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APPLICATIONS OF COMPUTERIZED DIGITAL DATA ACQUISITION SYSTEMS

Data Acquisition and Analysis at Sea

A Solution to a Measurement Problem for:
WOODS HOLE OCEANOGRAPHIC INSTITUTION
Woods Hole, Massachusetts



THE APPLICATION

The Woods Hole Oceanographic Institution in Woods Hole, Massachusetts, is engaged in a wide variety of oceanographic studies covering the basic disciplines of physics, chemistry, biology, meteorology, and geology. A fleet of research vessels, manned by professional crews and equipped with modern instrumentation, enables scientists to conduct many different types of investigations at sea. In the course of a year the larger vessels cover tens of thousands of miles in a field program that provides researchers with the essence of ocean sciences.

THE PROBLEM

Research projects at Woods Hole cover the entire spectrum of oceanography, ranging from studies of microscopic cells to thousands of square miles of ocean. Most of these projects are essentially basic scientific research involving a great deal of experimentation and testing. Consequently tremendous amounts of data are produced, helping investigators to explain specific phenomena, test fundamental theories, and establish reasons why things exist as they do in the sea.

While technological advances provided the scientist with increasingly more sophisticated methods and instrumentation to acquire the data on location at sea, he usually had no onboard data reduction facilities, so he was obliged to store the raw data (the equivalent of from one to six 2400 ft. reels of magnetic tape or one to 100 rolls of paper tape) for subsequent reduction to usable form by onshore computers. This technique, however, *did not provide an immediate method of determining instances of incomplete or unusable data until the vessel returned to shore.* The only alternative then was to return to sea and repeat the tests – a very costly and time-consuming procedure. Thus, it became necessary to provide some on-line shipboard data reduction to determine validity of the data as the investigations progressed.

THE SOLUTION

In 1961 the Woods Hole Oceanographic Institution first began preparing to utilize a digital computer at sea. Using leased equipment, a computerized system (System I) was installed on a research vessel and studies were conducted between June 1962 and September 1963 to determine how well a commercial computer would operate on board a seagoing vessel while at the same time performing real-time data acquisition and processing. The studies demonstrated that a commercial computer could be operated satisfactorily on the high seas, and that real-time acquisition and reduction of scientific data were not only feasible and practical, but advantageous. Moreover, computer processing at sea can allow the scientist to more readily evaluate, assimilate, and interpret data while an investigation is in process.

System II was placed in operation onboard ship and used from November 1963 through December 1966. Improvements over the original system included magnetic disc pack units, on-line digital plotting, malfunction detection and alarm generation, plus other computer control and data reduction functions.

Based on its experience with the earlier systems and the improvements in small digital computers coupled with a sharp downtrend in cost, Woods Hole returned the leased equipment and purchased the Hewlett-Packard instruments shown in the block diagram; this is System III. Initially, System III included one computer, the larger HP 2116, and since has been expanded to include the HP 2114 Computer. Woods Hole does not consider the development of System III to be an experiment. The HP computers were selected primarily because (1) They are specifically designed to interface to instruments, (2) Reliability and environmental considerations are important design criteria in HP computers, and (3) They met the power requirements for shipboard use. Comprehensive software support from HP was also an important selection factor.

SYSTEM OPERATION

The computerized data system onboard ship consists of two main elements: (1) A computer (HP 2114) with associated instrumentation to provide the basic data acquisition and (2) A second, and larger, computer (HP 2116) with associated peripheral devices to provide computation and analysis of the acquired data and record the results.

All inputs to the system are in digital form and include date and time, gravity, ship's velocity, earth's magnetic field, and water depth. Ambient temperature is also available on an analog strip chart record. An electromagnetic ship's speed log (which measures the speed of the ship through the water) supplies ship's speed information to the gyrocompass, which in turn resolves that information with heading information into velocity vectors north and east. These vectors are sampled and recorded by the 2114 Computer system. Satellite navigation receivers obtain information transmitted from navigation satellites circling the earth. These data are entered into the HP 2116 Computer which reduces the values obtained to ship's position in latitude and longitude. The latitude and longitude position fix information in turn is then used to supply reference points for the interpolation of position by the ship's velocity vectors recorded by the HP 2114 acquisition system. The navigational information and detailed information of the ship's velocity, are required for the reduction of measurements of the earth's gravity field.

