

## DEVELOPMENT OF AN INTEGRATED DATA ACQUISITION SYSTEM FOR RESEARCH VESSELS

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### **ABSTRACT:**

*This article describes an integrated data acquisition system (IDAS) designed and developed for multi-oceanographic research vessels. The prime motivation was to provide a flexible system, which could be used in the context of ocean related observational studies. It uses personal computers interfaced to the various scientific equipments on-board, which are then interconnected using a high speed Ethernet local area network. The system logs data from navigational, bathymetric, meteorological and other connectable equipments that are available on the vessel. The system was successfully field-tested and installed on-board research vessel- ORV Sagar-Sampada in May-1995 and later, also on three other vessels.*

## INTRODUCTION

This article describes an integrated data acquisition system for research vessels. These vessels are equipped with sophisticated instruments used by oceanographers and meteorologists for their scientific programs, which are usually distributed in different ship locations. Consequently, the interrelated data had to be physically transported from one laboratory to another for post-processing. The prime motivation behind the present work was to provide a highly flexible system with data processing capabilities, which could be used, for large class of observational studies. In early research vessels, facilities were not available for automation. As a result, a lot of effort went into developing indigenous dataloggers for specific applications such as meteorology, geology, bathymetry etc. Meteorological sensors are generally found to be difficult to handle, especially on ships. The main reason for this being the complicated assembly of the sensors and long cables routed through the ship's super structure from the mast to the data acquisition and display systems. This approach makes calibration and maintenance very difficult. The integration of data acquisition has largely been confined to the meteorological systems as described by Ratcliffe and Sheen 1964, Donald et al. 1966, Kaimal et al. 1966, Marilyn 1989, Prabhudesai

et al. 1992 and others, where the various sensors were integrated as a single module.

The distributed processing for data acquisition for the ship-board environment was well accepted (Swift, 1983). Hence, a computer-controlled local area network (LAN) appeared the most suitable answer to these requirements. We have to design a system, to which available equipments could be hooked up with minimal hardware overheads. As a part of this effort, we have developed an automatic weather station (AWS) using standard sensors and a sea surface temperature (SST) unit. The mechanical packaging of sensors, electronics and interconnection was considered carefully. The first such system was installed on board RV-Gaveshani, in 1993. The system was designed using a 2.5 Mb/s ARCNET local area network (LAN) for interconnecting computers that used a deterministic token passing type protocol (Prabhu Desai et al. 1992). In 1994, Department of Ocean Development, New Delhi (DOD), encouraged us for further development of IDAS for ORV-Sagar Sampada (Fig 1).

The system described in this paper is the realization of our initial goal. It was successfully tested and installed on ORV-Sagar Sampada. The subsets of the same system were also installed on ORV-Sagar Kanya, CRV-Sagar Paschimi and CRV-Sagar Purvi and are routinely collecting the data. This conglomeration of various devices is reflected in its name: "Integrated Data Acquisition System (IDAS)".

## DESIGN CRITERIA

ORV-Sagar Sampada had a state-of-art integrated navigation system. This system consisted of mini computers (HP-1000) for the integrated navigation, weather radar processing and for post processing of the data. The computers were interconnected using RS-232 links to collect the data. However such configurations have limitation by their maximum speed of 9600 baud. Another technique is to use a high-speed parallel bus, which cannot drive signals beyond a few feet, such as IEEE-488 GPIB. With the advent of local area network (LAN) in recent years, transmission speeds in excess of 10 Mbytes/seconds are possible and they have become the ideal choice. The main design consideration was that the data at one node should be simultaneously monitored, analyzed and then displayed by one or more nodes in a distributed system. It was estimated that the data transfer rate over the network from any node would not exceed 100 bytes/sec. The maximum data transfer rate for a 10-node system would then be less than 1000 bytes/sec. For our application the desired access time to the network to share the data was one second from any node. Thus the required throughput was easily achieved, as an Ethernet network is rated for 10 Mb/sec. As the application does not demand time critical response, a commercially available Ethernet served our requirements. An AT&T category 5-shielded twisted pair cable was routed through the special conduits to avoid electromagnetic interference. Also the provision was made for new equipments, which could be added to the network

to share the data collected in real time.

