The ICS computer also uses this channel to transmit requests for data to the DAS (C/V) Computer. This will happen during ICS restart do to a prior system failure. The DAS can provide the recent history required for normal operation.

4.4 AP <--> DAS (C/V) [4]

The Acoustic Navigation & Positioning System (AP) transmits the calculated positions of the mobile and fixed undersea transponders to the DAS (C/V) over this interface. Each transponder will have its position updated approximately every one hundred and ten (110) seconds. This is a hard-wire RS-232C Serial Digital Communications Link.

The Acoustic Navigation & Positioning System (AP) receives geodetic navigation position information over this link from the DAS (C/V) and uses it to initialize its internal processor. The DAS(C/V) is able to supply this information when the Acoustic Navigation & Positioning System requests it because the DAS (C/V) receives these data each second from the Flexservice 3 ship's computer. The ship's computer receives this information from the Syledis and Microfix geodetic navigation systems by a direct data path over data channels 6 and 7.

4.5 SYLEDIS <--> (DP)[6]

This is an established Coflexip hard-wire data link between Flexservice 3 subsystems. The Flexservice 3 Dynamic Positioning System receives surface vessel coordinates from the Syledis navigation system over this data channel.

4.6 MICROFIX --> FS 3 COMPUTER [7]

This is a Coflexip hard-wire data link between Flexservice 3 subsystems. The Flexservice 3 computer receives surface vessel coordinates from the Microfix navigation system over this data channel.

4.7 SHIP'S COMPUTER--> DP [8]

This is a Coflexip hard-wire data link between Flexservice 3 subsystems. The ship's Computer transmits to the Dynamic Positioning System the Microfix the Geodetic/Surface vessel coordinates.

4.8 (DP) SHIPS COMPUTER [9]

This is a Coflexip hard-wire data link between Flexservice 3 subsystems. The Dynamic Positioning System transmits real time data describing cable vessel position, speed and heading to the ship's computer over this channel. Items transmitted that are critical to the HDWC program are listed in section 4.1, items 1-20.

4.9 WAVERIDER BUOY --> WAVERIDER RECEIVER [10]

This is an analog data communications radio link. This link operates on a 27.50 MHz to 27.75 MHz carrier (0.2 watt power output) which is AM (Amplitude Modulated) by a 259 Hz Subcarrier. The Subcarrier is pulse-width modulated (a method of achieving FM) with a change in subcarrier frequency of 1.86 Hz representing one (1) meter of wave height.

The Waverider buoy continuously transmits wave height data to the Waverider receiver over this channel. The Waverider buoy generates this information internally by double-integrating the instantaneous acceleration which it measures at its location.

The Waverider receiver demodulates the FM subcarrier to generate an analog current signal. Wave height is represented by a voltage generated across an external load resistor at an analog current output terminal pair provided for this purpose. A resistor value of 10,000 ohms (the minimum resistance recommended by the receiver manufacturer) will generate a voltage signal of one (1) volt per meter of wave height.

Please see the next section for further details about the Waverider receiver characteristics.

4.10 WAVERIDER RECEIVER --> DAS (C/V) [11]

This is a single channel hard-wire analog data link. The parameter being measured is an analog signal which represents wave height at the remote Waverider buoy.

Since the Waverider receiver will be in close proximity to the C/V DAS computer, the length of the connecting cable will be only 25 ft. Two conductors plus an internal shield will be used.

The signal presented to channel #4 of the A-D converter board on the C/VC DAS computer is a slowly varying near-DC voltage (0.02 volts to 40.00 volts) measured across a 10,000 ohm (1 watt) 1% precision wire-wound resistor at the A-D converter end of the cable. The output current is supplied by a controlled current source within the Waverider receiver.

The Waverider receiver is calibrated to supply 0.01 milliamperes per meter of wave height when used with the Datawell Waverider buoy. Passed through a 10,000 ohm resistor this translates into 1 volt per meter of wave height.

The Waverider receiver processes the received signal through a butterworth filter which effectively limits the maximum frequency to less than 0.8Hz. 0.8Hz is equivalent to a minimum period of 1.25 seconds. This translates into a minimum sampling frequency of 1.6 Hz or a sample no less frequently than every 0.625 seconds. The selected sampling frequency is 2.0 Hz.

4.11 STERN ACCELEROMETER --> DAS (C/V) [12]

This is a three channel hard-wire analog data link.

The Accelerometer Instrumentation Package is located at the stern of the Cable Vessel at a respectable distance from the DAS (C/V) computer.

The Parameters being measured are:

A-D channel #1 - vertical acceleration (heave)
A-D channel #2 - pitch
A-D channel #3 - roll

Vertical acceleration is represented by a voltage generated by electronics within the accelerometer package. Two conductors are required to transport the measured voltage signal and signal ground.

Pitch and roll are each represented by shaft positions on internal double-ended 5,000 ohm wirewound potentiometer. There is one potentiometer for pitch and another for roll. Each potentiometer is capable of dissipating 0.5 watts of power. The potentiometers require an external regulated power source (-5 VDC -0- +5VDC) which must be located at or very near the accelerometer. Three wires are required for pitch and three more for roll. The balanced differential outputs will be connected to differential A-D Converter input channels. The signal range is -5 VDC to +5 VDC.

Since the A-D converter input channel connections present nearly infinite input impedance, there is virtually no load and therefore negligible current to generate a measurement error due to the resistance of the connecting conductors. There is, however, the possibility of noise.

A 250-foot eight conductor shielded cable will be used to connect the stern-mounted accelerometer to the A-D converter differential input connections on the DAS.

4.12 (ADCP) --> DAS [13]

This is a hard-wire RS-232C serial data communications link.

The Acoustic Doppler Current Profiling system (ADCP) measures the underwater current velocity of a 750 m vertical water column. Each output packet (which occurs approximately every 100 seconds from the ADCP consists of a U Velocity, a V Velocity, Signal Strength, Standard Deviation and 2 additional measures of data quality for each of the thirty-two (32) vertical water column segments. Velocity is measured in centimeters per second (cm/sec). Each output datum value has four (4) decimal digits plus sign and decimal point.

4.13 DAS (S/V) <--> DAS (C/V) [14]

This is a full duplex serial data communications link which uses full duplex radio transceivers (RF Modems). It supplies bi-directional serial digital data communications using RS-232C protocol with hardware assisted verification of data integrity.

The RF Modems selected for this application accept data and return data at the instantaneous data rate of 9600 baud. That is, they will be connected to RS-232C ports on the respective computers which are set to operate at 9600 baud using standard RS-232C handshakes and communications protocol.

In actual operation the real data through-put rate will be somewhat less than 9600 baud. Just what rate will be realized depends on the radio transmission conditions, especially noise and signal strength. Digital data are radio transmitted in blocks of bytes (30,000 bytes maximum) along with parity check sums and other sophisticated error detection/correction data. If an error is detected at the receiving end then a re-transmit request is issued over the radio channel and the whole process is repeated. Under poor conditions this can occur a number of times for the same data block.

During the data checking and the attempts at re-transmission the computer at the sending end will be signalled that no further data will be accepted for transmission in that direction.

4.14 (CHE) --> SHIP'S COMPUTER [15]

This is a Coflexip hard-wire data link between Flexservice 3 subsystems. The Cable Handling Equipment (CHE) aboard the Flexservice 3, uses this data path to continuously update the computer with the following data:

Cable Length
Cable Speed
Cable Tension
Detection of Length Mark

4.15 ICS --> CHE CABLE CRT MONITOR [16]

This is a video channel which supports the display of instructions to the Operator of the Flexservice 3 Cable Handling Equipment (CHE).

The video signal is generated by the ICS and is intended to drive a CRT monitor which is located in a prominent position in direct view of the Flexservice 3 CHE operator's console.

4.16 CHE OPERATOR --> CHE [17]

This is a manual operational link to the CHE. The operator manually adjusts the operating speed of the CHE to match the ICS instruction on the CRT. See Figure 6.

4.17 ICS --> DP CRT MONITOR [18]

This is a video channel which supports the display of instructions to the Operator of the Flexservice 3 Dynamic Positioning System. See section 3.3.

The CRT display is a remote terminal of the ICS Computer and provides X, Y way point instructions, ship speed instructions, ship heading instructions and a timing sequence for updating the way point. The keyboard of this terminal is nonfunctional.

4.18 DP Operator (-->) DP [19]

This is a human interface and represents the manual input of instructions by the DP operator on the Flexservice 3 into the DP computer. The DP system has a keyboard, and the operator manually inputs the ICS provided instructions at the times requested. The entered instructions are fed back via the ship's computer to the ICS, and if there is an error, the operator will be informed within a few seconds.

4.19 DATA TIME RECORDS

All data collected during the At-Sea Test will have a time stamped attached to the data at the source. Current profile, transponder locations, ship's positions, etc., will be tagged with a time. Each data generating system will rely on an internal clock as a time reference. There will be 5 critical clock systems during the At-Sea Test:

1. DP Computer
2. Acoustic Navigation Computer
3. ADCP System
4. ICS Computer
5. DAS Computer

The internal clocks will be checked carefully prior to the At-Sea Test against a standard time source and will require an accuracy of 2 sec/24 hrs. Prior to and immediately after each individual lay, the above 5 computer clocks will be synchronized manually to within 1 sec.

SECTION 5

SYSTEM SOFTWARE

5.1 INTRODUCTION

This section provides some of the details on the software for the Data Acquisition System and the Integrated Control System. General overall descriptions of the programs and the basic control approaches are detailed in Sections 1, 2 and 3 of this report. Details on the functional performance of this equipment is provided in the report: "Conceptual Design of Reduced Scale At-Sea Test" - January, 1987.

The software for the DAS and the ICS have not been completed. The final writing and implementation of the software on the actual At-Sea Test hardware is part of the fabrication process which is now underway. Many of the control system programs, however, have been written beforehand in order to test their performance and accuracy. Other programs are more dependent upon the final hardware used for the At-Sea Test - this applies particularly to all data transfer and storage by the various computers involved in the At-Sea Test.

5.2 DAS SYSTEM SOFTWARE

5.2.1 PROGRAMS MODULES

During normal operation the main DAS computer (on the C/V) will be occupied with a programmed service loop which constantly checks the status of input buffers dedicated to each of the RS-232C interface ports and the status of the A/D converters. Refer to Figure 19 for a schematic diagram of this service loop. The Real Time Data Acquisition Software Module maintains the input buffers and their status indicators.

When a complete data stream or datum has been received at an interface, the data will be subjected to a preliminary check to determine that is has been received without detectable error and in some cases it will be checked for reasonability (within prescribed limits, etc.). Some of the data will require processing to normalize or convert instrumentation output to meaningful parameters. This is accomplished by the Data Input Service Routines.

Next, the data are compressed for storage, if necessary, and placed in a storage buffer by the Historical Database Update Module in a format suitable for retrieval at a later time. This module also determines when the buffer is nearly full and dumps the buffer contents to the hard disk.

Some data items will be transmitted on an RS-232C channel to the ICS computer by the Real Time Data Distribution Module. The Automatic ICS Data Delivery Service Routine will support the repeated delivery of regularly supplied data. Other

MAJOR PROGRAM CONTROL LOOP
DAS (C/V)

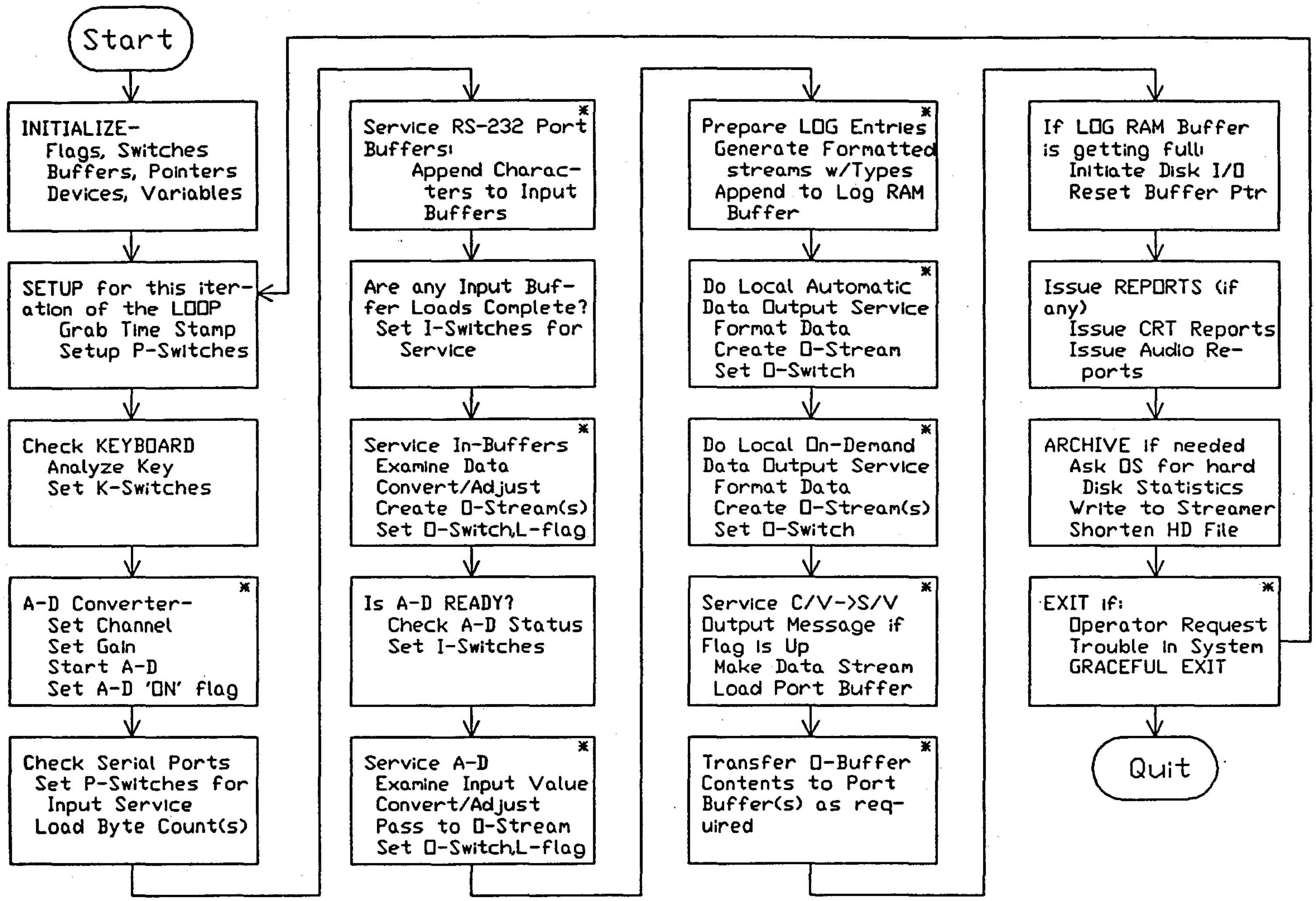


Figure 19

data items will be transmitted to the ICS on a request basis by the On-demand Data Delivery Service Routine.

Similarly, during normal operation the secondary DAS computer on the S/V will gather and process ADCP data. The data will be transmitted to the C/V DAS for delivery to the ICS and for entry into the Historical Database. Refer to Figure 20 for a schematic diagram of the S/V programmed service loop.

When the hard disk on the DAS C/V computer is nearly full the Historical Database Archive Module will transfer the information to an archive medium such as a tape streamer or CD ROM.

In the event of the failure of one of the instruments or data links the DAS C/V will attempt to continue to operate without the data and will alert the operator to the condition.

In the event of ICS failure or shutdown, the DAS will provide copies of historical data records when requested to facilitate the restart of the ICS.

Report generators will be supplied to allow the operations staff to examine the contents of the historical database in text form or, when possible, as a graph or diagram.

Calibration and diagnostic programs will be available to adjust data input normalization parameters and to diagnose malfunctions. The diagnostic programs will allow the operator to examine the input channel control parameters and data streams individually.

5.2.2 REAL TIME DATA ACQUISITION SOFTWARE

This section describes the real time DAS.

During data acquisition the DAS Computer(s) continuously cycle through their respective service loops. The loops are described schematically in Figures 19 and 20.

The Data Input Service Routines specified in the sub-sections which follow will be written in Turbo Pascal and will access data from input buffers which are filled with data by Interrupt Driven I/O Service Routines supplied with the RS-232C board and the A-D converter board. These routines will initiate the process of updating the historical database by calling upon routines in the Historical Database Update Module (Section 4.4.3).

The multiple port RS-232C interface boards on both DAS computers and the multiple channel A-D converter board on the DAS C/V computer are supported by Interrupt Driven I/O Service Routines which are very fast. These routines frequently bypass the many levels of software used by the operating system to help achieve the required speed. They consist of very fast, efficient and tight

MAJOR PROGRAM CONTROL LOOP
DAS (S/V)

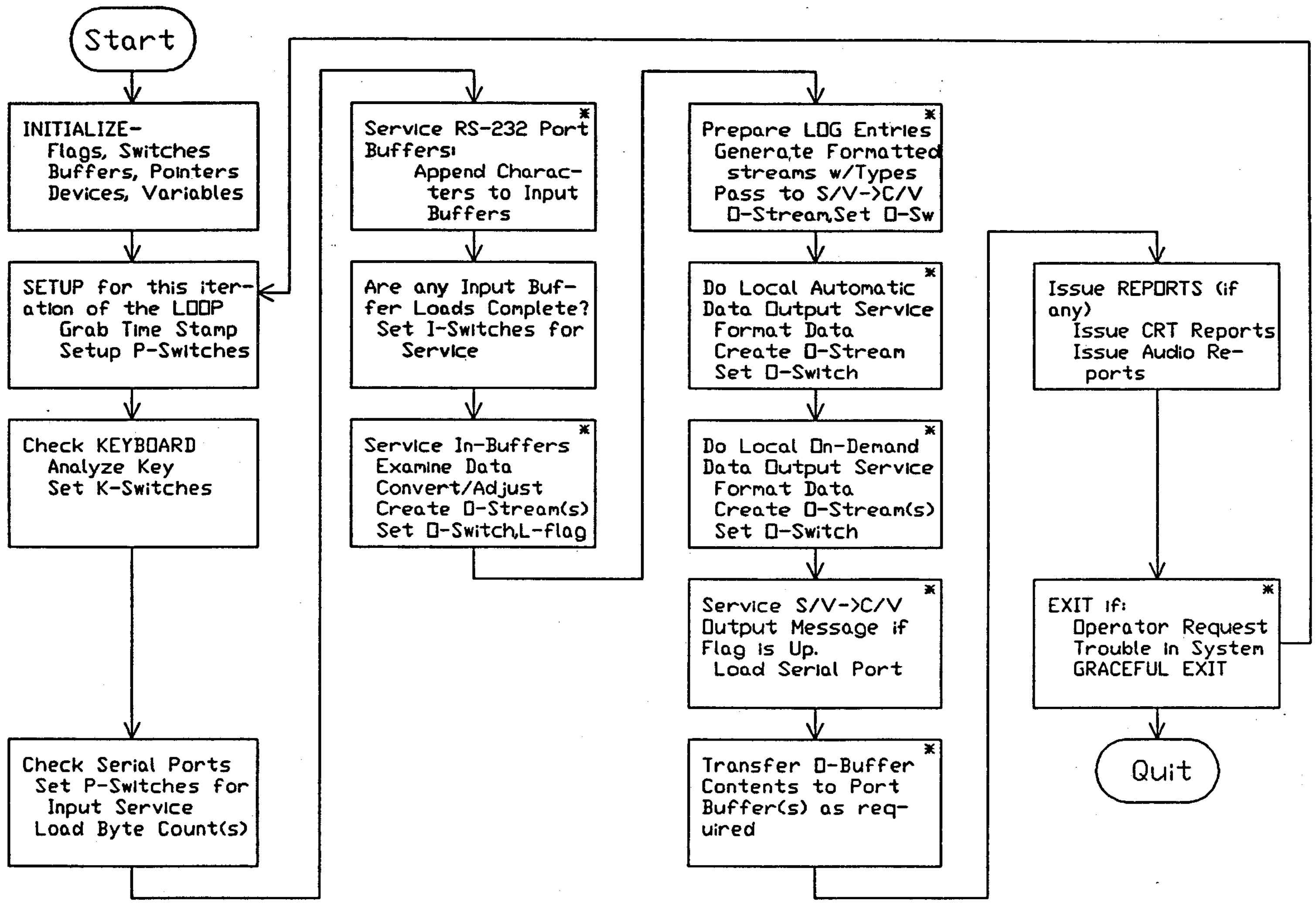


Figure 20

code, written for speed. They are usually written in machine language (assembler) or sometimes in the 'C' language.

The Interrupt Driven I/O Service Routines have been produced by specialists who understand the special timing requirements and the hardware interfaces which are involved. They service all of the RS-232C ports very rapidly and segregate the data from each port into an input buffer for each port. They also support data output on each of the RS-232C ports from individual output buffers.

This is a partial list of the Data Input Service Routines which the DAS will use to analyze and otherwise process input data:

1 Shipboard Computer System Data Input Service Routine

2 Geodetic/Surface Navigation System(s) Data Input Service Routine

3 Shipboard Dynamic Positioning System (DP) Data Input Service Routine

4 CHE Data Input Service Routine

5 Acoustic Positioning & Navigation (AP) Subsystem Data Input Service Routine

6 Control System (ICS) Data Input Service Routine

7 Acoustic Doppler Current Profiling (ADCP) Subsystem Data Input Service Routine

8 Wave Height Monitoring Subsystem Data Input Service Routine

9 Stern Accelerometer Subsystem Data Input Service Routine

5.2.3 REAL TIME DATA DISTRIBUTION SERVICE MODULE

This Module contains the DAS software which controls the distribution of real time and historical data packets to the ICS and to certain DAS subsystems.

The Automatic ICS Data Delivery Service Routine periodically supplies packets of selected real time data to the ICS on a frequent and regular basis as it is received by the various real time inputs to the DAS. For example, the current profile is forwarded to the ICS as soon as it is received from the Support Vessel (S/V) over the RF modem radio link. This is the data that the ICS uses to update the cable model and to issue instructions to the DP operator.

The ICS also has its own individual data path (RS-232C connection) to the real time information supplied by the Acoustic Positioning & Navigation Subsystem.

The Automatic ICS Data Delivery Service Routine supplies data, on demand, to the ICS when the DAS receives an asynchronous request for retrieval of data from the active Historical Database.

Other subsystems occasionally need data from the active Historical Database. For example, the Geodetic Navigation Initialization Data Service Routine supplies the data necessary to synchronize Acoustic Positioning and Geodetic Navigation coordinates.

The On-demand ICS Data Delivery Service Routine provides automatic data delivery tasks which do not require specific requests for data. An example of an automatic data delivery task is the regular transmission of current profile information to the ICS Control Computer as soon as it is received by the DAS.

The On-demand ICS Data Delivery Service Routine provides on-demand data delivery tasks which require specific requests for data before any action will be taken. An example of an on-demand data delivery task is the transmission of packets of data to the ICS describing the most recent history of cable model data and ship data which the ICS Computer programs may use to restart the ICS system in the event of an interruption in the operation of the ICS.

The Geodetic Navigation Initialization Data Delivery Service Routine supplies this information to the AP System which requires Geodetic/Surface Navigation information to calibrate initial position at startup. This is a special case of on-demand data delivery.

5.2.4 HISTORICAL DATABASE UPDATE MODULE

This module appends data items or data packets to the Historical Database as the data are acquired by the DAS in real time.

Data is compressed when possible prior to entry into the database. Each entry is associated with a time stamp and has a data type ID.

During data acquisition data items are inserted into a very large RAM buffer and allowed to accumulate until the buffer is nearly full or until an orderly shutdown of the DAS programmed service loop is initiated. When either of these conditions occurs an image of the total information in the buffer is transferred to the hard disk and the buffer space is freed for further use.

5.2.5 HISTORICAL DATABASE ARCHIVE MODULE

This module retrieves accumulated Historical Database data from the hard disk and appends it to the end of the Archival

Database for permanent storage. The hard disk space is cleared and released for reuse.

5.2.6 REPORT GENERATORS - TEXT & GRAPHS

Detailed descriptions of the report generators listed in this section will be supplied during the development of the DAS operator's procedures.

Display historical data as a table of values

Display a data stream from the Historical Database as a time plot

Display input data stream for a specified instrument or input channel

Display transponder positions on X-Y grid

5.2.7 CALIBRATION AND DIAGNOSTIC PROGRAMS

Detailed descriptions of the Calibration and Diagnostic Programs will be produced as a part of DAS system development.

Instrument Calibration Programs

Test RF Modem Data Link Program

Archived Data Retrieval Module

5.2.8 DATABASE ORGANIZATION

The Historical Database is the major active database of the DAS. This database is constructed and manipulated in a large sequential RAM buffer and is stored on the hard disk.

When the hard disk space allocated to the Historical Database is nearly fully used, or when the experiment reaches its conclusion, data from the Historical Database hard disk file is transferred to the Archival Storage Device and the data becomes part of the Archival Database. If the experiment has not yet concluded then only 80% of the data stream is transferred to Archival Storage, leaving the last 20% remaining in the Historical Database. The Data Acquisition System will continue to log newly arrived data into the Historical Database until the hard disk is once again nearly full or until the experiment reaches its conclusion.

The Archival Database contains data which were earlier in the Historical Database. Archival Data is not available for use by the DAS when the DAS is operating in the programmed data acquisition loop mode (the normal state of the DAS during an experiment). This is because the Archival Storage Device does not support random access.

The DAS will insert items into the Historical Database data stream which are not the result of acquired experimental data, but are used to record changing conditions in the progress of the experiment or in the setup of the equipment. For example, database entries will be made to record changes in serial port setup parameters, or changes in the constants used to calibrate instrumentation and to normalize data. Interruptions in the course of the experiment will also be noted in this way.

A. Organization of the Historical Database

Each entry into the historical database has a type ID, and a prescribed format. Each data entry or packet also has a time stamp. The entries are made serially, as they are received, as in an activity journal or a log.

There are many data types. The type ID occupies the first byte of a data entry (also called a data record). Type-IDs will be used to distinguish data sources, data elements and experiment progress reports.

Each data type is associated with a particular data source or group of sources and has a unique length (# of bytes). This makes the use of 'Start Record' and 'End Record' entries unnecessary.

A Table of Data Types is presented in section 5.2.4.

B. Organization of the Archival Database

The Elements of the Archival Database have exactly the same structure as those in the Historical Database. The distinction is that the Archival Database is much larger and is recorded on a serial storage medium. It is constructed of serially concatenated segments which are copies of Historical Databases.

The Archival Database also has a header block which contains experiment identification information, initial I/O port configuration information and initial values for data input normalization parameters.

5.2.9 DATA RECORDS AND THEIR CONTENTS

This section identifies the data records associated with the data types and the associated data stream contents used to organize the historical and archival databases.

This is a partial list of data types associated with real data acquisition:

Type ID	Description of Contents
A	Log Report of Accelerometer Reading
D	Log Report of Acoustic Doppler Current Profile System Input
H	Log Report of HDWC Control System Computer Data Snapshot
P	Log Report of Acoustic Positioning System Input
V	Report of Cable Vessel Computer Telegram
W	Log Report of Waverider Data Input

This is a partial list of data types associated with system configuration and experiment progress:

Type ID	Description of Contents
C	Data Source Calibration
P	Port Configuration
Q	Status at Orderly Shutdown of DAS

5.3 CALCULATION OF CABLE CONFIGURATION

The various cable configuration programs used by the ICS all have in common a basic mathematical model of the suspended cable. This section describes the static version of this model (Figure 21).