Geophysical parameters are visually displayed for monitoring purposes. The principal parameters are recorded on 10" analog strip chart recorders for monitoring continuity and also to provide back-up in case of instrumentation failure. (This sort of back-up provides assurance to the scientist at sea because, to him, instrumentation failure falls

COVER: *Measuring Earth's magnetic field is an important function in oceanographic research. Here a magnetometer is being lowered into the sea from an oceanographic research vessel. (Photos, except cover: Courtesy Woods Hole Oceanographic Institution, Woods Hole, Massachusetts)*

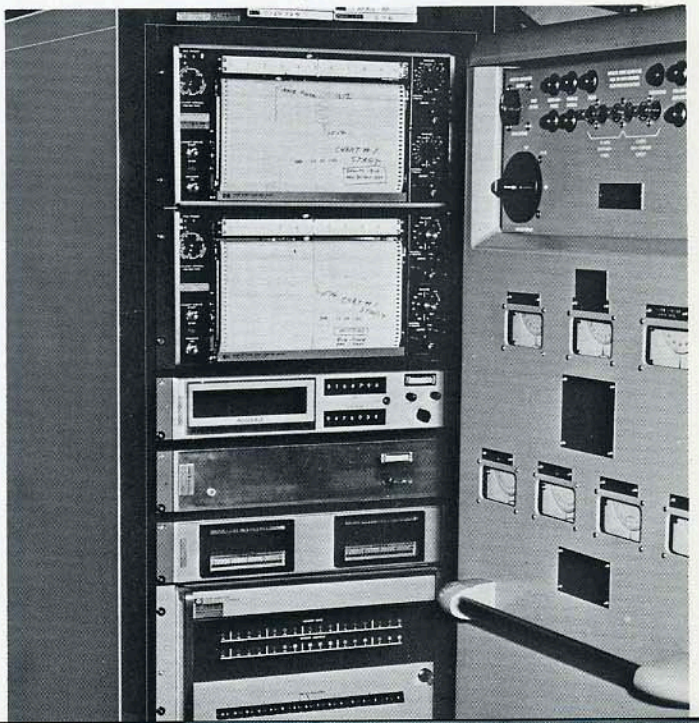
into the same category as bad weather and personal injury, any of which can curtail the experimentation.)

Measurement results are recorded on the teleprinter in typewritten form and paper tape complete with date and time identification. The teleprinter is also used to input some system parameter constants. Cassette tape recorders (each with three individual transports) are used in both the acquisition and analysis systems. Transport #1 is used for program input in lieu of the punched tape reader while the other two are used to record data output. The data transports are used alternately, with automatic switching as the tapes become full. Data may be fed directly (hard-wired) into the analysis computer system (HP 2116) or carried to it in paper tape or magnetic tape cassette form. Here, the data is reduced and related directly to the latitude, longitude, and ship's velocity and used to plot profiles and charts in real-time. The 12-inch plotter generates profile plots. The 30-inch plotter constructs mercator charts, indicates the ship's track, and writes the value of selected variables along the track line. Thus, both the plan and profile views of the data are available to the scientists onboard the vessel.

A copy of the raw data, in printed form from the teleprinter or magnetic tape cassette form, is sent back to Woods Hole from the ship's next port stop for security reasons. At least two copies of all important data are produced, one sent back to Woods Hole and one retained on the vessel. Data processed by the HP 2116 is also recorded on magnetic tape which is used as the principal storage medium and as a vehicle for further processing by a large onshore computer at Woods Hole.