Network communication software uses NETBIOS protocol for peer-to-peer communication and file input/output services are based on the NetWare IPX/SPX protocols. Additionally, windows for workgroup uses NETBUI for workgroup connectivity. Thus, the network environment should support coexistence of three protocols viz. NETBIOS, NETBUI and IPX/SPX, so as to support DOS (disk operating system), windows for workgroup and NetWare. It was decided that software would be written to run under windows, however data logged on the NetWare based server could be accessed from any computer using either DOS or windows.

The experience gained with the new ships, along with the availability of the personal computers with open system architecture and networking support have led to the design of the IDAS. A star topology has been adopted for this system using a 12-port hub, also providing flexibility for additional nodes. For example, the computer in navigational laboratory (NAV-PC) collects data from satellite navigator, echo sounder, echo integrator and so forth. Network communication has been implemented using session services between closely coupled processes with the other computers and broadcast data-gram to update real time displays. The nodes in the other laboratories such as meteorological lab., wet lab. and dry lab. log data from the available computer-interfaceable instruments. A separate node has been provided in

the bridge to enable the navigators to view, set and log the ship's trajectory. A general-purpose node has been made available for computing and other documenting tasks. The computers used in different laboratories were assigned the corresponding name. All the major components of the system are shown in the block diagram in Fig 2.

### SYSTEM DESCRIPTION

IDAS involved two major components — development of the software and related hardware.

### IDAS PROGRAM

This program was developed to work under Windows operating system (OS). Windows provide several features such as multitasking, built-in networking support, access to large physical memory and most importantly the graphical device interface (GDI). Windows-GDI provides support for the mouse-activated windows with menus, dialog boxes and a variety of controls such as buttons, scroll bars etc. These features of the OS have been utilized in the program to provide a user-friendly interface. Windows-Application Programming Interface (API) has a rich set of function calls to access input/output (I/O) ports and also asynchronous serial ports. Acquisition of data from PC add-on cards to read status and data from parallel ports or analog-to-digital converters (ADC) have been accomplished by using standard API calls to access either memory mapped I/O or I/O without having to use any device drivers. Additionally, windows timer

support allowed scheduling data acquisition activity. The program has been written using Borland C++ compiler. It can be classified into three important components viz; acquisition of data, network communication and graphical display.

A major software development effort went into developing a reliable network communication using NETBIOS support. These applications need to be carefully structured, so that any communication error would not bring down the entire data acquisition activity. Windows environment being a non-primitive multitasking type, application programs are usually subdivided into small tasks that can be executed in quick succession. If a task take too long or do not complete, then the job should not affect the entire application. Hence NETBIOS communication commands have been executed asynchronously i.e. application does not wait for the commands to complete nor do they poll for the command complete status. Instead a small post-processing interrupt routine is attached to the NETBIOS commands. Post-processing associated with the command is then performed inside the main message-handling task of windows application program. Several NETBIOS related techniques are documented (Schwaderer 1988 and Alok Sinha 1993).

The display part of the IDAS software has been designed to look identical on all computers irrespective of the background data acquisition

activity. Updated information is available at every node, as the entire data from different computers are collected and broadcasted by the NAV-PC every second. Software allows selecting navigational, meteorological or wet lab. data. The data can be viewed in normal text fields, in scrolling windows or in graphical mode incorporating bitmaps in the form of dials, gauges etc. Setup menu allows selecting different options using mouse. Graphical support is included for cruise track entry. A real time display of actual ship track along with the coast map and user selectable depth contours etc with facilities to zoom and scroll has been implemented. The various display modes are shown in Fig 3.