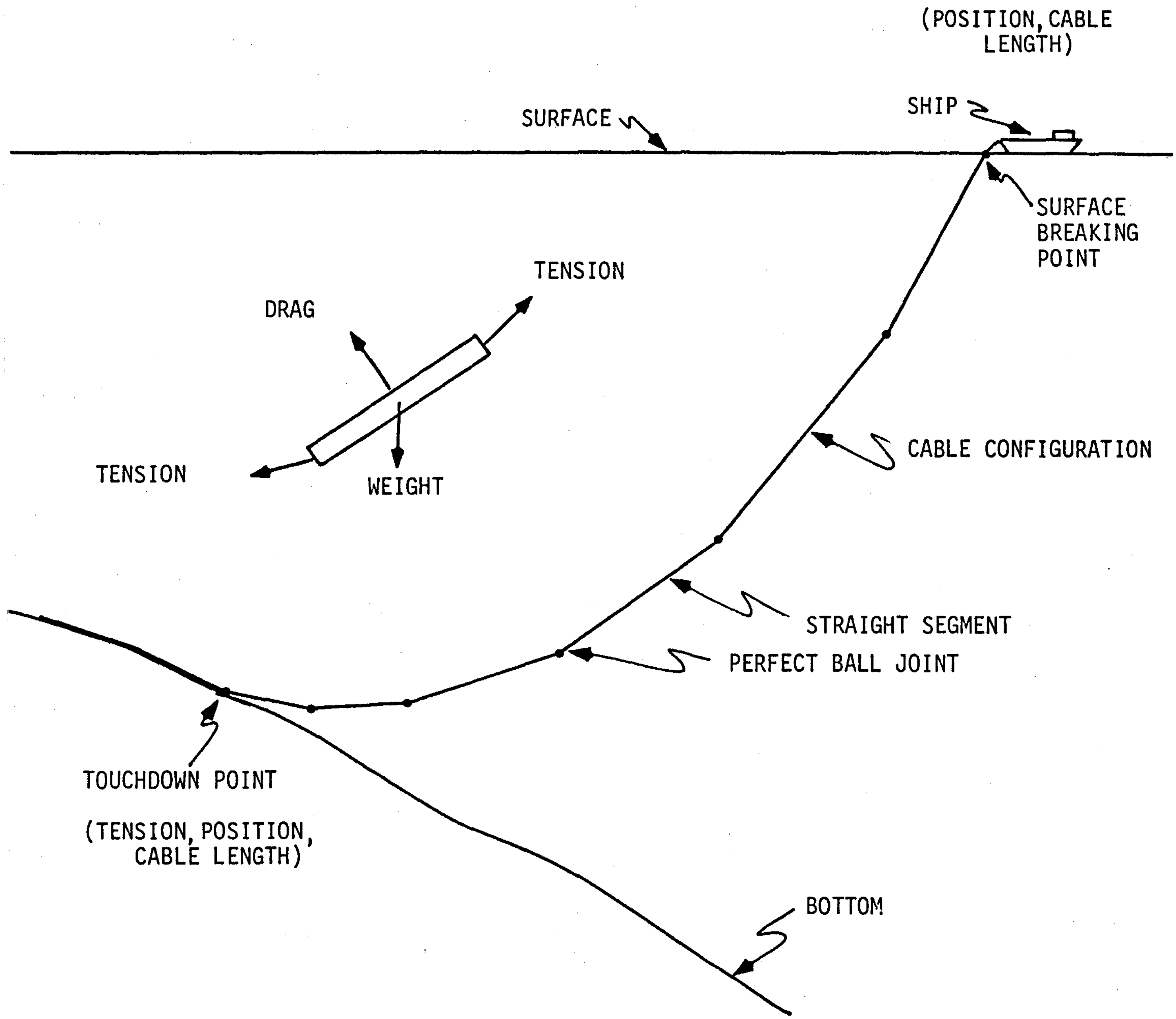
The cable configuration is assumed to be made up of a finite number of straight segments connected by perfect ball joints. The tension vector is assumed to be known at the cable bottom. Also assumed to be known are the cable segment absolute velocities, the current velocity, and the drag coefficient. The current velocity is assumed to vary only with depth and time. The drag coefficient is assumed constant. (See section 5.9 and Figure 26 for cable variable definitions.)

The cable is assumed to have zero flexural rigidity and infinite axial rigidity. Because of the zero flexural rigidity assumption the cable can support no shear or bending moments. Thus the net resultant force vector at each segment end is equivalent to the tension and is directed axially along the cable. Because of the infinite axial rigidity assumption the cable does not stretch.

Both cable and water properties are assumed constant. For cable PCC-116, these properties are:

diam	cable diameter	(0.0691 meters)
rhoc	cable density	(5161.7 kg/m^3)
rhow	water density	(1054 kg/m^3)
muw	water absolute viscosity	(1.17x10^6 m^2/s)
C_d	normal drag coeff	(1.8)

The cable configuration is calculated by starting at the touchdown point with known (or assumed) values of the bottom tension



SEGMENTED CABLE SOLUTION

Figure 21

(T_b), it's direction (A_b and B_b), and the coordinates (X_b, Y_b, Z_b). Each cable segment is then calculated consecutively until the surface is reached. The independent variables for each segment are the two polar angles representing the segment orientation and the segment length. Each segment length is controlled separately in order to optimize both accuracy and speed.

5.3.1 CALCULATION OF A CABLE SEGMENT

Figure 21 shows a general free body diagram of a differential element of cable being deployed. In the finite segment approach, a segment of finite length is treated as a differential element. The accuracy of this approximation can be justified by comparison to known solutions.

The forces acting on each cable segment consist of tension, weight, drag, and inertia. The drag forces consist of both normal and tangential components. (The normal drag is predominantly a pressure drag whereas the tangential drag is a skin friction effect.) The accelerations can be classified as kinematic (centripetal) accelerations and kinetic. For the parameters of this problem all accelerations and the tangential drag are small. They are, however included in the solution in the general case. The centripetal acceleration is due mainly to the cable payout speed and the segment curvature whereas the other accelerations depend upon the change in velocity of the segment over time. The reason for their separation is that the centripetal acceleration can be calculated from knowledge of the cable payout rate and the segment curvature alone.

A. <u>Drag forces</u>:

The drag forces consist of both normal and tangential components. The normal drag is predominantly due to pressure loss as the cable acts as a blunt body passing through the water. The magnitude of this drag is normally correlated empirically with Morrison's equation using a drag coefficient C_d such that:

Dn = 1/2 * rhow * A * C_d * Vn**2

where:

Dn = normal drag force
C_d = drag coefficient
A = cross sectional area normal to flow (diam*ds)
rhow = fluid density
Vn = fluid relative velocity normal to cable

Values of C_d vary widely for different geometries. In addition C_d is typically a strong function of the Reynolds number. Because the normal drag is the dominant force (other than weight) in determining the cable shape, the value of C_d must be known to a relatively high degree of accuracy. Thus C_d must be obtained experimentally either prior to and during the cable lay operation.

The tangential drag is a small force, especially during cable payout, however it's inclusion is not extremely difficult. This force also must be calculated through the use of a coefficient Cf and is given by:

Dt = 1/2 * rhow * pi * diam * Cf * Vt**2

where:

diam = cable diameter
Vt = cable to water relative tangential velocity

and

Cf = 0.55/Re**0.14

B. <u>Accelerations</u>:

In order to calculate the accelerations of the cable configuration it is necessary to keep track of the velocity of each cable segment at the previous time step as well as the position. From the change in this velocity over time the acceleration can be calculated.

It was found that for the velocities and dimensions involved in our cable laying problem, the accelerations were always very small compared to the normal drag force. This is understandable since the accelerations depend only upon the change of velocity whereas the normal drag depends upon the velocity squared. Unless the element moved very slowly yet changed velocity very quickly, the drag force would always predominate.

In the cable calculation the user has the option to include either just centripetal accelerations, all accelerations, or no accelerations. The solution with accelerations is virtually identical to the solution without, and since the accelerations require enough additional calculation to make a difference, they are usually not included.

C. <u>Iterative Segment Solution</u>

An initial value is selected for the segment length. Although any value could be used, it is shown below that a certain value will allow each segment to contribute approximately equal amounts to the total error. Since the weight of the segment depends only upon it's length, this vector is now determined.

The drag and acceleration vectors depend upon the segment orientation (defined by the two polar angles A and B). Since this is not known we must assume values and iterate to convergence. The initial guesses of these orientations can usually be set to those of the previous time step. If no values are available from the previous configuration, they can be started with the values from the previous segment. The iterative solution is sufficiently robust such that a poor guess has never caused non-convergence unless the cable segment velocities are much larger that we expect to encounter.

Once the segment orientation is fixed, all forces on the cable segment can be calculated except the top tension. The three components of the top tension can be calculated by force equilibrium in the three orthogonal directions.

Since the resultant of the force components at the segment top or bottom equal the tension they must lie axially along the cable. We have assumed, however, zero curvature for the segment. But this by itself would give us no way of allowing the segment orientation to change. In order to calculate a new orientation we must assume - for this purpose only - that the segment curvature is given by the change in the tension direction. If this curvature is assumed constant, then the segment average orientation must be equal to the average direction of the tension vectors.

Thus new values for the segment polar angles can be determined. If these agree with the guessed values that were used to calculate the forces on the segment, then the segment solution is complete. If not then new guesses must be found and the process repeated until orientations are found such that all forces balance.

In the general case it is not possible to simply use the newly calculated segment polar angles directly as the next guess. Although this will usually work especially for the low velocities involved in this problem, it is more stable and usually also faster to calculate the next guess using a Newton-Raphson technique.

Once the segment polar angles have converged, the estimated error introduced by the finite length of the segment must be checked against the desired accuracy of the solution. If the segment is too long or too short it must also be adjusted and the whole process repeated. Normally a rather wide tolerance on the segment length is allowed (since it's contribution to the error is only an estimate), so a single iteration is usually all that is required to adjust the segment length if an adjustment is required (normally it is not).

Each segment in turn is calculated in the above manner. The three components of the tension at the bottom of each segment are set equal to the just calculated values from the top of the previous segment. The cable is thus marched up from the bottom until the point where it breaks the surface.

The length of the top segment must be adjusted to match the surface. This is done by calculating to convergence given a first estimate of the segment length (assuming that it is fully submerged). The distance between the segment top and the surface is then used as a convergence criterion and the correct segment length is found using the secant method. Each new segment length estimate must of course be calculated to convergence before the distance from the segment top to the surface is calculated.

5.3.2 ADDING/REMOVING SEGMENTS:

The number of segments representing the cable configuration can be thought of as a property of the cable configuration. As each successive configuration is calculated it may become necessary to increase or decrease the number of segments. Initially the cable configuration is assumed to have the same number of segments as the previous configuration (if no previous configuration exists then the first segment calculated extends from the ocean bottom to the surface).

If the surface is reached in less segments than the previous configuration then the additional segments are removed from the cable configuration. This can happen in going uphill or when decreasing the accuracy of the solution. If additional segments are needed to reach the surface then these must be added to the cable configuration. In order to avoid flip-flopping once a cable segment has been removed it can not be added back during the same time step.

The top segment length must be checked against the error criterion just as with the other segments. In order to avoid excessive calculation, once either the surface is reached or the number of segments equals or exceeds that of the previous time step, a flag (srflg) is set true to indicate that the current segment is probably the surface segment. It's length is then adjusted to match the surface. If this length exceeds the error criterion, then it must be subdivided. If this requires an additional number of segments above the previous configuration then a segment is added.

The segment length adjustment algorithm is fundamentally different between a surface segment and a non-surface segment. The flag srflg controls which algorithm is used. An additional flag (dflg) controls whether the surface segment meets the length/accuracy criterion. When both srflg and dflg are true the cable configuration calculation is complete. (Note: in the APC solution instead of matching the surface in CABLE - since the total cable out (S_{tot}) is already known - the variable to be matched in CABLE is S_{tot} and Z_t=0 is matched in NEWRAP.)

5.3.3 ACCURACY CONTROL OF SEGMENT LENGTH:

It is important in these programs to be able to calculate cable configurations quickly. For this reason it is desirable to make the segment lengths variable. The most logical way of varying the segment lengths is as a function of curvature along the cable (i.e. the more curvature the shorter the segment length.) For example if the actual cable configuration was a straight line then we would only need a single segment and our solution would be exact. In reality the cable curvature is usually greater near the bottom and decreases as the surface is reached.

Perhaps the simplest method of controlling the cable segment length then is to require that:

1) $dTheta * ds = constant = TOLC$

TOLC becomes a single parameter controlling the spatial accuracy of the solution.

5.3.4 THE STEADY STATE SOLUTION:

In order to check the accuracy of our approximation of the cable configuration, it is desirable to compare it to known exact solutions. One exact solution is provided by the catenary equation:

2) $\tan Theta = ws/T_o$

which is valid when all forces except tension and weight are zero. Solving the catenary equation to obtain the arc length and horizontal offset as a function of the depth yields:

2a) $y = y_o + T_o/w \, [\cosh((w/T_o)(x-x_o)+c) - \cosh c]$

2b) $s = s_o + T_o/w \, [\sinh((w/T_o)(x-x_o) + c) - \sinh c]$

where:

$c = \sinh^{-1} (\tan Theta_o)$

An additional exact solution is provided by Zajac (1957). Zajac considered the suspended cable configuration on flat ground in the limit as time goes to infinity. The ship speed is assumed constant and equal to the cable payout speed. The currents are assumed zero. Under these conditions the ship velocity can be superimposed over the system and the configuration will remain stationary. Zajac showed that the tension is given by:

3) $$\ln [(T-rho_c V_c^2)/(T_o-rho_c V_c^2)] = \int_{Theta_o}^{Theta} \frac{[w \sin zeta - Lambda\ t] \, d\ zeta}{[w(\cos zeta - Lambda \sin zeta \, |\sin zeta|)]}$$

where:

$Lambda = (C_d \, rho \, D \, V^2)/2w$

and the shape of the suspended cable configuration by:

3a)

$$S = \int_{\Theta_o}^{\Theta} \frac{(T - \rho_c V_c^2)\; d\zeta}{[w(\cos\zeta - \Lambda \sin\zeta\, |\sin\zeta|)]}$$

3b)

$$S = \int_{\Theta_o}^{\Theta} \frac{\cos\zeta\, (T - \rho_c V_c^2)\; d\zeta}{[w(\cos\zeta - \Lambda \sin\zeta\, |\sin\zeta|)]}$$

3c)

$$S = \int_{\Theta_o}^{\Theta} \frac{\sin\zeta\, (T - \rho_c V_c^2)\; d\zeta}{[w(\cos\zeta - \Lambda \sin\zeta\, |\sin\zeta|)]}$$

It has been verified that this solution reduces to the catenary solution as $V_s \to 0$. Note that $Vc=V_s$ in the steady state solution, the bottom must be flat, and the currents must equal zero.

5.3.5 COMPARISON OF SOLUTIONS:

The solution calculated by the straight segment approximation was compared to the exact solution for several different depths (Z_b), Ship velocity (V_s) and bottom tension (T_b). The exact solution was obtained by using the catenary equation (2) for $V_s=0$ and equation (3) for $V_s>0$. The numerical integration of (3) was performed with such small interval size that for all intents and purposes it can be considered exact. In making the comparison the depth was assumed to be known and the cable touchdown point set to $(0,0,Z_b)$.

The purpose of the cable laying program is to lay the cable on the bottom with accurate tension and position. This requires an accurate measure of the cable suspended length and the horizontal distance between the ship and the touchdown point. Since the touchdown point and bottom tension were specified, the solution accuracy criteria were the suspended cable length (S) and the surface breaking point (X_t). For all the runs made it was found that S was calculated with much more accuracy than X_t. For this reason only X_t is used as an accuracy criterion.

The results have been used to determine the appropriate segment length for the cable under the actual laying conditions in the Alenuihaha Channel. With a value of Tolc of 5 or less, cable laying accuracies of considerably less than 1% have been computed (based on the distance from the ship to the touchdown point) compared to the exact solutions given above. With these accuracies in the cable solution, the numerical solution is considerably more accurate than the input data (currents, ship location, etc.) and therefore more than adequate for the HDWC program.

5.4 CALCULATION OF UNSTEADY CABLE CONFIGURATIONS

The previous section detailed the basic theory involved in calculating a straight segment approximate solution to a suspended cable configuration. In that calculation, the cable segment absolute velocities were assumed to be known. This section discusses how these velocities are determined in an actual cable laying situation where the ship is changing course, speed, or cable payout speed, the currents are changing, and/or the bottom is sloping. (See section 5.9 and Figure 26 for cable variable definitions.)

5.4.1 SUMMARY:

In the steady state solution each cable segment is subjected to a velocity component in the x-y (horizontal) plane equal to the ship velocity. In addition to this the cable is moving tangent to it's axis at the cable payout speed. The steady state solution assumes zero cross currents and that the cable is being laid on a flat bottom. Under these circumstances the cable will be heading at the same horizontal angle as the ship (ie $B_b = B_s$).

In the unsteady case the cable segment absolute velocities must be found from the change in position of the cable segment over the time step in question. B_b will be equal to the angle of the cable laying on the bottom at the point where the cable leaves the bottom. A_b will be determined by the bottom bathymetry and B_b.

It is assumed that a complete cable solution is known at some time t_o and that the cable configuration is desired at some future time t_o + dt. For the purposes of these calculations the configuration at some initial time t=0 is taken to be the steady state solution. In reality it may be necessary to start the cable solution with a configuration that is not a steady state configuration. This will have to be considered as a separate problem although the same basic techniques as discussed here will apply - the main difference will be in the bottom boundary conditions.

Since the ultimate objective of the cable program is to lay the cable along a desired path at a desired bottom tension, and since the cable solution begins at the bottom with T_b, A_b, and B_b and marches up to the top, it might be supposed that given the desired bottom conditions, it would be possible to directly integrate up the cable from the bottom to obtain the necessary ship conditions (This is in fact the way that the steady state solution is calculated). While this may be true theoretically it is impossible numerically. The reason that it is impossible is that the cable segment velocities (V_{cs}) are not known a priori (as they are in the steady state solution). The calculation of these velocities is discussed further below.

5.4.2 THE ABSOLUTE VELOCITY APPROXIMATION:

If each cable segment velocity is assumed to be equal to the velocity of it's midpoint, then this velocity can be approximated by the change in position of this midpoint over time. (Figure 22). The vector V_{cs}*dt represents this change in position. The previous configuration can be searched for the same physical point by matching the absolute distance along the cable from the same common origin (for example the previous touchdown point).

The problem with this approximation is that it tends to overestimate the cable segment velocities. This is true because the cable is slowing down as it approaches the bottom (and in fact equals zero at the bottom). Since the segment midpoint at the previous time step is further from the bottom it is going faster and the V_{cs} obtained by this approximation will thus be larger than the true value. The approximation becomes better as dt approaches zero, however it is necessary to use fairly large time steps in this program (ie at least 10 seconds and preferable 60 seconds).

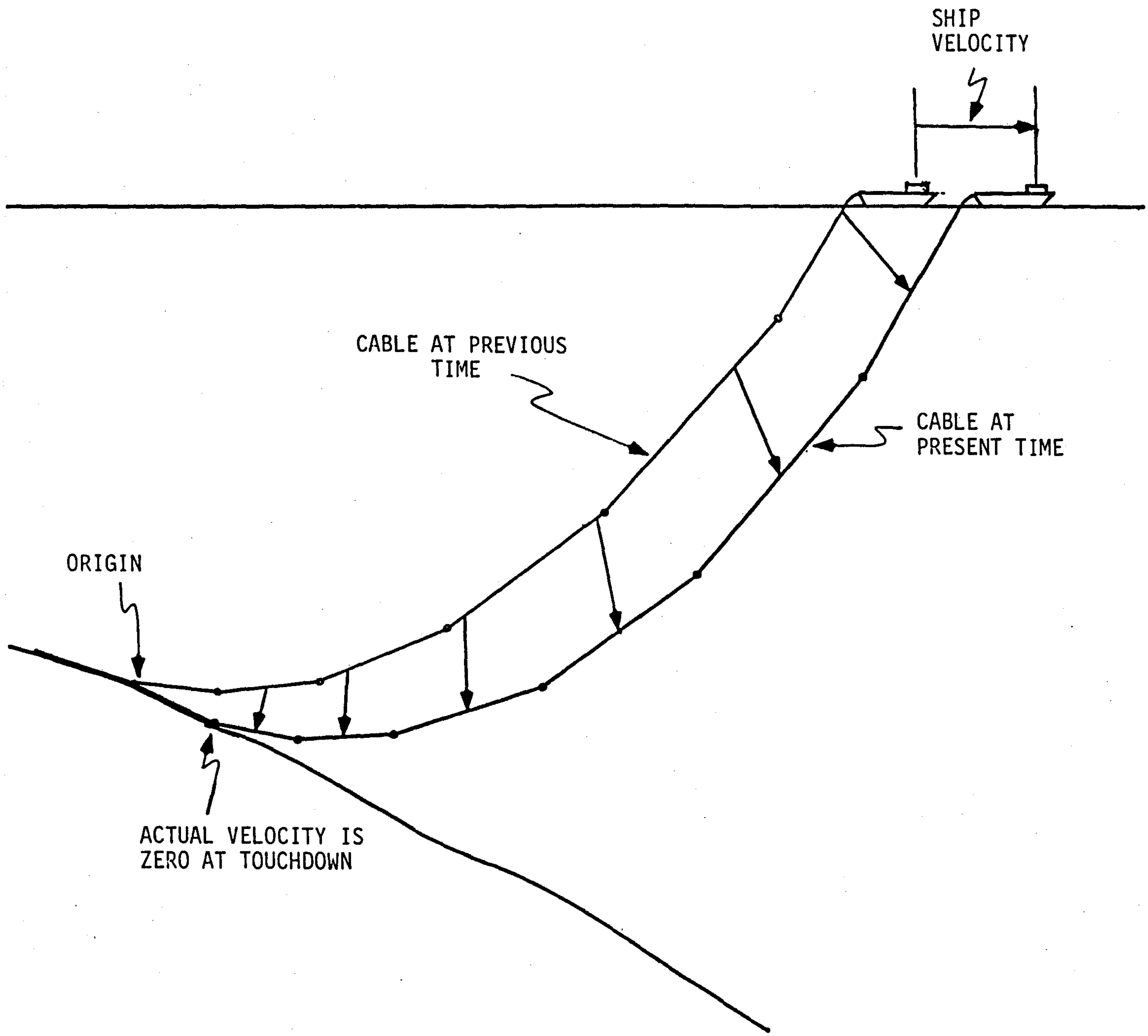
Since V_{cs} is overestimated, the cable segment tends to lie more horizontal than it really should (this becomes equivalent to a faster ship velocity in the steady state solution). Thus the top of the segment will be further away from the previous configuration than it should be.

When the next segment up the cable is calculated, a similar error will occur, however, since the segment bottom is already too far away due to this error from the previous segment, the effect is magnified. Thus as each new segment is added the velocity builds until soon it causes the configuration to head back down towards the bottom.

5.4.3 THE LINEAR 'EFFECTIVE SHIP VELOCITY' APPROXIMATION

One method of alleviating the instability of the absolute velocity method of V_{cs} approximation is to break the velocity up into two components - 1) a horizontal (effective ship) velocity which can be calculated from the change in position between the two time steps - but at the same depth and 2) the cable payout velocity - which is known exactly since it must be tangent to the cable.

This method works extremely well on flat ground but runs into difficulties on sloping bottoms especially when going down hill. If the bottom is steep and/or the time step long it may be possible that no data exist at the previous time step for the depth of a particular cable segment. On a very steep bottom the first cable segment actually goes down rather than up. What do we base the horizontal velocity component on in this case. In addition, if



FINDING CABLE SEGMENT VELOCITIES

Figure 22

the cable segment lies exactly horizontal, it becomes impossible to calculate a vertical velocity component (other than zero).

In summary the problem with the horizontal 'effective ship' velocity approximation is that it allows no way of introducing vertical velocity components except through the cable payout velocity vector. This is fine when the cable lay conditions are close to steady state (and in fact is exact for steady state), but if for example the cable payout was stopped then the solution would fail dismally. The advantage of this method over the absolute velocity method (other than increased stability) is that it allows very large time steps and avoids the problem with calculating the velocity of a cable segment when the previous time step puts it above the surface.

5.4.4 REMOVING THE INSTABILITY:

The instability of the absolute velocity approximation method made it unsuitable for any but the shallowest depth calculations. The inability to correctly account for vertical velocity components made the linear velocity approximation unsuitable. Of the two methods, the absolute velocity method is the most appealing from a physical modeling standpoint. However the instability was too large to use it as above. The basic problem is that each segment V_{cs} depends on the previous calculated segment. Even though each segment's velocity tended to be overestimated due to the effect discussed above, it was only after several segments had been calculated that the velocity grew to absurd values. The bottom segment for example never gave any problem. This effect had a multiplicative effect on the error which quickly got out of control.

The solution then was somehow to remove this effect. This was accomplished by removing the V_{cs} calculations completely from within the cable configuration routine. Instead the cable configuration is calculated with an assumed set of cable segment velocities and these velocities are only updated following convergence of the cable configuration. They are updated using the absolute velocity approximation, however, as this is now outside of the segment calculation loop, the instability effect is nonexistent. The calculated V_{cs} depend only upon the shape of the two configurations and not upon the other V_{cs} values. There still exists an error due to the overestimate of the V_{cs}; however this error is sufficiently small and does not cause solution instability.

5.4.5 DEFINITION OF A CABLE CONFIGURATION CALCULATION:

It is necessary to define what we mean by a single cable configuration calculation. This will consist of a single iteration from the cable touchdown point to the surface. Each configuration calculation consists of multiple iterations on each segment starting from the bottom and working to the top until the surface (or the end of the cable in the case of APC) is reached. Each segment is iterated on until the orientation of the segment (represented by the two polar angles A and B) causes the resultant force balance to equal zero. The total number of segment iterations can be regarded as a good indicator of amount of calculation required (ie the configuration calculation time).

To this purpose let us assume that we have a set of cable segment velocities. (In order to start the iterations we can assume that each cable segment has a velocity equal to that of the previous time step.) If we have N segments then we need N*3 assumed cable segment velocities.

We now assume values for the bottom tension (T_b) the bottom horizontal angle (B_b), and the amount of cable laid on the bottom during the time step (dS_b). We also assume that we have available current velocities as a function of depth at time = t + dt and that these are constant with respect to x and y. The cable and water properties and the drag coefficient are also assumed known and constant. It is now possible to integrate from the bottom to the surface segment by segment. When we break the surface we will be at a certain point say X_t, Y_t and a certain amount of cable will be suspended between the surface breaking point and the touchdown point.

Instead of looking for the surface, an alternative method is used in the APC calculation. In this case the total amount of cable out (S_t) is known. Since this is a known quantity it would be inefficient to adjust it in CABLE only to have to readjust it later in NEWRAP in order to match the ship position (this is discussed later). Instead the CABLE configuration calculation is assumed complete when S_t is reached and the value of (X_t,Y_t,Z_t) is passed back to NEWRAP. It is not possible to use this method in INIT or VRS since S_t is not known beforehand but must be calculated.

In summary then a cable configuration calculation takes an assumed set of V_{cs} with assumed T_b, B_b, and S_b, calculates X_b, Y_b, Z_b, and A_b based upon the previous configuration and the terrain data, and marches to the top using an assumed set of V_{cs} resulting in calculated top conditions (X_t,Y_t,S_t) at Z_t=0 or (X_t,Y_t,Z_t) at S=S_{tot}.

5.5 ACTUAL PATH CALCULATOR:

There are two problems to solve in the cable laying system. The first and perhaps the most basic is to calculate where the cable configuration is in terms of the bottom conditions (T_b, X_b, and Y_b), given known ship conditions (X_t', Y_t', Z_t', S_t', and t), bathymetry, currents, etc. The second problem is to find the required ship conditions needed to obtain previously defined desired bottom conditions. The solution to the first problem is known by the acronym APC (Actual Path Calculator). The solution to the second problem is known by VRS (Vessel Response Specifier). (See section 5.9 and Figure 26 for cable variable definitions.)

The APC was historically the first problem to be solved. In the specification of this problem we assume as above that the previous configuration is completely known as well as all cable and water properties, C_d, the currents and the bathymetry. In addition the absolute length of the cable and the coordinates of the surface breaking point are assumed known. All variables are assumed constant over dt. The cable payout rate can thus be found:

$$Vc = (S_t - S_{to})/(t - t_o)$$

If the bottom conditions T_b, A_b, B_b, and S_b are guessed, then assuming that the previous configuration is exact:

$$X_b = X_{bo} + fb*(S_b-S_{bo})*dcos(A_b)*dcos(B_b)$$
$$Y_b = Y_{bo} + fb*(S_b-S_{bo})*dcos(A_b)*dsin(B_b)$$
$$Z_b = Z_{bo} + fb*(S_b-S_{bo})*dsin(A_b)$$

where $0<=fb<=1$ accounts for the fact that the cable does not lie in a straight line between any two touchdown points.

