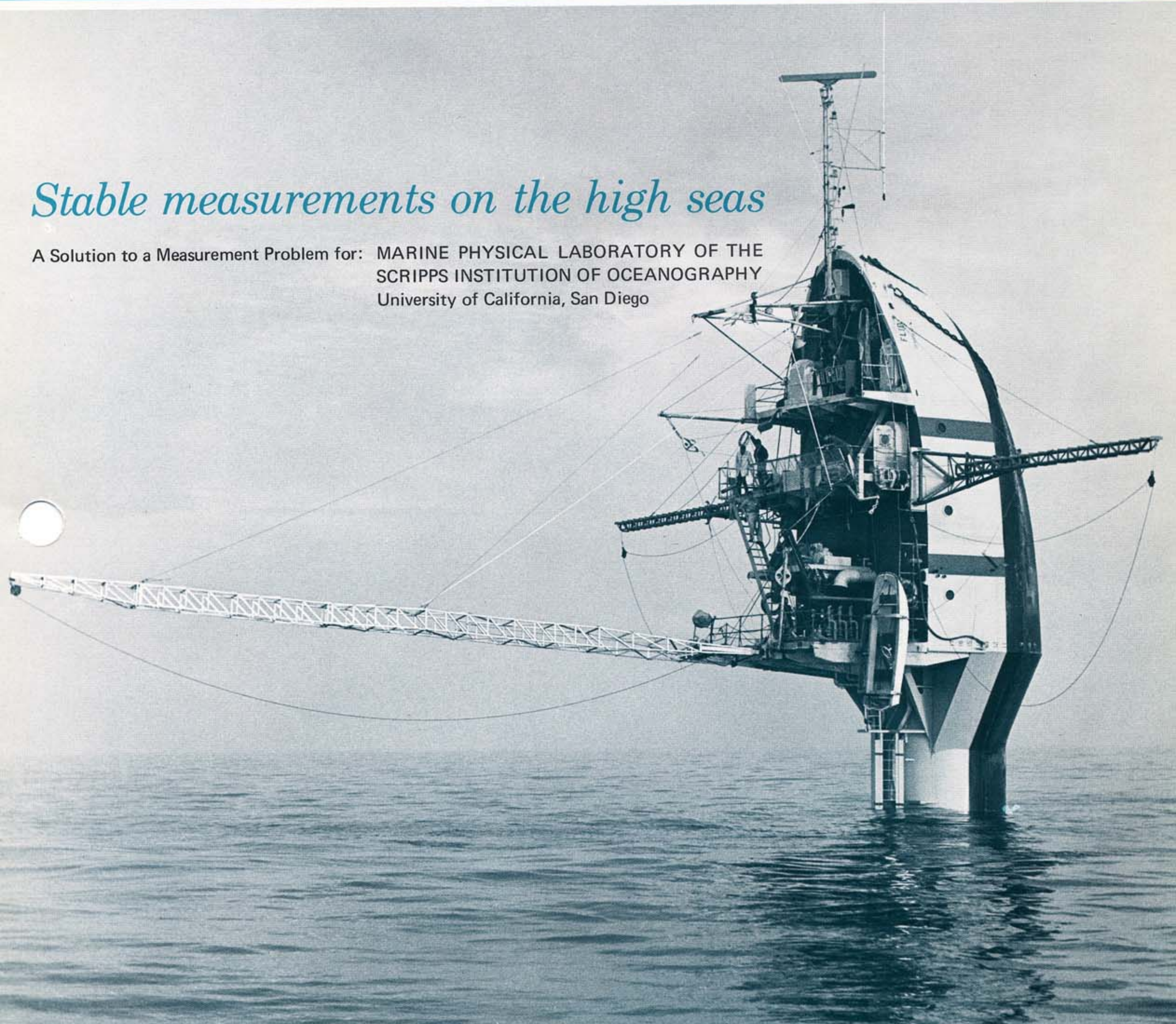
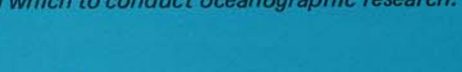
APPLICATIONS OF COMPUTERIZED DIGITAL DATA ACQUISITION SYSTEMS

Stable measurements on the high seas

A Solution to a Measurement Problem for: MARINE PHYSICAL LABORATORY OF THE SCRIPPS INSTITUTION OF OCEANOGRAPHY
University of California, San Diego



Research vessel FLIP (floating instrument platform) is shown in the vertical position on site. Only 55 feet of her total 355-foot length is above water level, providing scientists with an extremely stable platform from which to conduct oceanographic research.



