REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	November 30, 1999	Final Report (6-96-12/31/97)

4. TITLE AND SUBTITLE
Scientific Information System for R/V Roger Revelle

5. FUNDING NUMBERS
31101A
N00014-96-1-0702

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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
ONR CODE 321RF

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

19991220 105

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
UNLIMITED

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

R/V Roger Revelle has been equipped with a Scientific Information System (SIS) which consists of a centralized multiprocessor UNIX computer server that receives, logs, processes, displays and broadcasts data in real-time over an Ethernet network and via serial lines. This computer server is backed by an identical machine used for non real-time data processing applications, and switchable to a real-time mode should the on-line machine fail. Communication between the computer server, the scientific sensors, users' computer workstations (SUN Sparcstations, PCs and Macs) or computer peripherals (disks, CDWORM, and tape drives; printers and plotters) distributed throughout the ship, is achieved via the ship's fiber optics network and the SIS wiring installed after the ship was delivered. Ship-to-shore email communication is handled through the off-line computer server with modem transmissions via INMARSAT. The scientific sensors connected to this Information System include GPS receivers, gyrocompasses, vertical reference units, meteorology sensors, sonars (acoustic Doppler current profiler, multibeam swath bathymetry system, 12kHz/3.5kHz bottom/subbottom profiler) and a magnetometer. All the computers and sensors attached to the SIS network share a common time base provided by a time server synchronized to the GPS reference clock.

14. SUBJECT TERMS
Shipboard Scientific Instrumentation, Information Technology,
Computer Networks, Real-time data logging

15. NUMBER OF PAGES
23

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

Scientific Information System Aboard R/V Roger Revelle

FINAL REPORT

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ABSTRACT

R/V Roger Revelle has been equipped with a Scientific Information System (SIS) which consists of a centralized multiprocessor UNIX computer server that receives, logs, processes, displays and broadcasts data in real-time over an Ethernet network and via serial lines. This computer server is backed by an identical machine used for non real-time data processing applications, and switchable to a real-time mode should the on-line machine fail. Communication between the computer server, the scientific sensors, users' computer workstations (SUN Sparcstations, PCs and Macs) or computer peripherals (disks, CDWORM, and tape drives; printers and plotters) distributed throughout the ship, is achieved via the ship's fiber optics network and the SIS wiring installed after the ship was delivered. Ship-to-shore email communication is handled through the off-line computer server with modem transmissions via INMARSAT. The scientific sensors connected to this Information System include GPS receivers, gyrocompasses, vertical reference units, meteorology sensors, sonars (acoustic Doppler current profiler, multibeam swath bathymetry system, 12kHz/3.5kHz bottom/subbottom profiler) and a magnetometer. All the computers and sensors attached to the SIS network share a common time base provided by a time server synchronized to the GPS reference clock.

I. INTRODUCTION

With funding from the Office of Naval Research, the Shipboard Computer Group of the Shipboard Technical Services (STS) at the Scripps Institution of Oceanography (SIO) configured and installed a Scientific Information System (SIS) aboard R/V Roger Revelle in the Spring of 1996. The core system was tested successfully during the ship's delivery voyage from Pascagoula, MS to San Diego, CA in July 1996. During the ship's post delivery availability, SIO contracted and supervised the installation of a permanent network of SIS cables linking shipboard scientific instruments installed in various parts of the ship to a central location in the Electronics Laboratory. This cabling network became an integral part of the SIS whose data logging, processing, display and broadcasting functions over computer networks have been fully operational since the Summer of 1997.

The general architecture of the SIS is depicted in Figure 1 where the ship's fiber optics network provides the main communication channel linking a centralized computer server, users' workstations, and scientific instruments installed permanently aboard the ship. The computer server is a pair of SUN Microsystems Ultra 2 machines running the UNIX operating system. One machine, named "Randall", is devoted to all real-time applications and the other, named "Revelle", is used for post-processing applications and can be switched to a real-time mode should the on-line machine fail. This second machine also acts as a disk server for dataless workstations (Sparc 5) distributed throughout the ship's laboratories for accessing and processing data off-line.

The sensors interfaced to the computer server include (1) sonar systems such as the SeaBeam 2112 multibeam swath mapping sonar, a conventional 12 kHz echo-sounder, a 3.5 kHz subbottom profiler, an acoustic Doppler current profiler (ADCP); (2) navigation sensors including the ship's gyrocompasses, several GPS receivers, and a time server; (3) geophysical sensors such as a magnetometer; (4) environmental sensors such as an expendable bathythermograph (XBT), an integrated meteorology station (IMET), and conductivity, temperature and depth (CTD) sensors.

All the instruments and computers attached to the SIS network receive time from a single source: a Bancomm Tymserver 2000 NTP time server with a built-in GPS receiver and IRIG-B time code generator. Time is broadcast over Ethernet by the NTP server, and the IRIG-B code is distributed via a dedicated serial line to the instruments that are equipped to receive it. The time server also feeds two remote displays: one on the forward bulkhead of the Electronics Laboratory and one on the Bridge

Navigation information, including time, position, heading, and speed, is compiled into an ASCII message by an Integrated Navigation System (INS) PC and broadcast once a second over an RS-232C serial line. This PC can be run independently of the computer server, thus providing a very simple navigation and positioning option when other instruments are not needed.

Details of the SIS network architecture, its computer systems, and the scientific sensors and their data flows, are provided in this report. This constitutes the final report for ONR contract N00014-96-1-072.

II. SIS NETWORK ARCHITECTURE

As shown in Figure 2A, the SIS computer network is based on the Ethernet standard (IEEE 802.3) with a main hub installed in the 19" racks located at the aft end of the Electronics Laboratory. This hub consists of two 24 port 10-baseT distribution boxes and one 12 port fiber optic hub. The latter routes information over the ship's fiber optic network to seven 12 port 10-baseT hubs installed in the ship's laboratories (one in the Hydro Lab, three in the Main Lab, one in the Analytical Lab and one in the Electronics Lab) and on the Bridge. One of the 24 port 10-baseT hubs is dedicated to the SIS computer servers and PCs, whereas the other serves computer outlets in the crew's and scientists' staterooms as well as in the ship's library and lounge. A separate Ethernet network is devoted to data acquisition and logging to avoid potential network traffic jams that might cause loss of data. This is the real-time network shown in Figure 2B.

The UNIX computer environment includes the two SUN Ultra 2 servers, ten SUN Sparc 5 workstations, three laser printers, two inkjet color printers and one E-size inkjet color plotter, all linked via Ethernet (Figure 3). The E-size HP-755C inkjet color plotter, equipped with postscript software drivers and the additional memory option, is used for post-processing applications requiring large plots. The HP-1600C deskjet printer is used for page-size (8.5x11") color-fill plots. In addition, one HP-4MV laser printer and two HP-4M+ laser printers (one in the Main Lab and one on the Bridge) are used for black & white hardcopy printed outputs of text, software programs or small plots.

Five PCs installed in the 19" racks at the aft end of the Electronics Lab are connected to the Ethernet and their files are accessed through the Network File System management software (PC NFS) running on each of these machines (Figures 1, 4). One of these PCs is used as a console for the UNIX computer server, one is the INS PC and the other three are nominally associated with a scientific instruments (e.g. Sippican MK12 XBT, ADCP, CTD) but can be used for other purposes when the instrument is idle. In parallel with these instrumentation PCs, a number of general purpose PCs and a few Macs are distributed throughout the ship (Library, Lounge, Electronics Lab) and connected to the SIS via Ethernet. PCs installed on the Bridge, in the Bridge Chart room and in the ship's officers staterooms are connected to the SIS in the same fashion.

Cabling for a video network has been installed throughout the ship as part of the ship's post-delivery SIS wiring. A video distribution system, installed in the 19" racks located at the aft end of the Electronics Laboratory, can handle 20 video input channels and drive 64 video monitors. A 14 channel closed circuit television system is interfaced to this video network.

III. SIS COMPUTER SYSTEMS

As seen in Figures 5 and 6, both SUN Ultra 2 computer servers have almost identical peripherals attached, including:

- Twentyfive 4 gigabyte disk drives installed in a dual-port disk server. 40 gigabytes are attached to the on-line machine "Randall", and 60 gigabytes to the off-line machine "Revelle". We opted to install several disk drives with medium storage capacity, rather than a few drives with large storage capacity, to retain enough storage space should one drive fail.

- A 2.2-gigabyte DAT and a 5-gigabyte Exabyte magnetic tape drives and one CD-ROM drive on each machine's SCSI bus. The tape drives are used to unload and archive data from the on-line disks on a daily basis. Two copies of each tape are made to limit the risk of data loss due to faulty magnetic tapes, or stray shipments from foreign ports back to SIO. At the end of each cruise all the data collected are downloaded as well to CD-ROMs for archival purposes, using the CD-WORM drive connected to the off-line computer server "Revelle".

- An S-Bus card with 16 RS-232C ports for serial I/O, one card on each machine. Most of the data acquisition and connections to the pen-plotter or modems, are done via RS-232C serial lines, and since each server already has 2 built-in RS-232C ports, a total of 18 serial I/O lines can be accommodated on each computer server.

- A second SCSI Bus and a second Ethernet connection are installed on each server.