The hardware part was divided into various laboratories and here we describe connectivity of different systems and their functions:

### **NAVIGATIONAL SYSTEM**

The navigation computer (NAV-PC) is the heart of the system for two reasons. Firstly, it supplies basic navigational and bathymetric data to all the nodes in the network, to geo-reference the data. Secondly, NAV-PC was also configured to acquire information collected by other nodes in the network and retransmit the integrated data back into the network, so that all the nodes in the network can access it. The various instruments connected to NAV-PC are shown in Fig 4.

#### **GPS Satellite Navigator:**

A low cost TRAXAR MG+ GPS from Motorola, USA was procured for use with the system. The

navigator provides data in ASCII strings in NMEA-0183 format. The data are sent on RS-232 port at 4800 baud, 8 data bits, no parity and 1 stop bit format. Different message strings are decoded by the NAV-PC to retrieve the following information: *Time and date, Latitude, Longitude, Speed over ground, Course with respect to true North, Quality of data, Antenna height, Satellite number used for the position computation, Horizontal dilution of precession and Magnetic variation.* The GPS navigator updates the data every second. All the operations such as sampling and recording of data on the NAV-PC as well as on other computers executing IDAS software are synchronized to the GMT time given by GPS. The NAV-PC stores navigational data on the NetWare File Server. The user can select recording interval of every 10 seconds, 5-minute or 10-minutes by using set-up option depending on his requirements.

#### **Echo Sounders:**

NAV-PC is placed in the acoustic laboratory where the scientific echo sounders and fishing sonar equipment are installed and forms a natural cluster. They are interfaced to NAV-PC instead of dedicating a separate PC exclusively for the acoustic data. The echo sounders are from Simrad, Norway (EK 200 make). They operate at 38 kHz and 120 kHz. The depth data is given in 5 digit parallel BCD format. The output of the echo sounder is opto-isolated using data line driver NAVDLD. The opto-isolated output is sensed using Dynalog input/output card PCL-221,

installed in the NAV-PC. The data from either of the echo sounders could be viewed on the screen by selecting options under **combo box** control from any node running IDAS software. However depth data are logged from only one echo sounder selected using setup option on the NAV PC.

#### **Scientific Echo Integrator:**

This is a sophisticated acoustic equipment and provides valuable information on the target strength or acoustic back scattering intensity from different layers of the water column. This information if properly correlated with the fish catch data using trawl sonde etc. can provide a valuable database, which could be used for on-line classification purposes. The echo integrator output has been connected to COM3 port of the NAV-PC and the data are stored on the server. This data-file has been provided with multiple access privilege, so that the file can be opened from any node to view the data being logged. Unlike other data in the network, which is normally sent by the NAV computer to other computers using NETBIOS protocols, the echo integrator data is accessed using connectivity services of either Windows for Workgroup or NetWare to read the data from the server.

#### **Log Gyro:**

The speed and heading of the vessel, provided by the GPS navigator is correct, only when the vessel is in motion. Therefore, it is important to log the speed and heading information from the Log/Gyro of the ship. Unfortunately this equipment is of old

eneration and does not provide standard computer compatible interfacing options.

#### **METEOROLOGICAL SYSTEM**

The meteorological system supplied with the vessel was not operational, hence it was decided to develop an Automatic Weather Station (AWS), which could also be used from the remote locations such as coastal and offshore sites, on oceanographic data buoys and vessels for long term measurements (Prabhudesai et al. 1995&1997; Mehra et al. 1995). The sensors used in this system are listed in Table 1. Sensors were mounted on two arms as shown in Fig 5 (a)&(b). The sensor arms were mounted on a mast of ~ 3m. Underwater connectors and cables have been used to carry the signals from the sensors to the sealed electronics unit, which in turn was housed in a weatherproof aluminum bin depicted in sketch (Fig 6). AWS electronics consists of a low power microcomputer coupled to a signal-conditioning unit. The electronic unit works on a 12-16 Volt power supply and consumes ~ 50 mA of current. The analog-to-digital converter (ADC) has eight analog-channels with a resolution of 12-bits and provides a maximum sampling rate of 100 kHz. The analog and digital signals from the sensors are converted into engineering units by the microprocessor and the data string is placed on the serial link (RS-232) to MET- PC.