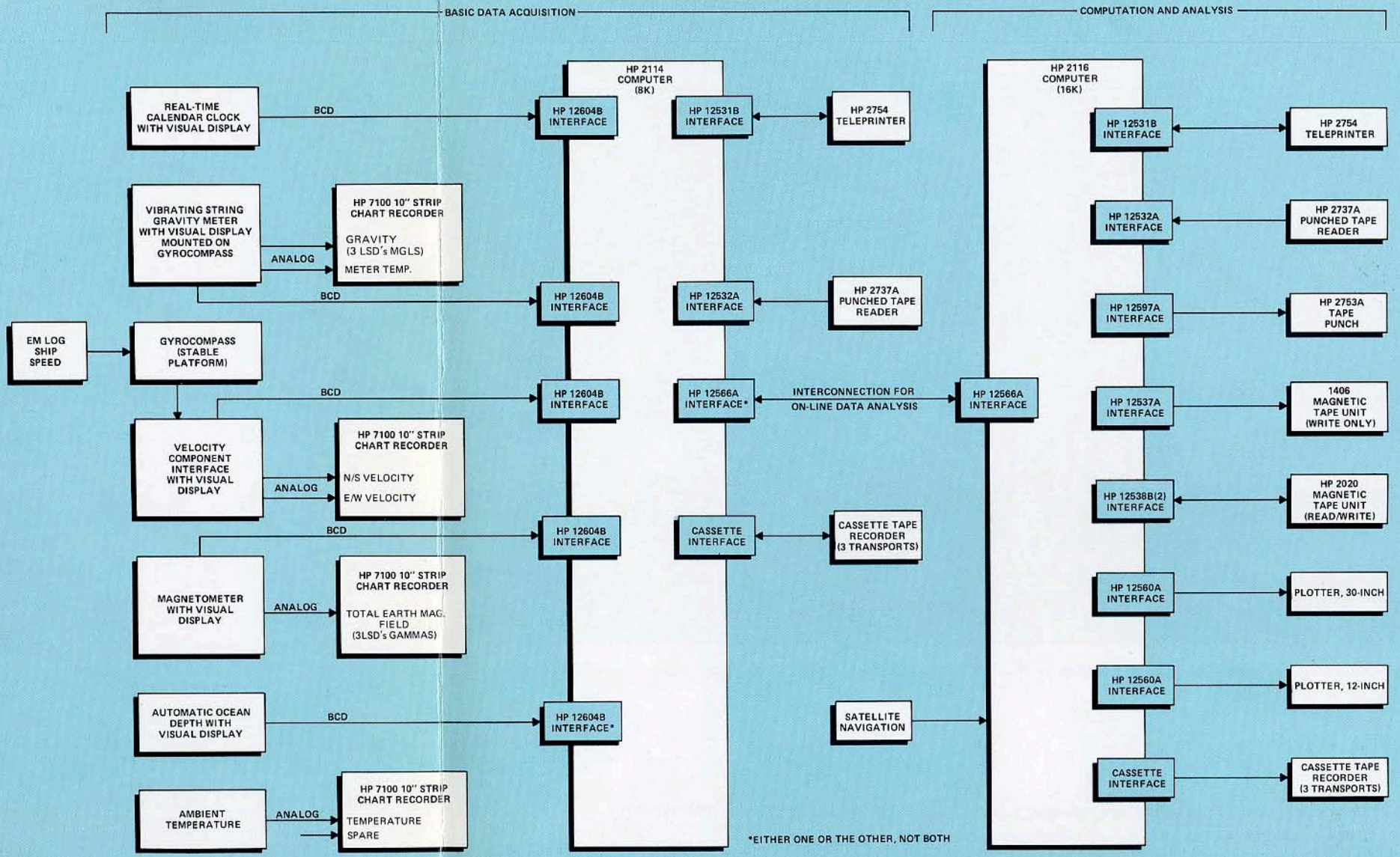
Experience with previous systems has shown that operator fatigue (4 hours on, 8 hours off, every day of the cruise) is probably the cause of many of the errors which had occurred. To alleviate this situation, only those controls required for routine operation are exposed; all others are accessible only to an experienced supervising operator.

The basic data acquisition system (2114 Computer with input and output devices) is installed in a portable van and needs only a power source and ship's speed input to become fully operational. Thus, it can be easily transported for use on other vessels as well as for onshore applications. The 2116 Computer system is installed in four racks which are bolted to dollies with wheels. The computers can be operational aboard ship or ashore in a matter of a couple of hours.