The real-time computer server "Randall" (Figure 5) receives and sends data over RS-232C serial lines and over Ethernet. Serial sources include the GPS receivers (P-Code, Ashtech 3DF, Trimble 200D), the magnetometer, the INS computer and the vertical references. Serial outputs go to the belt-bed pen plotter: a 34" Calcomp 965 4-pen plotter. This plotter is used to display in near real-time bathymetry contours and other underway geophysical data projected on a geographic grid along the ship's navigation track, thus helping to monitor the ship's route and the swath bathymetry output while conducting seafloor surveys. The belt-bed plotter can accommodate overlays, thereby allowing scientists to follow a survey plan or relocate on a seafloor contour map collected previously.

Ethernet connections to sensors include a dedicated Ethernet link for the SeaBeam 2112 sonar system, and the SIS primary Ethernet link for the ADCP sonars, the Bathy2000 bottom profiler sonar, the INS computer, the Sippican MK12 XBT, and a Seabird CTD system. The ship was delivered with a 150 kHz broadband ADCP sonar built by RD Instruments. However this sonar interfered with the ship's 180 kHz ODEC Doppler speed log. A narrowband 150 kHz ADCP has been installed as well, and the SIS has been configured to access data from either type of ADCP, whichever is powered at the time. A 600 kHz speed log has been installed on the ship's hull to avoid acoustic interferences from the ADCP sonars.

The Post Processing computer server "Revelle" (Figure 6) has no scientific instrumentation attached. It obtains data via shared access of the real-time data file available on "Randall". The only RS-232C serial devices connected to "Revelle" are the modem used for ship-to-shore email traffic over INMARSAT B.

The INS shown in Figure 7 is a 486-PC equipped with eight RS-232C serial ports and an 8 channel analog-to-digital converter. Serial data input to the INS include P-Code GPS data, IMET meteorology data, seawater conductivity and temperature data at keel depth, and the ship's gyrocompass output. The INS outputs every 30 s via Ethernet all the data it receives to the real-time server for logging and broadcasting. In addition, the INS formats and sends via RS-232C serial lines to the SeaBeam 2112 sonar system two ASCII messages, one transmitted once a second containing time and navigation information, and the other transmitted every 6 seconds containing the seawater sound speed at keel depth which has been computed from the conductivity and temperature data. The navigation message can be sent also to any other instrument that requires it. To make this INS self-sufficient, a GPS receiver card could provide position information when input from an external GPS receiver is not available. A VGA to video conversion box takes the navigation message created by the INS computer and displays it on a TV monitor in the Main Lab.

A software package developed at SIO for operations aboard R/V Melville has been adapted to and installed on the SIS computer server along with UNIX-based public-domain software packages used for data processing at sea and ashore (e.g. GMT, MBsystem, and Matlab) .

The main functions included in the SIO software package are:

- Acquire data from the various scientific sensors (SeaBeam 2112 bathymetry and acoustic backscatter amplitude; INS, magnetometer, IMET, ADCP) .
- Acquire data from the XBT system, compute a sound speed profile and pick inflection points.
- Merge SeaBeam 2112 bathymetry data with navigation.
- Display data (bathymetry, magnetics, ship position) in near real-time on the belt-bed plotter in geographic coordinates.
- Display SeaBeam 2112 acoustic backscatter amplitude data on X-window terminals.

- Display SeaBeam 2112 instantaneous cross-track bathymetry profiles as a waterfall plot on X-window terminals.
- Archive all data to post-processing system.

Overall, the SIS software packages (i.e. SIO, GMT, MBsystem, Matlab etc.) require about 5 gigabytes of disk storage to maintain the program sources and executables. The Solaris 2.x operating system, associated Fortran and C compilers, and other device drivers occupy 5.7 gigabytes of disk space. Disk space requirements for data logging, processing and display depend on the number of days of data being processed; to log one day of survey data, navigation, swath bathymetry and acoustic backscatter amplitude data requires about 300 megabytes of disk storage.

IV. SIS SENSORS AND THEIR DATA FLOWS

Real-Time Navigation Data Logging (Figure 8)

A set of xxx_drnav programs running on the real-time computer server reads navigation data from GPS receivers or the INS and logs them to disk. One of the data sources is selected by the operator to update every minute the two data files holding the current ship's position: (1) file **saved** that contains only the current position and several related navigation parameters; (2) file **drfil** that contains latitudes, longitudes and times for the latest 1440 position fixes (about 1 day's worth). This file is read by many programs that need navigation data.

Sea Surface Conductivity/ Temperature Sensor System (Figure 9)

Probes for seawater conductivity and temperature manufactured by FSI have been installed in the bow-thruster compartment and in the Hydro Lab (Figure 9). A continuous flow of seawater is extracted at keel depth near the bow and used to derive salinity, temperature and sound speed parameters that are needed to operate the SeaBeam 2112 system. The conductivity and temperature data come out in ASCII format over an RS-232C serial line connected to the INS computer that sends them to the SeaBeam system.

IMET System (Figure 10)

An "IMET" meteorology system consisting of sensors to measure wind speed and direction, hygrometry, sea and air temperature, short and long wave solar radiation, and precipitation has been installed on a mast at the bow. These sensors are interfaced to a PC and the PC-NSF file management software is used to transfer and log the corresponding data to a disk-file on the real-time computer server "Randall".

ODEC BATHY2000 Echo-Sounder (Figure 11)

The PC computer that is part of the ODEC Bathy2000 sonar system has been fitted with (1) an Ethernet board to allow data transfer and logging on the shipboard real-time computer server, and (2) a driver for remote monitor, keyboard and mouse to provide a display of this sonar's output by the winch control located along the forward bulkhead of the Electronics Laboratory.

SEABEAM 2112 Bathymetry And Acoustic Backscatter Amplitude Data (Figure 12-13)

Two PCs were delivered with the SeaBeam 2112 system to serve as operator console and display monitors. To facilitate maintenance, these computers have been installed in a 19" rack adjacent to the SeaBeam 2112 electronics rack and fitted with drivers for remote display, keyboard and mouse (Figure 12). In addition, the host PC of the SeaBeam 2112 system was modified to accept sound speed profiles transfer via ftp over Ethernet.

Bathymetry data are broadcast by the SeaBeam 2112 host computer over a dedicated Ethernet channel using the TCP/IP protocol. A program called SB2100_ether, running on the real-time computer server, receives the data and writes them to an archive data file (sb2100_inpf) in which bathymetry, acoustic backscatter amplitude, and navigation data received from the SeaBeam 2112 system are constantly appended. This file is closed every hour to keep manageable file sizes and provide post-processing access to the data in a timely fashion. This file is read by program SB2100_decode which separates bathymetry and acoustic backscatter amplitude data (sidescan in Figure 13) and (1) stores the bathymetry in a buffer file (rtm.seabeam) that contains data from the latest 5000 pings in a binary format for use by the real-time display programs, and (2) feeds program xvchart to update the greyscale raster display of acoustic backscatter amplitude data appearing on the underway watch workstation monitor.

Program SB2100_merge reads the new data in the rtm.seabeam file, obtains navigation data for the ping from file drfil and returns the data to the same place in the rtm.seabeam (this is a redundant operation because SeaBeam 2112 bathymetry and acoustic backscatter amplitude data are already merged with navigation data when read by program SB2100_ether; however the functionality was kept to maintain compatibility with software used for the SeaBeam 2000 system installed aboard R/V Melville) File rtm.seabeam is then accessed by program SB2100_contour to update the contour plots on the belt-bed plotter, and by program SB2100_waterfall to update the waterfall display of instantaneous cross-track bathymetry profiles appearing on the underway watch workstation monitor.

Once a day (usually at GMT midnight) all the logged data are archived to magnetic tape. This is done by first renaming the data files. SB2100_ether and other logging programs will then open a new file for logging the incoming data. The renamed files are archived on an Exabyte tape. Other underway data such as navigation, time series of magnetics data are also archived on this tape. This data tape can then used by the post-processing system, or the corresponding files can be transferred from on-line disks to off-line disks over Ethernet.

Magnetics Data (Figure 14):

Seafloor magnetic anomaly data are obtained with a Geometrics 886 towed magnetometer that outputs its readings in nT over a serial line. Program read_MAG reads the data from an RS-232C serial port every 4 seconds, appends the current time and writes the data to the log file called MAG886inpf. Once a day, this file is renamed and archived. Program read_MAG sends the current magnetic field value to the sensor electronics once an hour or any time it starts sending data. The magnetometer auto tunes, but on power up it must be initialized with a realistic magnetic field value

Magnetic field values averaged over one minute are written to a circular data file called Magfil. This file is used by program rtmmagplt to plot the magnetic anomaly on the belt-bed plotter in geographic coordinates. In addition, program mag_profile plots the magnetic field in near real-time on an X-window strip chart display and allows the operator to send new tuning values to the sensor when necessary. This feature has been implemented for seafloor regions or ship's headings where the magnetic field strengths are too weak to maintain auto-tuning.

Expendable Bathythermograph (XBT) Data:

An XBT system, consisting of an expendable temperature probe, a launcher and a PC, is used for measuring seawater temperature as a function of depth. This temperature profile is converted to a sound speed profile to be used by the SeaBeam system for refraction corrections. Using the XBT software and the PC-NFS file management software, the data are logged directly on the disk drive of the on-line server. The data are then converted to sound speed and a program selects a subset of inflection points that best represent the profile. If the profile is not deep enough, historical databases (e.g. Carter, Levitus) are used to extend the profile to the desired depth. This sampled sound speed profile is then transferred by ftp via Ethernet to the SeaBeam host computer.