Given these values of X_b and Y_b, the terrain data file can be interrogated to find a more accurate value of Z_b (say Z_b') . If Z_b' agrees with Z_b then the set is consistent. If not then we can calculate:

$$A_b = atan((Z_b'-Z_{bo})/sqrt((X_b-X_{bo})**2 + (Y_b-Y_{bo})**2))$$

Plug this value of A_b back into the above equations, calculate a new value of Z_b' and continue the process until Z_b' agrees sufficiently with Z_b.

A complete set of bottom conditions is thus defined as:

$$phi_b = (T_b, A_b, B_b, X_b, Y_b, Z_b, S_b)$$

Once this complete set has been generated using the above method, the program CABLE can be called (remember that the set of V_{cs} has already been fixed outside this loop). The output from CABLE will consist of (T_t, T_t, B_t, X_t, Y_t, Z_t, S_t). Since we are not able to measure usefully T_t, T_t, or B_t and since APC uses S_t to complete the cable configuration calculation, we can form the three residuals:

$$R1 = X_t - X_t'$$
$$R2 = Y_t - Y_t'$$
$$R3 = Z_t - Z_t'$$

If all three of these residuals equal zero then the calculated cable configuration matches the measured cable configuration.

In order to force these residuals to zero it is necessary to find suitable values of T_b, B_b, and S_b. This is done using a standard Newton-Raphson technique where each new guess of T_b, B_b, and S_b is obtained through solution of the matrix equation:

$Ax = B$

where A is the matrix of partial derivatives:

$$\begin{vmatrix} \frac{X_t}{T_b} & \frac{X_t}{B_b} & \frac{X_t}{S_b} \\ \frac{Y_t}{T_b} & \frac{Y_t}{B_b} & \frac{Y_t}{S_b} \\ \frac{Z_t}{T_b} & \frac{Z_t}{B_b} & \frac{Z_t}{S_b} \end{vmatrix}$$

and B the vector of residuals:

$B = (R1\ \ R2\ \ R3)$

and $x = (dT_b\ \ dB_b\ \ dS_b)$ the amount by which T_b, B_b, and S_b have to be adjusted for the next iteration.

The partial derivatives that make up the matrix A are calculated by changing each of T_b, B_b, and S_b in turn by a small interval and calculating a new cable configuration. The size of this interval is extremely important. If it is too small then the difference between the two solutions may be dominated by numerical roundoff, if too large then the partial derivative may cause the new guess to shoot back and forth around the solution. Even when the interval is within a sufficient range, the rate of convergence depends strongly on the interval size.

The program that performs the above iterations is called NEWRAP.

It may be wondered why the independent variables are not simply T_b, X_b, and Y_b. This would eliminate the above problem of iterating to find Z_b given B_b and S_b. B_b and S_b could be simply calculated as:

B_b = atan2($(Y_b - Y_{bo})$, $(X_b - X_{bo})$)
$S_b - S_{bo}$ = sqrt($(X_b - X_{bo})$**2 + (Y_b-Y_{bo})**2)

It was found though that under the conditions of a very small S_b-S_{bo} the value of B_b could vary drastically for small changes in Y_b and/or X_b. Since the cable configuration is highly dependent upon B_b this would cause non-convergence of the solution. For this reason the independent variables were changed to B_b and S_b.

Once the residuals have converged to within a reasonable value, NEWRAP can be said to have converged. The bottom conditions phi_b have been found such that the calculated ship position and suspended cable length match the measured values. The solution would be complete if the actual V_{cs} values for each segment were correct.

New V_{cs} values can be obtained by using the absolute velocity approximation based upon the known configuration at t_o and the just calculated configuration at t_o+dt. These will in general not be the same set of values that were used to calculate the previous cable configuration. Thus it becomes necessary to assume a new (hopefully more accurate) set of V_{cs} values and recalculate the cable configuration.

In order to obtain a better estimate of the cable segment velocities several approaches could be used. The most obvious is to simply use the newly calculated values as the next guess and continue to iterate until they (hopefully) converge. In some cases this will work however it can't be always relied on. Another option would be to use a Newton-Raphson scheme as above but with the partial derivatives found by modifying each cable segment velocity in turn, calculating a new cable configuration, a new set of cable segment velocities, and the difference between this new set and the nominal set for each component. The partial derivatives to be loaded into the Newton-Raphson matrix would thus take the form:

$dE(i)/dV_{cs}(j)$

where

$E(i) = V_{cs}(i) - V_{csnom}(i)$
$V_{csnom}(i)$ = assumed value of V_{cs} for component i
$V_{cs}(i)$ = subsequently calculated value of V_{cs}
$dV_{cs}(j)$ = interval used for component j

Thus the matrix dimension is 3*N where N is the number of cable segments. For 11 segments we must solve a 33x33 matrix for each new guess of the set V_{cs}. Although the solution of this matrix does not take an excessive amount of time, the loading of it does - typically requiring on the order of 5000 segment iterations.

This method was implemented and proved to be extremely stable. It's disadvantage was that it required an extremely long time to calculate the partial derivatives. As an example suppose that there were 11 segments. Then 33 NEWRAP calculations would be required to calculate the partial derivatives. Each NEWRAP calculation may require 3 or 4 cable configuration calculations each of which may require 50 or so segment iterations. Thus it easily might require 5000 segment iterations (and often considerably more) just to load the matrix. Since it is impossible to complete any particular time step until these partials are known, this can cause a considerable interruption in the total system flow. It is very hard to predict how long any given time step will require since it is not known a priori how often these partials will need to be recalculated.

An alternative method is presently used. This method relies on the numerical technique called under-relaxation. The new V_{cs} are calculated by the formula:

$V_{csnew} = omega*V_{cs}* + (1-omega)*V_{cs}$

The value of omega is controlled separately for each V_{cs} but usually is around 1/2.

The advantage of the under-relaxation technique is that the number of segment iterations per time step is much more constant. In addition, it is usually not much larger than the Newton-Raphson method discussed above (without matrix loading). It's disadvantage is that it is not as stable and the control of omega is not a trivial task. Empirical evaluation has shown, however, that, under the conditions expected to be encountered during the test lay, the under-relaxation method is sufficiently stable. In reality because omega is adjusted downward whenever instability is detected, instability per se is not a problem; the worst that can happen is that the required accuracy will not be achieved within the maximum allowable number of iterations.

5.6 VESSEL RESPONSE SPECIFIER

The ultimate purpose of the computer software is to control the ship such that it lays the cable within acceptable tolerance of the bottom path. The bottom path is defined basically by a set of desired (X,Y) coordinates and tension. The ship conditions that can be varied are the speed, course, and cable payout rate. Note that the ship heading may be completely different than the ship course (in fact for the Flexservice III these may be at right angles to each other). The ship heading will presumably be optimized by the ship's navigation system to reduce pitch and roll etc. By the ship course is meant the horizontal angle (B_s) formed by the difference between two successive absolute ship positions. (See section 5.9 and Figure 26 for cable variable definitions.)

It can be shown and is also intuitively obvious that if all three of the above ship conditions are allowed to vary in any manner an infinite number of solutions are possible. For example we could lay the cable down any reasonable path at almost any ship velocity by varying the cable payout rate or alternatively at almost any cable payout rate by varying the ship speed. On the other hand the ship course must be a primary independent variable (ie it is almost impossible to change the bottom angle, B_b, merely by adjusting V_s or V_c). Since the ship can most easily adjust V_s and B_s, these will be considered as the primary independent variables. Obviously during startup and finish it will also be necessary to adjust V_c. These adjustments however can be defined outside of the control logic and then the set (V_s, B_s) adjusted so as to obtain the desired (T_b, B_b, S_b) with V_c assumed constant over the time interval of calculation (dt).

With the cable segment velocities calculated outside of the cable configuration calculation (as discussed above in reference to the APC) it is possible to start with the desired bottom conditions and march up the cable to obtain the required ship conditions. Since the time step is not known a single variable must be iterated on (in contrast to 3 variables needed in APC). The most obvious selection for this variable is dt itself. Unfortunately the solution is very sensitive to dt so it is necessary to move this iterative loop outside of the Vcs iterative loop. This allows the new touchdown point to be specified exactly.

This method of calculating time steps is thus much faster than the APC since only a single variable needs to be iterated on (not counting the Vcs of course). On the other hand the VRS must look at least several time steps ahead. The net result is that the two programs take the same order in calculation time.

A disadvantage of the above method of approach is that the desired ship velocities and courses calculated each time step tend to fluctuate somewhat wildly depending upon the smoothness of the path. In order to use this approach a smooth path must be defined. Even then the calculated ship conditions must be smoothed somewhat to avoid slight vibrations. These vibrations are caused by discontinuites in the derivatives of the path. Minimal fluctuation is achieved by ensuring that both the zeroth and first derivatives are continuous.

5.7 EFFECT OF CURRENTS ON CABLE CONFIGURATION

The current data will be available as a series of measurements of current magnitude and direction at various depths. Assuming that the current varies relatively slowly with both time and in the x-y plane these measurements can be extrapolated (or interpolated) to a given time and applied over the entire cable length (which will vary considerably in x-y space over it's entire depth). (See section 5.9 and Figure 26 for cable variable definitions.)

Since the current data are only available as a discrete set of points some variation between the points must be assumed. The simplest possibility is a linear variation. Due to the fact that the number of current meters will probably be insufficient to accurately sample the depthwise current fluctuations, it is probably no more accurate to use more than a linear approximation.

The program converts the magnitude and direction of the current readings into x-y components and each of these components is treated separately. Thus the following discussion refers to either the x or y component of the current velocity.

There are several questions which must be answered in order to determine the effect of the current profile on the cable configuration. Among these are:

How important is the magnitude of the current profile. In particular assuming that the cable surface point is known, how much variation in the bottom conditions can we expect due to uncertainty in the current magnitude.

How many current measurements will we need. Obviously this is a function of how the current profile varies with depth. If the current profile is flat from top to bottom then a single measurement will suffice.

How important is it to account for the current profile variation over a single segment. Due to the model used for the cable, the current force is calculated from a single current velocity applied at the center of the cable segment. How should this value be obtained from the actual current profile and how will variations in the profile over the segment length affect the results.

In order to answer the above questions the following situations were analyzed. The runs were made over a flat bottom with nominal T_b=10 kN, Z_b=2000 m, and V_c=.1667 m/s. In general the ship position was held constant and the effect on T_b and Y_b due to variations in the current profile examined:

5.7.1 EFFECT OF THE CURRENT MAGNITUDE

Given a flat current profile (top to bottom) with a nominal current magnitude of 1 knot (0.5 m/s) at 90 degrees to the cable lay direction, the effect of increasing this magnitude by varying amounts was examined. These runs were also done at various depths. The results of these runs are plotted in Figure 23 in a form suitable to determine how close to the bottom a transponder would need to be in order to reduce the positional error due to current uncertainty to some acceptable level.

5.7.2 EFFECT OF THE CURRENT DEPTH

Given the same nominal profile as in 1), what is the effect of increasing the current magnitude by 10% (to 0.55 m/s) over only a certain discrete depth range. The depth range chosen was 100 m. The representative current profile then was 0.5 m/s over the entire depth except over the given 100 m interval where it was 0.55 m/s. The results are plotted in Figure 24 for a depth of 2000 m and a current 90 degrees from the cable lay direction.

From Figure 24 it can be seen that for a cross current the effect of currents near the cable bottom is much more important than near the surface. This behavior can be explained by noting that 1) the tension in the cable near the bottom is much less, therefore the shape of the cable is affected more by a given current force; and 2) for a cross current there is much more cable in the water over any given depth interval near the bottom than near the top, thus the total force on the cable is much greater near the bottom.

5.7.3 EFFECT OF DEPTHWISE FLUCTUATION OF CURRENT PROFILE

The purpose of this numerical experiment was to determine how fluctuations in the current profile affect the cable solution. Since we will only be able to sample the current at a certain number of discrete depths, it is important to know how many of these samples will be required in order to ensure that the configuration will be calculated with sufficient accuracy. In addition since each cable segment is of finite length, and the variation in current over

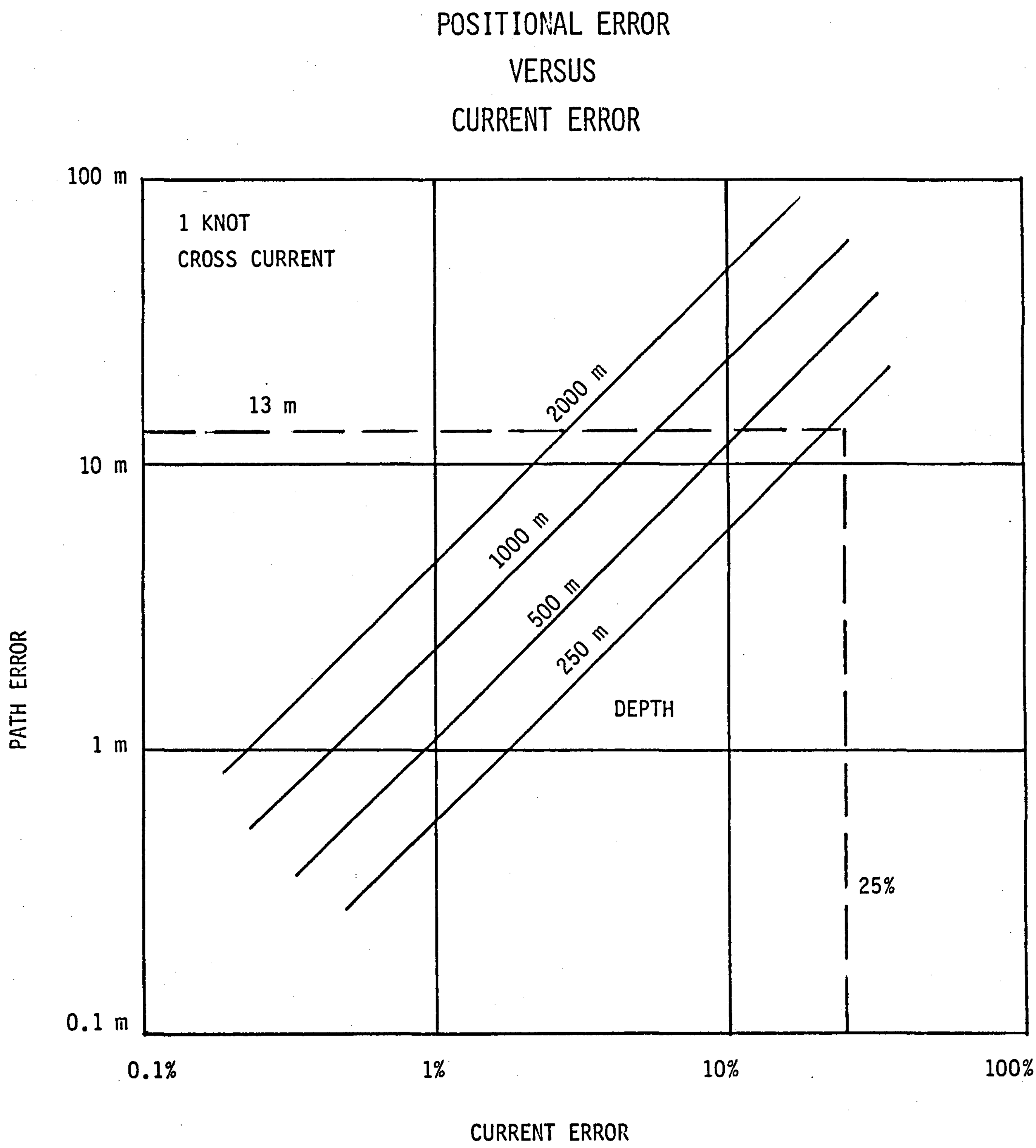

POSITIONAL ERROR
VERSUS
CURRENT ERROR
100 m
10 m
1 m
0.1 m
1 KNOT
CROSS CURRENT
13 m
2000 m
1000 m
500 m
250 m
DEPTH
25%
0.1%
1%
10%
100%
CURRENT ERROR
PATH ERROR

Figure 23

CABLE RESPONSE AS A FUNCTION
OF DEPTH OF CURRENT ERROR
(CROSS CURRENT)

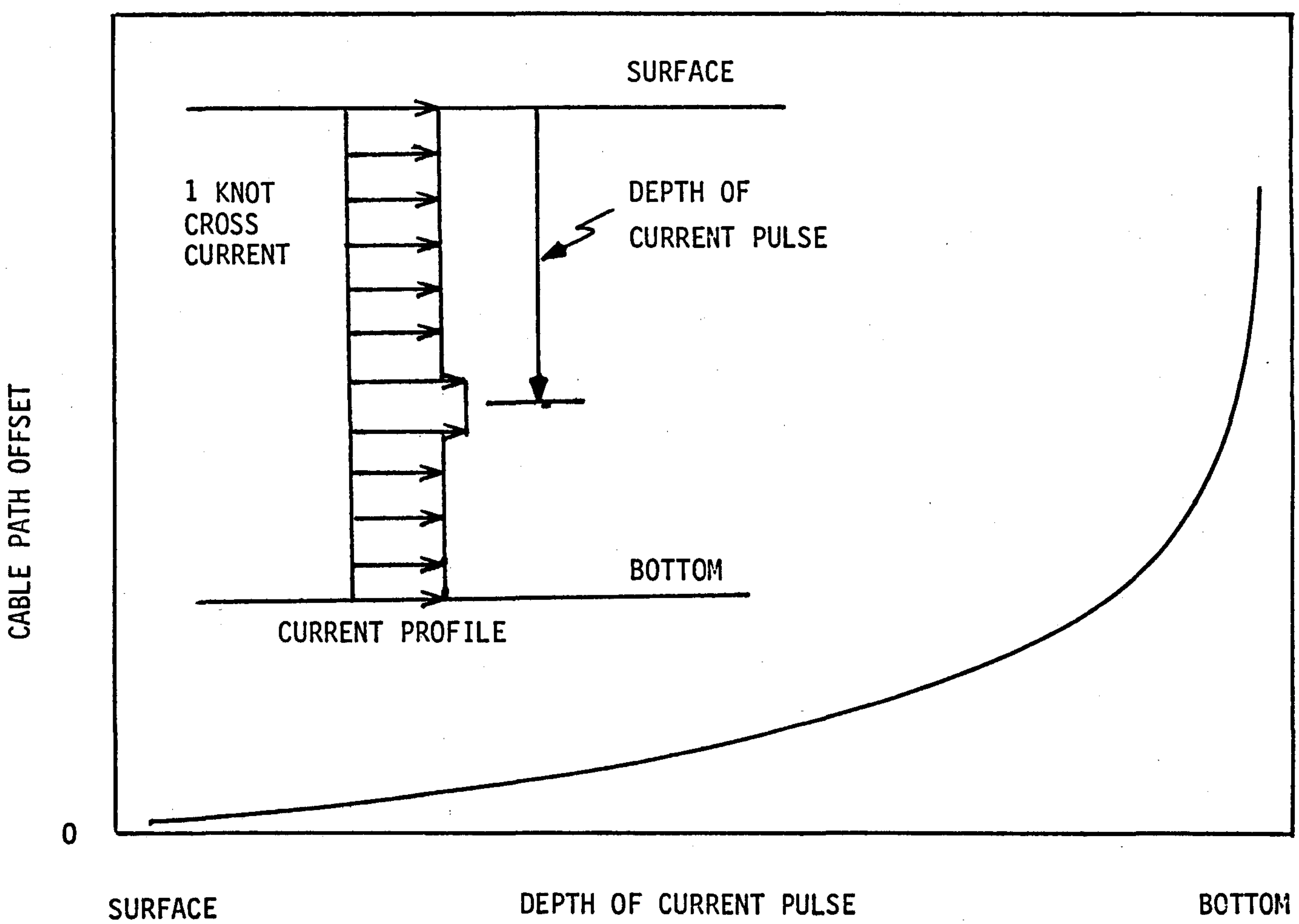


Figure 24

each segment must be represented as an effective current velocity at the segment midpoint, it is important to know how current variation over a single segment affects the solution.

The method used to examine the above effects was to digitize an actual current profile as obtained from one of the Horizon Marine current measurements in the Alenuihaha channel. A profile was selected that showed significant depthwise fluctuation. The Horizon Marine Data shows considerable "noise" on the current profiles which appears as high frequency variation with current increasing and decreasing over a few meters in depth. These high frequency data are considered due to water turbulence. Cable solutions were run both including and excluding these high frequency data and it was found that the high frequency "noise" made no significant difference in the cable touchdown point or tension. The cable and cable segments effectively average the currents and these high frequency fluctuations are not important.

Carrying the principle of averaging currents even further, it was found that averaged current profiles can provide excellent cable solutions. Currents that are averaged over several hundred meters of depth variation give cable solutions that are nearly identical to the exact solution. Profilers that can provide this type of information, therefore, are more valuable. An acoustic doppler current profile, for instance, can provide these averaged data.

Relative to individual current meters on a string, by looking at the actual Horizon Marine data, it has been concluded that a minimum of 10 meters would be required on any given current meter string providing data for the At-Sea Test. These meters would be distributed such that they would be more closely spaced near the bottom of the profile than at the top.

The final conclusion from the evaluation of the Horizon Marine current profile data is that the Acoustic Doppler Current Profile system is preferred and that this system should concentrate on the lower portion of the current profile. The upper portion is not necessary as long as cable transponders are available.

5.8 DEFINITION OF THE CABLE PATH AND TERRAIN

5.8.1 PATH

The cable path is completely defined by the following information:

X	the absolute X-coordinate of a path point
Y	the absolute Y-coordinate of a path point
B	the desired cable horizontal angle
Tmax	the maximum allowable tension
Pr	path width to the right of the path
Pl	path width to the left of the path

In addition the following information is included in the path definition file to simplify processing:

- Z — The depth
- R — the radius of curvature (in the horizontal plane)
- Sp — the integrated horizontal path length from the path origin.
- Sp* — the integrated path length (including depth) from the path origin.

Note that the path is currently made up of discrete segments such that when viewed from above (in the horizontal plane) each segment has a constant curvature. In addition the cable horizontal angle Bp is continuous (ie it does not undergo any discontinuity between successive segments).

Table 1 summarizes the segments making up the path. There are a total of 18 path points. For non-zero curvature the x and y coordinates of any point along the path can be calculated by the following formulae:

```
Xp = Xp(j) + R(j)*(dsin(B) - dsin(Bp(j))
Yp = Yp(j) - R(j)*(dcos(B) - dcos(Bp(j))
```

where

```
B = Bp(j) + 1/R * (S-Sp(j))
```

if the curvature is zero then the formula must be modified to:

```
Xp = Xp(j) + (S-Sp(j))*dcos(Bp(j))
Yp = Yp(j) + (S-Sp(j))*dsin(Bp(j))
```

In order to describe how accurately the cable is being laid, two additional variables are defined. These variables are defined by drawing a perpendicular (in the horizontal plane) from the current touchdown point to the path.

- P = perpendicular horizontal distance from the current touchdown point to the ideal path. Positive is defined as to the left of the path (ie in the positive y direction in looking along the direction of path lay).
- dT_b = difference between the tension at the current touchdown point and the tension at the intersection of this perpendicular with the ideal path.

In order to keep track of where we are along the path the variables S_h* and S_b* are defined as:

S_h* = total length of the ideal path in the horizontal plane.
S_b* = total length of the ideal path including depth.

The value of these variables for the current touchdown point is defined by the value where the perpendicular meets the path (since these variables vary continuously along the path). S_b* is obtained by integrating along the defined ideal path the total amount of cable that would be laid including depth. (This variable is stored in the path file).

X_p, Y_p coordinates of path point
S_p horizontal distance along path between two points
R radius of curvature between two path points
T_p desired tension at path point

5.8.2 TERRAIN

The data defining the depth (Z) at discrete (X,Y) points are referred to as the terrain data. These data have been defined by linearly interpolating known depths obtained from experimental data stored in an existing database.

The terrain data are defined in terms of pages. Each page is oriented along the cable path such that a single page covers at least the entire path width and usually a considerable overlap. Each page also overlaps the previous page so as to afford some redundancy when the cable is near the border of a page. (Figure 25)

Each page is rotated an angle approximately equal to the path angle at the page centerpoint. Thus each page has it's own coordinate system with the positive x-axis lying along the cable path.

The node spacing is not necessarily equal in each direction. The number of nodes in each direction is also not necessarily the same. (The number of nodes in each direction however must be an odd number so that a node exists at the page centerpoint.)

Each page is thus fully defined by the following parameters:

i unique page number (integer from 1 to 33)
Xp absolute X-coordinate of page centerpoint
Yp absolute Y-coordinate of page centerpoint
Bp page rotation angle (relative to absolute coordinate system).
Nc Number of columns in page (odd)
Nr Number of rows in page (odd)
dx distance between columns (in meters)
dy distance between rows (in meters)

The above information is stored in the direct access file PAGE.DAT. Whether or not a given (X,Y) point lies within the bounds of a page can be quickly determined from the above parameters.

The depth data corresponding to each node of each page are stored in the direct access file TERRAIN.DAT. This file is

HOW DEPTH DATA IS DEFINED TO PROGRAM

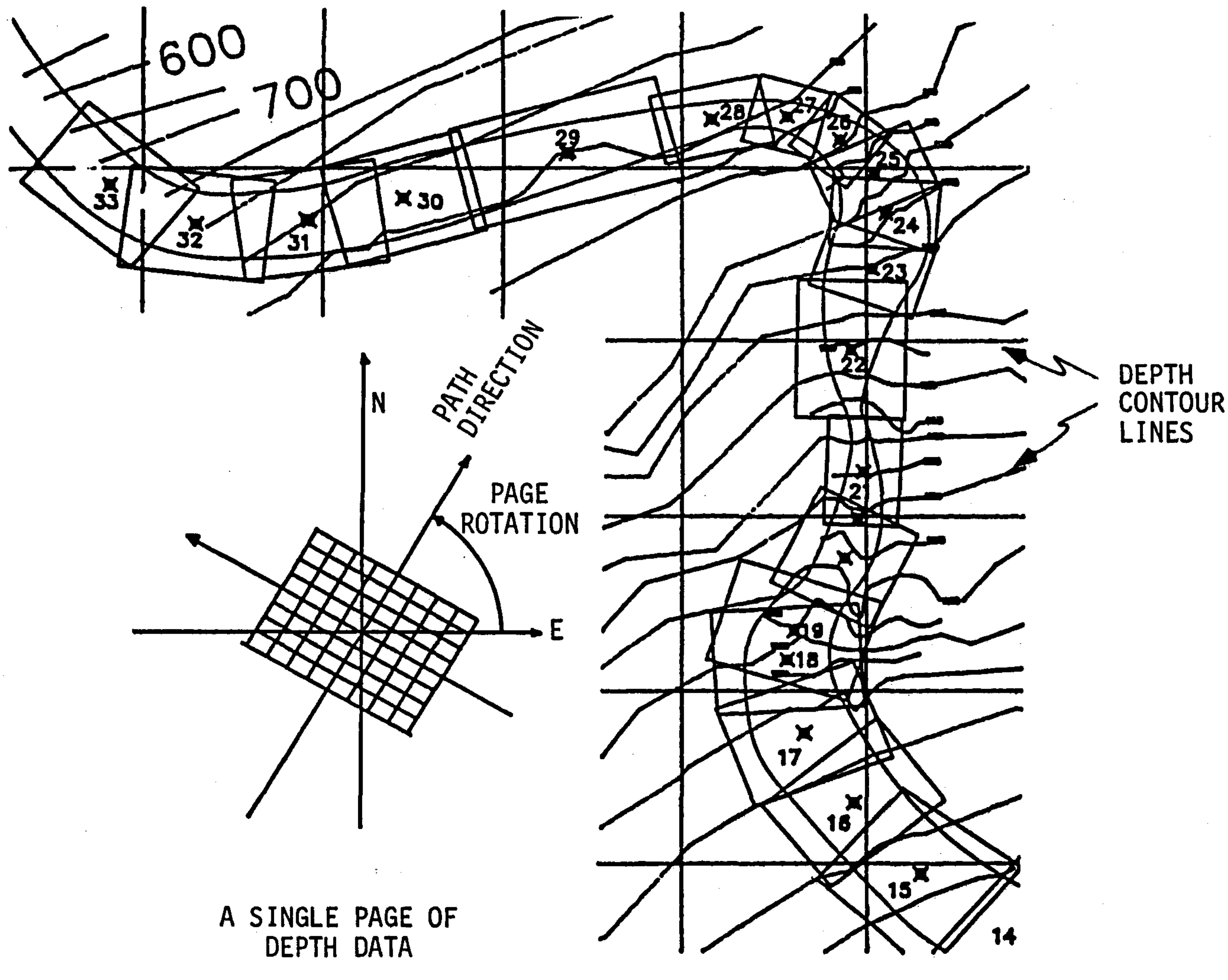


Figure 25

currently just over 125000 bytes in size. It consists of 33 records of length 8192 bytes each. Thus the entire depth data for a page are stored in a single record. The data are stored in double precision.