Stable measurements on the high seas

Anyone who has ever been on an ocean voyage and experienced "rough seas" more than likely remembers being tossed about with every up-and-down movement and also the discomfort caused by the side-to-side excursions of the ship. Picture now an oceanographer trying to conduct, say, underwater acoustic experiments under the same conditions. Even though he may have his "sea legs" and use highly sensitive measuring instruments, he still faces the fact that the ship itself is in constant motion, making it extremely difficult for him to obtain the kind of accurate and dependable measurements necessary for scientific research. How about calming the water? Why not wait for the water to calm by itself? The first is impossible, and the second is costly since costs accrue whether or not experiments are in progress. A third alternative: build a vessel which would remain quite stable under extremely adverse ocean surface conditions. The latter has been achieved.

While ocean waves may be extremely fierce on the surface, only tens of feet beneath there is a zone of relative calm (wave action falls off exponentially with depth, the longer waves going further into the ocean). A few years ago a rather unusual looking vessel, called FLIP, was developed specifically to take advantage of this calm region. The result is that oceanographers now have a very stable platform from which to conduct experiments with far more accurate results than possible with a conventional surface ship. Submarines, of course, operate in this region, and can sometimes be used for certain types of oceanographic measurements. However, the initial costs for FLIP were considerably less than that for a modern submarine, and FLIP's operating expenses are virtually negligible in comparison.

FLIP (for Floating Instrument Platform) was developed by the Marine Physical Laboratory (MPL) of the University of California San Diego, Scripps Institution of Oceanography (SIO) with financial assistance from the Office of Naval Research. Launched in 1962, FLIP has completed 79 expeditions in the Gulf of Alaska, Hawaiian waters, the Caribbean, and extensively off the California coast.

FLIP has no motive power of her own; she is towed in the horizontal position to the area where research is to be conducted, and "flipped" to the vertical position by flooding ballast tanks. (She can be seen in the vertical position on the front cover; elsewhere she is shown in the horizontal position being towed to the research site, and also in the process of being flipped.) In the vertical position only 55 feet of FLIP's 355-foot length are above the surface, while the other 300 feet extend down into the motionless portion of the ocean, exerting a stabilizing influence on the entire structure. In the vertical position a person onboard FLIP can feel little or no vertical motion. While on station in Alaska, for example, with gale force winds and seas, in 35-foot waves vertical oscillation averaged *less than one-tenth the wave heights.*

The working portion of FLIP is divided into four stories or compartments, each about 14 by 25 feet, plus four compartments below this in the circular portion of the hull. From the top these are: (1) berthing quarters for the crew, (2) electronics laboratory, (3) galley, mess, and scientists' quarters, (4) engineering compartment housing diesel generators, fuel, etc., (5) air compressor room, (6) ship's officers' quarters, (7) second electronics laboratory, and (8) pump room.