V. CONCLUSION

The Scientific Information System installed aboard R/V Roger Revelle is designed to log and display in real-time data for navigation, meteorology, oceanography, swath bathymetry and seafloor acoustic backscatter imagery, subbottom profiling, magnetics and other underway marine geophysical data. The data collection and real-time processing functions are reserved to an online computer server, and the post-processing function to an offline computer server. This ensures that scientists can access and process the data offline without interfering with data logging.

The SIS is expandable and can accommodate temporary additional computers or sensors to suit the program of a particular research cruise, or new sensors for permanent installation aboard ship (e.g. gravimeter). Likewise, the computer hardware and the various peripherals (disk, tape, CD drives; printers, plotters) can be upgraded without major disruptions to the system.

Future improvements of the SIS must include software for online quality control of the data being logged as well as diagnostics to help scientists and technician recognize and fix problem as they arise.

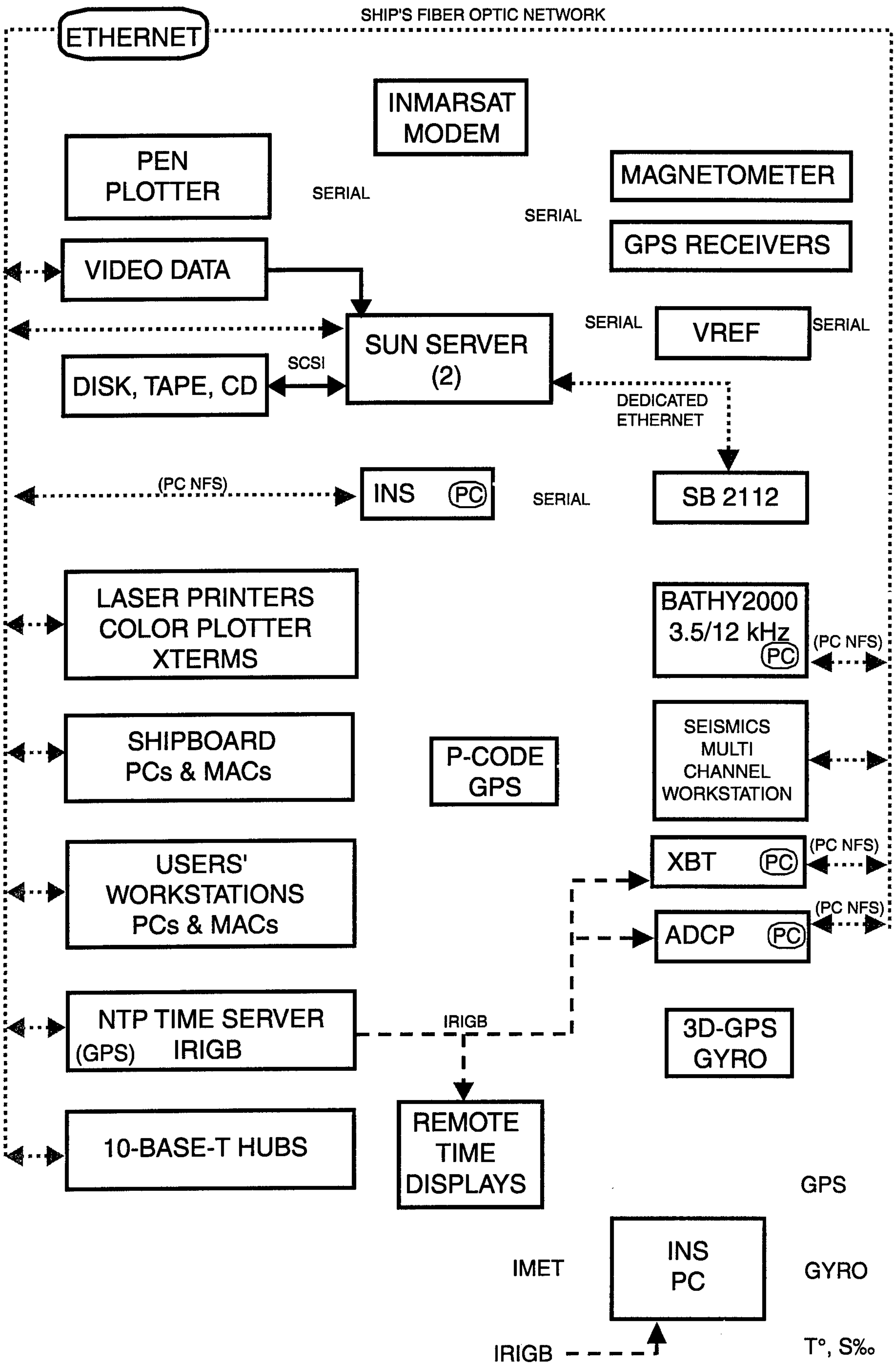

Figure 1. Science Information System Aboard R/V Roger Revelle

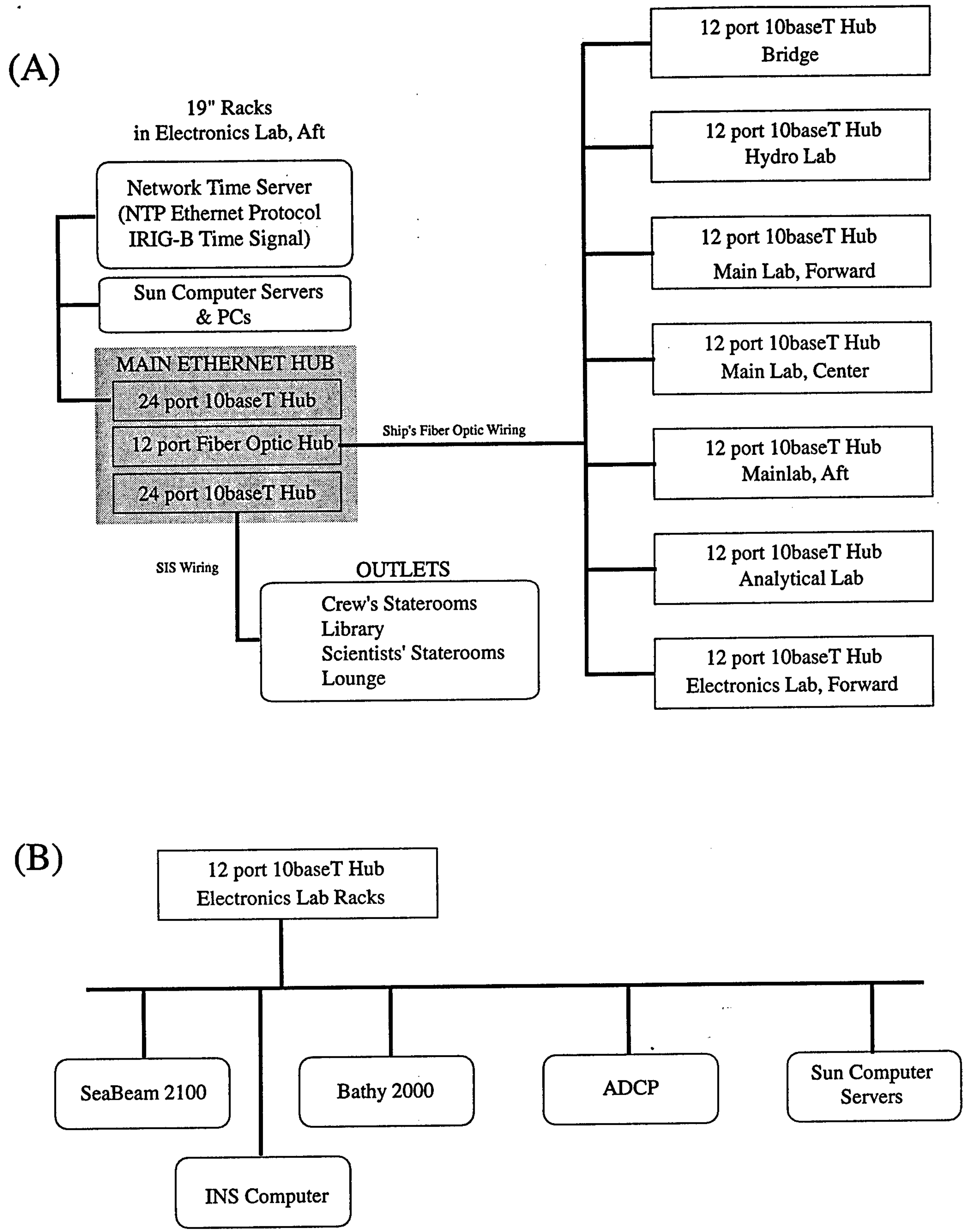

Figure 2. R/V Roger Revelle Ethernet Network (A) Primary, (B) Real-Time. The real-time ethernet is used for data logging computers that have problems surviving on a busy network. All such computers log their data to "Randall".

