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ABSTRACT (Maximum 200 words)

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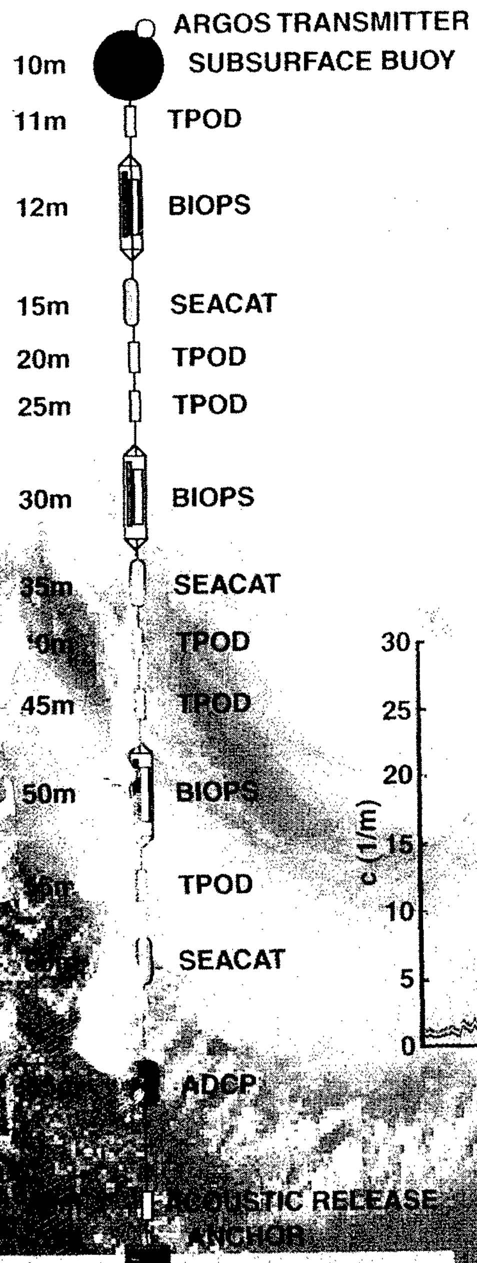