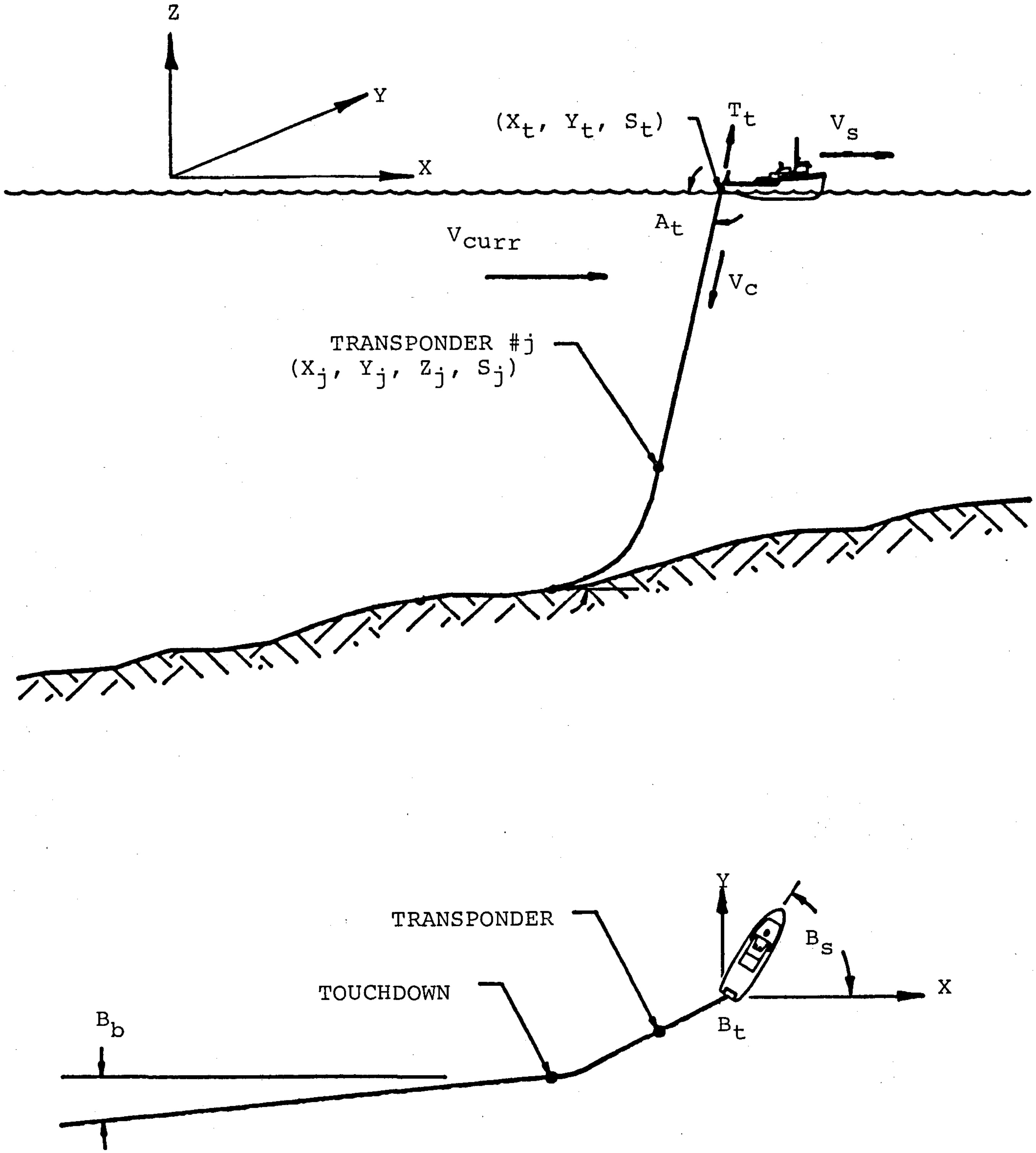
5.9 CABLE PROGRAM VARIABLES AND FILES

5.9.1 VARIABLES (see Figure 26)

Notes:

1) The arc length of the cable (S) is measured from some arbitrary point on the cable. This point will presumably be the beginning of the cable. The 'end' of the cable (or cable segment under consideration) is the end closest to the surface.
2) The coordinate system is right-handed cartesian. Positive x is assumed due east. The surface is at Z=0 and depths are negative. (All depths output to the screen are positive). B is measured counterclockwise with B=0 on the positive x-axis.
3) Effective 11/1/88 the solution uses sections as well as segments. The section index (m) precedes the segment index (n) in dimensioned variables however may not be shown below.

A	(vertical) angle between x-y plane and cable segment
acc	solution accuracy (fractional) between two consecutive segments
addm	added mass coefficient for calculation of dynamic forces (1.5)
alpha	Critical angle (angle cable will assume with no cross currents
nr	Matrix of partial derivatives in NEWRAP
B	horizontal angle between cable and x-z plane
Bbstar	Value of Bb that VRS is shooting for
Bnr(3)	Vector of residuals (function values that approach 0 in NEWRAP)
caberr	error flag set to true in CABLE if an error occurs
C0(j)	Directional derivatives of segment C0(1) = cos(A)*cos(B) C0(2) = cos(A)*sin(B) C0(3) = sin(A)
C1(j)	Normalized cable directional vectors at bottom of segment
C2(j)	Normalized cable directional vectors at top of segment
Cd	Normal Drag Coefficient
Cdiff(j)	C2(j) - C1(j)
Cn(j)	Unit directional vector normal to segment in direction of Vcw
diam	Cable diameter (m)
Dncons	constant multiplication factor for normal drag



Variables Used In The Control Cable Model

Figure 26

ds(n)	Segment length for segment n under consideration (m)
dsi	Initial value of ds to use for segment #1
dt	Time step (s)
Dtcons	constant multiplication factor for tangential drag
dtheta	estimate of curvature of cable segment sum(c2(j)-c1(j))
eps	small number used for many convergence criteria
errv	normalized error of Vcs
f(k)	functional values to minimize in NEWRAP f(1) = (Sp - S)/S0 f(2) = (Xtp(1) - Xt(1))/C f(3) = (Xtp(2) - Xt(2))/C where C = dsqrt((Xt0(1)**2-Xb0(1)**2) + (Xt0(2)**2-Xb0(2))**2)
f1(i)	Tension components at bottom of segment
f2(i)	Tension components at top of segment
fcen(3)	centrifugal force components
fdyn(3)	dynamic force components
Gn0	Magnitude of normal drag force vector
Gn(i)	Normal drag force vector components
Gt0	Magnitude of tangential drag force vector
Gt(i)	Normalized tangential drag force vector components
H	cable hydrodynamic constant
iconst(60)	integer constants used for various program variables
icurr	flag controlling when current values are updated 0 = do not update (using current file) 1 = update
idyn	flag controlling when dynamic forces are included 0 = no dynamic forces 1 = dynamic forces
ihead	controls header output in OUTDATn.DAT
iout	output flag for main programs (see also file OUTS.DAT)
istep	error flag returned by STEP
Maxit	Maximum number of iterations per segment
Nsects	Total # of sections in cable configuration
Nsegs(m)	Total # of cable segments
Npath	unique integer assigned to each desired path point
Ns	APC time increment counter (ie...t = t(Ns-1) + dt(Ns))
Ntiter	total number of segment calculations required for a time step
Nvars	total number of dependent variables to calculate in NEWRAP
pi	3.141592...... (double precision 16 digits)
rconst(60)	real constants used for program (read from input file)
rhoc	Mass density of cable (kg/m^3)

rhow	Mass density of water (kg/m^3)
rn(i)	normalized relative velocity vector comps. normal to cable
rt(i)	normalized relative velocity vector comps. tang. to cable
rtd	radians to degrees conversion factor (180/pi)
S	Length of suspended cable
Sb	Cable T.D. point arc-length coordinate. (see notes above)
Sbstar	Value of Sb that VRS is shooting for
Spaid	Length of cable paid out during dt (Vc*dt)
St	Cable surface breaking point arc-length coord
Sts(i)	Cable segment top arc length
surf	Distance from segment top to either end of cable or surface
Tts(n)	Cable tension at top of segment n
Tb(m)	Cable tension at bottom of section m
Tbstar	Value of Tb that VRS is shooting for
TD	True = cable has touched down; else not
time	value of time (main variable used to keep track of solution)
Tolc	Criterion for ds adjustment.
tolc - dtheta(n)*ds(n) -> 0	
Vb	Rate of cable lay on bottom (Sb/dt)
Vc	Cable payout speed
Vcs(n,j)	Cable segment midpoint velocity
Vcurr(n,j)	Current velocity vector at middle of segment n
Vcw(n,j)	Vcs(n,j) - Vcurr(n,j)
Vn(i)	Cable to water relative velocity components normal to cable
Vn0	Magnitude of relative velocity vector normal to cable
Vs	Ship speed (scalar)
Vt(i)	Cable to water relative velocity components tang. to cable
Vt0	Magnitude of relative velocity vector tangential to cable
Xb(m,j)	coordinates of bottom of section m
Xnu	Kinematic viscosity of water (m^2/s)
Xt(m,j)	coordinates of top of section m
Xts(n,i)	Cable segment top coordinates
Xtp(m,j)	'Measured' coordinates of top of segment m
wt	Cable wet weight (kN/m)
Zb	depth of bottom as a function of x and y.

subscripts:

0	at time = 0
b	bottom (touchdown point or bottom of segment)
cs	center of cable segment
nom	nominal values used in CABLE to initialize variables
p	path point

s ship
t top (surface breaking point or top of segment)
ts top of cable segment

5.9.2 FILES

INIT.DAT contains complete cable configuration definition. Read by GETDATA. Written by PUTDATA.

INIT0.DAT carbon copy of INIT.DAT. Only created by program INIT. Never modified or read again. User can recreate initial cable configuration by copying INIT0.DAT into INIT.DAT.

CURRENT.DAT Current data. Read by CURRENT. Written by CURGEN if appropriate flag in CONSTS.DAT is set.

CONSTS.DAT Contains program parameters. User maintained.

OUTS.DAT Contains program output flags. User maintained.

PROPS.DAT Contains cable and water properties. User maintained.

TERRAIN.DAT Contains Terrain data. Unformatted file. Accessed by TERRAIN. Created by set of programs in directory TERRAIN.

PAGE.DAT Unformatted data file that goes along with TERRAIN.DAT. Contains page definitions. Read by TERRAIN and GETPAGE. Created along with TERRAIN.DAT.

PATH.DAT Contains path definition data. Unformatted. Created and maintained by user.

5.9.3 OUTPUT AND FILES

OUTDAT1.DAT log file giving a summary output from each time step. A single time step occupies only a single line in this file. This file is appended to each time step and never overwritten (unless an appropriate flag in CONSTS.DAT is set).

OUTDAT2.DAT log file giving detailed summary of forces, velocities, and angles for each cable segment. This file is not written unless the appropriate flag in CONSTS.DAT is set. A new file is started each time APC or VRS is restarted. Each segment requires 5 lines in this file.

OUTDAT3.DAT log file similar to OUTDAT2.DAT. This file however only contains a single line per segment summarizing the positions, angles, tensions, and velocities on that segment. Forces are not included.

OUTDAT5.DAT   log file containing sufficient information to plot the cable configuration from any angle. This file will presumably be used to generate any graphic output desired.

LAY.DAT   .an unformatted file which contains certain relevant information from each time step.

SECTION 6

AT-SEA OPERATIONS

The previous sections have discussed the DAS and ICS operations during a continuous cable lay. Additional procedures will be required such as initialization, starting, stopping, etc. and these are discussed in this section. The details of many of these procedures are still under development and therefore the discussion is not intended to be rigorous but rather reflect the present approach being used.

6.1 CABLE LAYING INITIALIZATION CONTROL

In addition to the obvious hardware and software initial cable lay checks (these will be described in detail in the At-Sea Test protocol plan), the following initialization procedures will be required in order to insure accuracy of the cable laying process.

6.1.1 CABLE DRAG COEFFICIENT MEASUREMENTS

The cable drag coefficient is a critical parameter in the cable modeling program. Drag coefficients from the literature vary significantly and are not sufficiently accurate for this cable laying procedure. It will therefore be necessary to measure the average drag coefficient for a suspended and lowered cable below the cable ship.

The At-Sea Test involves cable lays along the Kohala slope and the Maui slope of the Alenuihaha channel. Both of these cable lays will require first lowering the cable either 1000 or 2000 meters below the cable ship depending upon the starting location. The suspended cable will have an anchor at the lower end weighing from 2000 to 4000 kg and be instrumented with multiple transponders, one located at the anchor. With sufficient information on the shape of the cable (knowing the bottom tension exactly - weight of the anchor and knowing the ship's position and history of the suspended cable), the average drag coefficient for the entire cable length can be computed.

The drag coefficient measurements will be based on a computer model of the hanging cable identical to the model being used during the cable laying test. In order to assure the highest accuracy, multiple measurements will be made and these will be conducted under varying conditions. Cable speed and ship's speed can be varied in order to measure C_d under a variety of conditions.

6.1.2 DEPTH AND CABLE LENGTH CHECKS

Keeping track of the total geometry and shape of the cable lay is critical to the cable laying procedures being used during the At-Sea Test. Because the suspended cable are of such great size, length measurement is critical in this program. Ship position, bathymetry, and cable length all involve large distance measurements to a relatively high degree of accuracy. A potential problem is that these measurements are all used together in the control system computer model of the suspended cable but these length measurements are from a variety of different sources. Ship position is monitored by a surface radio range-range navigation system while underwater transponders are measured relative to a bottom mounted long-base acoustic navigation grid. Cable length has been measured by the cable manufacturer and bathymetry measured with a combination of pressure transducers and fathometers on the Scripps Deep Tow System.

It will be important to conduct some initial tests cross-checking these various measurements. Several tests can be performed:

> The Flexservice 3 ship position can be independently tracked by both the surface radio navigation system and the long base underwater navigation system. These two systems must be calibrated such that there is agreement within 3 meters.
>
> Cable length and acoustic length measurements can be checked by knowing the position of transponders on the suspended cable and the exact length of cable paid out. These two measurements should agree within the resolution accuracy of the transponder system: ± 3 meters.
>
> Bathymetry, cable length and underwater acoustic length measurements can be cross checked when initially lowering the test cable. Bottom contact should be detected with the transponders and knowing the cable shape based on currents, ship position and transponders, the exact depth can be accurately calculated and compared to the known bathymetry.
>
> In order to tie the previous Scripps survey into the new underwater navigation grid, the Pisces V submersible will physically locate one or more bottom transponders at highly identifiable bottom features that were observed in the Scripp's survey. One such feature has already identified on a Pisces 5 dive along one side of the narrow passage on the Maui slope.

6.2 CABLE LAY STARTING CONTROL

The cable lay starting procedure for the HDWC AT-Sea Test is not a conventional cable laying practice since it is not normal to start a cable lay in the middle of the channel. The starting procedure, therefore, is not considered to be a part of the actual test but simply a procedure to get into the test. The following steps constitute the cable lay starting procedure:

The cable is lowered from the Flexservice 3 with a 2000 to 4000 kg anchor attached to the bitter end and an acoustic transponder attached to the anchor.

The lowering progress is acoustically monitored and the Flexservice 3 is guided into position by the ICS in order to drop cable anchor on the desired cable path.

A steady-state solution is generated by the ICS based on a higher than necessary bottom cable tension and the cable angle, B_b, correctly along the path. The ship slowly proceeds toward this location paying out cable appropriately. The cable lay starting location will be selected in an area which is free of bottom obstacles in order to minimize the possibility of cable fouling.

Once reaching the above starting position, the ship and the cable payout are stopped for 5 to 10 minutes in order to establish a stationary cable position which is independent of the movement to that location.

Under control of the ICS, the ship and CHE are issued instructions to start the cable lay. The bottom tension in the cable will initially be high but lowered to the desired bottom tension in the first several 100 meters of cable laid.

6.3 STOP CABLE LAYING CONTROL

For a variety of reasons, it may be necessary to stop the cable lay. Problems within the control system, problems in attaching transponders to the cable, an emergency declared by the Flexservice 3's captain, or simply nearing the end of the cable will call for stopping the cable lay.

Most cable lay stop instructions will simply instruct both the ship and tensioners to simultaneously stop. The CHE will hold the cable and the DP will maintain ship position. With the ship and cable payout stopped, the suspended cable below the ship will take a slightly different configuration and tensions at the bottom will elevate slightly.

If the cable lay stop is to be a prolonged one, the ship may be directed to move slightly further down the previous ship's course without paying out further on the cable - this elevates bottom tensions and minimizes cable movement on the bottom due to changes in current. This position is maintained by the ship's systems, independent of the ICS, until the problem is corrected and the cable lay resumed.

6.4 CABLE LAY RESTART CONTROL

Restarting the cable lay after a stop procedure is nearly identical to the initial start. The cable is suspended below the ship in a "steady state" configuration and the tensions on the bottom are slightly elevated. Under command of the ICS, the cable lay is resumed and the bottom tension is restored to the desired levels. Even though the bottom tension was higher than necessary while the cable laying procedure was stopped, the cable tensions should readjust once the lay is resumed.

6.5 CABLE RECOVERY CONTROL

The cable recovery is not a part of the actual At-Sea Test but is simply a necessary procedure in order to run repetitive tests. The recovery procedure does not test the accuracy of laying the cable or tensioning the cable on the bottom. As a result, attempts will be made to recover the cable without the guidance of the ICS. By freeing the ICS system, control personnel and equipment will be free for correcting procedures, reprogramming, repair, etc.

In order to recover the cable without the guidance of the ICS, the recovery procedure must be independent of currents. A varying current profile is the only parameter that might distinguish one cable recovery from another. It is presently planned to recover the cable at an elevated bottom cable tension such that cable deflections near the bottom are minimized and thus overall current impact is reduced.

The Integrated Control System will provide for the ship a printout at the end of the cable lay for the recovery procedure. The output will be unique for the cable just laid. This printout will include:

Intermediate way points and ship speed for the Dynamic Position System.

Corresponding cable speeds and total cable payout cable length marks for each way point.

Anticipated cable tensions at the top. (for checking bottom tensions and cable fouling during recovery)

Warnings of transponder locations in order to recover transponder pendants.

Provide particular warnings for locations for transponders that have not released.

6.6 CABLE LAYING CORRECTION CONTROL

Between cable lays and possibly during the course of a cable lay there may be corrections initiated in the cable laying procedures and programs in order to more properly place a cable on the bottom. Throughout the cable laying procedure there will be checks on the cable drag coefficient, the bottom bathymetry and the total length of the cable layed on the bottom vs the length predicted by bathymetry. As each cable lay is conducted, these parameters may be adjusted. In addition, the techniques used to predict currents 5 to 15 minutes into the future may be adjusted as more current data are collected and analyzed throughout the At-Sea Test.

Other correction procedures that might be initiated at sea could involve actual changes in the cable laying procedures. The number of transponders that are placed onto the cable, the spacing of the transponders, and the location of the transponders may be changed from one test to the next in order to more accurately lay the cable. In addition, the amount of the current data which is collected from expendable current profilers and the depth at which the acoustic doppler current profile operates may additionally be adjusted.

6.7 ADDITIONAL TESTS REQUIRED

The basic plan for the At-Sea Test involves laying the cable repeatedly on both sides of the Alenuihaha channel and following a procedure similar to an actual power cable lay. Additional tests can be performed with a surrogate cable that will provide invaluable information relative to the performance and capabilities of the Integrated Control System. Some cable lays should be performed under extreme cable payout and ship maneuvering conditions in order to introduce a large dynamic input into the laying cable. Following the cable path with the transponders will provide valuable information relative to the overall cable models capabilities. During the development of the cable model programs, such extreme ship maneuvering and cable payout variations are regularly used to test the capability of the program.

6.8 CABLE LAYING CONTINGENCY OPERATIONS

In general, the Integrated Control System is not being programed to automatically handle contingency operations. It is being programed to report back to the ICS operator the status of all programs and to provide parameters reflecting the uncertainty of the cable lay at any given time. Based on this information, the operator can halt the cable laying operation at any given time. Stopping and restarting the cable laying is a normal procedure as discussed in sections 6.3 and 6.4 above. The basic contingency operation, therefore, is to stop the cable lay if there are problems, fix the problem, and than continue the cable lay.

Depending upon the test being performed, the time available and the current location of the lay operation, it may be desirable and/or necessary to recover some of the cable in order to relay it. Such operations can be done under the control of the ICS. At least one such recovery and relay operation should be included in the At-Sea Test.

APPENDIX A

INTEGRATED CONTROL SYSTEMS HARDWARE

Evaluation of Computer Systems for the HDWC Integrated Control System

Background

In selecting the hardware and software for the computer system for the HDWC Integrated Control System (ICS) the overriding criteria has been ability to perform the job. Ability of a computer system to preform includes computational speed, operational utility, programming functionality and vendor support. These four abilities are critical to the success of the HDWC program due to the complex control model involved and the limited development time remaining.

Vendors were presented with the algorithm, budget and schedule of the ICS and asked to recommend products to meet the criteria. Due to the limited development time, only products that are currently available and testable were considered and evaluated. The evaluation of computational speed was made quantitatively by a benchmark version of the control programs. The evaluation of utility, functionality and vendor support was qualitative based on information collected from the vendors and the experiences with the vendors and their computers while testing the products with the benchmark program.

The control programs operate on discrete packets of data from a given instant of the cable lay. Each data packet is processed sequentially through a series of algorithms. Such a process can be "pipelined" such that sequential data packets are in each of the algorithms on separate computers simultaneously like a manufacturing assembly line. In this way three computers can work on the computation together greatly increasing the computational speed. A system where the computers work together on a process is called a distributed processing system. For the computers to work together a Local Area Network (LAN) that will support distributed processing is required. The programming of and operating overhead of the LAN are the penalties for the increased speed of pipelining. Due to the limited development time very little LAN programming can be required by the ICS computer system.

Distributed processing has just become available at the applications/end user level. Distributed processing is distinguished from a common LAN by the ability of one computer in the network to spawn processes that will run on the other computers. A common LAN can only readily access peripherals. Several vendors are offering products that perform distributed processing to varying degrees. Distributed processing performance differs between vendors in all four areas of evaluation for this project.

The preferred alternative is for a single, very fast, computer to perform the entire process step by step. For a single processor the overriding criteria becomes computational speed. The iterative numerical solution developed for the control system requires thousands of calculations and tests to be performed for every cycle of the control system. The operational utility and programming functionality of a single computer are much higher than in a network, as distributed processing is avoided.

To evaluated the computational speed of the computers a benchmark program containing the iterative cable solution was used. Analysis of the timing of the ICS and projections of programs in development indicated that to be sure of success, a single processor would have to run the benchmark program in less than 2 minutes. The timing analysis also gave quantum breaks for the number of computers required in a distributed processing network as a function of processor speed. Effort was made to port the benchmark onto all computers being considered.

During the laying operation, the ICS operator must be able to interact with several processes at the same time. A windows environment offered by the current generation of computers allows the operator to move from process to process on a single screen from a single keyboard. A color monitor allows keying the processes by color for fast identification.

The programming functionality of the computers is critical due to the short development time. The windows operating environment greatly increases productivity in the same way that a desk can increase productivity over a clipboard. To utilize the windows tool a large color graphics monitor, allowing room on the "desk" and identification by color, is best.

Vendor support is critical to the ICS development due to the limited resources and time for the ICS development and the advanced nature of the application being developed. Insufficient vendor support could cause loss of man-hours from ICS development to computer problem resolution. Vendor support takes the forms of product maintenance, problem resolution and debugging and application developers support. The vendor support services allows the ICS programers to concentrate on their task and provide a resource to resolve problems or questions.

EVALUATIONS

The results of the benchmark have been tabulated with information on the operational utility, programming functionality and vendor support for each of the vendors. Several products could not perform the benchmark, including the IBM RT and the Apollo Domain 10000, due to bugs in the product. These were eliminated from consideration as untestable. No vendor could be found to offer a system using Compac 386s (or equivalent) with a LAN supporting distributed processing though benching showed that such a system could operate. Several major vendors were approached but all decided the technical support of such a system was beyond them.

Successful benchmarked systems were obtained from 3 vendors: Hewlett-Packard, Sun and Apollo. The Sun and Apollo systems are multi-processor using distributed processing. The Hewlett-Packard system is a single processor. All the benchmarked systems are currently in production.

Sun

The Sun system, the 386i/250s, would require four computers in a distributed processing network. The system supports only Network File System (NFS) level Remote Procedure Calls, (RPCs) making the development of a distributed processing application interface with the system on a very low level. Developing the interface to this low level would required large amounts of programer time and vendor support. Sun's support is good but heavily taxed by its continuing expansion.

The Sun 4 was also explored as a single processor option but found too costly.

Hardware support and maintenance would be from the LA office. The process would be: MOE personnel initially diagnose the problem using Sun's diagnostics, MOE calls Sun and reports the problem and diagnostic results, Sun sends a replacement part by a one day express service, MOE swaps the part and retests the system, if ok the bad part is shipped back, if not the good part is shipped back and we start at the beginning again. During development an average of 3 days to bring equipment back up would be expected. At sea during the lay it may be longer, requiring a higher level of backup redundancy. The program will have to arrange and pay for the transfer of the shipped part from the express service to the ship.

Apollo

Apollo proposed 2 solutions, a system using its competition to Sun's 386i/250 the Domain 3500 in a network or a single Domain 10000. Bugs in the compiler prevented the Domain 10000's Fortran from compiling the benchmark eliminating it from consideration (it is still in beta testing). The successfully benchmarked Apollo system is three Domain 3500s in a distributed processing network. Apollo has developed a higher level distributed processing system called the Network Computing System (NCS). NCS allows applications programers to utilized distributed processing over a network using Apollo subroutines called from higher level languages such as Fortran. Development of the distributed processing system for the ICS would be greatly facilitated by using NCS, saving significant amounts of programer time over other LAN distributed processing offerings.

The development environment on the Apollo is intended for technical personnel making it very appropriate for the ICS development. X-windows is supported with either Unix V or Apollo's Aegis operating systems. All the parameters are operator modifiable and extensive online manuals are supported. Development on the Apollos would be near optimum productivity.

Hardware support and maintenance would be from the LA office. The process would be the same as for Sun except for use of a 2 day express service to Hawaii (Sun has a special contract with Federal Express). This service is offered at the same cost as on-site service where available (not in Hawaii). During development down time would average 4 days to bring equipment back up. At sea during the lay it may be longer requiring a higher level of backup redundancy. A second backup computer would be provided for the at sea operation under the maintenance agreement. The program will have to arrange and pay for the transfer of the shipped part from the express service to the ship.

<u>Hewlett-Packard</u>

Hewlett-Packard was the only vendor to successfully offer a single computer solution, a HP 9000 Series 800 Model 835CHX. The HP 9000 Model 835CHX is a Reduced Instruction Set Computer (RISC) that has been shipping for 9 months. The RISCs (Apollo's Domain 10000, IBM's RT, and the Sun 4 are also RISCs) are the fastest mini-computers and workstations available in the price range. Based on the benchmark test and current estimates of ICS execution time, the 835 would be busy less than 50% of the time. If the execution time estimates are low by 100% the 835 is busy less than 75% of the time. For reference the 835 using HP's Fortran is 18.8 times faster in program execution than a 8 MHz PC-AT running Ryan-McFarland Fortran.

The use of a single processor eliminates the development of distributed processing within the ICS. Only recently has distributed processing been considered for the ICS. The added development work was not included in the previous time and cost estimates.

The HP 9000 Model 835CHX can be utilized both as a single user workstation (for the At-Sea Test phase) and as a multi-user mini-computer (for the development phase). The operating system is Unix V with X windows supported on graphics stations. The 835 system would consist of 3 graphics terminals and 4 ASCII terminals. All of the terminals would be utilized during the development. During the lay one graphics terminal would be the operator's, the second for programming, and the third would be on the backup system. Two of the terminals would be for display to the helm and CHE operator, the third for display of parameters and the last as backup. The HP 9000 Model 835CHX's terminals at the helm and CHE avoid the cost and programming of PCs for these tasks in a LAN.