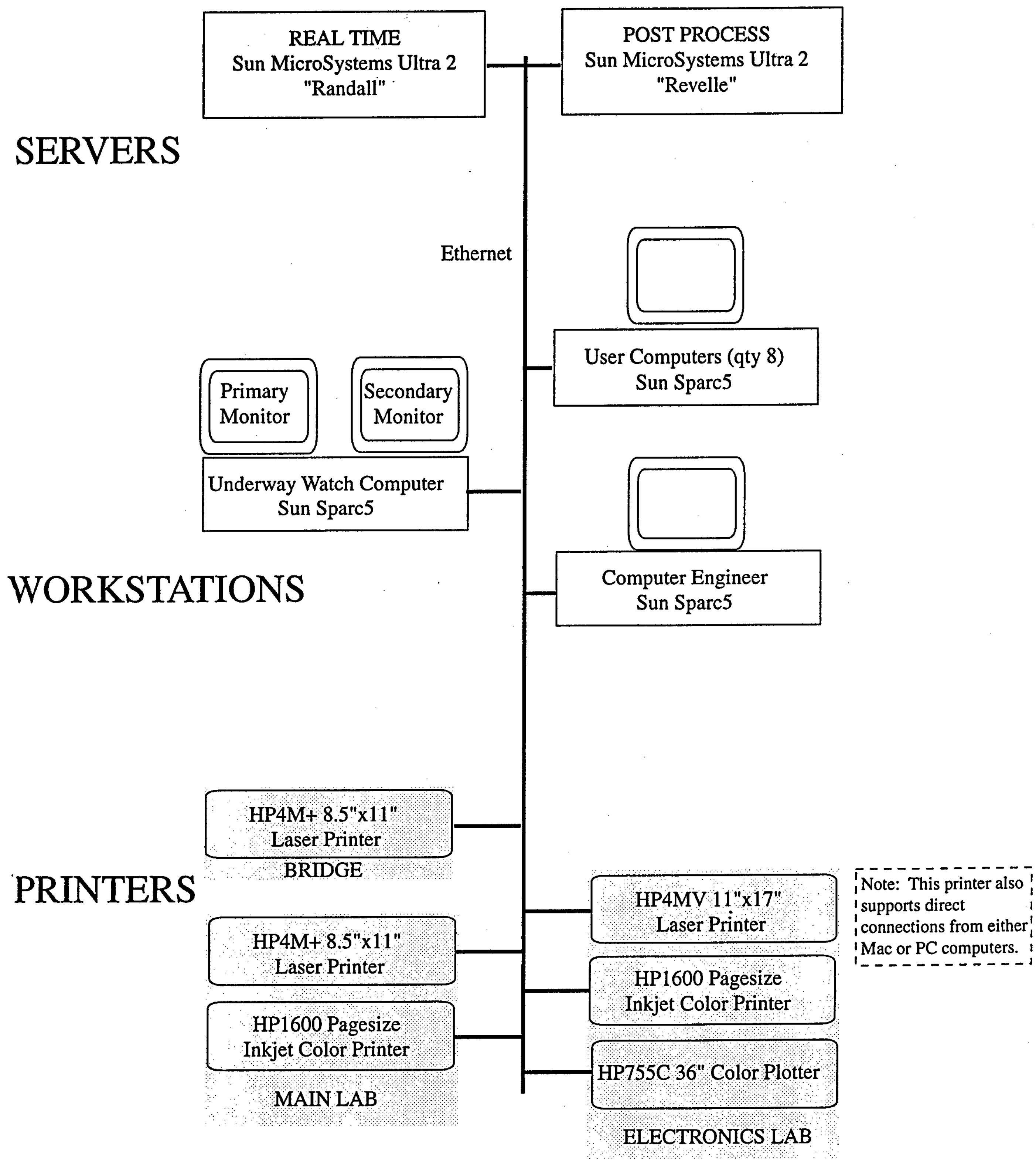

Figure 3. R/V Roger Revelle UNIX Computer System

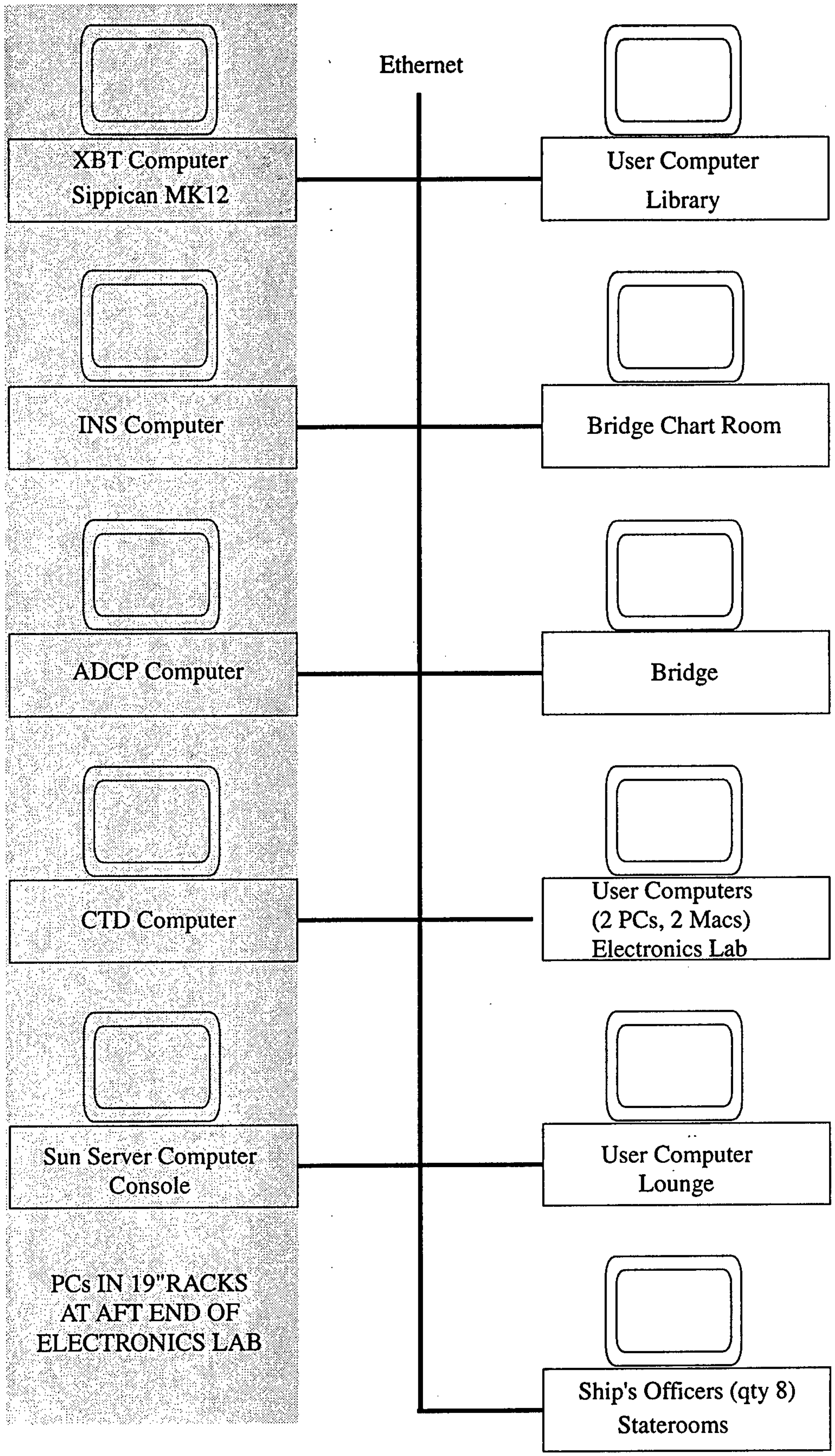

Figure 4. R/V Roger Revelle, Networked PC & Mac Computers

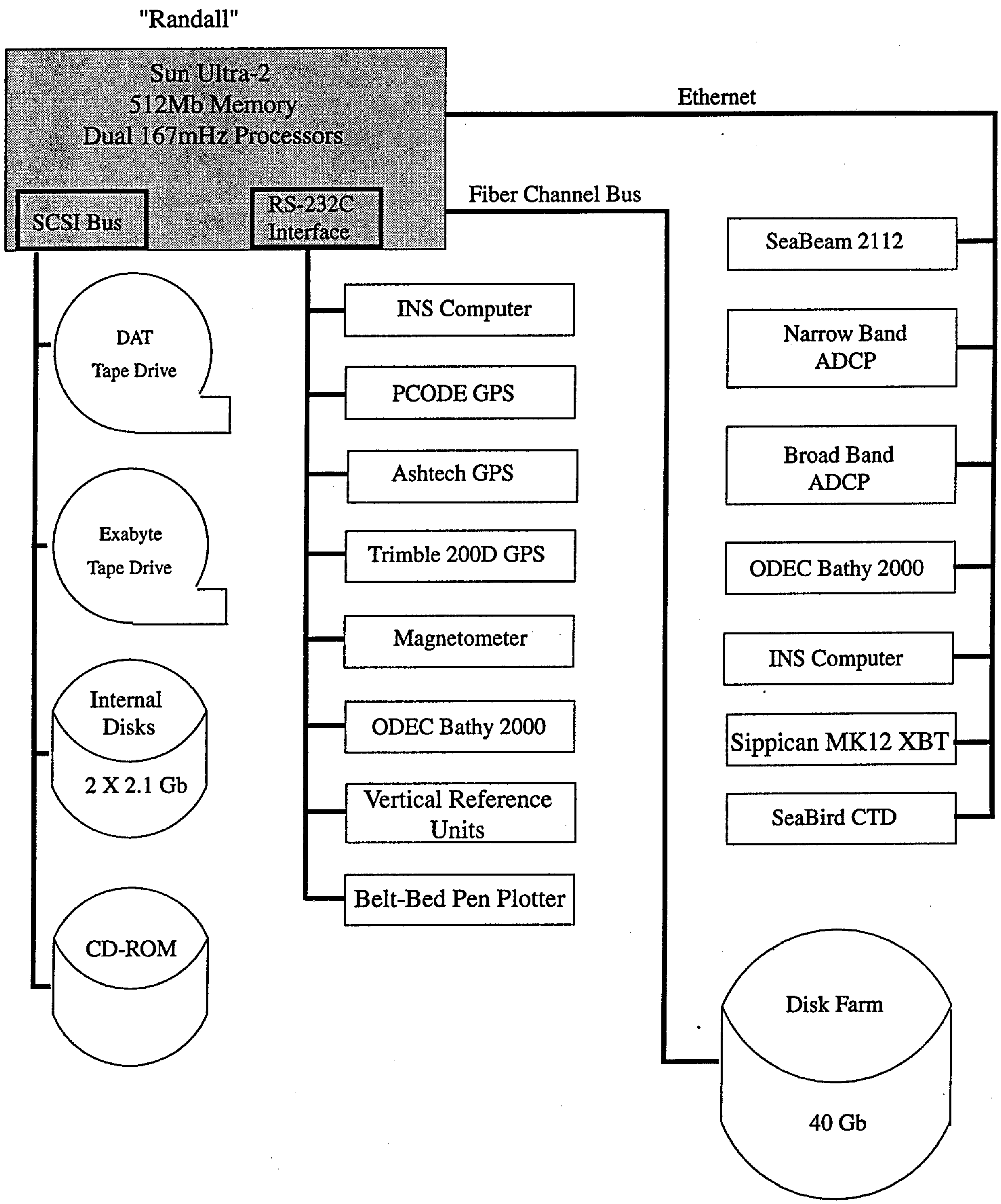