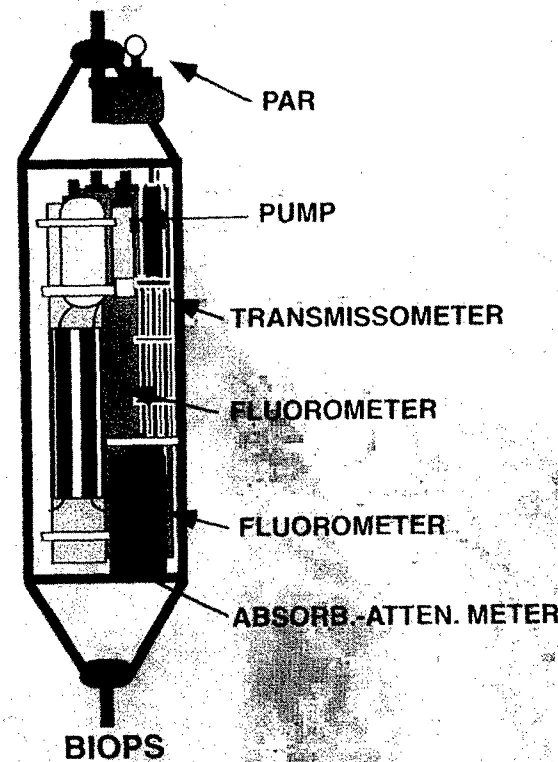

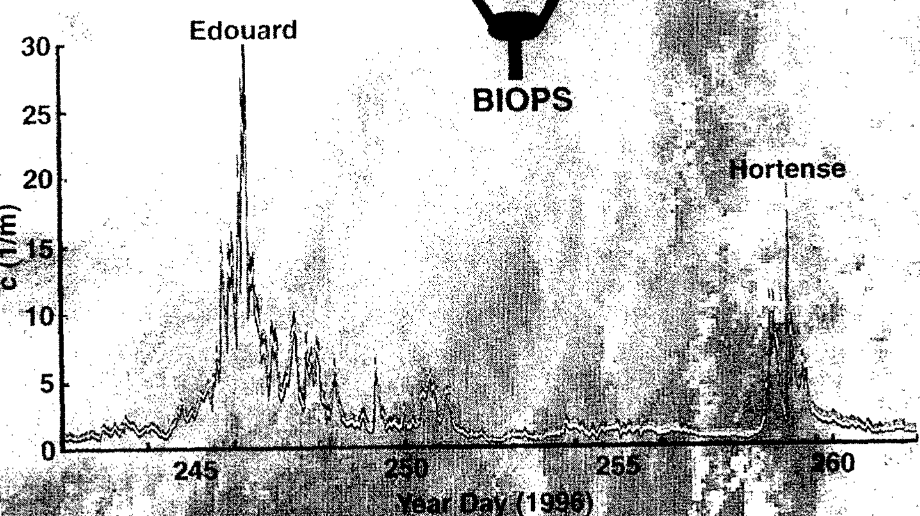

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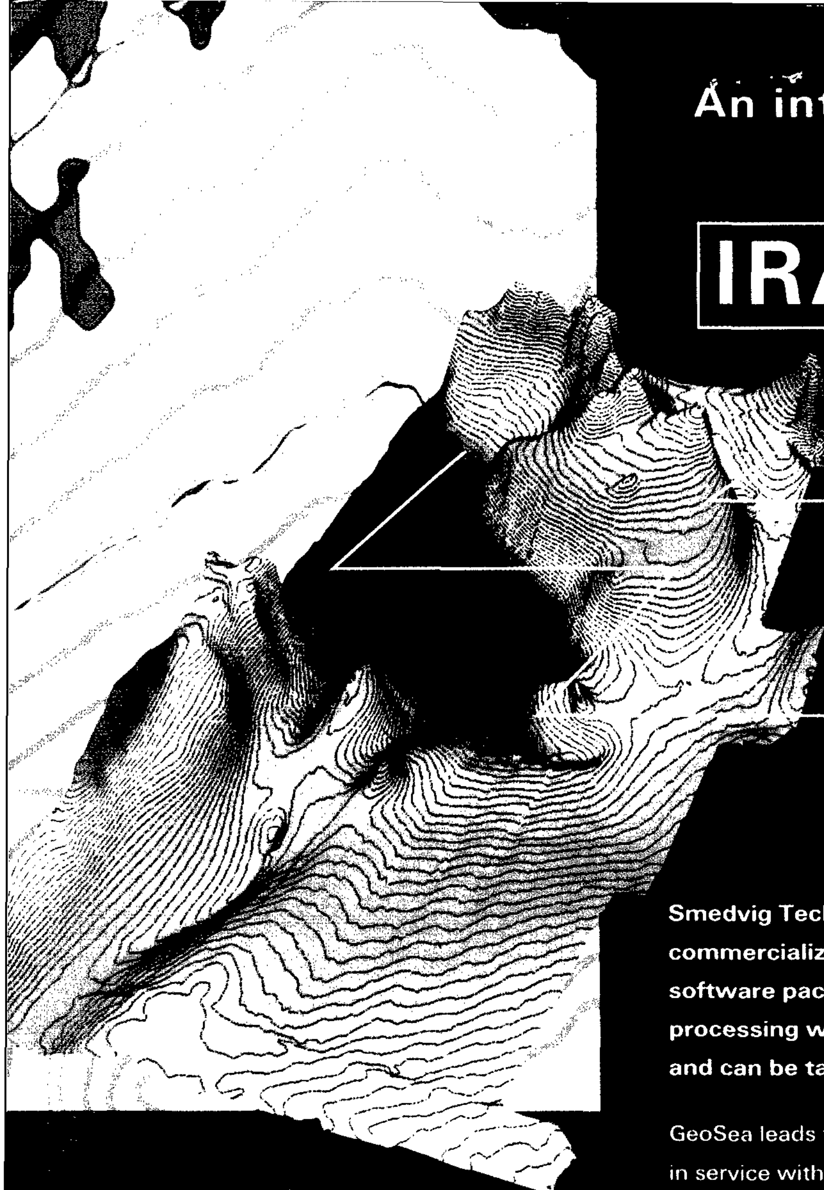