#### **Sea Surface Temperature (SST) Unit:**

The AWS has a provision for SST sensor and the signal cable was required to be taken through a

distance of more than 100 meters. We have, therefore decided to develop a standalone unit with display as shown in Fig 5(c). The SST unit has been installed in the laundry room and a thermistor probe has been inserted within the chamber, where the seawater is pumped-in and circulated as shown in Fig 6. The ON/OFF status of the pump was sensed using a relay and the same was tagged along with the SST data. An RS-232 to RS-422 converter was designed to drive the data to the MET-PC.

### **WET LABORATORY SYSTEM**

The Wet laboratory is equipped with wave recorder and analytical instruments like Autosal, Spectrofluorometer etc.

#### **Sea Borne Wave Recorder (SBWR):**

It consists of a pressure transducer mounted in the hull of the ship to determine the height of the water level "P" above it. This is added to the vertical displacement "D" of the ship with respect to an imaginary reference level by measuring its vertical acceleration and then integrating it twice by using electronic techniques. The sum (P+D) results in the height of the sea surface above the reference level and is independent of the motion of the ship. Pressure sensors and accelerometers are fitted on both the sides of the vessel and their average is taken as output. The full-scale analog output of  $\pm 1$ -Volt form SBWR corresponds to  $\pm 10$ -meter wave height. WET-PC, continuously samples and displays the wave height using a Dynalog analog to digital converter card PCL-812.

The data sampling and recording interval is user programmable and the data gets stored on the NetWare fileserver.

### **DRY LABORATORY SYSTEM**

This laboratory was equipped with electronic balances and recently an Acoustic Doppler Current Profiler (ADCP) was installed. Electronic balances are standalone systems and are not linked to IDAS. A link between the NAV-PC and the ADCP has been established using serial communication ports. The Navigation data was routed to ADCP computer through this serial link.

### **NEW TECHNOLOGIES**

There have been significant advances in the information technology, since the inception and the successful commissioning of the IDAS network. We have highlighted some of these developments. Personal computers (PC) performance in terms of the clock speed, memory, input/output throughput has increased many folds. High-end multimedia and real time graphical animation capabilities are now realizable in the PC domain. Windows operating systems have gone through major revisions. Windows-NT/2000 version is well suited for IDAS in view of its true preemptive multitasking, support for threads and capability to run 32-bit applications. In the area of the networking, 100 MHz fast Ethernet products are offered at entry level and gigabit Ethernet is gaining acceptance. Thus, it should be possible to build more graphic intensive applications. Internet domain TCP/IP protocols could be used for

communications. A network could also support diverse operating systems (LINUX, UNIX etc.) and platforms (PCs & workstations). The applications for real time could be built on a web server using JAVA application applets, communication protocols etc. A standard Web browser then could be used to monitor, configure and control, IDAS environment from the client machines. The system could have a mix of low end networks such as I<sup>2</sup>C, RS-485, CAN etc. for sensor level interfaces and high end large bandwidth networks interconnecting computers for improved visualization, with right gateways for interconnection.

## CONCLUSION

The IDAS was tested and installed on ORV- Sagar Sampada in May -1995. The subsets of this system have also been installed on ORV- Sagar Kanya, CRV- Sagar Purvi and Sagar Paschimi. The system has incorporated technologies available at the time of its inception. We have also highlighted the scope for new technologies and the trends in this field.

With the current information technology explosion and the tremendous improvements in internet and e-mailing facilities, the capabilities of this system can be easily extended to other domains. For example, by suitable networking of the vessels, port authorities can monitor the trajectories of outgoing or incoming vessels in near real time at a central control station (say, Vessel Traffic Control Station).