Figure 5. Real-time Data Logging Unix Computer Server "Randall".

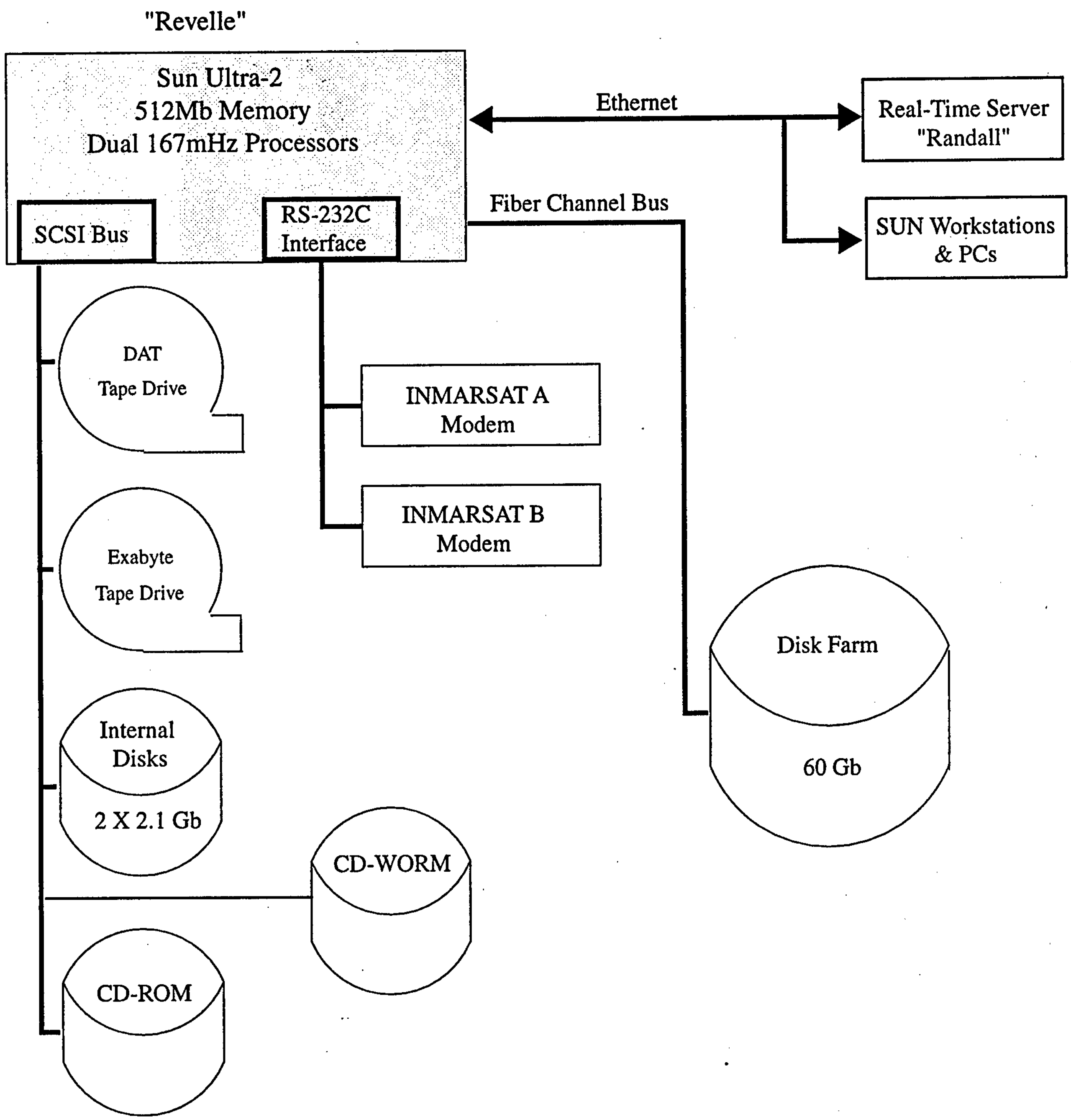

Figure 6. Post Processing Unix Computer Server "Revelle".

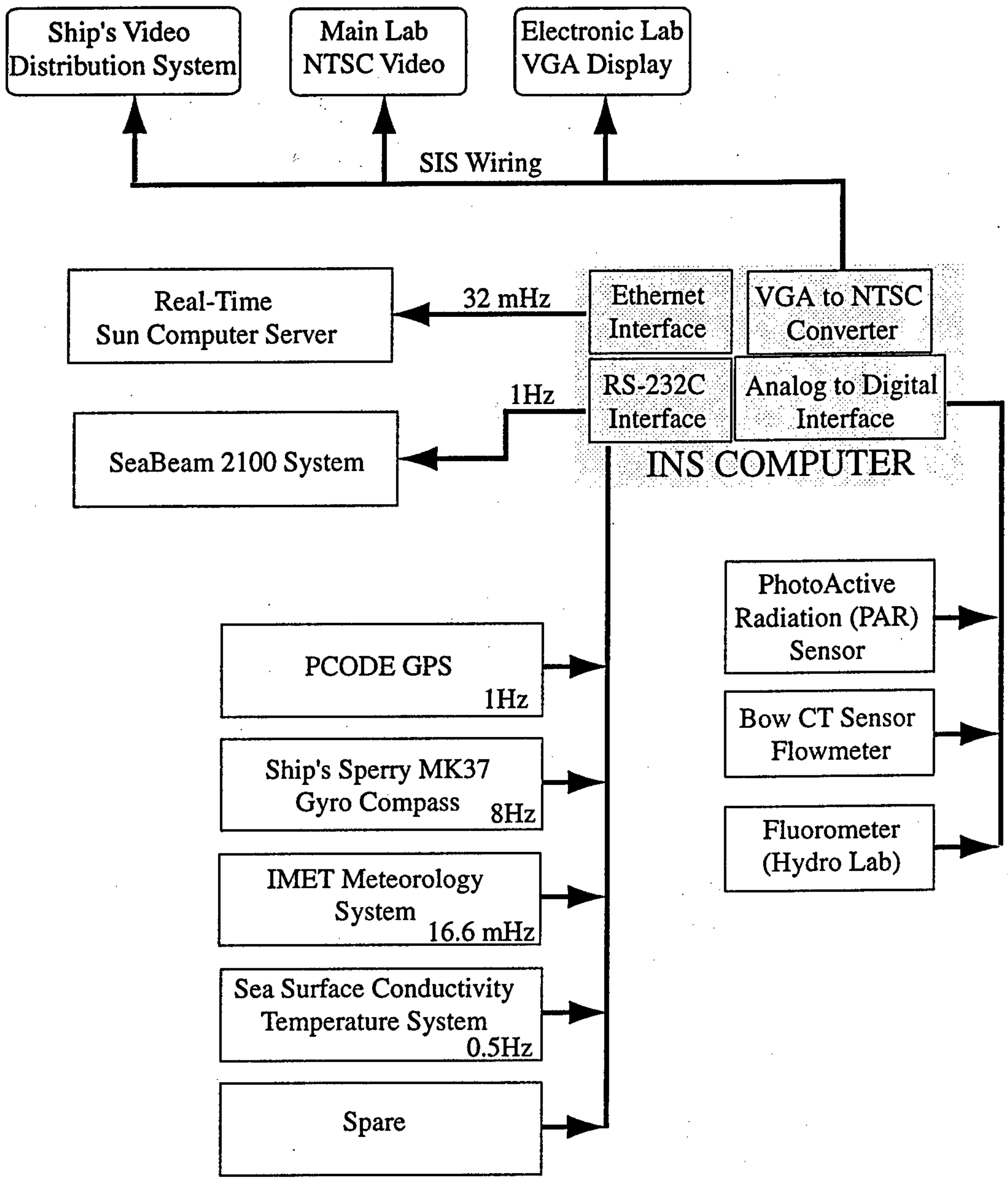

Figure 7. Integrated Navigation System (INS) Computer System.