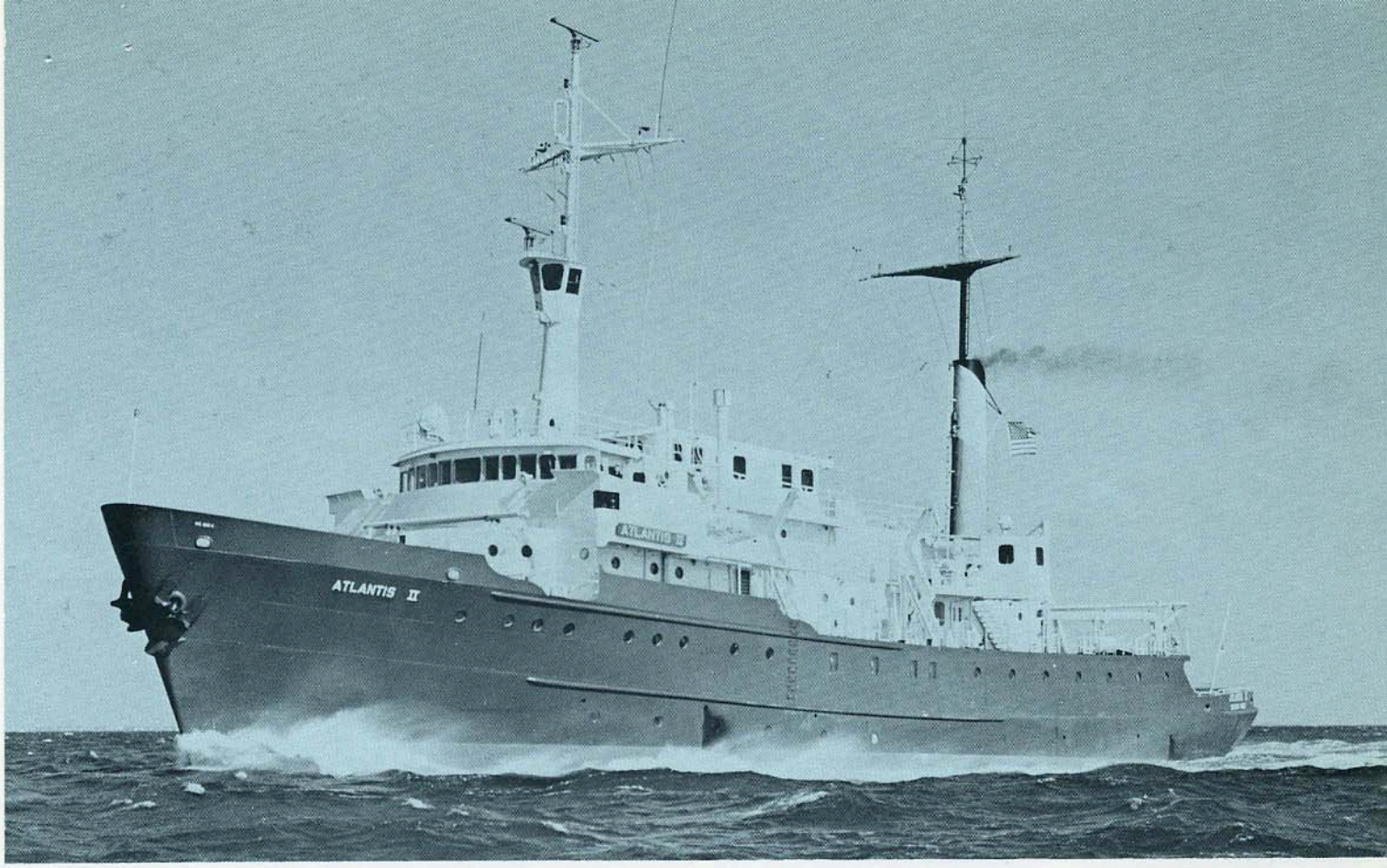


BENEFIT OF COMPUTERIZED DATA ACQUISITION

The HP computer system allows scientists to better evaluate and interpret data while an investigation is being conducted at sea. Onboard data reduction makes it possible to repeat measurements on location to replace bad data or augment with more information if required, and modify the cruise plan as necessary, with resultant savings in time and cost by reducing the possibility of unknowingly returning home with faulty data.