BROAD RANGE OF STUDIES

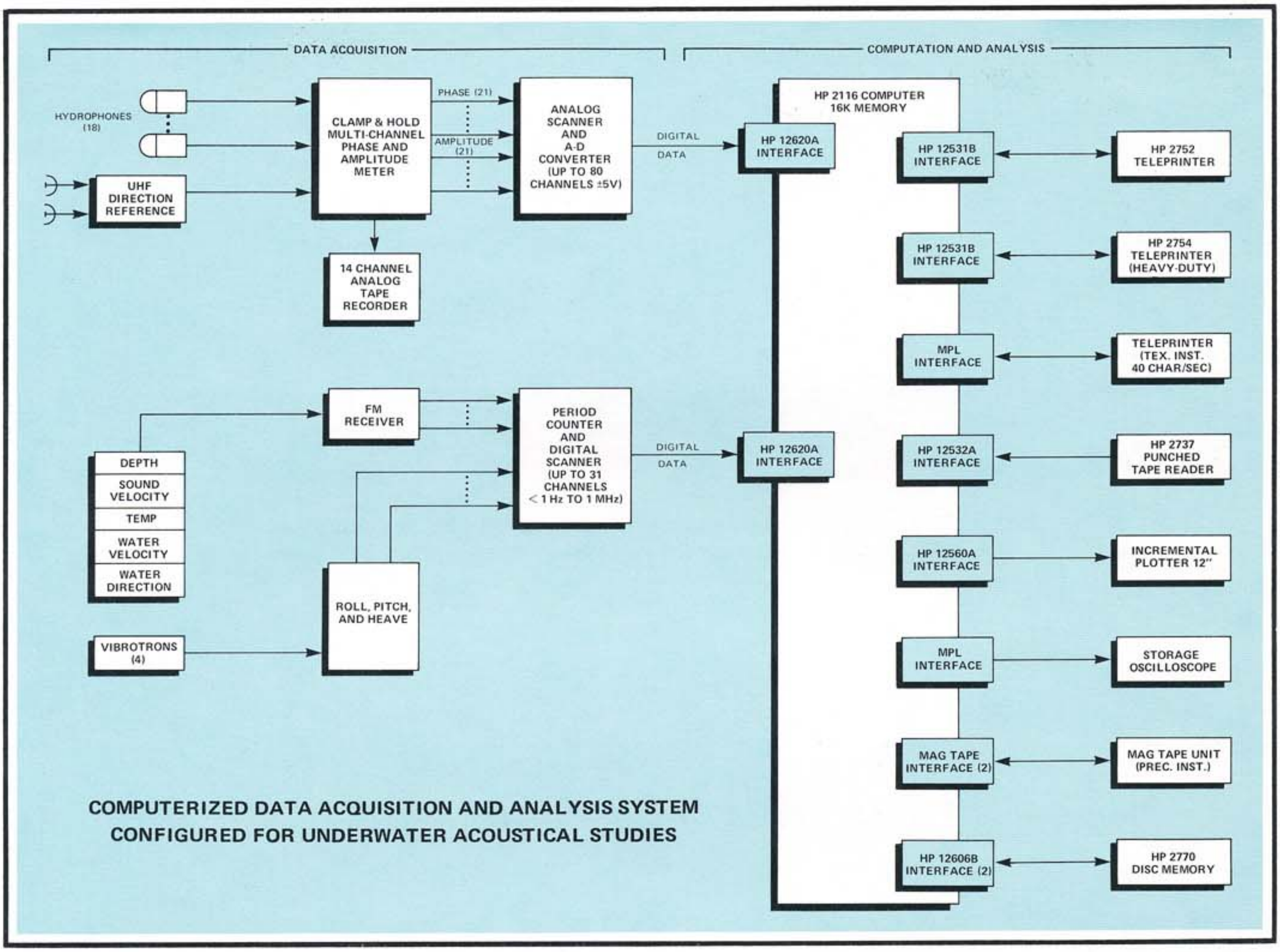
Leading scientists from both the MPL and SIO have been well satisfied with FLIP's excellent stability and practically all have requested more FLIP time for future work in their specialties. While one of the MPL's chief fields of study is underwater acoustics, FLIP will eventually be used in studies of marine biology, geophysics, and other oceanographic specialties. So far, studies have been conducted in wave attenuation, sound propagation and bearing accuracy phase fluctuation, micro-thermal recording, ambient noise, seismic wave recording, wave pressure and acceleration measurements, and measurement of internal waves by means of a thermistor chain.

ONBOARD COMPUTER SYSTEM

FLIP's excellent performance on the high seas has made apparent another need to further enhance her effectiveness as an important research tool: an onboard computer-based data acquisition system. Specifically, Scripps required a system that could measure and record signals from many sources, and perform some on-line data manipulation including statistical and spectral analyses. *Such an onboard system must, of necessity, operate reliably under conditions at sea involving changes in temperature and humidity beyond those of a typical land-based installation.*

Using these requirements as a basis, Scripps selected the Hewlett-Packard system shown in the block diagram. At the heart of the system is a general-purpose, stored-program digital computer with 16K (16-bit words) memory. The computer is able to interface with a wide variety of data logging and display peripherals and data input devices, in addition to those specifically used in the Scripps system. The system presently uses a comprehensive software package including the Basic Control System (BCS), a real-time executive (RTE), and a BASIC language executive (more on these software systems later).