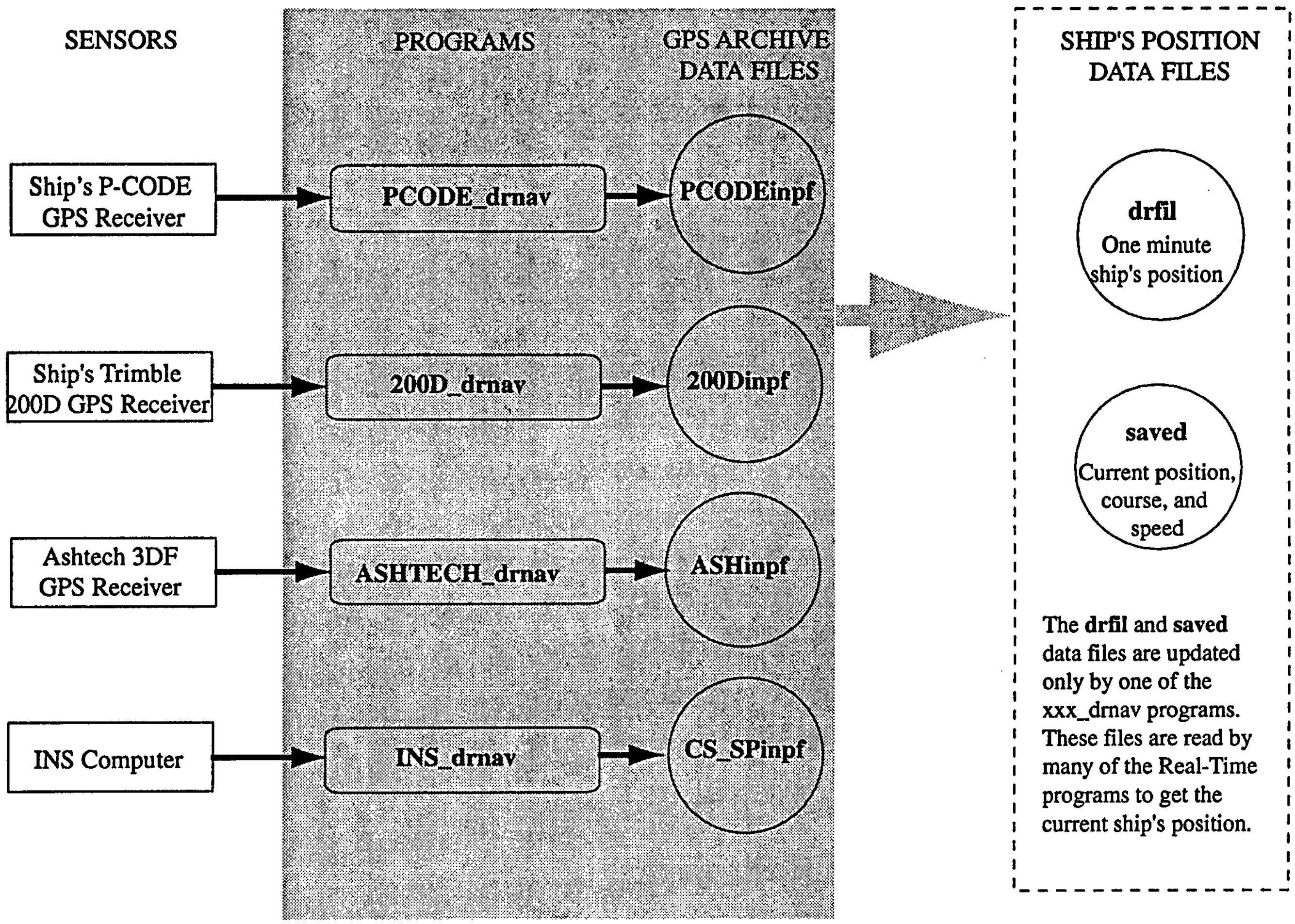

Figure 8. Real-Time Navigation Data Logging On SUN Computer Server (Randall)
The programs read navigation data from the sensors' RS-232C ports and write them to data files.

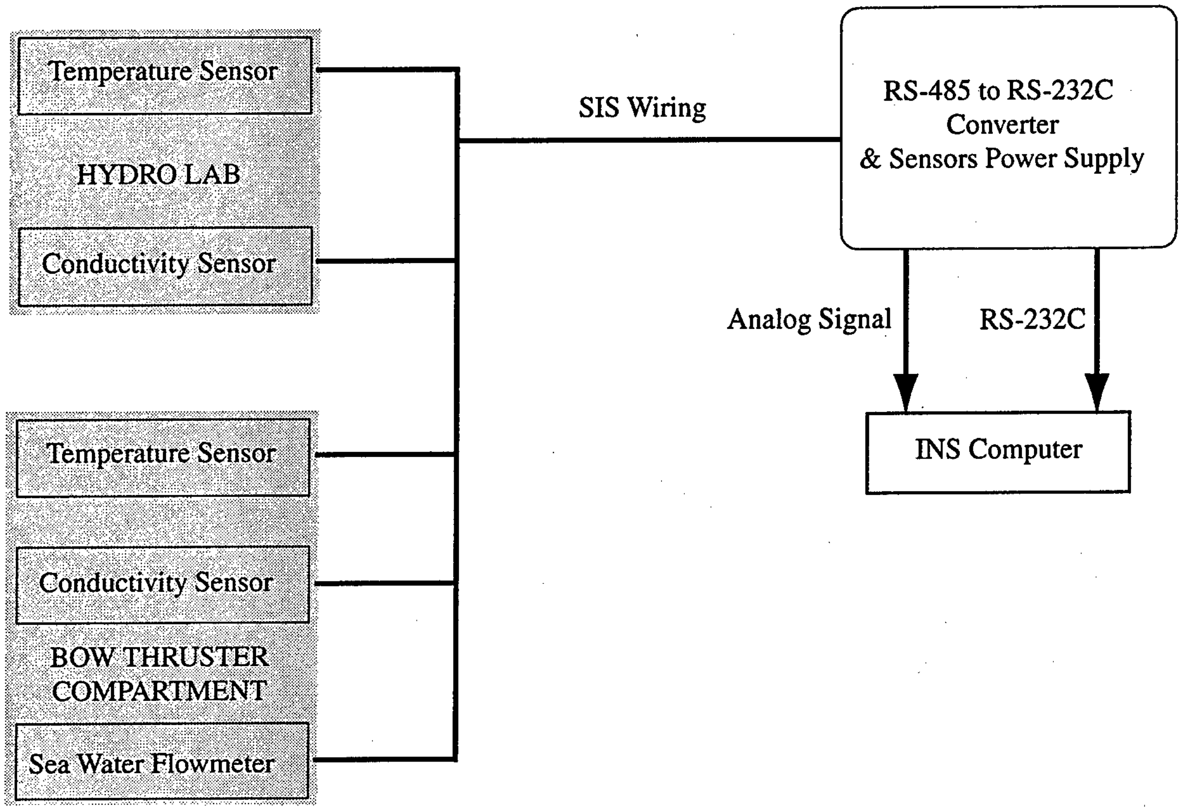

Figure 9. Sea Surface Conductivity/Temperature (CT) Sensor System
If both pairs of CT sensors are active, both data streams are logged. The INS computer determines the surface sound speed for use by the SeaBeam 2100 from the sensor pair that has been selected by the operator.