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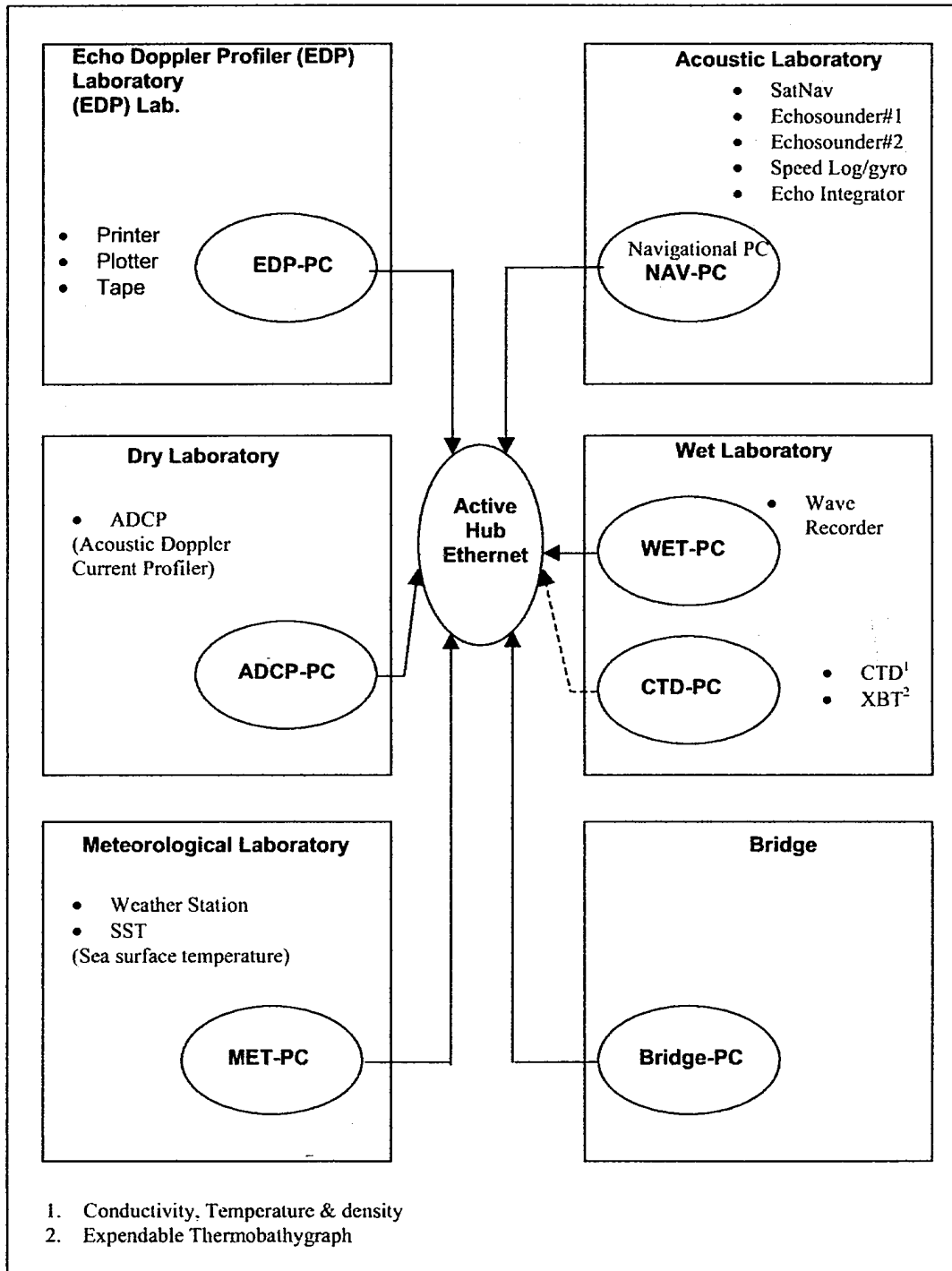
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Parameters	Sensor	Range	Accuracy	Output
Wind speed	Propeller	0-60 m/s	$\pm 0.3$ m/s	Sinusoidal signal
Wind Direction	wind vane	0-355°	$\pm 0.5^\circ$	Voltage
Relative humidity	capacitive	0-100%	$\pm 2\%$	Voltage
Air temperature	thermistor	-5 to 45 °C	$\pm 0.15$ °C	Voltage
Air pressure	capacitive	950-1050 mb	$\pm 0.4$ mb	Digital
Solar radiation	photocell	0-200 mw/cm <sup>2</sup>	1% of F.S.	Voltage

TABLE 1. Specifications of the sensors used in the Automatic Weather Station (AWS).