Inputs to the system are through two devices: (1) an 80-channel analog scanner and A to D converter or (2) a 31-channel period counter and digital scanner. (As an aside, it is noted that both of these devices were made in the MPL facilities on campus as a means of satisfying their needs more closely, and at the same time staying within a limited budget.) The heavy-duty teleprinter is the main system



COMPUTERIZED DATA ACQUISITION AND ANALYSIS SYSTEM CONFIGURED FOR UNDERWATER ACOUSTICAL STUDIES

command terminal; the other teleprinter is used as an auxiliary to handle occasional inputs such as program debugging. A third teleprinter (faster) also handles some of the system input/output functions. The punched tape reader handles program inputs to the computer at the rate of 300 characters per second. The plotter and oscilloscope provide scientists with visual displays of data such as power spectra. The read-write magnetic tape unit functions both as a data logger and as system input for subsequent analysis. The disc memory provides bulk storage for programs and data plus *high-speed swapping functions to allow scientists a choice of using the real-time executive software operating system or the BASIC language software system.*

THE BEST FROM TWO SYSTEMS

Particularly gratifying to Hewlett-Packard is to note that many HP computer systems undergo constant upgrading of methods and applications as programmers gain confidence and experience. The practice is quite common and very clearly shows the proficiency of some in-house programmers in utilizing the very comprehensive standard software supplied by HP, and writing their own drivers and subroutines to meet specific needs. (The HP Contributed Software Program Library plus assistance from HP Data Center analysts are excellent sources of help to system programmers.)

At Scripps the system programmers early recognized that the system would be used by scientists, rather than experienced computer programmers such as themselves, and have devised some very efficient techniques to obtain the maximum usefulness from their computer system. Very briefly stated: the original computer system was purchased with the HP real-time executive (RTE) software operating system which very well satisfied the need for real-time data acquisition and analysis. Many scientists, however, are not familiar with the RTE programming languages (FORTRAN and Assembler), but are familiar with BASIC language. The need then was to provide a means by which both the RTE and BASIC could operate on the same computer. But, since these are two separate and distinct operating systems, their designs are such that they cannot *simultaneously* reside in computer core.

While the need was quite uncommon, the problem was not insurmountable. Scripps, with the aid of HP software analysts (as needed) wrote computer programs (subroutines) which allow both the RTE executive and the BASIC executive to reside on the disc and, as desired, either could be called from disc into core for execution. Now, scientists onboard FLIP have available the *choice* of real-time acquisition and analysis under RTE control, or data acquisition and analysis using the BASIC executive software system.

BASIC LANGUAGE CAPABILITIES

When FLIP is in home port (San Diego) the computer system is unloaded and set up in the MPL on campus. Here the system programmers have the opportunity to work on computer-compatible hardware (such as the period counter), perfect existing software, and also write new software programs for future needs. Another very important service provided is that of acquainting scientists with the computer.

Scientists usually visit the lab a week or so before going to sea to receive instructions on running their programs in BASIC so they can control their own experiments. As a further guide to the scientist, he is given a list of the capabilities available through BASIC. A particularly useful core-resident BASIC subroutine, written at Scripps, allows disc-resident relocatable programs to be called into core (swapped with the BASIC executive), executed, and then returned to disc. Thus, by storing routines such as transforms, linear X-Y plots, simple statistics, etc. on disc and calling only when needed, more core is available for data manipulation. Other BASIC-callable subroutines enable scientists to: (1) read and write on magnetic tape and disc, and output on punched paper tape, (2) input data through the analog scanner and period counter, (3) perform integer processing such as log distribution, histograms, etc., and (4) perform such general purpose routines as controlling winches on submerged transducers.

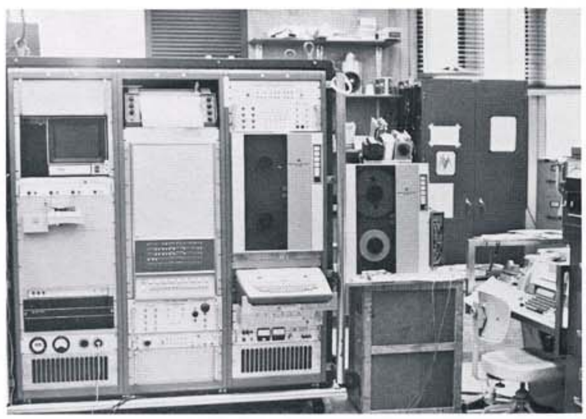
A REAL-TIME APPLICATION

While most scientists at Scripps conduct their experiments onboard FLIP using the BASIC language, other scientists need the capabilities provided by the RTE operating system. A particularly useful feature of the RTE is the ability to compile, edit, assemble, and debug programs *without interrupting the real-time acquisition of data.* (Real-time data acquisition is accomplished in an area of core memory designated as "foreground", while compiling, editing, assembling, and debugging are done in the "background" area of core.) Scientists readily appreciate this feature of the RTE, especially in situations where changing conditions at sea require new programs to be written or existing programs to be modified.