Hewlett-Packard is the only vendor with a Hawaii office that includes full hardware maintenance and support. During development this assures a high uptime rate through an on-site, 24 hour response maintenance contract. During the test lay a backup will be provided as part of the agreement on maintenance coverage. A single backup is consider sufficient as on-ship service will be available within 30 hours.

SELECTION

At the end of the evaluation process only three vendors had qualified, Sun, Apollo and Hewlett-Packard. Of these Sun was eliminated due to complexity of the development distributed processing in the NFS environment and high cost. The preference of the development team was to avoid, if possible, the added complexity in development caused by distributed processing. To this end the HP was selected over the Apollo system.

The HP 9000 Model 835CHX is the recommended system for the ICS. It has a capability in speed greater than double our estimated requirements. HP provides excellent support, critical for the timely development of applications such at the ICS. Finally, the comparable cost is the least of the qualifying systems.

HP 9000 Model 835CHX

Speed APCT Bench Mark: x Wang
    Run   1:34
    Compile (opt)   3:58

# of running units   1
# of backup units   1

System Cost ($1000, List/GSA) $134/$102

Technical information support
    Cost $200/mn (+$115/hr * 30 hrs)
    Ability   Exceptional: HP has support structures in place for both supporting HP products the customer is using and assisting in the development of new applications.
    Mechanism   Subscription to call up resource center. Tech on site on T&M on request, est. need 30 hrs.
    LAN   Several supported, experts available
    Alien Intrfcg.   Good

Hardware Maintenance support
    Cost $675/month
    Mechanism   24 hrs response on site at MOE. Willing to do crash priority T&M - we fly their man to the ship for actual at-sea test.

Programming
    Fortran   Good
    OS   Unix Good, limited number of X-windows terminals
    LAN   NFS - ok for information transfer
    Alien Intrfcg.   Supports PC-AT, VAX and most others interfacing.

Applications
    AutoCad   Not available - HP prog substatuted
    FE   Available

Peripherals
    printers   Many available
    plotters   will talk to ours.

Apollo 3500

Speed APCT Bench Mark:
    Run   4:45
    Compile (opt)   7:41

# of running units   3
# of backup units   2

System Cost ($1000, List/GSA) $136 / $110

Technical information support
    Cost   ~$400/mn (on site @ T&M)
    Ability   Good - large able staff with excellent availability of equipment.
    Mechanism   Calling designated contact at resource center.
    LAN   Good
    Distrib. Prcsg.   Good
    Alien Intrfcg.   Avg. software and hardware products are supported.

Maintenance support
    Cost $653/month

    Mechanism   Customer diagnostics by phone and board swapping by express.

Programming
    Fortran   Does not currently support Double Complex expressions, and missing a few complex intrinsic functions.
    OS   Unix / Aegis, good X-windows throughout.
    LAN   Avg.
    Distrib. Prcsg.   Excellent: NCS is a superior OS structure for true distrib. prcsg as with the control system.
    Alien Intrfcg.   Supports PC-AT, VAX and most others with Hardware and software.

Applications
    AutoCad   Supported
    FE   available

Peripherals
    printers
    plotters

Sun 386i/250

Speed APCT Bench Mark:
    Run 5:55
    Compile (opt) 5:07

# of running units 4
# of backup units 2

System Cost ($1000, List/GSA) $176 / $147

Technical information support
    Ability Fair. > 50% staff increase in last 12 months; limited availability of equipment.
    Mechanism ?
    Cost ?
    LAN Internal Ethernet, NFS OS
    Distrib. Prcsg. Supported at the development level
    Alien Intrfcg. PC and VAX network support

Maintenance support
    Cost ?
    Mechanism We diag with them on phone, they next day courier fix to us and we send bad back.

Programming
    Fortran Covered full RMF, opt level selectable, good error tracing in debug mode.
    OS Unix - Icon driven X windows
    Editor Screen/Window - menu driven
    LAN Resource access designed
    Distrib. Prcsg. RPC's are supported in C.
    Alien Intrfcg. ?

Applications
    AutoCad Yes
    FE Yes

Peripherals
    printers ?
    plotters ?

Compac 386/25

Speed APCT Bench Mark: x Wang
  Run 5:47
  Compile 10:41

# of running units 4
# of backup units 2

System Cost ($1000, List/GSA) Have not found a vendor willing and able to provide

Technical information support
  Cost
  Ability
  Mechanism
  LAN 3COM has several day call back time for pre-sale calls, but may offer better, paid post sale support.
  Distrib. Prcsg.
  Alien Intrfcg.

Maintenance support
  Cost
  Mechanism

Programming
  Fortran Several available including current RMF and some faster compilers.
  OS DOS, OS/2
  LAN 3COM appears to be best choice
  Distrib. Prcsg. Berkeley Sockets are supported by at a very low level.
  Alien Intrfcg. EtherNet hardware has broad use and 3COM is common.

Applications
  AutoCad Yes
  FE Micro packages

Peripherals
  printers Many
  plotters Many

DEC Micro VAX 2000

Speed APCT Bench Mark: x Wang
  Run 13:07
  Compile 4:41

# of running units
# of backup units

System Cost ($1000, List/GSA) $40000

Technical information support DEC did not offer a faster machine nor a network solution.

IBM RT

Would not run the benchmark due to bugs in IBM compilers.

PRIME

Not responsive to requests for sales information.

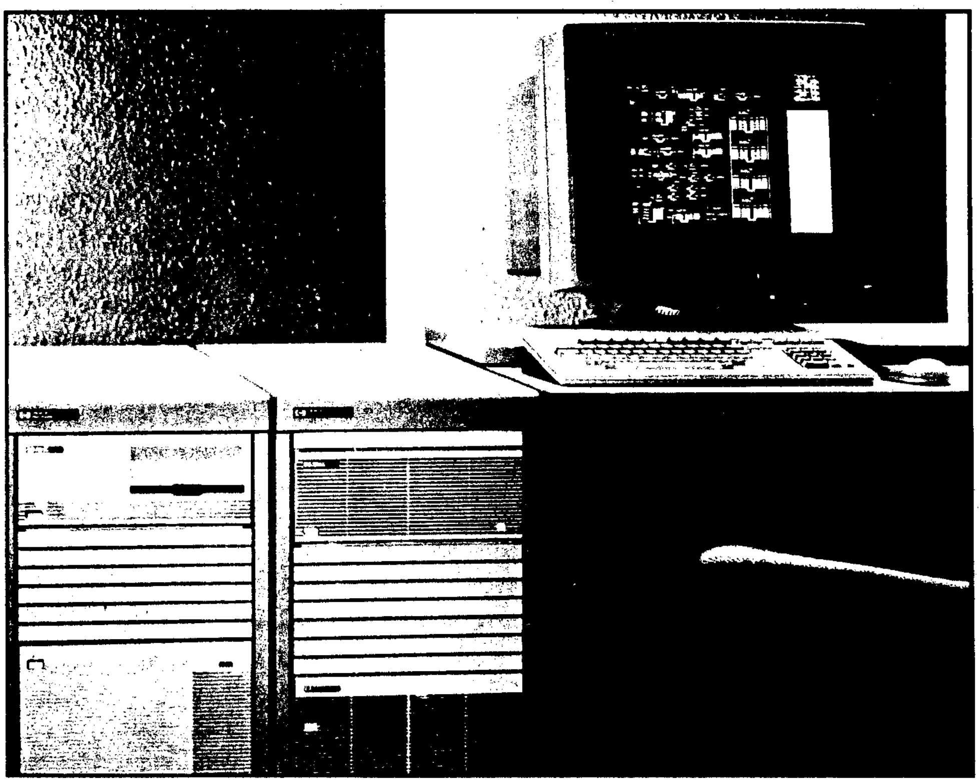
Clone 386s

No units available for benchmarking.

HP 9000 Series 800
Models 825CHX and 835CHX
Hardware Technical Data

HEWLETT PACKARD

Effective: April 1988*



Product Description

The HP 9000 Models 825CHX and 835CHX superworkstations combine advanced bit-mapped graphics with high-performance computational engines to meet the interactive needs of computer-aided engineering applications such as integrated circuit and printed circuit board layout. Hewlett-Packard has applied Very Large Scale Integrated (VLSI) technology to deliver a fast, reliable computing and graphics solution for the demands placed on engineering workstations.

Using HP Precision Architecture, the Models 825CHX and 835CHX provide system processing power to match the graphics performance of the CHX two-dimensional (2D) graphics subsystem. The performance and features of these systems meet the needs of the electrical engineering and general scientific application areas which benefit from the balance of high-performance 2D graphics and system processing power.

Like the other Series 800 systems, Models 825CHX and 835CHX run the HP-UX operating system, a superset of AT&T's UNIX ® System V Interface Definition (SVID). HP-UX provides an excellent environment for advanced graphics applications requiring a powerful and flexible operating system.

*Data subject to change without notice.

CHX Graphics Features

- Two overlay planes for ease of application development
- Color palette of 16.7 million colors
- 256 simultaneously-displayable colors
- Eight frame buffer planes or four double-buffered planes
- Integer-based accelerator for enhanced graphics performance
- Displayable resolution of 1280 x 1024 pixels
- True pan and zoom for object manipulation
- Pixel pan and zoom for imaging applications that require fast manipulation of pixel data

System Hardware Features

- HP Precision Architecture
- Single-chip VLSI Central Processing Unit (CPU)
- Parity checking for translation lookaside buffer and cache
- Instruction pipelining techniques
- Real-time clock with battery backup
- 48-bit virtual addressing
- 8 Mbytes Error Checking and Correcting (ECC) RAM, expandable to 96 Mbytes
- Support for up to four interactive graphics subsystems
- Support for 6.85 Gbytes disc storage using Hewlett-Packard Interface Bus (HP-IB), IEEE 488 standard
- Support for 9.14 Gbytes disc storage using Hewlett-Packard Fiber-optic Link (HP-FL)
- Support for numerous HP peripherals
- HP-UX license available for up to 64 users
- Up to two I/O channels with 5-Mbyte bandwidth each
- I/O Expander, providing second I/O channel and additional I/O slots (optional)
- Powerfail recovery system (with optional battery backup unit)
- Remote console capability for invoking diagnostics and system reset (optional)

Model 835 System Features

- 128 Kbytes high-speed, unified, two-set associative cache
- 14 MIPS* (workstation environment)
- 66.7-nanosecond instruction cycle time
- 2.02 MFLOPS† floating point coprocessor performance
- 4096-entry translation lookaside buffer for virtual-to-physical address translations

Model 825 System Features

- 16 Kbytes high-speed, unified, two-set associative cache
- 8 MIPS* (workstation environment)
- 80-nanosecond instruction cycle time
- 0.65 MFLOPS† floating point coprocessor performance
- 2048-entry translation lookaside buffer for virtual-to-physical address translations
- Model 825 field upgradable to Model 835

System Software Features

- HP-UX operating system, compliant with AT&T's SVID; contains over 200 utilities from AT&T's System V.2 and Berkeley System Distribution (BSD) 4.2 enhancements
- Object code compatibility with HP 9000 Series 800 computer systems
- Source code compatibility with HP 9000 Series 300 computer systems
- Support for:
  - C, FORTRAN 77, and Pascal programming languages with optimizing compilers
  - ALLBASE, a database management system offering both network and relational model interfaces
  - HP Visor, an end-user query and report writing tool
  - HP TODAY, a fourth-generation language for transaction-oriented and data-management application development
  - Starbase Graphics Library, based on ANSI Computer Graphics Interface (CGI) standards, enhanced to implement advanced 2D and 3D techniques
  - Starbase Display List
  - HP GKS, a high-level, industry-standard 2D graphics library
  - HP Network Services
  - ARPA networking services
  - NFS networking services
  - The X Window System™, a network-compatible, industry-standard, configurable window system

CHX Graphics Subsystem

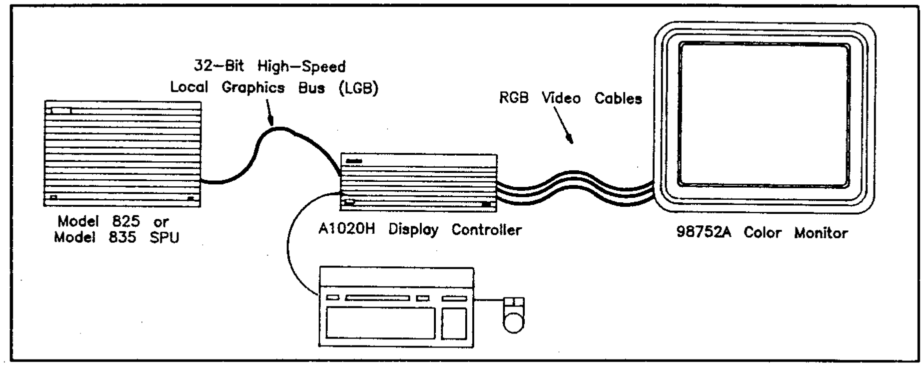
The Models 825CHX and 835CHX graphics subsystems include the Display Controller (HP A1020H) and an integer-based Graphics Accelerator (HP 98556A) which is physically contained within the Display Controller box. User interface components include the color monitor (HP 98752A), keyboard, two-button mouse, and cabling.

* Million Instructions per Second (MIPS) performance is relative to a DEC VAX 11/780 in a single-user, multi-tasking environment, as calculated from the geometric mean of a suite of 15 integer benchmarks.

†Million Floating Point Operations per Second (MFLOPS) performance is measured using the Linpack benchmark, double-precision, with coded Basic Linear Algebra Subprograms (BLAS).

The X Window System is a trademark of the Massachusetts Institute of Technology

The Display Controller provides two overlay planes as well as the resolution and number of displayable colors necessary for high-end 2D graphics applications. The integer-based Graphics Accelerator sharply improves performance for 2D vector-intensive graphics applications that use integer data. Both models support up to four interactive graphics subsystems or workstation seats.



CHX Graphics Subsystem

Graphics Architecture

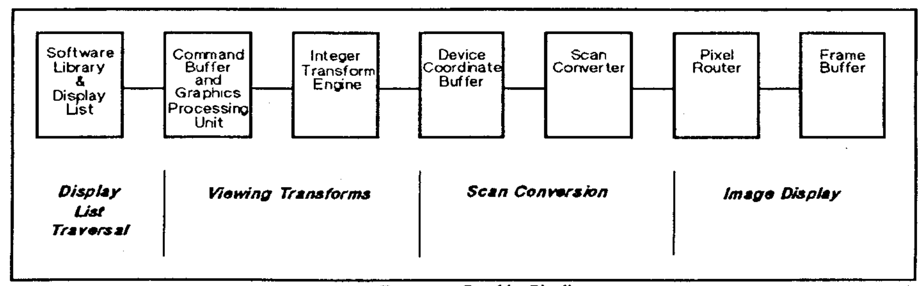
The CHX subsystem uses a traditional four-stage graphics pipeline architecture modified to obtain interactive graphics performance:

- Dual-ported memory between each stage allows each stage to operate independently, increasing throughput of the pipeline
- VLSI eliminates pipeline bottlenecks while improving reliability and decreasing cost
- 2D integer-based Graphics Accelerator enhances interactive response by reducing software overhead

Graphics Subsystem Hardware

Display Controller (HP A1020H)

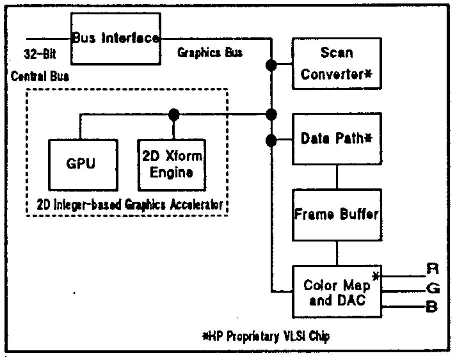
The Display Controller supports the 1280 x 1024 displayable pixels needed for demanding 2D graphics applications. Eight planes of frame buffer memory provide 256 simultaneously-displayable colors out of a palette of 16.7 million hues. The eight color planes can also be used as four double-buffered planes for interactive pan and zoom of 16-color images. Two overlay planes offer the capability to do windowing, cursors, menus and alpha independently of the frame buffer. A hardware scan converter provides high-speed vector, polygon and circle generation.



Four-stage Graphics Pipeline

Graphics Accelerator (HP 98556A)

The 2D integer-based Graphics Accelerator extends the graphics performance of the A1020H Display Controller. Through use of a dedicated MC68020 CPU operating as a Graphics Processing Unit (GPU) and a 2D integer-based transform engine, the Graphics Accelerator provides the capability to realize real-time, interactive pan and zoom functions for graphics-intensive, 2D integer-based applications.



Graphics Subsystem Architecture

The 2D Graphics Accelerator provides a 32-bit world coordinate interface directly to the graphics pipeline. This interface speeds the display process by moving the software-intensive operations of transform calculations and device coordinate scaling directly to the graphics hardware that has been optimized to perform those tasks. The Starbase Graphics Library supports the 2D Graphics Accelerator with integer interface commands optimized for the full performance of the accelerator.

CHX Graphics Capabilities

Primitives

- Vectors
- Polylines
- Circles
- Polygons (256-sided, concave, convex, crossing, doughnut)

Dimensional Capabilities

- Geometric transformations in two dimensions
  - Scale, rotate, translate
  - Concatenation of transformations
- 32-bit integer
- 2D integer coordinates
- Programmable radix point for controlling precision and dynamic range of viewing operations

Price/Performance Optimization Features

- Double buffering
- Fast-stroked text
- Two overlay planes
- Integer-based Graphics Accelerator
- Cursors, including stroked and rastor cursors and picking
- Window acceleration

User Interface

High-resolution Color Monitor (HP 98752A)

The HP 98752A is a 1280 x 1024 resolution, 19-inch color monitor. This high-quality monitor has a 60-Hz non-interlaced refresh rate and a P22 phosphor for true-to-life colors. The CRT offers a clear, vivid image that does not wash out. The cylindrical face and antiglare coating, both ergonomic design features, provide maximum eye comfort. A 16-inch color monitor (HP 98789A) with identical features is also available.

Cabling Extension/Input Devices (HP-HIL, Audio, RGB)

Through cabling extensions, human interface devices such as the monitor, keyboard, and mouse can be placed up to 30 meters from the host system processing unit and graphics subsystem. The extensions are compatible with the standard Hewlett-Packard Human Interface Loop (HP-HIL) and RS-343 video requirements. Cabling is provided for three types of signals:

- HP-HIL for keyboard, mouse, and other compatible input devices
- Audio for the speaker (included with each cabling extension) to provide audio output for the system
- RGB for video signals to the color display

Graphics Performance

Display Controller (HP A1020H)

Frame buffer size, displayable .... 1280 x 1024
Frame buffer planes ...... 8 (4 when double-buffering)
Overlay planes 2
Video signals RS-343
Color palette .... 16.7 million
Simultaneously-displayable colors .... 256 (16 when double-buffering)

Graphics Accelerator (HP 98556A)

Graphics processing unit MC68020
Integer math unit .... Weitek 8137

Color Monitor

	19-inch Color Monitor (HP 98752A)	16-inch Color Monitor (HP 98789A)
Screen size	480 mm (19-in.) diagonal	406 mm (16-in.) diagonal
Rastor size	343 mm x 274 mm	295 mm x 236 mm
Phosphor	P22	P22
Refresh rate	60 Hz non-interlaced	60 Hz non-interlaced
Display resolution	1280 x 1024	1280 x 1024
Brightness	27 FL	35 FL

System Performance*

	2D integer vectors† (device coordinate)	3D floating point vectors† (world coordinate)	Polygons‡
825CHX without Graphics Accelerator	85,700 vectors per second	10,800 vectors per second	5,200 polygons per second
825CHX with Graphics Accelerator	208,000 vectors per second	9,200 vectors per second	6,600 polygons per second
835CHX without Graphics Accelerator	116,000 vectors per second	23,400 vectors per second	7,600 polygons per second
835CHX with Graphics Accelerator	276,000 vectors per second	17,400 vectors per second	6,600 polygons per second

Peak Performance

Frame buffer to frame buffer:
Screen clear .... 94 million pixels per second
SOURCE rule .... 40 million pixels per second
XOR rule .... 28 million pixels per second
Accelerator vector speed .... 300,000 10-pixel vectors per second
Stroked text .... 6000 characters per second

HP Precision Architecture

The HP 9000 Series 800 computer systems use HP Precision Architectu re to provide high performance and reliability at a low cost. HP Precision Architecture embodies the concepts of Reduced Instruction Set Computing (RISC).

As a design approach, RISC leads to greatly simplified computers that are optimized to provide the highest performance for a given integrated circuit technology. The inherent simplicity of HP Precision Architecture means machines can be implemented with fewer components to achieve higher reliability.

At the core of HP Precision Architecture is an instruction set containing 140 carefully selected, fixed-format instructions. Because the instruction set is simple, instructions can be hardwired directly in the CPU. Hardwiring eliminates the need for microcode and the necessity to decode complex instructions. HP Precision Architecture utilizes a load/store design and register-to-register operations to reduce memory access times. To further enhance performance, optimizing compilers schedule instructions and manage the instruction pipeline. With hardwired control, a load/store design, and optimizing compilers, instructions can be executed on virtually every clock cycle. Single-cycle instruction execution accounts for much of the superior performance of HP Precision Architecture.

HP Precision Architecture incorporates many other features that greatly enhance its capabilities. These features include support for attached processors and coprocessors such as the floating point coprocessor, extended virtual addressing for future expandability, and a memory-mapped I/O subsystem which simplifies I/O communication.

VLSI Technology

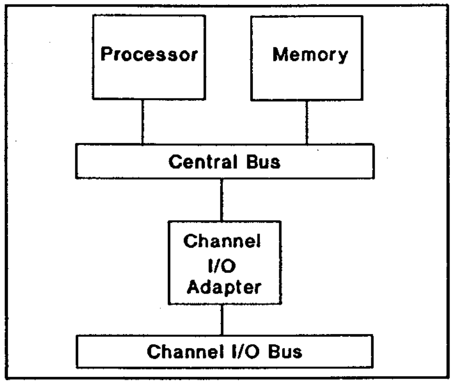
The Series 800 computer systems use HP's proprietary NMOS III VLSI technology. This technology allows the CPU to be integrated onto a single chip. Using new surface mount technology, the entire Model 835 processor, including the cache, translation lookaside buffer and floating point coprocessor subsystem, resides on a single printed circuit board. In the Model 825, part of the floating point subsystem resides on a separate board from the other processor components.

System Processing Unit

The System Processing Unit (SPU) manages the processor, memory, and I/O for the entire system. The processor accesses memory and I/O via the central bus. The 10-MHz central bus (8.33 MHz in Model 825) provides a 32-bit data path and supports sustained data transfer rates of 22.3 Mbytes per second (18.6 Mbytes per second in the Model 825). The central bus interfaces with the Channel I/O Bus via the Channel I/O Adapter. The 5-MHz Channel I/O Bus houses the Local Area Network (LAN) and HP-IB interfaces shipped with each system.

*Significant performance increases can be achieved by using the integer-based Graphics Accelerator. Applications which use floating point display data do not benefit from using the accelerator.

†10-pixel vectors
‡10-pixel per side rectangles



SPU Organization

Models 825 and 835 Processors

The Model 825 processor resides on two printed circuit boards: the main processor board and the system board. The main processor board contains six custom VLSI chips: the CPU, the control unit for the translation lookaside buffer, two control units for the cache, a Math Interface Unit (MIU), and a System Interface Unit (SIU) which monitors communication between the components of the processor and the central bus. The main processor board also contains the translation lookaside buffer, which provides the virtual memory capability, and the cache, which minimizes the need to access system memory.

The system board contains the Channel I/O Adapter and three floating point math chips (ADD/SUB, MUL and DIV). The three math chips and the MIU chip which controls them form the floating point subsystem.

The Model 835 processor resides entirely on one printed circuit board and contains eight VLSI chips. Six of these chips are custom VLSI chips: the CPU, the control unit for the translation lookaside buffer, two control units for the cache, the SIU, and the Floating Point Controller (FPC). The FPC and two commercially-available VLSI floating point math chips (ALU and MULTIPLIER) work together as the floating point subsystem. The Channel I/O Adapter and real-time clock reside on a second board, the processor dependent hardware board. The real-time clock has a battery backup to maintain time and date while the system is powered down.

Cache

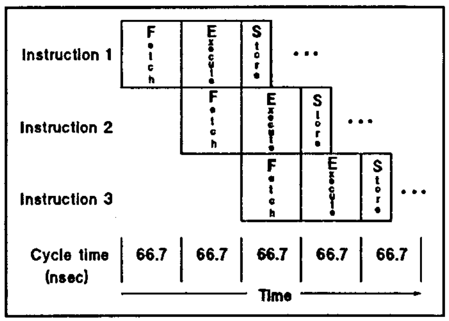
The Model 835 uses 128 Kbytes of high-speed, unified cache, and the Model 825 uses 16 Kbytes. The use of cache minimizes CPU requests for instructions or data stored in system memory. By storing frequently-used instructions and data in high-speed cache memory, the CPU can execute instructions or process data without using the SIU and the central bus.

The cache operates in a write-back mode. Write-back means the cache writes modified data to system memory only when the processor needs the cache location for other data, when the operating system flushes the cache location due to a direct memory access operation, or in the event of a power failure.

The cache is two-set associative. Parity checking protects the cache, and a parity error triggers a recovery algorithm that resolves most failures.

Instruction Pipelining

Models 825 and 835 use staged instruction pipelining that allows operation on three instructions simultaneously. The net effect is that one instruction completes with essentially every 66.7-nanosecond instruction cycle for the Model 835 and every 80-nanosecond instruction cycle for the Model 825. The following diagram shows instruction pipelining for the Model 835. The Model 825 is identical except that each cycle is 80 nanoseconds.



Model 835 Instruction Pipelining

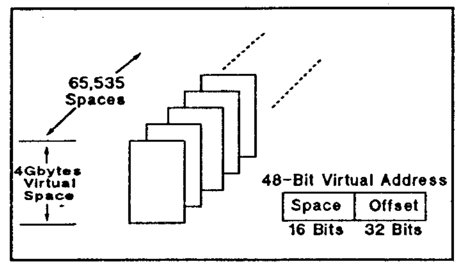
Floating Point Coprocessor

Single-precision and double-precision floating point calculations are performed by the floating point coprocessor subsystem. The Model 825 uses a floating point subsystem composed of the MIU chip and three floating point math chips (ADD/SUB, MUL and DIV). The Model 835 replaces the MIU with a Floating Point Controller (FPC) and replaces the three math chips with high-performance ALU and MULTIPLIER chips.

The floating point subsystem in the Model 835 increases floating point performance by more than three times when compared with the lower-cost Model 825. This performance increase is due to more advanced math chips and improvements in the FPC compared with the MIU. The FPC allows floating point operations to overlap with CPU operations, as long as there is no interlocking data. Additionally, the FPC allows overlap of floating point operations within the floating point subsystem. Results from one step can be routed directly to the next step without the need for intermediate storage in a register. The changes in the floating point subsystem, increases in the cache and translation lookaside buffer, and decreases in instruction cycle time are the significant factors contributing to the dramatic performance increase of the Model 835. Through an upgrade to the Model 835, Model 825 customers can realize this performance increase.

Virtual Memory

Virtual addresses are 48 bits in length, ensuring ample expandability to meet growing software needs. Virtual memory is divided into 65,535 spaces with each space 4 Gbytes in length. Spaces are further divided into fixed-length 2-Kbyte pages, with a page holding code or data. A single data structure can be up to 1 Gbyte in length. This virtual memory scheme can accommodate virtual memory of more than 260,000 Gbytes.



Virtual Memory Organization

The Translation Lookaside Buffer (TLB) performs translations from virtual addresses to physical addresses. The TLB stores recently-accessed virtual page translations and converts the 48-bit virtual address into a 29-bit physical address. The TLB in the Model 835 holds translations for 4096 virtual pages (enough room to map 8 Mbytes of system memory). The Model 825 holds translations for 2048 virtual pages.

The increased number of TLB entries in the Model 835 means that a larger portion of virtual memory can be stored in the TLB at any given time. Mapping a larger area of virtual memory into the TLB reduces the number of TLB misses, thus improving performance. In both models the memory for the virtual pages is split in two parts, half for an instruction TLB and half for a data TLB. This split allows parallel translation of instructions and data addresses.