**Fig 2. Schematic diagram of Integrated Data Acquisition System.**

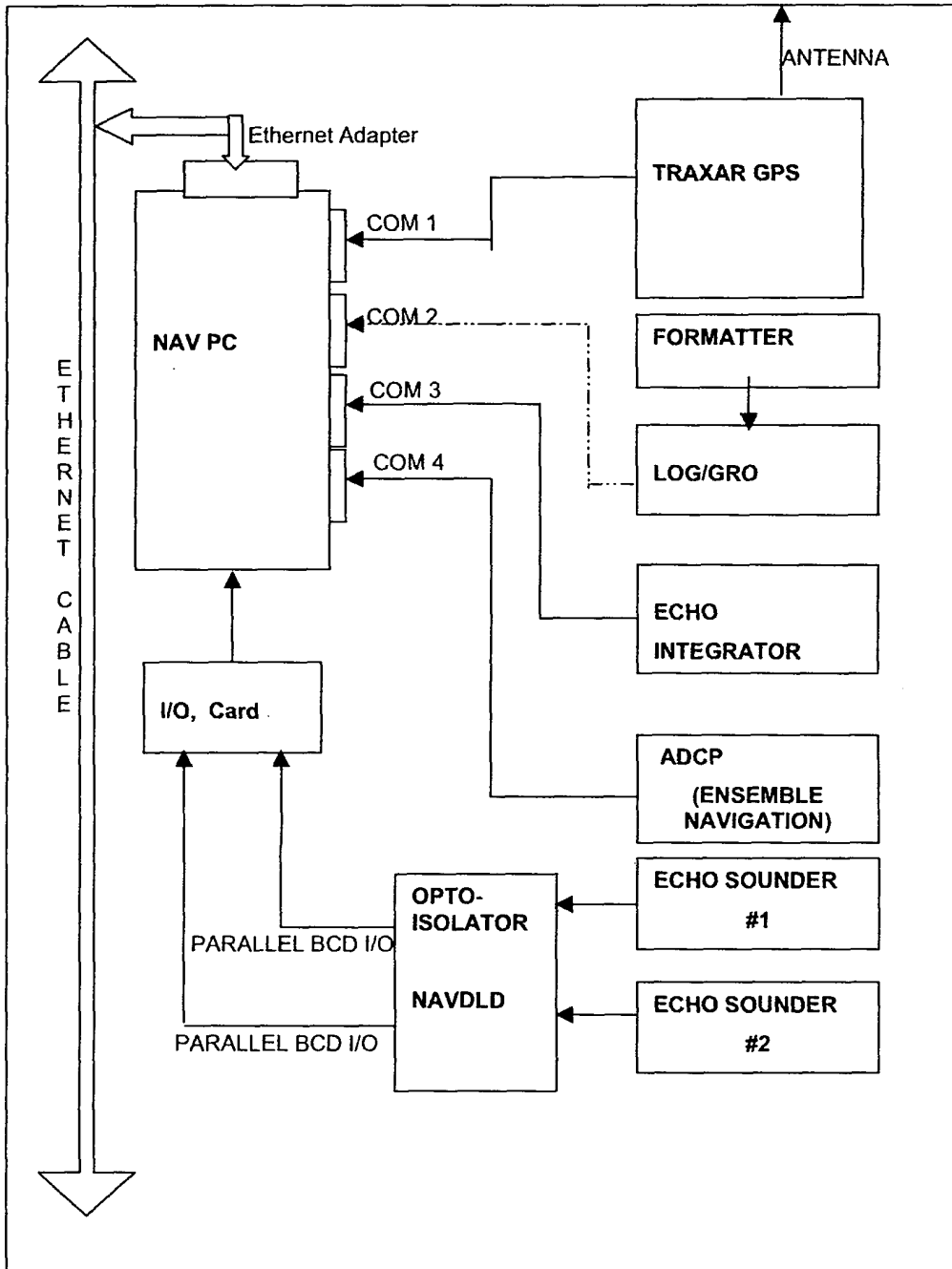


Fig 4. Schematic diagram of Navigational