A typical experiment in underwater acoustics employs an array of 18 hydrophones mounted on FLIP's hull to receive acoustical pulses from another ship some distance away. Due to inhomogeneities in the ocean, there are fluctuations in sound amplitude and phase between pairs of hydrophones. The purpose of the experiment is to measure these fluctuations and describe them statistically.

Analog inputs to the computer system consist of (see block diagram): (1) 42 channels of phase and amplitude information of acoustic pulses, (2) FLIP's azimuthal information, generated by a precision UHF direction finder, (3) roll, pitch, and heave information, consisting of FM signals, and (4) vertical profile information of sound velocity, temperature, and water velocity and direction, as a function of depth.

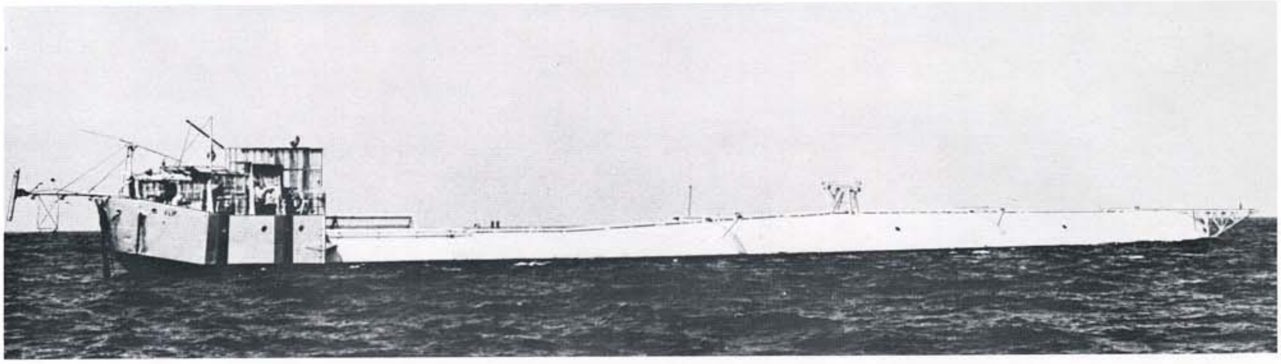
Upon receipt of an acoustical pulse, the computer is interrupted to a high-priority program which immediately measures FLIP's orientation. (Under RTE control, programs can be assigned priorities such that a higher priority program can interrupt a running program and gain control of the computer system.) The analog channels are then scanned, digitized, and input to a buffer in core which holds 8 pulses at a time, logging these onto magnetic tape as one record. Certain channels can be selected to be calibrated into physical units. Next, the phase fluctuations between hydrophones are corrected for the modulation produced by FLIP's motions. These data are then stored for statistical and spectral analysis in the background area of core. Other background tasks include: (1) plotting of time series in instrument or physical units, (2) plotting of bathythermograph information—sound, velocity, temperature, and water velocity and direction, versus depth, (3) plotting or displaying acoustic ray profiles from bathythermograph information, and (4) plotting spectra on log-log axes. Background processing is also used for the usual program development chores of compiling, editing, assembling, and debugging.