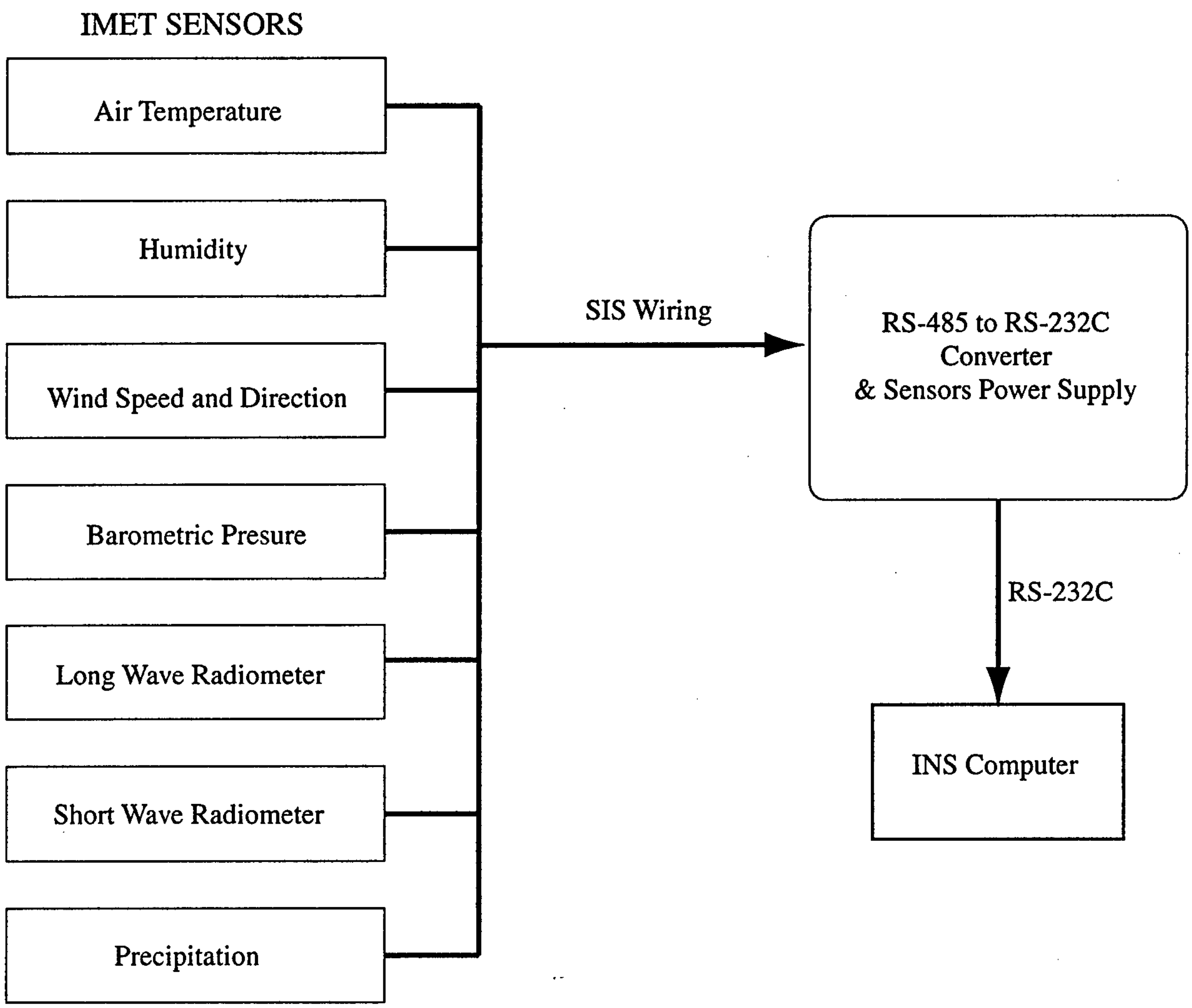

Figure 10. Meteorology Data These data are displayed on the INS computer console in the Electronics Lab. The data will be available on the video distribution system.

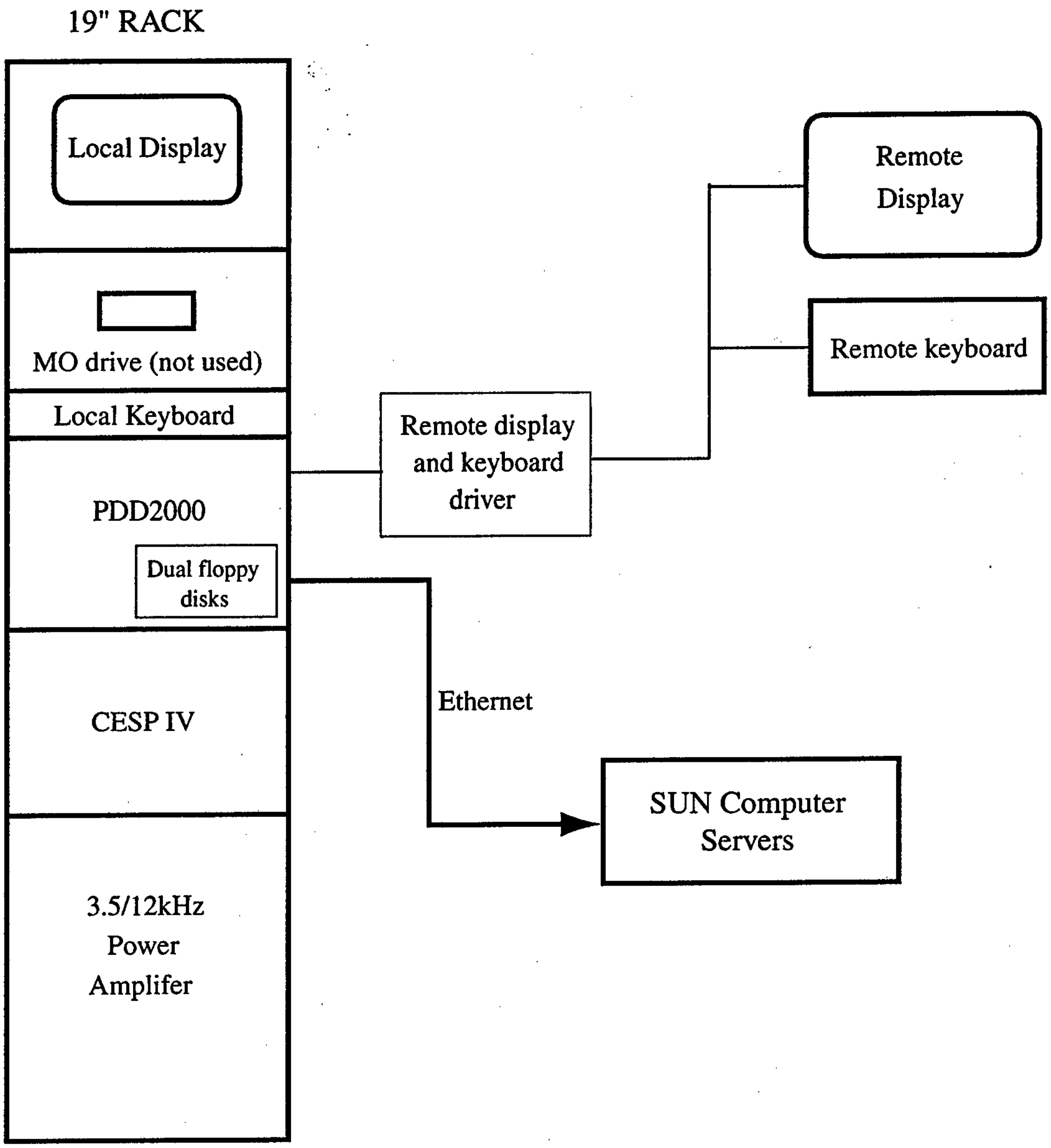

Figure 11. ODEC BATHY2000 (3.5/12 kHz Echo-Sounder)
SIO modifications include a remote display and keyboard, installed over the winch control station on the forward bulkhead of the Electronics Lab for near-bottom winch operations conducted from the Lab, and an Ethernet card to allow digital data logging on the shipboard computer servers and near-real-time access to these digital soundings.