Laboratory depicting the equipment's connected to the NAV-PC

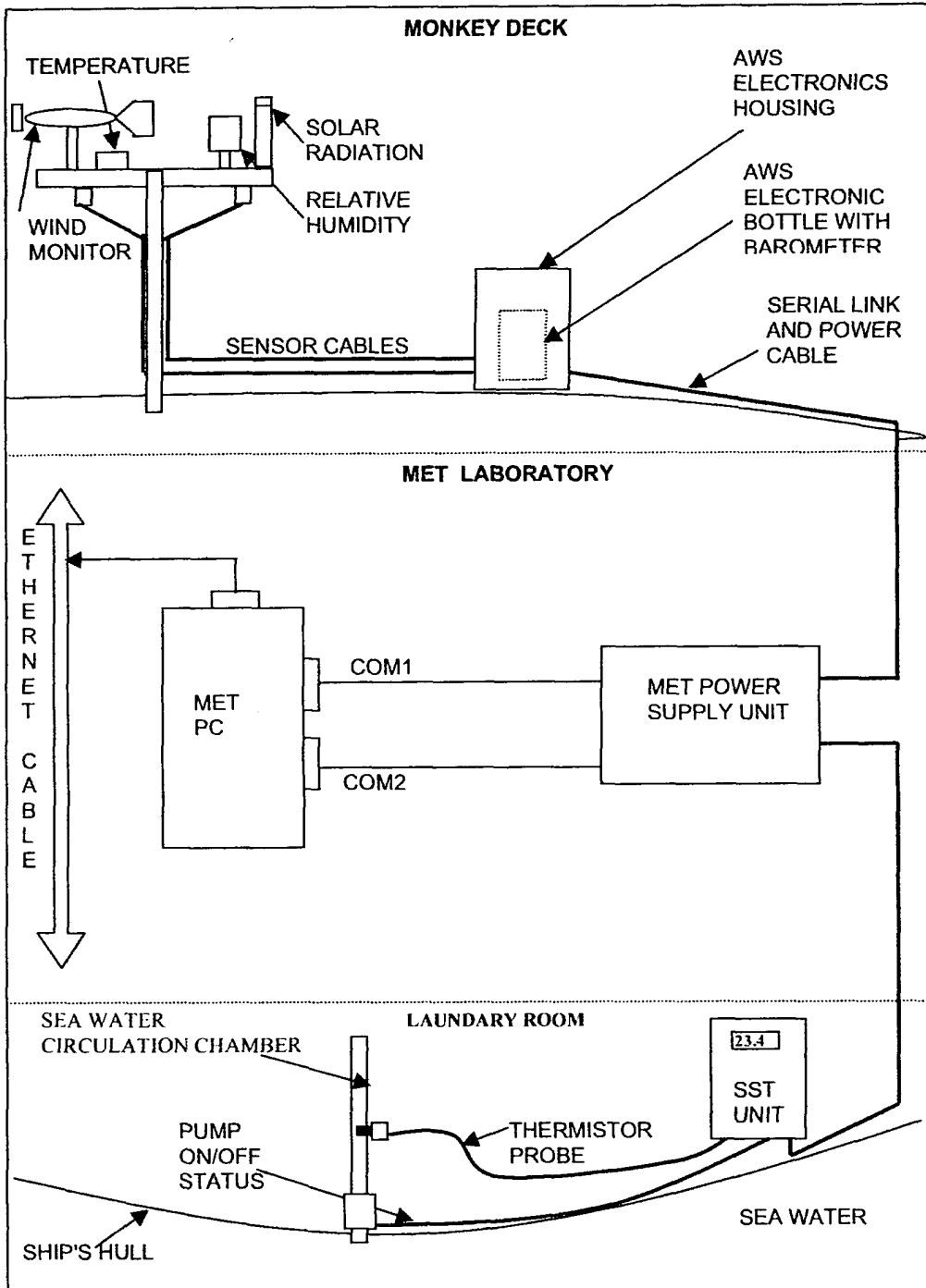
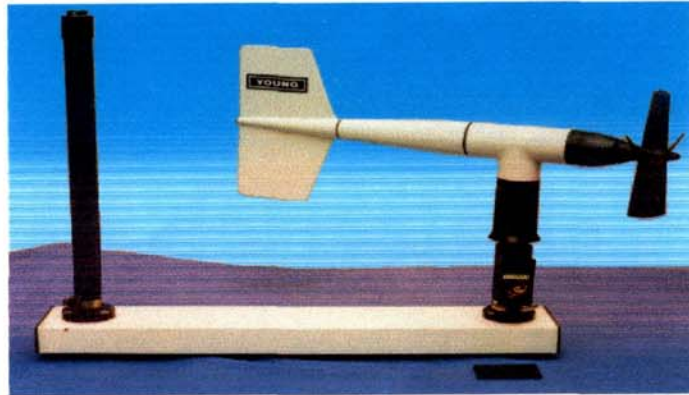