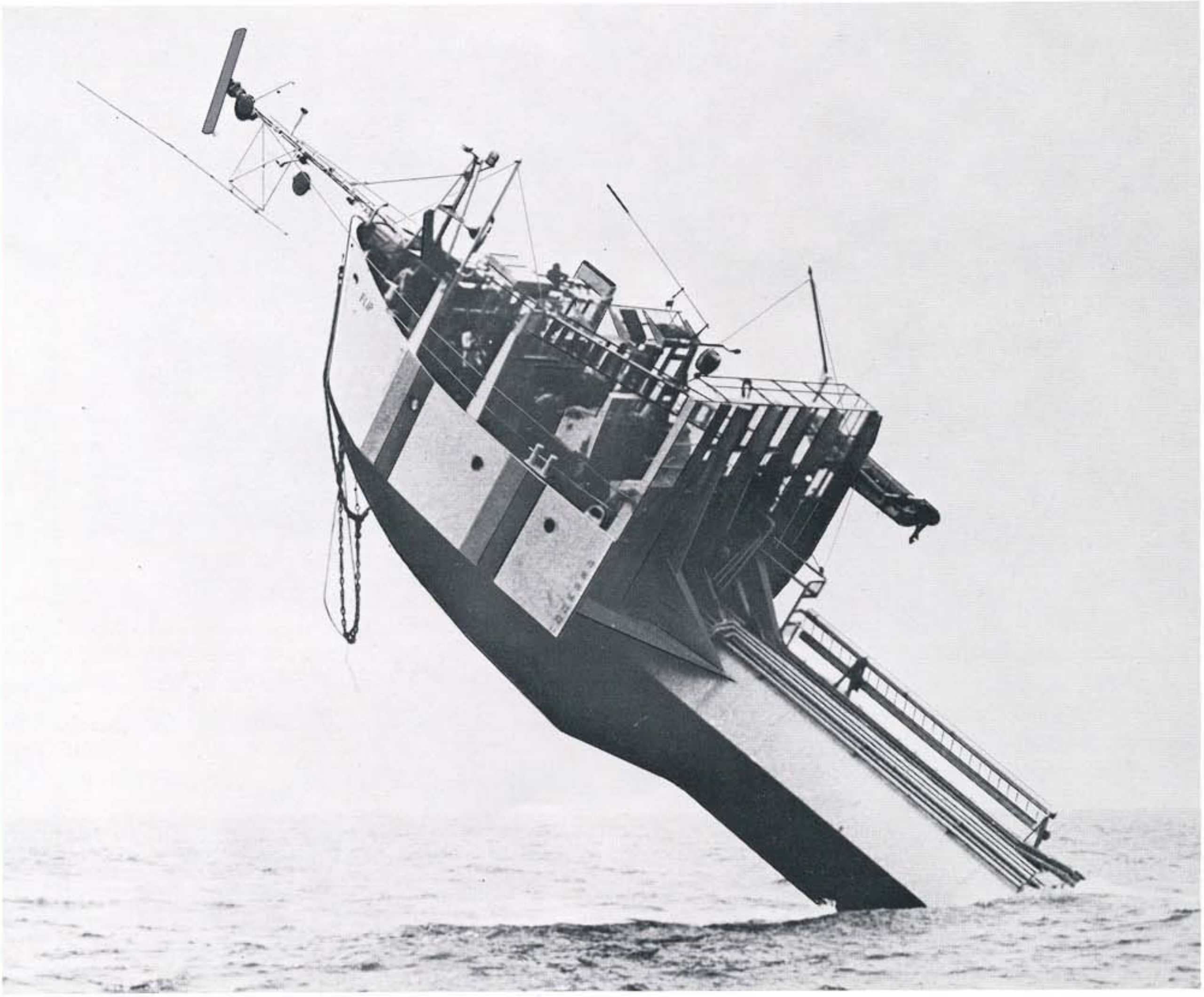
Outside its shipboard environment, the computerized data acquisition system resides at the MPL. In-between cruises system programmers take advantage of this time to develop new and more efficient computer programs. Scientists also use this time to familiarize themselves with the computer system before going to sea.

BENEFITS OF MODERN TECHNIQUES

Onboard data reduction allows scientists to better evaluate and interpret data while an investigation is being conducted at sea. Very early in an experiment scientists can determine validity of the data and decide whether to repeat certain measurements to replace bad data or augment with more information if required. By combining the rugged capability of the HP computer system with FLIP's excellent stability on the high seas, oceanographers are afforded a valuable research tool to aid their quest to further man's knowledge of the seas around us.



In the horizontal position, FLIP's unusual design and shape are clearly visible. In this position she is towed to the research site at sea (the computer system is on its side during this time).



FLIP is shown here in the process of "flipping" (ballast tanks are flooding) from the horizontal position to the vertical position where she will afford scientists an extremely stable platform from which to conduct scientific studies.

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