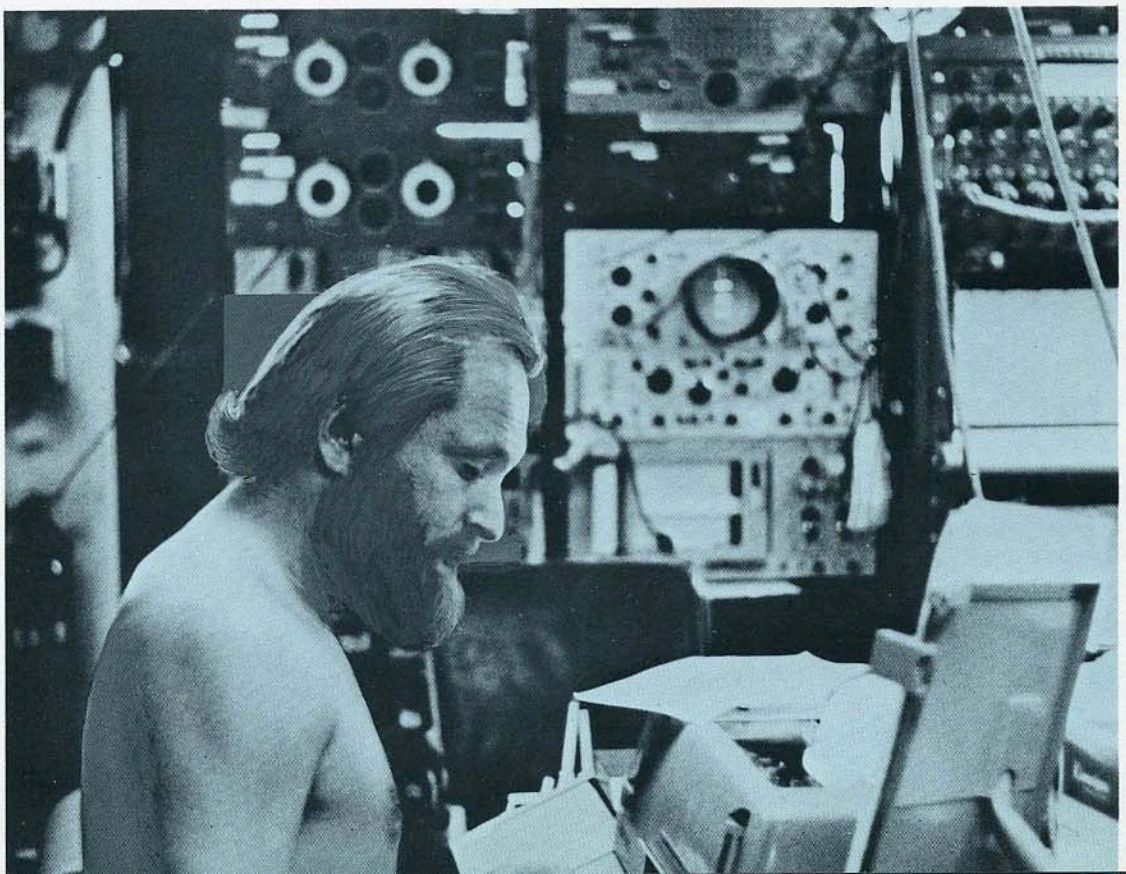


Shipboard Computerized Data Aquisition System (Woods Hole Oceanographic Institution System III Mod 1)



A Woods Hole Oceanographic Institution research vessel, typically equipped with an HP computerized data acquisition system to aid oceanographic research at sea.

Virtually surrounded by sophisticated measuring instruments, a member of the shipboard scientific team enters parameter constants through the system teleprinter.





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