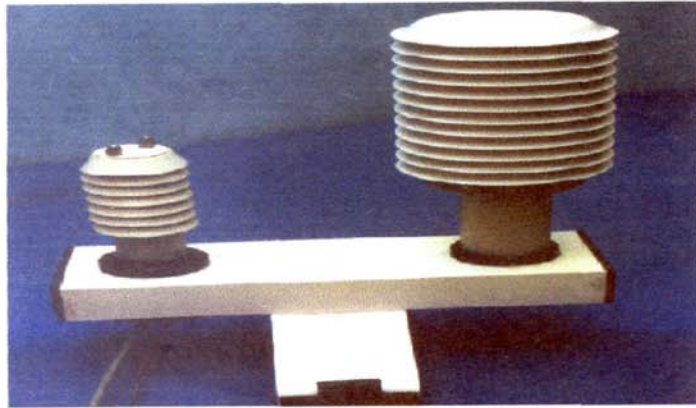
Fig 6. Artist sketch of the meteorological laboratory in which MET-PC is connected to AWS and SST units.



Fig 1. ORV-Sagar Sampada of Department of Ocean Development India, for which the IDAS was developed.



(a)



(b)



(c)

**Fig 5. Meteorological unit of IDAS. [a] Assembly arm of anemometer and solar radiation sensor. [b] Assembly arm of Humidity and temperature sensor. [c] Met-PC with the SST unit**



(a)



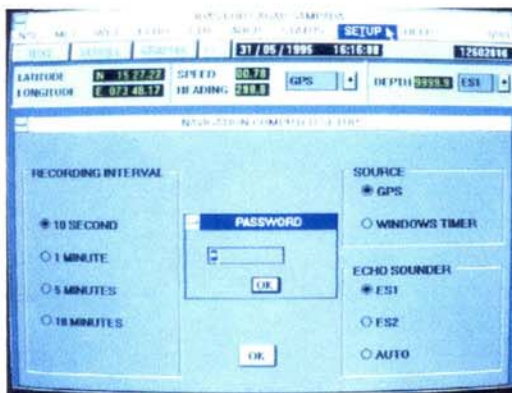
(b)



(c)



(d)



(e)

Fig 3. The different monitor displays of IDAS. [a&b]: Monitor displays in text mode. [c&d]: Monitor display in graphical form. [e] Setup menu