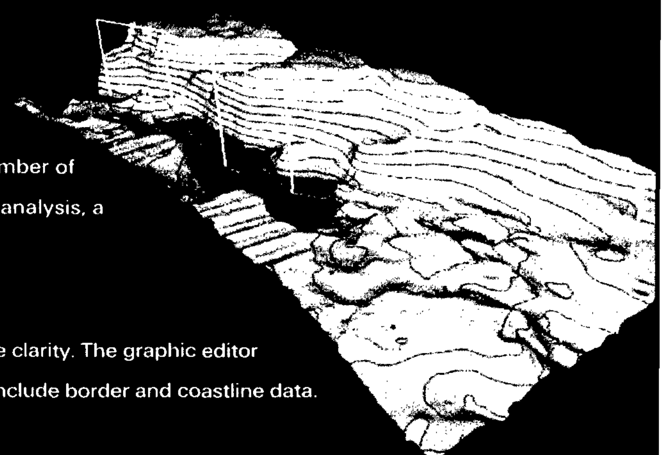

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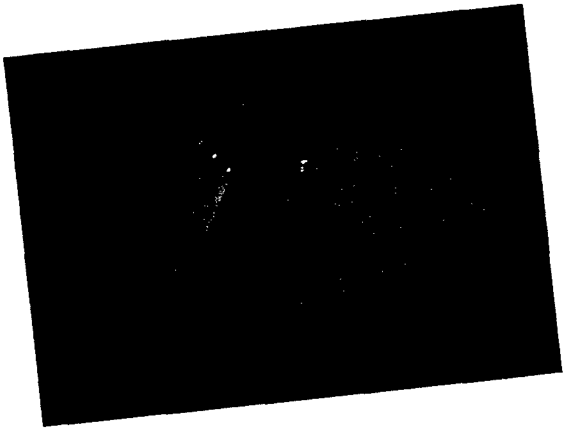

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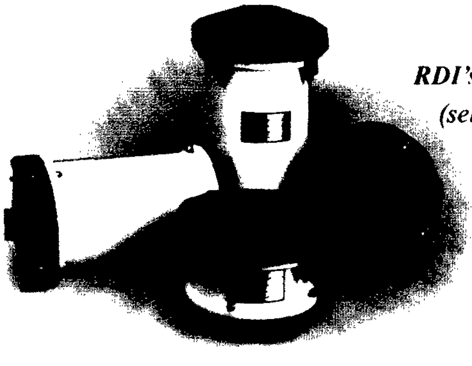

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February 1997, Volume 38, No. 2

Cover—Hurricanes Eduoard (shown) and Hortense passed near the ONR coastal mixing & optics mooring site (CMO site) south of Cape Cod on September 1 and 14, 1996, respectively. Optical instruments (BIOPS) were deployed at four depths by University of California/Santa Barbara scientists from a mooring and a bottom tripod. Data indicate major sediment resuspension events. Instrumentation and data figures supplied by Tommy Dickey, Grace Chang, and Derek Manov at UCSB. Satellite image provided by David Porter and Donald Thompson of The Johns Hopkins University Applied Physics Lab. Sensor manufacturers included WET Labs Inc., Sea Tech Inc., Sea-Bird Electronics Inc., and Biospherical Instruments Inc. BIOPS was developed under NSF and ONR funding.

Next Month—ECDIS status...Worldwide dredging activities roundup...Multibeam sonar in Canada..."Smart ships"...Bioluminescence applications...Preview of 24th Cable & Connector Workshop (Orlando, Florida).

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David M. Graham

Boost Priority for Ocean Instrumentation!

Instrumentation is the key element in determining where world climate is going as well as defining the "when" and "if" of global warming. Because this is our annual instrumentation issue, we direct this editorial to the White House staff, to members of Congress and federal agencies, and to private sector institutions concerned with ocean and atmospheric research—mostly of the "applied" variety. These research subjects can cover a lot of ground (and water). To be more specific, we are talking about oceans and the air-sea interface, atmospheric weather, and climate as it relates to man's activities.

Civilians frequently want to know what the weather will be like tomorrow, next week, and even next year. Billions of dollars being spent are involved with decisions by individuals, small businesses, corporations, and government depending on the weather and what will happen next. Does a farmer plant next month? Do you take vacation next year? What goods do merchants stock for next year? Equally critical are decisions made by the maritime industries and the U.S. Navy in scheduling and planning. A host of scientists need reliable ocean and atmosphere data covering various periods of time.

Ocean behavior and conditions are prime factors in determining climate and making forecasts.

Yes, we already have weather forecasts over land and the oceans and we have collected humongous amounts of world climate data—but they are far from what we need. More specifically we do not have enough data to prepare precise climate models. In the words of one senior oceanographer, we simply do not understand the oceans and have only a small fraction of essential data to do so.

Yes, the oceanographic community has been working on this problem for years, but only within the last ten years has it organized worldwide and used instrumentation to measure and observe the world's oceans. Three major projects—Joint Global Ocean Flux Studies (JGOFS), Global Ocean Ecosystem Dynamics (GLOBEC), and the World Ocean Circulation Experiment (WOCE)—illustrate this effort. They are truly fantastic international ocean programs. We salute the many oceanographers and scientist around the world for their never-ending efforts on behalf of these programs against many odds to envision, design, and implement these critical experiments.

JGOFS is an international project to determine the processes that control the amount of carbon and biologically active elements in the ocean—from the air-sea interface to the seafloor—and to improve predictions of the response of ocean processes to changes in climate.