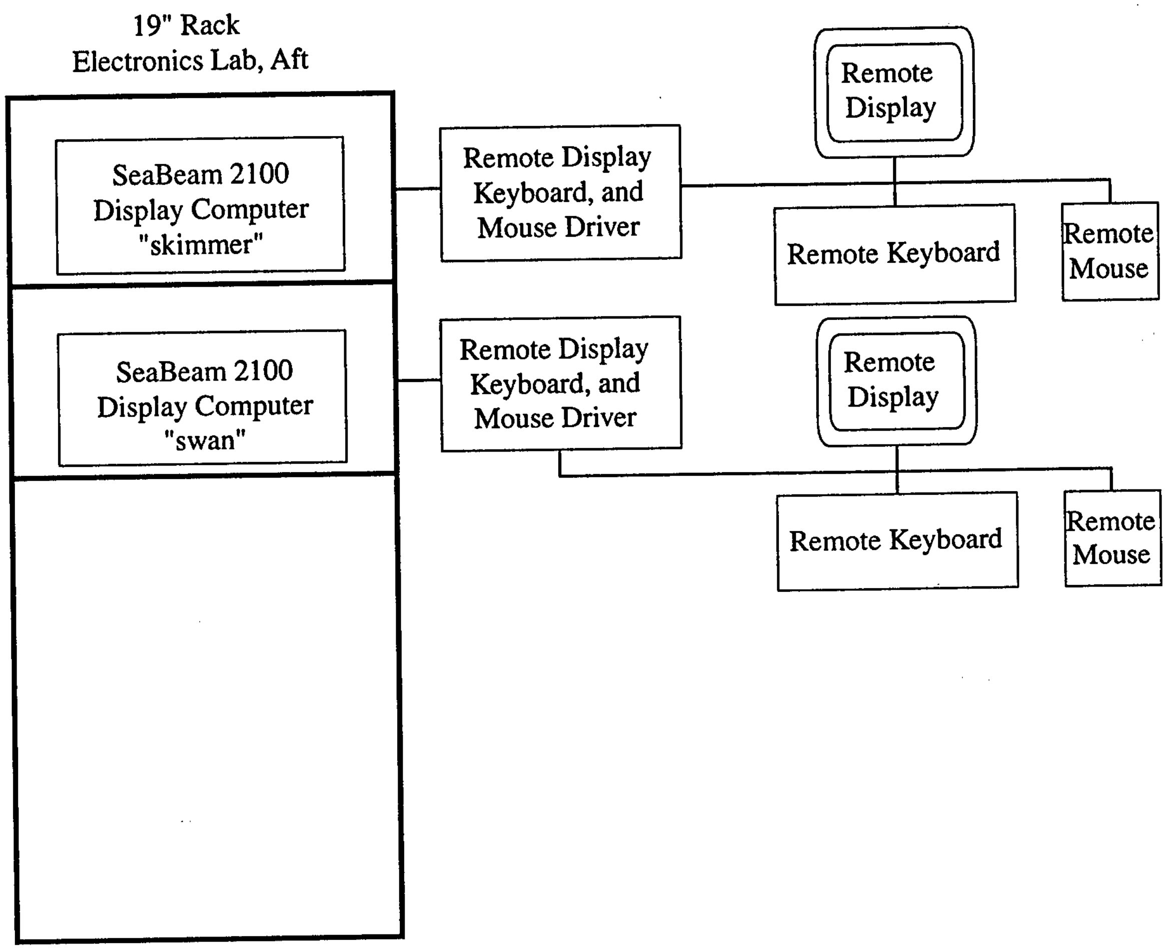

Figure 12. SeaBeam 2100 Modifications.
These modifications make the SeaBeam 2100 display easier to relocate during legs in which multibeam bathymetry data are not collected and bench space is needed in the Electronics Lab. The SeaBeam 2100 was modified also to accept sound speed profiles via ftp over Ethernet.

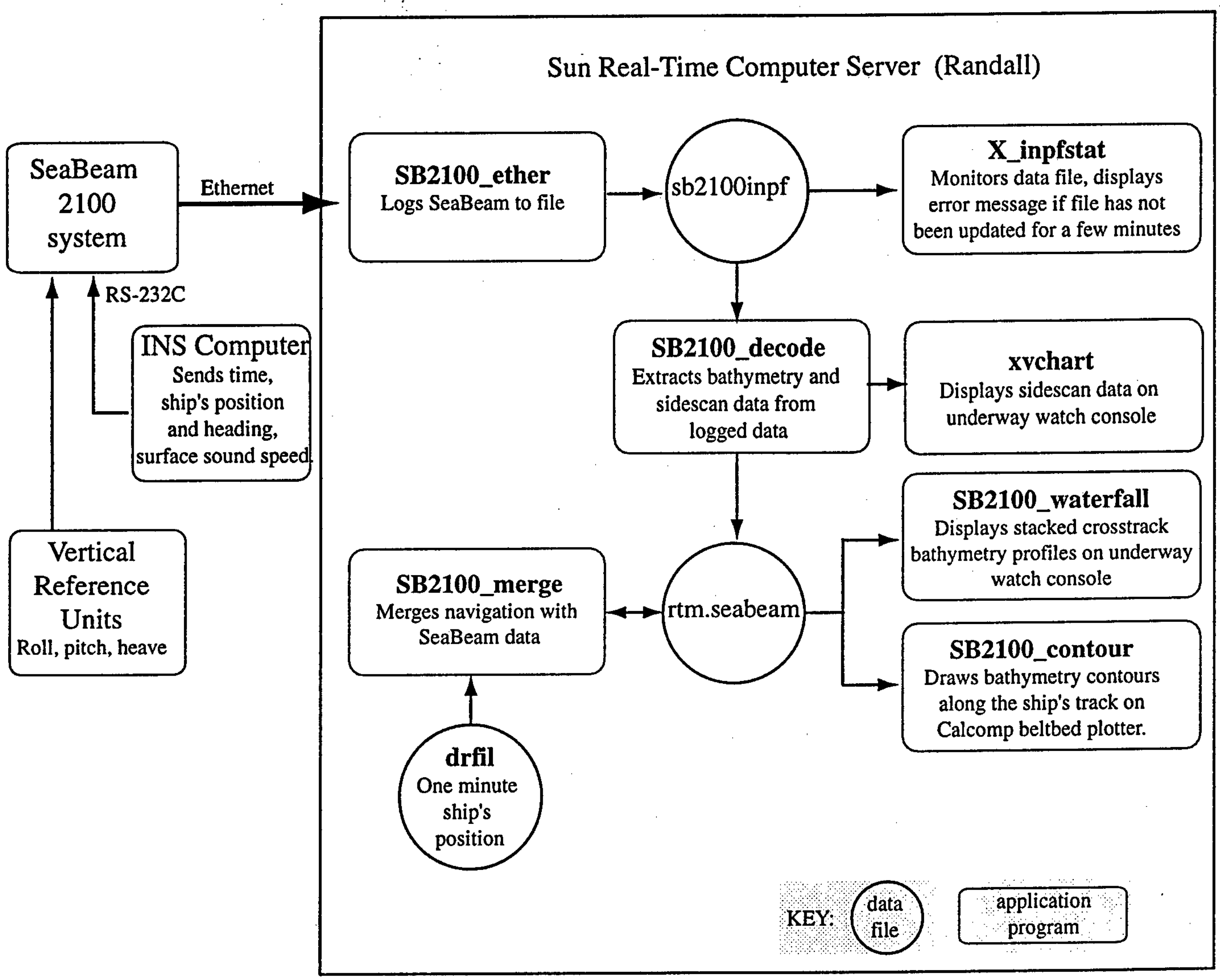

Figure 13. SeaBeam 2100 Data flow

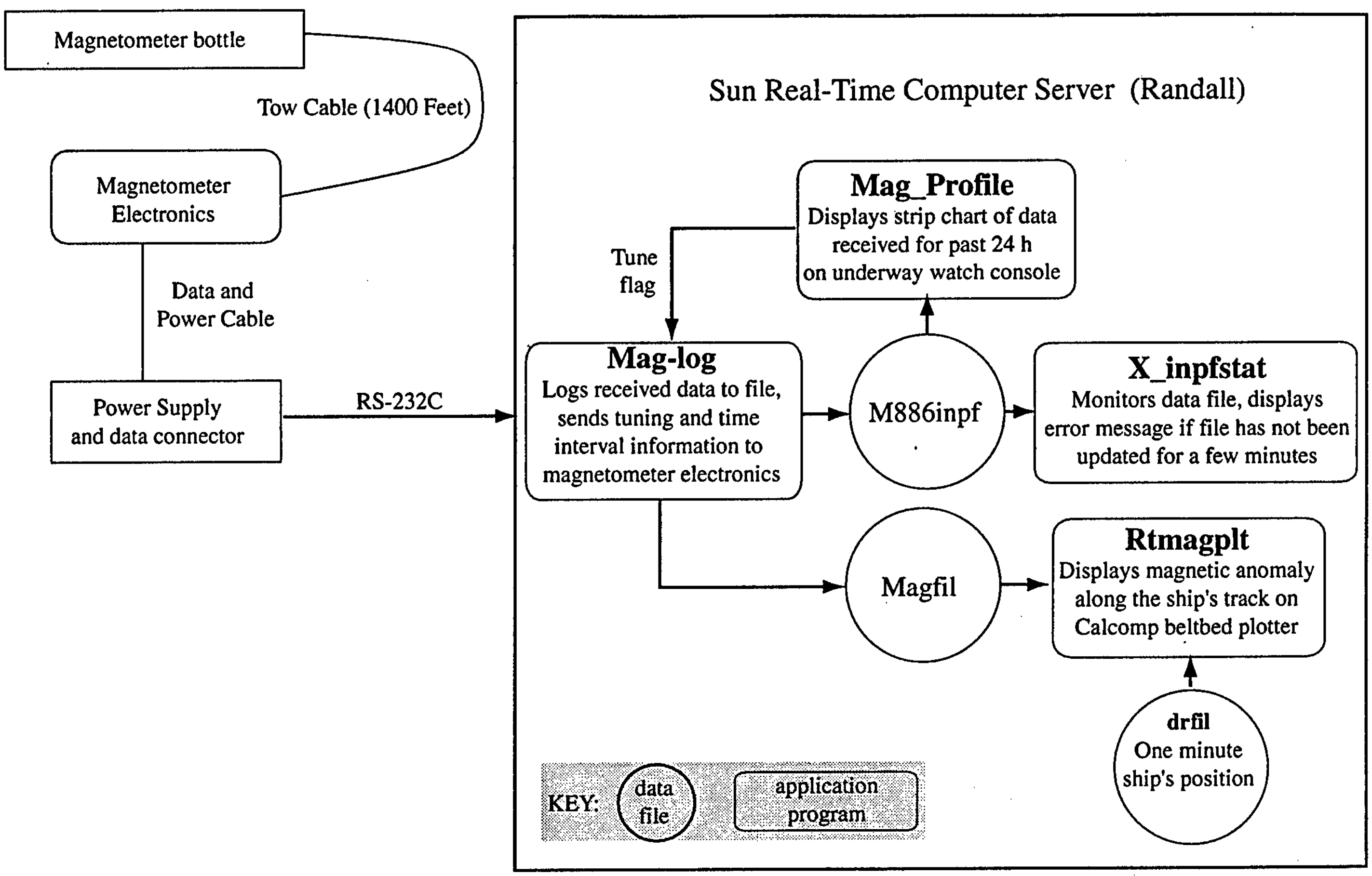

Figure 14. Magnetometer Data flow