Models 825 and 835 provide page-level access protection. The TLB hardware supports protection mechanisms to ensure the currently-executing process has sufficient authorization to perform the requested data, code, or I/O access. The TLB also uses parity checking which signals the CPU when errors are found.

Memory Subsystem

Models 825 and 835 include 8 Mbytes of ECC memory. The ECC memory is expandable in 8 and 16 Mbyte increments to 96 Mbytes. The internal memory word size is 72 bits, with 64 bits for data and eight bits for error detection and correction. Single-bit memory errors are automatically corrected. Rare double-bit errors are automatically detected, causing an interrupt or a high-priority machine check. The ECC memory assures high memory performance and availability.

The optional powerfail battery backup protects the system from AC power loss such that if power is lost, the state of the processor is stored in memory for at least 30 minutes. Maximum storage time depends upon the amount of memory in the system. If power is restored within this limit, the system restores itself and resumes processing. The powerfail system does not prevent loss of the graphics screen.

I/O Subsystem

Channel I/O Bus

Models 825 and 835 use a 16-bit, 5-Mbyte bandwidth Channel I/O Bus to connect peripheral and data communication cards. The Channel I/O Bus has seven I/O slots. Two slots contain the HP-IB and LAN interfaces shipped with each graphics superworkstation. The graphics interface card (HP A1017A) plugs into the central bus but physically covers a third I/O slot. This graphics interface card connects the graphics subsystem to the SPU. Adding an I/O Expander provides eight additional I/O slots (seven slots in the Model 825).

Channel I/O Adapter

Each Channel I/O Adapter manages I/O by interfacing the central bus with the Channel I/O Bus, synchronizing the differing speeds and bandwidths. Channel I/O Adapters also manage Direct Memory Access (DMA) transfers between system memory and channel I/O interfaces with their associated peripherals. The Channel I/O Adapter accomplishes this function with little CPU intervention, interrupting only to signal completion of DMA transfers. Large blocks of data can be transferred to and from system memory at rates of up to 5 Mbytes per second per channel with negligible CPU overhead.

Peripheral Connection

Disc drives, tape drives, printers, and plotters connect to the Models 825 and 835 via an HP-IB card which supports the 8-bit wide, IEEE 488 standard. Each HP-IB card interfaces with up to four high-speed devices or 14 low-speed devices.

The HP 7936FL and HP 7937FL disc drives are connected via HP-FL. Each HP-FL channel supports eight drives at up to 5 Mbytes per second per channel.

Six-channel multiplexers are available to connect workstations, terminals, modems, serial printers, and other serial devices. LAN interfaces allow connection to other systems.

System-to-System Data Communications

The HP 9000 Series 800 systems communicate with other HP systems and other vendors' systems via an IEEE 802.3 LAN using the LAN/9000 Series 800 link. Higher-level networking services are provided by NS/9000, ARPA Services, and NFS Services.

The HP 10Mbps-10Mbps LAN bridge provides interconnectivity and extendibility between two LANs, allowing the establishment of larger IEEE 802.3 and Ethernet networks. To conserve network bandwidth, the bridge provides address filtering capabilities to isolate traffic and add security between two work groups.

In addition to LAN communication, Series 800 systems can communicate with other UNIX-based systems via one or more multiplexer channels and hardwired modem links. The multiplexer channels and modem links use the HP-UX uucp capability for file transfer (uucp), remote command execution (uux), and terminal emulation (cu).

IBM communications are supported via SNA 3270 and 3770 products using a LAN-attached HP 9000 Series 300 as a non-dedicated gateway. Since the Series 300 also supports IBM BSC RJE communications, a Series 800 computer can use ARPA and Berkeley networking services to the Series 300 to submit and receive batch jobs.

System Software

HP-UX Operating System

The HP-UX operating system complies with AT&T's UNIX System V Interface Definition Issue 2, Volume 1, and has passed the System V Verification Suite 2 (SVVS2). HP-UX includes the following HP enhancements:

- Over 200 utilities from AT&T's System V.2 and BSD 4.2 enhancements
- Real-time features: predictable response, full functionality
- The Device I/O Library (DIL) for instrument control
- Native Language Support for creating applications and operating environments for end users in their local language
- Powerfail recovery capabilities (requires battery backup unit)

Model 825CHX requires HP-UX 2.0 or later revision. Model 835CHX requires HP-UX 2.1 or later revision.

Data Communications

- LAN/9000 Series 800: Provides all the necessary hardware and software to interface between an HP 9000 Series 800 and an IEEE 802.3 or Ethernet LAN; also provides interprocess communications through Berkeley sockets or Network Interprocess Communications (NET-IPC)
- ARPA Services: Provides multi-vendor communications to other computers supporting the standard ARPA and Berkeley networking services; provides ARPA services FTP (file transfer), Telnet (terminal login access), and SMTP (mail); provides Berkeley rcp (file transfer), rlogin (terminal login access), rsh (remote command execution), rwho and ruptime
- Network File System Services: Provides multi-vendor remote file access to other computers supporting the standard Network File System (NFS) services; also provides NFS-specific Remote Procedure Call (RPC) and Yellow Page (YP) network administration services
- Network Services/9000: Provides Network File Transfer (NFT) to transfer files to and from other HP 9000, HP 1000, HP 3000, HP Vectra (IBM PC-compatible) and DEC VAX/VMS computers; also provides Remote File Access (RFA) between HP 9000 HP-UX computers
- HP-UX Gateway SNA/3270 and HP-UX Gateway SNA/3770: Allows interactive and batch communications between an HP 9000 Series 800 and an IBM System/370-compatible mainframe using SNA 3270 or 3770 protocols

Languages

- HP TODAY/HP-UX: A fourth-generation language that integrates all the facilities needed to define, test and maintain applications into a single cohesive language
- COBOL/HP-UX: The COBOL/2™ compiler complies with the ANSI X3.23-1985 HIGH COBOL standard and the current X/OPEN definition for COBOL (Portability Guide Issues I and II)
- C/HP-UX: The portable C compiler complies with the de facto industry standard
- Pascal/HP-UX: A superset of the ANSI IEEE 770X3.97-1983 and ISO 7185-1983 standards for Pascal
- FORTRAN 77/HP-UX: A superset of the ANSI FORTRAN 77 standard; includes MIL-STD-1753 extensions and DEC FORTRAN extensions
- Ada: Compliant with MIL-STD-1815A*

* Available from a value-added software supplier.

COBOL/2 is a trademark of Micro Focus Limited.

Information Management

- ALLBASE/HP-UX: Provides both a network model interface (HP IMAGE) and an industry-standard, SQL-compatible relational model interface (HP SQL) in a single database management system
- HP TODAY/HP-UX: Provides a high-productivity application development environment which can access an HP SQL database when used with ALLBASE/HP-UX
- HP Visor/HP-UX: Allows users of the HP SQL interface in ALLBASE to quickly and easily perform ad hoc queries and generate customized reports

Graphics

The HP 9000 Series 800 systems support several graphics software libraries for development and support of applications. These software libraries are based on industry graphics standards.

- Starbase/HP-UX Graphics Library: Provides high-performance graphics based on the evolving Computer Graphics Interface (CGI) standard from ANSI
  - Supports 3D extensions to ANSI CGI
  - Accessible from FORTRAN, C, Pascal
  - Contains 2D and 3D primitives
  - Enhanced to provide full and convenient support of features implemented in microcode and hardware
- Computer Graphics Metafile* (CGM): Provides users with the ability to capture and display picture files on different hardware systems using the ANSI and Technical Office Protocol Version 3.0 standard
- HP GKS/HP-UX: Provides high-level, industry-standard, two-dimensional Graphics Kernel System (GKS) software
  - Implements level 2b of ANSI ISO GKS standard
  - Supports 2D primitives/transformations
  - Single-level segmentation
  - Metafile input and output
- X Window System: A multi-vendor standard based on a client/server model that supports construction of window-based user interfaces across networked systems
  - Distributes tasks to the hardware most suited through the client/server model; for example, the client (the system that runs the application program) does the CPU-intensive task while the server (the graphics workstation) displays the results
  - Allows the user to separate the client and server by a large distance; distance limited only by the LAN
  - Vendor consortium administration assures stability and broad support in the future
  - Allows software developers to write programs that run on many vendors' hardware by using the standard window system
  - Provides the primitives from which window managers and windowing applications can be created
  - Supports XrLIB, HP's contributed library of user interface development tools
- Starbase/HP-UX Display List: Supports hierarchical display lists for modeling graphics data
  - Graphics data and commands stored for later execution
  - Hierarchical networks and segments created, modified, or manipulated
  - Based on Programmers Hierarchical Interactive Graphics Standard (PHIGS) display list structure
- DGL/AGP/HP-UX Graphics Library: For migration of existing applications based on Device-independent Graphics Library (DGL) and Advanced Graphics Package (AGP)
  - Migration for existing applications
  - Basic primitives of color modeling through DGL
  - 2D and 3D transformations, segmentation, picking, and clipping through AGP

Application Software

A variety of application software packages are available for Series 800 systems. Contact your HP Sales Representative for information regarding specific applications.

*Hewlett-Packard anticipates shipping this product at the end of 1988 but reserves the right to make changes to the product and introduction date.

Technical Specifications

Electrical Specifications

Component	Line Voltage	Voltage Tolerance	Line Frequency	Maximum Current	Power Consumption
Display Controller (HP A1020H) and Graphics Accelerator (HP 98556A)	120 V 240V	90-125 VAC 198-250 VAC	50/60 Hz	5.0 A 3.0 A	250 Watts, 795 BTU/hr.
19-inch Color Monitor (HP 98752A)	120 V 240 V	90-125 VAC 198-220 VAC	48-66 Hz	2.9 A 1.6 A	220 Watts, 750 BTU/hr.
16-inch Color Monitor (HP 98789A)	120 V 240 V	90-125 VAC 198-250 VAC	48-66 Hz	2.6 A 1.5 A	200 Watts, 680 BTU/hr.
Model 825 or Model 835 SPU	100 V 120 V 240 V	90-110 VAC 108-132 VAC 180-264 VAC	48-66 Hz	9.5 A 8.0 A 5.3 A	600 Watts, 2034 BTU/hr.

Environmental Characteristics

Characteristic	Display Controller (HP A1020H) and Graphics Accelerator (HP 98556A)	19-inch Monitor (HP 98752A)	16-inch Monitor (HP 98789A)	Model 825 or Model 835 SPU
Temperature Operating Non-operating	 0° to 55° C -40° to 71° C	 10° to 40° C -40° to 65° C	 10° to 40° C -40° to 65° C	 0° to 55° C -40° to 71° C
Humidity Operating 40° C	 15% to 95%	 10% to 80%	 10% to 80%	 15% to 95%
Maximum Altitude Operating Non-operating	 4570 m (15,000 ft.) 15,240 m (50,000 ft.)	 3350 m (11,000 ft.) 15,240 m (50,000 ft.)	 3350 m (11,000 ft.) 15,240 m (50,000 ft.)	 4570 m (15,000 ft.) 15,240 m (50,000 ft.)

Regulatory Compliance

Characteristic	Display Controller (HP A1020H) and Graphics Accelerator (HP 98556A)	19-inch Monitor (HP 98752A)	16-inch Monitor (HP 98789A)	Model 825 or Model 835 SPU
Electromagnetic Interference VDE level FCC class VCCI class	 B A 1	 B A 1	 B A 	 B A 1
Safety	UL, CSA, IEC	UL, CSA, IEC, SEV, FEI	UL, CSA, TUV, SEV, FEI	UL, CSA, IEC

Physical Characteristics

Characteristic	Display Controller (HP A1020H) and Graphics Accelerator (HP 98556A)	19-inch Monitor (HP 98752A)	16-inch Monitor (HP 98789A)	Model 825 or Model 835 SPU
Height	130 mm (5.12 in.)	436 mm (17.1 in.)	380 mm (15.0 in.)	234 mm (9.21 in.)
Width	325 mm (12.8 in.)	408 mm (16.1 in.)	406 mm (16.0 in.)	325 mm (12.8 in.)
Depth	376 mm (14.8 in.)	535 mm (21.0 in.)	450 mm (17.7 in.)	500 mm (19.7 in.)
Weight	11.8 kg (26 lb.)	35 kg (77 lb.)	26.5 kg (58.3 lb.)	23 kg (51 lb.)

Vibration and Shock

HP 9000 Series 800 systems are type-tested for normal shipping and handling shock and vibration. Contact your HP Sales Representative for review of any application requiring operation under continuous vibration.

Acoustics

5.0 Bels (A) Sound Power

Ventilation

Forced air cooling; air flows from front to back

Supported Peripherals

The following list contains peripherals supported by Series 800 superworkstations at the time of publication. The list of supported peripherals changes as new peripherals are introduced and other peripherals are discontinued. Contact your HP Sales Representative for more information on currently supported peripherals.

Terminals

HP A1020H.................... CHX graphics Display Controller*
HP C1001A/G/W........... Model 700/92 Block-mode Display Terminal†
HP C1002A/G/W........... Model 700/94 High-performance Block-mode Terminal†
HP C1003A/G............... Model 700/41 Entry-level ASCII Terminal‡
HP C1004A/G/W........... Model 700/22 ANSI DEC VT220-compatible Terminal‡
HP C1006A/G/W........... Model 700/43 Fully Featured ASCII Terminal
HP 2392A .... Display Terminal†
HP 2393A .... Monochromatic Graphics Terminal†
HP 2394A .... Data Entry Terminal†
HP 2397A .... Color Graphics Terminal
HP 3081A .... Industrial Data Entry Terminal
HP 45610B...................... *Touchscreen* Terminal
HP 45711A .... *Portable Plus* computer
HP 45850A/B .... *Touchscreen II* Terminal
HP 724x5A...................... *Vectra PC*
HP 9666A .... Industrial 2397A Terminal
HP 9807A .... *Integral PC*
HP 98720A .... SRX graphics Display Controller*

NOTE: HP 9000 Series 300 Computers may also be used as terminals on Series 800 systems.

*Supported only on Model 825 and Model 835.
†Supported as system console.

‡Supported as applications terminals only. Verify compatibility with application.

Disc Drives

HP 7907A	20 Mbyte Fixed/20 Mbyte Removable Media
HP 7936FL	307 Mbyte CS/80 Fixed Disc (HP-FL)*
HP 7936H	307 Mbyte CS/80 Fixed Disc (HP-IB)*
HP 7937FL	571 Mbyte CS/80 Fixed Disc (HP-FL)*
HP 7937H	571 Mbyte CS/80 Fixed Disc (HP-IB)*
HP 7957A/B	81 Mbyte CS/80 Fixed Disc
HP 7958A/B	131 Mbyte CS/80 Fixed Disc*
HP 7959B	304 Mbyte CS/80 Fixed Dis*
HP 7963B	304 Mbyte CS/80 Fixed Disc*
HP 9122D/S	270-788 Kbyte 3 1/2-inch Flexible Disc
HP 9127A	270-380 Kbyte 5 1/4-inch Flexible Disc

Magnetic Tape Drives

HP 7974A	1/2-inch 1600 characters per inch (cpi) Tape Drive
HP 7979A	1/2-inch 1600 cpi Tape Drive
HP 7980A	1/2-inch 6250/1600 cpi Tape Drive
HP 9144A	1/4-inch CS/80 Cartridge Tape Drive
HP 35401A	CS/80 Cartridge Tape Autochanger

Printers

HP C1200A	Asian System printer
HP 2225D	*ThinkJet* RS-232C printer
HP 2227A	*QuietJet Plus* RS-232C printer
HP 2228A	*QuietJet* RS-232C printer
HP 2235B/D	*RuggedWriter* printer†
HP 2276A	*DeskJet* RS-232C printer‡
HP 2563B	300 lines per minute (lpm) dot-matrix impact printer
HP 2564B	600 lpm dot-matrix impact printer
HP 2566B	900 lpm dot-matrix impact printer
HP 2567B	1200 lpm dot-matrix impact printer
HP 2684A/D/P	*LaserJet 2000* RS-232C printer‡
HP 2932A	200 characters per second (cps) dot-matrix impact printer
HP 2934A	200 cps "Office" printer
HP 33440A	*LaserJet Series II* RS-232C printer
HP 3630A	*PaintJet* RS-232C color printer
HP 41063A	Asian printer

*Supported as system discs.
†HP-IB not supported as a graphics device.
‡Not supported as a graphics device.

Plotters

HP 7440A	A-size, 8-pen *ColorPro* plotter
HP 7475A	B-size, 6-pen plotter
HP 7550A	B-size, 8-pen plotter with auto sheet feed
HP 7570A	C/D-size, 8-pen *DraftPro* plotter
HP 7595A	E-size, 8-pen *Draftmaster I* plotter
HP 7596A	E-size, 8-pen *Draftmaster II* plotter with roll-feed

Data Communications Devices

HP 2334A	X.25 Multiplexer
HP 27140A	6-channel Multiplexer
HP 37212A	300/1200-baud Intelligent Modem
HP 92205A/C	Hayes *Smartmodem 1200*™
HP 92223A	LAN Repeater Kit
HP 98194A/91786A/ 91788A	LAN/9000 Series 800 Link

Support Services

A wide range of hardware and software support services is available worldwide for all HP 9000 products. Contact your HP Sales Representative for details on available support services.

Warranty Information

The warranty covering a specific system is determined by the HP WARRANTY AND INSTALLATION TERMS in effect at the time of purchase. These terms are specified in HP Pub. No. 5954-1617(D) for the United States and in similar documents for other countries.

Smartmodem 1200 is a trademark of Hayes Microcomputer Products, Inc.

HEWLETT PACKARD

Printed in U.S.A. 4/88
5951-6811

HEWLETT-PACKARD

HP 7959B

Winchester Disc Drive

Data Sheet

Features

New disc drive features HP's own 5.25-inch Winchester disc for high performance and reliability

- 304 megabyte capacity
- Quiet operation
- Simplified design
- Automatic error correction, logging

The HP 7959B disc drive is ideal for commercial and technical multi-user systems and workstations. Users of HP 1000, 9000 and 3000 computer systems will appreciate the new large capacity and solid reliability this disc drive offers. Plus, it features exceptional performance in a compact desktop package.

Reliability and Serviceability

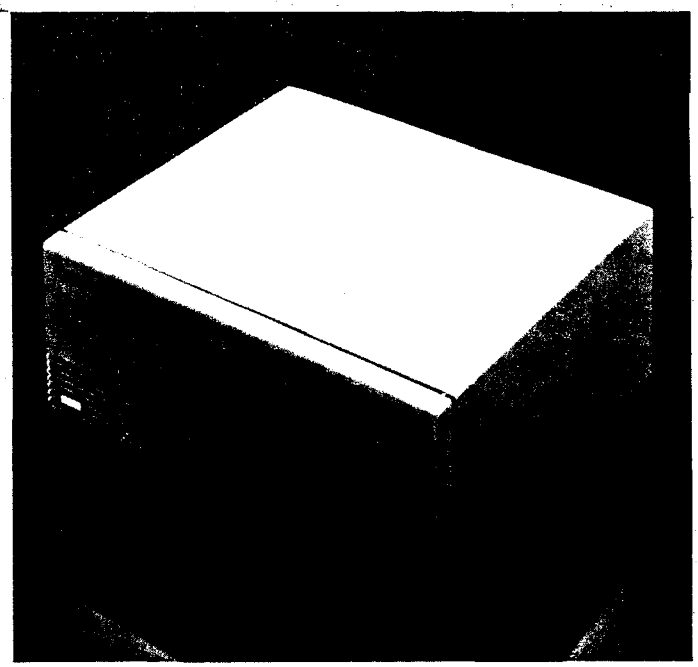
The inherent reliability of this new product is based on seven generations of disc drive design and manufacturing experience at Hewlett-Packard. The foundation of the HP 7959B is an HP-designed and built 5.25-inch Winchester mechanism. This high performance mechanism features a special track positioning system using embedded servo code that essentially eliminates seek errors. In addition, it enhances read/write accuracy over the entire operating temperature range.

The ability to service the product is enhanced by extensive self-test capabilities, error logging and autosparing. The package design contributes to easy service by allowing quick access to all replaceable assemblies. And new low maintenance costs mean a lower overall cost of ownership.

Performance

High performance traditionally found with large system disc drives is now available with this desktop midrange model. The HP-built 5.25-inch mechanism found in the HP 7959B boasts an impressive seek time of 17 ms and an average data transfer rate of approximately 700 kbytes per second. The new HP-IB controller reduces overhead to 1 ms while providing compatibility and cabling for HP systems.

The channel optimization feature of the HP 7959B is another key benefit. Similar to rotation position sensing (RPS), channel optimization allows multiple discs to better utilize a single HP-IB channel.



Compact Design

The HP 7959B's compact design offers quiet operation and the option of desktop use. It also fits into HP's 92211R mini-rack cabinet or can be mounted in a standard 19-inch EIA equipment rack. The disc drive is supplied with all the necessary accessories and is ready to operate after simply being plugged into an AC power source and the HP-IB of any supporting system.

HP 7959B Specifications

Performance Specifications

Formatted capacity	304 Mbytes
Average seek time	17 ms
Average rotational delay	8.96 ms
Average time to transfer 1 kbyte	1.4 ms
Average controller overhead	<1 ms
Total average transaction time	28.4 ms
Disc performance index	35.3 I/Os per sec
Data transfer rate	
Instantaneous	1.25 Mbytes per sec
Average sustained (full volume)	~700 kbytes per sec
Track average	875 kbytes per sec

Recording Characteristics

Bits per inch (maximum)	20,500
Tracks per inch	1,590
Bytes per sector	256
Sectors per track	63
Tracks per data head	1,572
Number of discs	6

Service Characteristics

Mean time to repair	30 minutes
Preventive maintenance frequency	None required
Service life	10 years

Overall Characteristics

Electromagnetic emissions
Radiated and magnetic interference
- For U.S., complies with FCC docket 20780 for Class B computing peripheral devices.
- For Europe, designed to meet EMI level FTZ 1046/84 and provides a Manufacturer's Declaration. Refer to your local sales representative for more information.

Safety

The HP 7959B disc drive meets all applicable safety standards of the following:
- IEC 380 and IEC 435 compliant
- UL listed 114 and 478
- CSA certified 22.2 No. 154 and 220

Power Requirements

Voltage:
115V setting: 100V, 115V, 120V, single phase (inclusive tolerance range is 90V to 132V)
230V setting: 220V, 240V, single phase (inclusive tolerance range is 180V to 264V)
Frequency: 47.5 to 66 Hz
Phase: Single
Power (typical):
115V setting: 65W (60 Hz)
230V setting: 65W (50 Hz)
Current (typical):
115V setting: 1.0A
230V setting: 0.6A
Heat dissipation (typical):
65W (222 Btu/hr, 56 Kcals/hr)
Heat dissipation (maximum):
85W (290 Btu/hr, 73 Kcals/hr)

Environmental Requirements

Temperature:
Operating: 5 to 45°C (maximum rate of change 20°C per hour)
Nonoperating: -40 to 65°C
Humidity:
Operating: 8 to 80% noncondensing
Nonoperating: 5 to 80% noncondensing
Shock:
Operating: 4 G @ 11 ms, half sine waveform
Nonoperating: 20 G @ 11 ms, half sine waveform
Vibration:
Operating: Random vibration with power spectral density (PSD) of 0.0001 g^2/Hz from 5 to 350 Hz; -6 dB/octave from 350 to 500 Hz; PSD of 0.00005 g^2/Hz at 500 Hz.
Nonoperating: Random vibration with power specral density (PSD) of 0.015 g^2/Hz from 5 to 100 Hz; -6 dB/octave from 100 to 137 Hz; PSD of 0.008 g^2/Hz from 137 to 350 Hz; -6 dB/octave from 350 to 500 Hz; PSD of 0.0039 g^2/Hz at 500 Hz.
Altitude:
Operating: Maximum 4,572 m (15,000 ft)*
Nonoperating: Maximum 15,240 m (50,000 ft)*
**Slew rate less than 5,000 ft/minute.*
Acoustic Emissions:

Average sound pressure level	~41 dB(A)
Sound power level	<54 dB(A)

Physical Characteristics

Dimensions:

Height:	132 mm (5.2 in.) with feet
	129 mm (5.1 in.) without feet
Width:	325 mm (12.8 in.)
Depth:	285 mm (11.2 in.)
Weight:	
Net:	10.6 kg (23.2 lb)
Shipping:	13.6 kg (29.9 lb)

Ordering Information

The HP 7959B includes a 304 megabyte hard disc drive, integral controller, power supply and 1-metre HP-IB cable. Warranty is standard one-year return-to-HP.

Options Available

015 – Voltage selector switch is set for 230V operation for non-U.S.A. shipments.
550 – Deletes 1-metre HP-IB cable.
W03 – Converts one-year return-to-HP warranty to 90-day on-site warranty.

Accessories

Available through the HP supply organization:
HP 19500B Rack slide kit for mounting in a standard 19-inch EIA cabinet.
HP 92211R Mini-rack cabinet.

United States: Hewlett-Packard Company, 4 Choke Cherry Road, Rockville, MD 20850, (301) 670-4300; Hewlett-Packard Company, 5201 Tollview Dr., Rolling Meadows, IL 60008, (312) 255-9800; Hewlett-Packard Company, 5161 Lankershim Blvd., No. Hollywood, CA 91601, (818) 505-5600; Hewlett-Packard Company, 2015 South Park Place, Atlanta, GA 30339, (404) 955-1500; **Canada:** Hewlett-Packard Ltd., 6877 Goreway Drive, Mississauga, Ontario L4V1M8, (416) 678-9430; **Australia/New Zealand:** Hewlett-Packard Australia Ltd., 31-41 Joseph Street, Blackburn, Victoria 3130, Melbourne, Australia, (03) 895-2895; **Europe/Africa/Middle East:** Hewlett-Packard S.A., Central Mailing Department, P.O. Box 529, 1180 AM Amstelveen, The Netherlands, (31) 20/547 9999; **Far East:** Hewlett-Packard Asia Ltd., 47/F China Resources Building, 26 Harbour Road, Hong Kong, (5) 833-0833; **Japan:** Yokogawa-Hewlett-Packard Ltd., 29-21, Takaido-Higashi 3-chome, Suginami-ku, Tokyo 168, (03) 331-6111; **Latin America:** Hewlett-Packard de Mexico, Sp.A. de C.V., Monte Pelvux No. 111, Lomas de Chapultapec, 11000 Mexico D.F., Mexico, (905) 596-7933.

Technical information in this document is subject to change without notice.

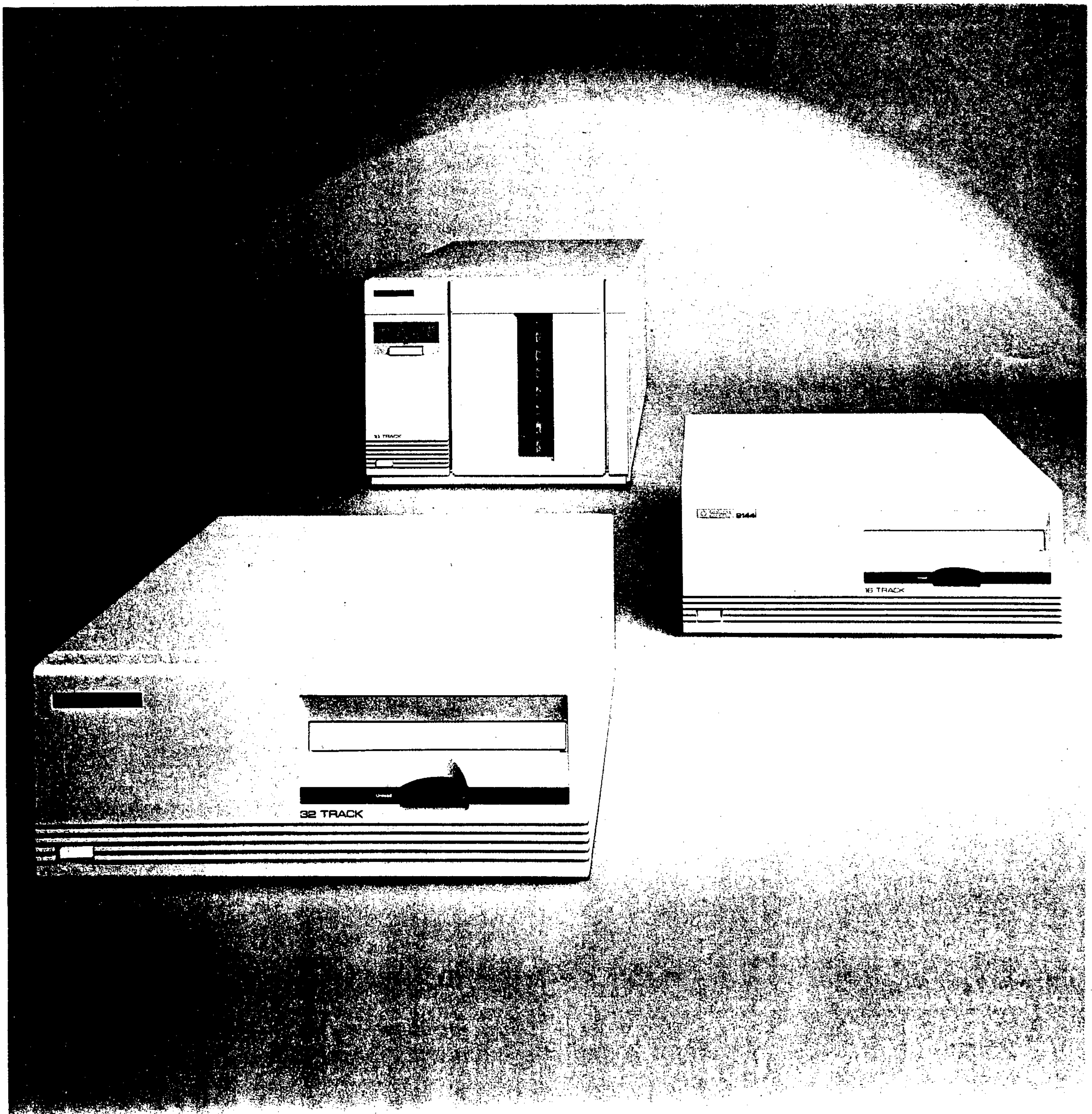
HEWLETT PACKARD

Printed in U.S.A. 0388
5953-3688

HEWLETT-PACKARD

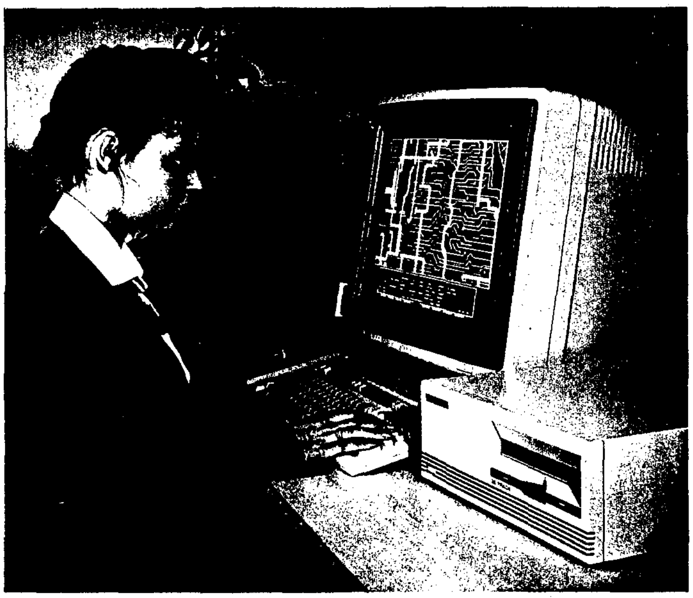
The HP 9144A/9145A/35401A
¼-inch Cartridge Tape Drives

Data Sheet



Hewlett-Packard appreciates that gathering and storing valuable data costs time and money. To help protect this investment, HP offers dependable solutions for your backup needs.

This competitive range of ¼-inch cartridge tape drives incorporates low price, high performance and high capacity, to suit the many and varied requirements of HP's technical and business systems.



Key Features

- **Reliability**
- **Designed for Office Use**
- **Compatible Tape Format**
- **Room for Growth**

Reliability

HP's ¼-inch cartridge tape drives offer features that ensure your data is secure. They use a new cartridge tape technology designed to achieve greater accuracy and reliability. Each product has Read-While-Write capability which verifies your data as it's written. The Error Correction scheme helps ensure that data can be recovered should the tape be damaged.

In addition, the HP 9145A has a front panel indicator light that tells you when to clean the tape head - giving you increased protection.

Designed for Office Use

HP's ¼-inch cartridge tape drives complement the office environment. Each product is quiet and space-efficient, and needs no special conditions in which to operate. In addition to being free-standing, they also fit into HP's range of system and disc cabinets.

The whole range is very easy to use, which means your staff won't need any special training.

Compatible Tape Format

Whether you own one of the current range, or an integral disc and tape drive like the HP 7912, 7914 or 7942, your existing data investment is secure. Before the introduction of the HP 9145A, HP's ¼-inch cartridge tape drives used a tape cartridge which stored data on 16-Tracks. To enable the HP 9145A to store more of your data, the number of tracks has been increased to 32.

Cartridges recorded in 16-Track format can be read by all of these products. The HP 9145A can also read 16-Track tapes, but it is a 32-Track tape drive and will only write to a 32-Track tape.

You will find a table explaining cartridge tape compatibility in the ordering information section of this datasheet.

Room for Growth

You may find your backup requirements growing faster than you anticipated. HP's compatible tape format ensures that moving through the range is straightforward.

For example, if you already own an HP 9144A, you should consider the following upgrades.

HP 9144A →	**HP 9145A**	High Performance
HP 9144A →	**HP 35401A**	High Capacity

Choosing Your Backup Solution

As an easy guide, choose . . .

. . . **The HP 9144A** for a dependable, low-cost solution.

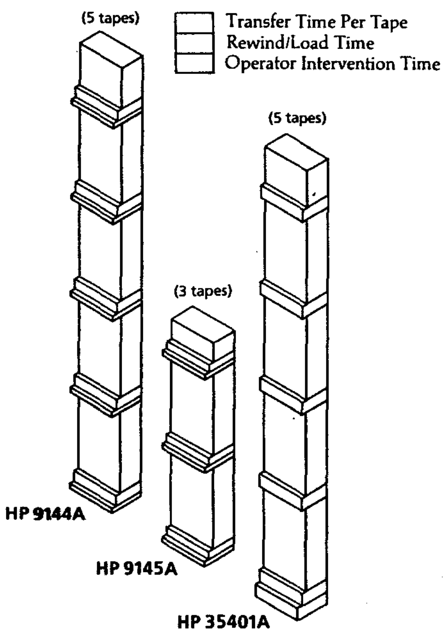
. . . **The HP 9145A** if you need a backup incorporating high transfer rate AND high cartridge capacity.

. . . **The HP 35401A** for high capacity, unattended backup and savings by freeing operator time.

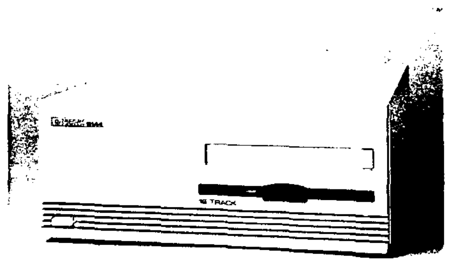
For further help, more information is given in the following graphs and product sections.

Comparison of Backup Time

(For 300 Mbytes of data)



HP 9144A

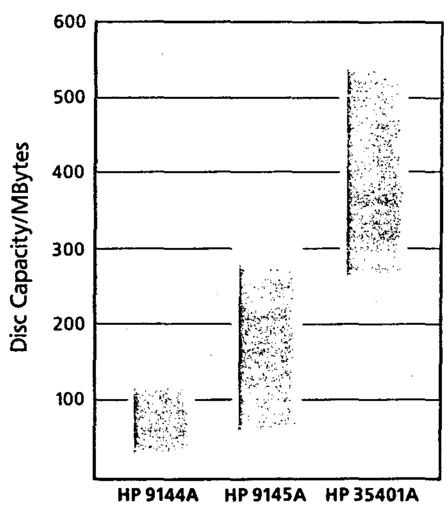


A low cost backup solution for technical and small business systems, the HP 9144A provides up to 67 Mbytes of data storage on each 16-Track cartridge.

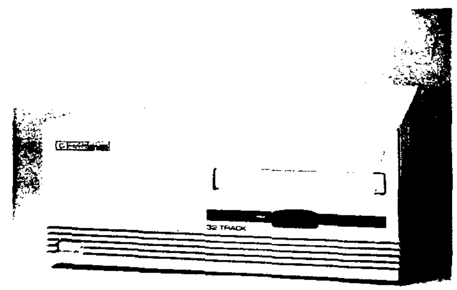
The HP 9144A also provides a more convenient and reliable backup alternative to multiple floppy disks for PCs. It is supported on the HP Vectra PC family using the HP 88500A interface card.

Comparing disc and tape

(Based on System Disc Capacity)



HP 9145A



The HP 9145A is a high-performance cartridge tape drive aimed at the ever-increasing backup requirements of HP's customers.

As your applications grow, your computer systems need more disc capacity and, as a result, a more powerful backup solution. The HP 9145A has been designed to meet the needs of these systems.

Key Features

- **Faster Transfer Rate**
- **Greater Cartridge Capacity**

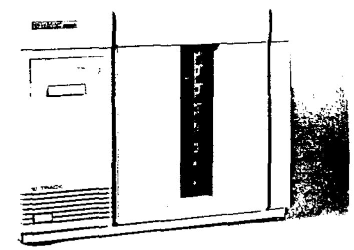
Faster Transfer Rate

As your backup needs increase, you may decide that the HP 9145A is the best solution to keep pace with your requirements. The HP 9145A has a tape speed of 120 inches per second, which doubles the data transfer rate to 4 Mbytes per minute when compared with the HP 9144A and HP 35401A. This cuts your backup time in half.

Greater Cartridge Capacity

The HP 9145A stores up to 133 Mbytes of data per cartridge – achieved by writing 32-Tracks on the cartridge tape. This increased capacity adds to your convenience because fewer tape changes are required, and you save space since there are fewer tapes to store.

HP 35401A



The HP 35401A is a ¼-inch tape drive with an autochanger mechanism. It automatically loads cartridges from a magazine which holds eight 16-Track cartridges. This provides you with unattended backup of up to 536 Mbytes of data.

Key Features

- **High Capacity Backup**
- **Selective Operation**

High Capacity Backup

High Capacity backup is particularly important for HP's business systems and technical workstation networks.

The HP 35401A offers an economical solution if your backup requires multiple cartridges. The automatic tape change allows you to reduce your staff costs. This can be achieved by running system backup at night or at weekends, without an operator. Scheduling backup at off-peak times will also increase your system's availability during the day. In many cases, the cost savings that this creates will be the justification you need for buying an HP 35401A.

With HP 3000 systems the HP 35401A provides the additional reassurance of full powerfail recovery. This ensures that unattended backup is completely dependable.

Selective Operation for Networked Systems

On HP 9000 HP-UX* systems you can select one of the HP 35401A's eight cartridges to read or write data in any sequence. Such flexibility allows a network of HP-UX* users to share and store data as required.

HP 9144A/9145A/35401A Technical Specifications

	HP 9144A	HP 9145A	HP 35401A
Transfer Rate*	2 Mbytes/min.	4 Mbytes/min.	2 Mbytes/min.
Tape Speed			
Read/Write	60 ips	120 ips	60 ips
Search/Rewind	90 ips	120 ips	90 ips
Storage Capacity			
150 ft cartridge	16 Mbytes	33 Mbytes	
600 ft cartridge	67 Mbytes	133 Mbytes	8 x 67 Mbytes
Tapes/Magazine	N/A	N/A	8 (maximum)

**Maximum Tape Drive Transfer Rate – Actual Transfer Rate is host dependent*

	HP 9144A	HP 9145A	HP 35401A
Tracks/Tape	16	32	16
User Blocks/Track			
150 ft cartridge	1022	1020	1022
600 ft cartridge	4088	4080	4088
Frames/Block	6 (4 for data, 2 for error correction)	6 (4 for data, 2 for error correction)	6 (4 for data, 2 for error correction)
Bytes/Frame	256	256	256
Encoding Technique	MFM	MFM	MFM

	HP 9144A	HP 9145A	HP 35401A
Interface	HP-IB (IEEE-488) Using CS80 protocol	HP-IB (IEEE-488) Using CS80 protocol	HP-IB (IEEE-488) Using CS80 protocol
Power Requirements			
Line Voltage	90–132 VAC 198–264 VAC (switch selectable)	90–132 VAC 198–264 VAC (switch selectable)	90–132 VAC 198–264 VAC (switch selectable)
Power Consumption			
Typical	25 watts rms	28 watts rms	60 watts rms
Line Frequency	47–63 Hz	47–63 Hz	47–63 Hz

	HP 9144A	HP 9145A	HP 35401A
Radiated and conducted interference	USA: Certified to FCC Rules, Part 15 Class B computing devices. Europe: Meets FTZ 1046/84 computing devices.	USA: Verified to FCC Rules, Part 15 Class B computing devices. Europe: Meets FTZ 1046/84 computing devices.	USA: Verified to FCC Rules, Part 15 Class A computing devices. Europe: Meets FTZ 1046/84 computing devices.
Hard Error Rate	1 in 10^{11} bits transferred.	1 in 10^{11} bit transferred.	1 in 10^{11} bits transferred.

	HP 9144A	HP 9145A	HP 35401A
Temperature			
Operating	5°C to 40°C (40°F to 104°F)	5°C to 40°C (40°F to 104°F)	5°C to 40°C (40°F to 104°F)
Non-Operating	–40°C to 75°C (–40°F to 167°F)	–40°C to 70°C (–40°F to 158°F)	–40°C to 75°C (–40°F to 167°F)
Relative Humidity			
Operating	Media limited to 20% to 80% at <26°C (79°F) maximum wet bulb temperature (non condensing).		
Altitude			
Operating	4572 m (15,000 ft)	4572 m (15,000 ft)	4572 (15,000 ft)
Non-operating	15000 m (50,000 ft)	15000 m (50,000 ft)	15000 m (50,000 ft)
Shock (in HP Packaging, 11ms duration)			
Non-Operating	30 g	30 g	30 g
Vibration (5 to 500 Hz)			
Operating	0.2 g rms	0.2 g rms	0.2 g rms
Non-Operating	2.1 g rms	2.1 g rms	2.1 g rms
Noise Level (A weighted sound power)	<6.0 Bels A	<6.0 Bels A	<5.0 Bels A

	HP 9144A	HP 9145A	HP 35401A
Temperature	–40°C to 45°C (–40°F to 113°F)	–40°C to 45°C (–40°F to 113°F)	–40°C to 45°C (–40°F to 113°F)
Altitude	15,000 m (50,000 ft)	15,000 m (50,000 ft)	15,000 m (50,000 ft)

	HP 9144A	HP 9145A	HP 35401A
Net Weight	7.6 kg (16.8 lbs)	8.0 kg (17.6 lbs)	22.6 kg (49.8 lbs)
Height	132 mm (5.2 in)	132 mm (5.2 in)	260 mm (10.2 in)
Depth	290 mm (11.4 in)	290 mm (11.4 in)	575 mm (22.6 in)
Width	325 mm (12.8 in)	325 mm (12.8 in)	325 mm (12.8 in)

CSA Certified to CSA 22.2 No 154
Meets all applicable safety standards of IEC 380 and IEC 435
UL listed to UL 114 and Ul 478.

1/4-inch Cartridge Tape Compatibility

	Tape Length	Media Capacity	Cartridge Product Number	HP 9144A and Compatibles	HP 9145A
16 Track	150 ft. (45.7 m)	16 Mbytes	HP 88140SC*	Read ✓	Read ✓
	600 ft. (182.9 m)	67 Mbytes	HP 88140LC*	Write ✓	Write x
32 Track	150 ft. (45.7 m)	33 Mbytes	HP 92245S*	Read x	Read ✓
	600 ft. (182.9 m)	133 Mbytes	HP 92245L*	Write x	Write ✓

* Box of five.

Ordering Information

67 Mbyte 1/4-inch cartridge tape drive .... HP 9144A
133 Mbyte 1/4-inch cartridge tape drive ...... HP 9145A
536 Mbyte 1/4-inch cartridge tape autochanger HP 35401A

		HP 9144A	HP 9145A	HP 35401A
Accessories Supplied		Head Cleaner Fluid/Swabs User Manual Power Cable	Cleaning Cartridge User Manual Power Cable Quick Reference Guide	Cleaning Cartridge User Manual Power Cable Cartridge Magazine Quick Reference Guide Applications Guide
Cartridges available	**5 150ft cartridges**	HP 88140SC (16 Mbytes)	HP 92245S (33 Mbytes)	HP 88140SC (16 Mbytes)
	5 600ft cartridges	HP 88140LC (67 Mbytes)	HP 92245L (133 Mbytes)	HP 88140LC (67 Mbytes)
	Cleaning cartridge	HP 92193E	HP 92193E	HP 92193E
Other accessories available	**1m HP-IB cable**	HP 10833A	HP 10833A	HP 10833A
	Head cleaner	HP 8500-1251	N/A	N/A
	Swabs	HP 93000-0767	N/A	N/A
	Replenishment kit for cleaning cartridge	HP 92193P	HP 92193P	HP 92193P
	Cartridge magazine	N/A	N/A	HP 92192C
Cabinets	**Design Plus Mobile Mini-rack System Cabinet**	HP 92211R	HP 92211R	HP 92211R
	HP 7936/37 Disc Drive Cabinet (2 Pack)	N/A	N/A	HP 19511A
	Rail Kit for Cabinets	HP 92211S	HP 92211S	HP 92211S
	Filler Panel Kit for Cabinets	HP 92211T	HP 92211T	HP 92211T
	19-inch Rackmount Kit	HP 19500B	HP 19500B	HP 35490A
Manuals	**User Manual**	09144-90000	09145-90000	35401-90902
	Quick Reference Guide		09145-90004	35401-90903
	Applications Guide			35401-90951
	CE Service Handbook	09144-90039	09145-90039	35401-90905
	Hardware Support Manual	09144-90030	N/A	35401-90904

Note: Contact your local HP Sales Representative to verify current host system support before ordering.

For more information, call the local HP sales office listed in your telephone directory or contact one of the HP regional offices listed below for the location of your nearest sales office. **United States –** Hewlett-Packard Company, 4 Choke Cherry Road, Rockville, MD 20850/(301) 670-4300; Hewlett-Packard Company, 5201 Tollview Drive, Rolling Meadows, IL 60008/(312) 255-9800; Hewlett-Packard Company, 5161 Lankershim Blvd., No. Hollywood, CA 91601/(818) 505-5600; Hewlett-Packard Company, 2015 South Park Place, Atlanta, GA 30339/(404) 955-1500; **Canada –** Hewlett-Packard Ltd., 6877 Goreway Drive, Mississauga, Ontario L4V IM8/(416) 678-9430; **Australia/New Zealand –** Hewlett-Packard Australia Ltd., 31-41 Joseph Street, Blackburn, Victoria 3130, Melbourne, Australia/(03) 895-2895; **Europe/Africa/Middle East –** Hewlett-Packard S.A., Central Mailing Department, P.O. Box 529, 1180 AM Amstelveen, The Netherlands/(31) 20/547 9999; **Far East –** Hewlett-Packard Asia Ltd., 22/F Bond Centre, West Tower, 89 Queensway Central, Hong Kong/(5) 8487777; **Japan –** Yokogawa-Hewlett-Packard Ltd., 29-21, Takaido-Higashi 3-chome, Suginami-ku, Tokyo 168/(03) 331-6111; **Latin America –** Hewlett-Packard de Mexico, Sp.A.de C.Y., Monte Pelvax Nbr. 111, Lomas de Chapu apec, 11000 Mexico, D.F. Mexico/(905) 596-79-33.

• HP-UX is Hewlett-Packard's version of AT&T's UNIX Operating System. UNIX is a registered trademark of AT&T in the U.S. and other countries.

HEWLETT PACKARD

Printed in U.K. 5/88
5954-1959

HEWLETT-PACKARD

HP 700/92

Display Terminal

Designed for Your HP System
The HP 700/92 Display Terminal performs harmoniously with your HP business and technical computer applications. It was designed especially to take advantage of block mode communications in software packages like the popular VPLUS/3000. The HP 700/92 delivers more power than the HP 2392A terminal it replaces, adding new capabilities to make your work easier and more productive.

Sophisticated Alphanumeric Display
What's new on the HP 700/92? Crisp characters on a 14-inch screen for easy viewing. 8 pages of display memory for increased productivity. And a standard printer port for printing your files locally. But it doesn't stop there. The HP 700/92 also has selectable 80 or 132 column display modes, data transmission rates up to 38.4k baud, and DEC VT220 terminal compatibility.

Superb Ergonomic Design
We fashioned the HP 700/92 with state-of-the-art ergonomics. Its keyboard has tactile feedback for a responsive touch. Its tilt and swivel mechanism lets you position the screen effortlessly. Select soft white, amber, or green phosphor, with a screen-saver function standard. 72 Hz refresh rate enhances screen readability especially when displaying black characters on a white background. With the HP 700/92, you can experience the superior quality that has made HP terminals the top choice for four years in a row in Datapro's User Survey.†

Worldwide Support and Service
You can feel confident that, with one of the largest worldwide networks of sales and service offices in the computer industry, Hewlett-Packard is ready to meet all your display terminal needs.

Features

- Enhanced Functions
  80 or 132 column display
  Up to 8 pages of display memory
  2 standard RS232C ports
  75 to 38,400 baud rates
- Ergonomics
  14-inch anti-glare screen
  Soft white, green, or amber phosphor
  Tilt and swivel
  Selectable 50, 60 or 72 Hz refresh rates
  Front panel controls
  Detached adjustable keyboard
- Compatibility Modes
  HP 2392A Mode
  VT220 mode
  VT100 mode
  VT52 mode
- Keyboard
  Enhanced 2392A layout
  Tactile feedback
  17 national layouts available
  8 function keys (16 shiftable)
- Additional Features
  Smooth or jump scrolling
  Insert and delete character with wraparound
  94 characters downloadable from host
  Easy setup menus
  Nonvolatile memory saves setup, function key info
  1 year warranty

DEC VT220, VT100 and VT52 are products of Digital Equipment Corporation.

† "User Ratings of Display Terminals and IVDTs," Datapro Report, 1983-86.

Display

- CRT: Etched anti-glare, 14 in. dia. P31 Green, P19 Amber or P188 White phosphor.
- Format: 24 lines × 80 or 132 col. 25th, and 26th lines for labels, 27th line for status. Jump/smooth scrolling.
- Character Cell: 7×11 character in 9×14 cell with half-dot shift (80 col). Equivalent to 18×14 cell for most characters.
- Character Set: ASCII, national, and line drawing.
- Cursor: Underline (blinking/static), Block (blinking/static), or Disabled.
- Display Enhancements: Inverse, underline, blinking, halfbright, security video.
- Display Memory: Up to 8 pages.
- Screen Saver: 5, 10, 15 min. or off.
- Refresh Rate: 50, 60, or 72 Hz.
- Editing: Ins./del. char. with wrap, ins./del. line, clear line/all.

Keyboard

- Style: Detached, slant adjustable, low profile, with coiled cable. Sculptured keys, tactile feedback.
- Layout: 109 key. Separate cursor and numeric pads. 17 national layouts.
- Function Keys: 8 screen-labeled user-definable, shiftable to 8 pre-defined functions. Labels and definitions are saved in non volatile memory.
- Operation: Auto-repeat, N-key rollover.

Data Communications

- Interface:
  Port 1 - Combined RS232C/HP422 data communications
  Port 2 - RS232C printer interface
- Baud Rates: 75 to 38.4k baud. Handshaking may be required.
- Handshake:
  Port 1 - ENQ/ACK, XON/XOFF, CS.
  Port 2 - XON/XOFF, CS, SRR.
- Parity: even, odd, zero, one, none.
- Operating Modes: character, block, format, VT220.

Physical Characteristics

- Display (H×W×D): 330 mm × 330 mm × 330 mm, 8.8 kg.
- Keyboard (H×W×D): 35 mm × 468 mm × 198 mm, 1.85 kg.
- Keyboard Cable: Coiled 0.8m (2.7 ft.), Extended 3m (9.8 ft.)

Power Requirements

- Input Voltage: 100V to 240V at 50-60 Hz.
- Power Consumption: 35 watts (average)
- Thermal Dissipation: 110 BTU/hr.

Environmental Conditions

- Temperature:
  Operating: 0°C to 55°C
  Non-operating: −40°C to 70°C
- Humidity:
  Operating: 15% to 95% (40°C)
  Non-operating: 90% (65°C)
- Shock: 105 g, 3 ms, 65 in./sec., ½ sine
- Vibration: Operating 5-500 Hz, .0001 g^2/Hz amplitude, 10 minutes/axis

Product Regulations

- Safety:
  United States—UL Listed 478
  Canada—CSA certified
  Germany—VDE/TUV (GS) Mark
  Finland—FEI approval pending
  International—IEC 380/435
- RFI:
  United States—FCC class A
  Germany—VDE 0871 level B Mark pending
  Japan—VCCI class 1
- DATACOMM:
  CCITT V.24, V.28 Approvals pending: Belgium, Germany, UK, and Finland.
- Ergonomics:
  Germany—ZH 1/618 "Safety Regulations for Display Work places in the Office Sector"

Ordering Information

C1001A	(amber display)
C1001G	(green display)
C1001W	(soft white display: black characters on white background)

Required Localization Options:

ABA	U.S.
ABB	STD. EUROPE - U.S.*
ABC	CANADA-French
ABD	GERMANY
ABE	SPAIN
ABF	FRANCE
ABH	NETHERLANDS
ABL	CANADA-English
ABM	LATIN AMERICA
ABN	NORWAY
ABP	SWITZERLAND-German
ABQ	SWITZERLAND-French
ABR	REP. OF SO. AFRICA—U.S.*
ABS	SWEDEN
ABU	UK/IRELAND
ABW	BELGIUM—Flemish
ABX	FINLAND
ABY	DENMARK
ABZ	ITALY
ACC	UK/IRELAND—U.S.*
ACD	SWITZERLAND—U.S.*
ACE	DENMARK—U.S.*
ACF	JAPAN—U.S.*
ACG	AUSTRALIA—U.S.*

*U.S. Keyboard, local power cord

Non-Required Warranty Option:

W03 Convert 1 year warranty to 90 days on-site

Cable Accessories:

40242M	US/European modem
40242X	HP direct connect 232
40242G	RS232C printer

Note: All cables provide RFI filtering. The HP 700/92 complies with RFI regulations only when used with these cables.

Technical information in this document is subject to change without notice.

HEWLETT PACKARD

Printed in U.S.A. 8/87
5953-8630

HEWLETT-PACKARD

HP 2235 Series Business Printers

Data Sheet

Fast, Rugged Operation

The new HP RuggedWriter 480 Printer offers *top-quality* 24-wire impact printing that's fast – 480-cps draft and 240-cps letter-quality printing. And it's rugged – durable and hardworking – designed for printing with excellent reliability.

A Multi-user Printer for Multiple Applications

When several users share the RuggedWriter 480 Printer, it zips through many tasks: top-quality letters, multipart forms, or spreadsheets.

Three independent paper paths accommodate hand-fed paper, tractor-fed paper and the sheet feeder accessory.

A Dedicated Printer for Transaction Applications

If you need a dedicated printer for transactions like purchase orders, shipping documents, paychecks or invoices, you can depend on the RuggedWriter 480 Printer. With a minimum of attention, it performs such tasks quickly, efficiently, and reliably.

Full Compatibility for Applications Flexibility

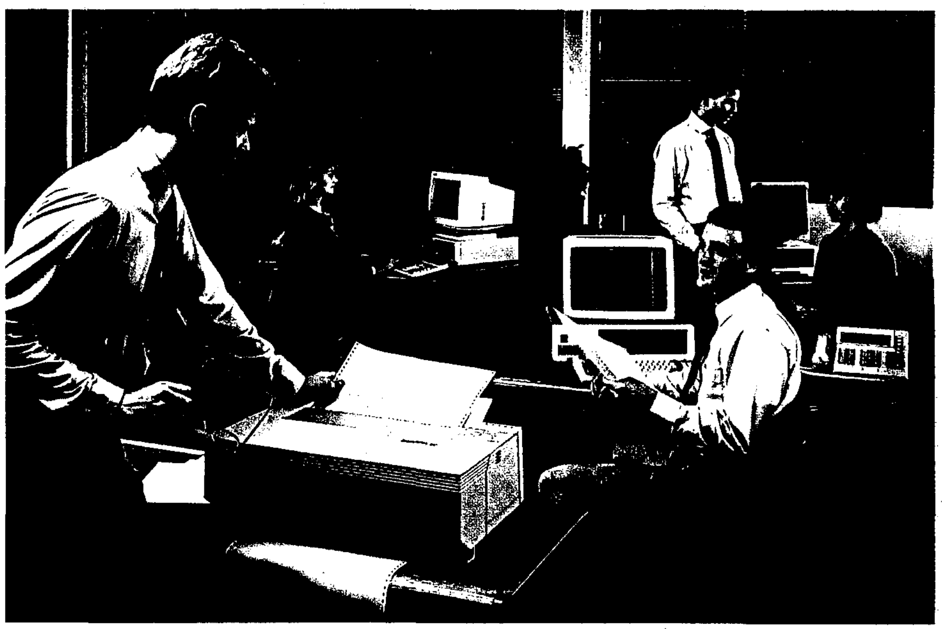
The RuggedWriter 480 Printer has a dual I/O (HP-IB or Centronics parallel and serial) for use with a variety of computer systems. It supports most popular software via HP and Epson command languages.

****

Winning Features

- 480/240 cps
- 20,000 hours MTBF
- Triple paper path
- Built-in tractors
- Quiet operation
- Dual I/O

****



FEATURES	BENEFITS
High-speed 24-wire, impact printing • 480-cps draft • 240-cps letter-quality	Provides fast, quality business printing for a variety of tasks – letters, multipart forms, reports, and program listings, to name a few.
Rugged and reliable • 20,000 hours MTBF (mean time between failures)	Keeps on printing and gets the job done on time – even handles high-volume printing with virtually trouble-free operation.
Industry compatible • HP and Epson printers • HP and IBM PCs	Works with a variety of computer systems, personal computers, software, graphics, preprinted forms.
Comprehensive print features • Full range of print pitches • Bold, underline, and italics • Superscripts and subscripts • Proportional spacing	Provides the printing versatility needed by today's business and technical professionals. A full range of print styles and pitches accommodate both custom and industry-standard preprinted forms.
Three paper paths • Z-fold paper • Cut-sheet paper • Hand-fed sheets	Allows you to conveniently handle all kinds of printing and to preload both z-fold and cut sheets for maximum time savings.
Adjustable tractors • Handles paper up to 15" wide	Allows full-size printing of spreadsheets and program listings.
Convenient key pad • Key-selectable print modes, paper movement, and paper paths	Saves time because print selections are easy to learn and easy to use.
Character cartridge accessory	Expands printing capability with four additional print styles and 16K RAM.

Specifications

Print Speed	Draft mode: 480 cps (12 cpi) Letter-quality mode: 240 cps (12 cpi)
Character Structure	Draft mode: 12×12 Letter-quality mode: 36×24 Wire size: .28 mm (.011")
Character Sets	PCL Mode: HP Roman8, PC-8(Dk/No), JISASCII, ECMA-94Latin1, ISO 7-bit languages (support UK, Germany, France, Italy, Norway, Sweden, Spain, Portugal) EPSON Mode: PC-8(Dk/No), Epson 7-bit languages (support USA, England, Germany, France, Italy, Norway, Sweden, Spain, Japan, Denmark, DenmarkII, SpainII, and Latin America)
Graphics	Resolution for PCL mode format: 90×90 normal, 180×180 high resolution Resolution for Epson mode format: 60×60, 60×180, 80×60, 90×180, 90×60, 120×180, 120×60, 180×180, 240×60, 360×180
Printing Format	For PCL mode control format: 10 - Pica (136 columns) 12 - Elite (163 columns) 16.7 - Compressed (227 columns) 20 - Compressed (272 columns) 5 - Expanded (68 columns). For Epson mode control format: 10 - Pica (136 columns) 12 - Elite (163 columns) 15 - Compressed (204 columns) 17.13 - Compressed (232 columns) 20 - Compressed (272 columns) 5 - Expanded (68 columns) 6 - Expanded (81 columns) 8.53 - Expanded (116 columns). Both (PCL/Epson) format: Proportional space Sub/superscript, italics, bold, and underline available in all pitches. Line spacing variable
Operational Modes	Switch selectable Epson and HP modes
Command Language and Emulation	HP Printer Command Language PCL Level 3; Epson Esc/P (LQ-1000/LQ-1500)
Paper Handling	Triple paper path: Adjustable tractors, Friction feed, Single bin sheet feeder accessory (up to 100 sheet capacity). Auto paper load 4-part forms Last-form tearoff
Forms/Paper Requirements	Tractor forms: maximum width (edge to edge) 380mm (14.95"), minimum width (hole to hole) 76.2mm (3"), forms thickness maximum .3mm (.012") Hand fed paper: maximum width 370mm (14.57") Paper length minimum: 104.14mm (4.1") Printable line: 345.4mm (13.6") maximum
Key Pad	Keys: On-line, Select Print Mode, Up Arrow, Down Arrow, Select Paper Path, Form Feed, Line Feed Indicators: Ready, Tractor Fed, Bin Fed, Hand Fed, Draft, Compressed, Letter Quality
Power Requirements	Input voltage: 100, 120, 220, 240 volts AC (+10%, −10%), user selectable All voltages: 47.5/63 Hz Power consumption: 20 W. maximum non-printing; 80 W. maximum printing
Interface and Datacomm	Dual I/O: HP2235A/C: Centronics Parallel, RS-232 Serial. HP2235B/D: HP-IB, RS-232 Serial Xon/Xoff Protocol, DTR Busy Handshake
Environmental	Operating temperature: 5°C (41°F) to 40°C (104°F) Storage temperature: −40°C (−40°F) to 70°C (158°F) Acoustics per ISO SP 7779 standard: Sound pressure level-Lpa: 56 dB(A) tested in draft mode with cut sheet feeder @ 1 meter bystander position. Humidity: 15% to 80% RH, noncondensing
Physical Specifications	209mm (8.2") H×600mm (23.6") W×350mm (13.7") D 15.9 kg (35 lbs.) net weight
Product Certifications	UL, CSA, IEC Compliance. FCC Class B certified per FCC Rules, Part 15, subpart J, when used with a Class B computing device.
Buffer	2K (Optional 16K with character cartridge)
Reliability and Duty Cycle	No duty cycle limitations; MTBF 20,000 hours based on 2000 hours power-on and 25,000 printed pages annual usage.

Print Sample:

Draft:
This is Draft Font 6 point
This is Draft Font 7 point
This is Draft Font 10 point
This is Draft Font 12 point
This is Draft
Font 24 point

Letter Quality:
This is Courier 10 point
This is Courier 12 point

Ordering Information

HP2235A - Centronics parallel and RS-232 dual I/O without sheetfeeder
HP2235B - HP-IB and RS-232 dual I/O without sheetfeeder
HP2235C - Centronics parallel and RS-232 dual I/O with sheetfeeder
HP2235D - HP-IB and RS-232 dual I/O with sheetfeeder

The standard unit includes: printer, power cord, ribbon, owner's manual. Sheetfeeder accessory is included for HP2235C and HP2235D. Power supply voltage is user-configurable to 100, 120, 220, or 240V. Cables must be ordered separately.

Supplies and Accessories

Number	Description
12235A	Font Cartridge (Includes: Prestige Elite 12, Letter Gothic 12, TmsRmn PS, Helv 10, 16K RAM for download or buffer.)
12235C	Demo Cartridge
12239A	Single-bin Sheet Feeder (8½"×11" size)
12239B	Single-bin Sheet Feeder (EUR A-4 size paper)
92166A	Desktop Printer Stand
92214P	Floor Printer Stand
92156S	Ribbon (5 million draft character-life)
02235-90002	HP RuggedWriter 480 Owner's Manual
02235-90003	HP RuggedWriter 480 Service Manual

12235A Font Cartridge: Print Samples

This is Letter Gothic 12 point
This is Prestige Elite 12 point
This is TmsRmn 12 point
This is Helv 10 point

Order by phone:
Austria: (0222) 2500-0 • Belguim/Luxembourg: (02) 761 31 11 • Denmark: (02) 81 66 40 • Finland: (0) 887 21 • France: (1) 60 77 83 83 • Iceland: (1) 67 10 00 • Ireland: (1) 60 88 00 • Italy: (2) 92 36 91 • Mediterranean and Middle East: Geneva – (22) 83 11 11 • Norway: (2) 24 60 90 • Scotland: (31) 331-1188 • South Africa: Johannesburg– (011) 802 5111; Cape Town – (021) 53 7954; Durban – (031) 28 4178 • Spain: (1) 637 00 11 0 • Sweden: (8) 750 20 00 • The Netherlands: (20) 547 69 11 • Switzerland: Widen – (57) 31 21 11; Meyrin – (22) 83 11 11; Lugano – (91) 22 78 31 • United Kingdom: (344) 773100 • United States: 800-538-8787 • West Germany: (6172) 400-0

Interface and Cable Requirements

HP/NON-HP HOST	PRINTER I/O	HOST INTERFACE	HP CABLE
Touchscreen PC/150	Serial	Built-in	13242G
	HP-IB	Built-in	10833A/B/C/D
Vectra PC	Parallel	HP24540A	24542D
	Serial	HP24541A (25-pin)	13242G
		HP24540A/41A (9-pin)	24542G
HP 250/260	Serial	See 250/260 documentation	13242N/M
HP1000 A/E/F	Serial	12040 C/D/ Multiplexer	92219G
	HP-IB	12009A HP-IB	10833 A/B/C/D
HP3000 (3X, 4X, 5X, 6X, 70, Micro3000, Micro3000XE)	Serial	ADCC and ATP (25 pin) or	13242Y, 92219G, or 13242N
		ATP (3-pin)	13242X
HP9000(200,300,500)	HPIB	Built-in	10833 A/B/C/D
HP2392/93/94/97 Terminal	Parallel	Opt. 093 or HP40210P	13242D or 40242D
	Serial	Opt. 092 or HP40210R	13242G or 40242G
IBM PC Family and compatibles	Parallel	IBM Parallel Printer Adaptor or HP24540A	24542D
	Serial	IBM Asyn. Com. Adaptor (25-pin)	13242H
		IBM Serial/Parallel Adaptor (9-pin)	24542G

HEWLETT PACKARD

For more information, call your local HP Sales Office.
Or write to Hewlett-Packard: 1820 Embarcadero Road, Palo Alto, CA 94303.

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5954-9944

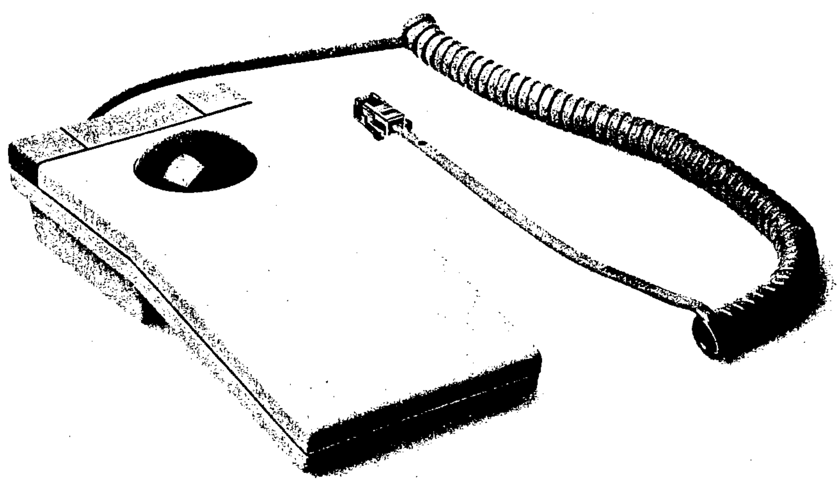
Technical Information

HEWLETT PACKARD

HP M1309A
Trackball

Features

- **Precise cursor control with Trackball movements.**
- **Saves space by remaining stationary on work surface.**
- **Easier to use than many other mouse devices.**
- **Easy to use in difficult locations.**
- **Ergonomic design.**
- **Simple 3-button-operation.**



Functional Description

The HP M1309A is a Hewlett-Packard interface device which is used as a human-interface loop, and is compatible with all HP digital instruments which operate with the HP-HIL protocol.

Technical Specifications

Electrical Specifications
HP-HIL Protocol

Dimensions
90 mm (3.5 inches) wide
207 mm (8.0 inches) deep
54 mm (2.0 inches) high

Weight
330 g (0.73 lb)

Standards
Meets FCC requirements
UL approved

Accessories Supplied

HP-HIL cable assembly	46020-60001
User Manual	M1309-90001

For more information, contact:
Hewlett-Packard Company
Medical Products Group
3000, Minuteman Road, Andover MA 01810 1085
Or contact your local HP sales office, or nearest regional office:
In United States,
East (301) 258-2000, **Midwest** (312) 255-9800,
South (404) 955-1500, **West** (213) 877-1282.

In Canada,
Hewlett-Packard (Canada) Ltd.
6877 Goreway Drive
Mississauga, Ontario L4V 1M8
In Europe,
Hewlett-Packard S.A.
150, Route du Nant-d'Avril
P.O. Box CH-1217, Meyrin 2
Geneva, Switzerland

In Japan,
Yokogawa-Hewlett-Packard Ltd.
3-29-21, Takaido-Higashi 3-chome
Suginami-ku, Tokyo 168
Other International Areas,
Hewlett-Packard Intercontinental Headquarters
3495 Deer Creek Road
Palo Alto, California 94304
(415) 857-1501

HEWLETT PACKARD

Subject to modification
5954-2397

Hewlett-Packard GmbH, D-7030 Böblingen, 3/88

Your application software running on UNIX* systems will improve the overall efficiency and productivity of your computer operations. The UNIX operating system, as a standard, can save you development time and money. Easy portability will maximize your return on investment for generating or purchasing software, as well. And networking standards with the UNIX operating system provide greater connectivity of new and existing systems.

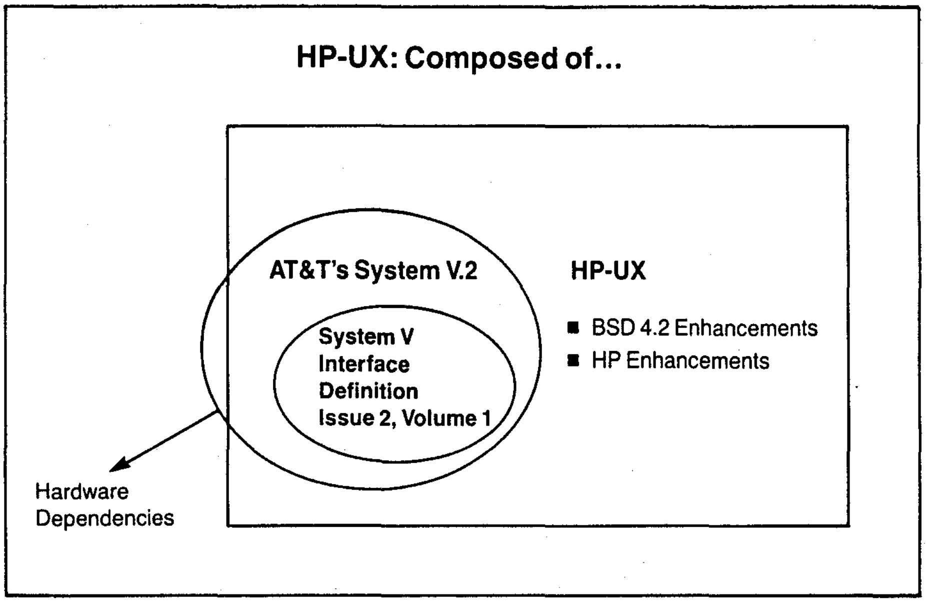
HP-UX is HewlettPackard's implementation of AT&T's UNIX System V.

HP has not only met the UNIX System V industry standard with HP-UX, but has enhanced it with value-added features that improve performance and response time, increase system control for real-time use, and allow easy adaptation of software to meet the needs of international markets.

Excellent for Software Development

The UNIX operating system was explicitly designed to facilitate software development and has a reputation as a premiere system for software developers.

The UNIX operating system contains over 200 utilities. Some perform simple, widely applicable tasks, while others automate complex operations commonly performed by programmers. The UNIX operating system also offers some unique and powerful tools rarely found in other operating systems. The ability to share files, pass messages and communicate within the project team is critical to software development. The hierarchical file system, electronic mail, electronic bulletin board and other UNIX operating system features greatly facilitate this communication process and enhance programmer productivity.



HP-UX is a superset of AT&T UNIX System V, SVID Issue 2, Volume 1, incorporating the best capabilities of Berkeley 4.2, plus value-added from HP for real-time and native language support.

The power and versatility of UNIX operating system and its broad range of utilities and communication features make it excellent for program development. It greatly increases programmer productivity, decreases software development costs, and enhances your competitive edge.

Abundant Application Software

The strength and acceptance of the UNIX operating system as a standard has caused a wide body of application software to be developed for it. One of the most significant benefits is the quantity and variety of software tools and applications available for UNIX systems.

*UNIX is a registered trademark of AT&T in the U.S.A. and other countries.

HP-UX Meets the Standard for Compatibility

HP-UX meets all requirements for full adherence to the industry standard—AT&T's UNIX System V Operating System. AT&T wrote the System V Interface Definition (SVID) to define the external interfaces required on all System V environments. HP-UX has demonstrated compliance with the SVID, Issue 2, Volume 1 by passing the System V Verification Suite (SVVS) issued by AT&T. HP-UX subsystems meet standards in other areas as well, ranging from networking to languages, database and graphics.
In addition to meeting these standards, HP actively supports new standards by participating on many industry standards committees.

HP-UX Goes Beyond the Standard

Hewlett-Packard has always been committed to providing products that make a contribution. HP-UX goes beyond industry standards to make contributions with value-added features, many of which are unique in the industry.

Real-time

HP-UX offers a high level of performance for real-time applications and provides excellent and predictable response time to external interrupts. This is made possible by kernel preemption, which allows the operating system to interrupt itself in order to schedule higher priority programs.

To allow you to control what the system does and when it does it, HP-UX has incorporated real-time features such as priority scheduling, memory locking, and device and file locking. Its preemptive, priority-based program scheduling allows the system to process higher priority interrupts in a pre-determined and predictable way. Memory locking allows a program to lock itself, its data, or shared data into memory and keep it there for fastest response time to unanticipated external events.

Features such as Unbuffered I/O and Driver Asynchronous I/O allow I/O capabilities to be tailored to the task at hand. Driver Asynchronous I/O is used to read and write to several devices without waiting for completion. Unbuffered I/O ensures maximum speed and is useful in high speed data acquisition applications.

Native Language Support

Localization is the process of adapting a software application for use in different countries. Often a user's native language or data processing requirements differ dramatically from those in the software developer's environment. Native Language Support's (NLS) set of HP-UX tools allow you to develop applications that are localizeable without source code modification. NLS can adapt sixteen different character sets (including Kanji) to local language needs. Additionally, NLS provides for regional and country requirements, such as date, time, and decimal number formatting. The interfaces for the X/OPEN Native Language System have been derived from those of the Native Language Support system developed by HP.

Quality, Support and Training

HP's 48-year reputation for excellent products and customer satisfaction further differentiate HP-UX from other computers running a UNIX operating system. In the HP tradition, quality has been "built in" to the HP-UX operating system, resulting in an extremely reliable product.

HP-UX is a powerful and flexible standard enhanced by HP's value-added features and industry-leading quality, support and training. It is the platform for meeting your computing needs—now and in the future.

If you would like more information on HP-UX, contact your local HP sales office or refer to "HP 9000 HP-UX Operating System: A Technical Supplement," PN 5954-8291.

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Printed in U.S.A. 8/87
5954-9459

APPENDIX B

DATA ACQUISITION HARDWARE

Table B-1

CABLE VESSEL DAS SYSTEM COMPONENTS

Item #	Description	Vendor/Mfg	Qty	Spare
1	IBM PC AT 100% Compatible Computer with MS-DOS (PC-DOS), an 80287 math coprocessor and the following enhancements:	TBD	1	1
1a	1.2 MB 5-1/4" Disk Drive	TBD	1	1
1b	360 KB 5-1/4" Disk Drive	TBD	1	1
1c	100 MB Hard Disk	TBD	1	1
1d	Archival Storage Device - Tape Streamer	TBD	1	1
1e	Parallel Printer Interface card - also includes 1 serial port main memory expansion to 640K and 1MB extended memory.	AST (6 PAK) (Premium)	1	1
1f	EGA Video Adapter Card	TBD	1	1
1g	Mouse Bus Adapter Card	TBD	1	1
1h	Audio Input/Output Card	Antex (VP-620E)	1	1
1i	Serial Interface Board with at least 4 RS-232 ports, each capable of 19.2 Kb and 38.4 Kb. An RS-422/485 adapter is required for each port used.	Sealevel (COMM+4)	1	1
		Sealevel (FP-422)	4	1
1j	High speed Analog to Digital (A-D) Converter with at least 4 Differential Input Channels, 12 Bits + Sign Resolution, 100 microsecond settling time.	Sealevel (ADC-01)	1	1
1k	Standard PC AT Keyboard	(Included)	1	1

2	Color Monitor (14") - EGA compatible, with swivel base, rubber feet and a filter to reduce glare.	TBD	1	1
3	Printer Plotter - HP LaserJet Series II	Hewlett Packard	1	1
4	Mouse-trak (3 button) - Desktop trackball with mouse interface	ITAC (MQ3)	1	1
5	Amplifier and Loudspeaker	Radio Sh.	1	1
6a	RF Modem - 9600 Baud, capable of communicating in both directions, DB25 connectors, 110 VAC 60Hz power.	Repco (RDS 9600)	1	1
6b	Antenna, Mounting Device and Cable for RF Modem	TBD	1	1
7a	Waverider with Internal Transmitter and Shipboard Receiver	Datawell	1	0
7b	Antenna, Mounting Device and Cable for Waverider Receiver	TBD	1	1
8	Stern Instrumentation Package (Vertical Stabilized Accelerometer containing a gimbal mounted electrically driven gyroscope) to measure: Vertical Acceleration/Heave (Accelerometer) Pitch (Gimbal Sensor) Roll (Gimbal Sensor)	Humphrey (SA09-) (0101-1)	1	1
	A mating power supply/inverter is required to provide single phase (115v,400Hz) power for the gyroscope motor. This inverter requires 27.5 VDC as input power.	Humphrey (PS27-) (0101-1)	1	1
	Weather Proof Housing for the Stern Instrumentation Package - The equipment is delivered	TBD	1	0

	in a sturdy tubular housing, but must be enclosed in a water-tight mounting package which will be manufactured locally.			
9	Power Supply for Stern Instrumentation Package: (27.5 VDC nominal, 1.8 A) , (-15 VDC -0- +15 VDC , 10 Milli-amperes, regulated and noise-free) & (-5 VDC -0- +5 VDC, Balanced, 10 Milli-amperes, regulated and noise-free).	Coastal Leasing	1	0
10a	Acoustic Navigation Computer	Oceano	1	0
10b	Acoustic Navigation Transducer	Oceano	1	0
11	Uninterruptible Power Supply for Computer, Peripherals and Modem	Coastal Leasing	1	0

Table B-2

SUPPORT VESSEL DAS SYSTEM COMPONENTS

Item #	Description	Vendor/Mfg	Qty	Spare
21	IBM PC AT 100% Compatible Computer with MS-DOS (PC-DOS), an 80287 math coprocessor and the following enhancements:	TBD	1	1
21a	1.2 MB 5-1/4" Disk Drive	TBD	1	1
21b	360 KB 5-1/4" Disk Drive	TBD	1	1
21c	50 MB Hard Disk	TBD	1	1
21d	Parallel Printer Interface card - also includes 1 serial port and memory expansion to 640K.	AST (6 PAK) (Premium)	1	1
21e	EGA Video Adapter Card	TBD	1	1
21f	Mouse Bus Adapter Card	TBD	1	1
21g	Audio Input/Output Card	Antex (VP-620E)	1	1
21h	Serial Interface Board with at least 2 RS-232 ports, each capable of 19.2 Kb and 38.4Kb. An RS-422/485 adapter is required for each port used.	Sealevel (COMM+4)	1	1
		Sealevel (FP-422)	2	1
21j	Standard PC AT Keyboard	(Included)	1	1
22	Color Monitor (14") - EGA compatible, with swivel base, rubber feet and a filter to reduce glare.	TBD	1	1
23	Printer Plotter - HP LaserJet Series II	Hewlett Packard	1	1
24	Mouse-trak (3 button) - Desktop trackball with mouse interface	ITAC (MQ3)	1	1

25	Amplifier and Loudspeaker	Radio Sh.	1	1
26a	RF Modem - 9600 Baud, capable of communicating in both directions, DB25 connectors, 110 VAC 60Hz power.	Repco (RDS 9600)	1	1
26b	Antenna, Mounting Device and Cable for RF Modem	TBD	1	0
27a	Acoustic Doppler Current Profile (ADCP) Processor	Evans & Hamilton	1	0
27b	Acoustic Doppler Current Profile Instrumentation (Transducer and Cable)	Evans & Hamilton	1	0
28	Uninterruptible Power Supply for Computer, Peripherals and Modem	Coastal Leasing	1	0
29	Range-Range System for Support Vessel Navigation (uses same ground stations as Syledis on Cable Vessel)	Syledis	1	0

Table B-3

DAS SYSTEM INTERCONNECTION CABLES

Item #	Description	Vendor/Mfg	Qty	Spare
1	Cable to connect PC AT/XT parallel interface to printer - 25 ft with connectors at both ends.	TBD	2	1
2	Plastic Covered Shielded single conductor audio cable with 'RCA' phono plugs at both ends to connect audio output card to amplifier - 25 ft.	TBD	2	1
3	Speaker wire (2 - conductor) to connect audio amplifier to loudspeaker - 25 ft.	TBD	2	1
4	Coaxial RF Cable to connect RF Modem to its Antenna - 100 ft.	TBD	2	1
5	Coaxial RF Cable to connect WaveRider Receiver to its Antenna - 100 ft.	TBD	1	1
6	RS-232C Cables - These cables must all have the full IEEE - specified conductor compliment including hardware protocol control lines:			
6a	DAS Computer to RF Modem - 10 ft.	TBD	2	1
6b	DAS (C/V) Computer to ICS Computer - 50 ft.	TBD	1	1
6c	DAS (C/V) Computer to FS3 MicroVAX - 200 ft. (shielded)	TBD	1	1
6d	DAS (C/V) Computer to the Acoustic Navigation (AP) Computer - 50 ft.	TBD	1	1
6e	DAS (S/V) Computer to the Acoustic Doppler Current Profile Computer - 50 ft.	TBD	1	1

7	Two (2) Conductor Shielded Cable to connect WaveRider Receiver analog output to DAS (C/V) Computer A-D Converter Input Channel -25 ft.	TBD	1	1
8	Eight (8) Conductor Shielded Cable to carry Stern Accelerometer Package Signal Output to the DAS (C/V) Computer A-D Input Channel - 250 ft.	TBD	1	1
9	Four (4) Conductor Power Cable to furnish 27.5 VDC and 110 VAC to the support power supplies located in the Stern Accelerometer Package. Should be rated at 15 amperes - 250 ft.	TBD	1	1

Table B-4

SYSTEM DEVELOPMENT, UTILITY
and TOOLBOX
SOFTWARE

Item #	Description	Vendor/Mfg	Qty
1	Turbo PASCAL - Version 5.0	Borland Internat'l	1
2	Turbo Graphix Toolbox	Borland Internat'l	1
3	Turbo Toolbox	Borland Internat'l	1
4	Turbo Asynch	Blaise Computing	1
5	HALO (Turbo Pascal Version)	Media Cybernetics	1
6	COMMBUFF - Communications Buffer Software	Sealevel Systems	1
7	COMMBIOS - Serial Port Device Driver and Language Interface	Sealevel Systems	1
8	COMM-UTILITY - Communications Utility Program	Sealevel Systems	1
9	MID - Multiline Interrupt Driver	Personal Computing Tools	1
10	LINK-VIEW - Async Data Link Analyser for the IBM PC	Syltel Information Systems	1