GLOBEC is an international project focusing on the coupling of physical ocean processes and population changes of 200 plankton and fish and how climate change may effect this coupling and the abundance of marine animals.

WOCE is a project aimed to improve models of the ocean and its circulation for climate prediction and the collection of a quasi-synoptic global dataset of unprecedented accuracy and comprehensiveness.

A major success of these programs to date has been development of new and "smarter" instrumentation. We especially salute those working in private companies, research organizations, academic labs, and in government agencies who design and build hundreds of different oceanographic instruments. Small businesses are significant contributors to the success of these programs.

Although the planned field work for WOCE and JGOFS will be completed in the next two years, many observations and measurements will be continued to determine space structure and scale climate changes. Now the work begins in merging datasets, analysis, interpretation, modeling, and synthesis.

New and better instruments are needed to secure more data and complete the work—primarily in the biological discipline. While there has been remarkable growth in numbers of new sensors and instruments—particularly in bio-optics, acoustics, and sampling—oceanographers and marine scientists still need better systems for collecting and handling plankton in all stages of the life cycle. Interdisciplinary instrument sensors and systems are advancing to include physical and chemical parameters with biological parameters.

We ask responsible federal agencies, research institutes, and quasi-government groups to extend their horizons and fine work in defining ocean/marine research programs needed to have complete understanding of the oceans. This is where it starts. Bold new approaches must be taken. We ask the House and Senate committees to support ocean/marine budget proposals and provide incentives to small businesses for instrument research and development. We ask the White House to place a higher priority on marine environmental programs in the budget process. And we ask the ocean community to keep up its excellent work. */st/*

))) **Effort Continues for Second Civil GPS Frequency.** Emphasizing that the United States remains committed to expanding civilian use of the global positioning system (GPS), the Department of Transportation was to determine the frequency assignment of a second civil frequency. "The addition of a second civil frequency to the GPS satellites will demonstrate this nation's continuing dedication to the civilian use of GPS throughout the world," said Frank Kruesi, assistant secretary of transportation policy. "The department is committed to improving the GPS system to make it the best and most useful positioning system possible." DoT, working with the Department of Defense and other federal agencies, accelerated the effort to determine a second civil frequency after a decision was made last month to execute the second frequency development option of the GPS Block IIF contract. A specific frequency was to be selected by February 21, according to contract requirements. The contract imposes frequency band limitations on the choice of the second civil frequency of 20.46 MHz to 102.3 MHz around the L2 center frequency of 1227.6 MHz.

))) **Navy's Newest T-AGS 64 Survey Ship to be Named by Schoolchildren.** In a first for the U.S. Navy, one of its ships will be named through a nationwide competition among schoolchildren. Navy Secretary John Dalton will have final approval authority. The ocean survey vessel, fifth in the series, will be built by Halter Marine Group Inc. in Gulfport, Mississippi, under a recently announced $51.7 million contract with delivery expected in 36 months. Borrowing a page from NASA (which organization fielded a highly successful competition in 1988 to name one of the space shuttles), the Navy expects to capitalize on recent growing interest in the marine sciences. Current plans are to announce the competition formally before the end of this school year.

))) **Renew your Atlantic Tunas Permit by Phone or 'The Web.'** Responding to fishermen's requests, a new automated Atlantic tunas permitting system developed for NOAA's NMFS is expected to improve service and speed the delivery of annual tuna permits to fishermen. The new system is designed to provide permit holders with a quick, easy way to renew their permits on an annual basis, while also improving the collection of fishing data, providing more current and timely permit and catch information, and reducing the regulatory work load for both fishermen and fisheries service managers. The permitting system can be accessed by either a touch-tone telephone (888-USA-TUNA) or through the Internet (http://www.usatuna.com). Developed by Portlant, Oregon-based NEXTLINK Interactive Inc., the telephone/interlink permitting system is one of the first of its kind in the nation to take advantage of new or improved technology to speed service to customers while reducing work load.

))) **Navy, Russian Scientists Discover Methane Hydrates in Norwegian-Greenland Sea.** Researchers, led by Dr. Peter Vogt of the Naval Research Laboratory, recently revisited the "Haakon Mosby Mud Volcano" and found thin white sheets of methane hydrates (or possibly bacterial mats) covering the deep-sea, warm mud volcano south of Spitsbergen. Vogt and his colleagues from Russian and Norwegian research institutions were operating from the 5,700-ton *Professor Logachev* out of St. Petersburg. A kilometer in diameter, the mud volcano was detected previously at 1,250 meters depth by an NRL-led side-scan sonar mapping project on Norway's continental slope. The "cow-pie-shaped" mound has a heat flow at least 10 times above normal and hosts a new species of tubeworm, "evidently associated with chemosynthetic bacteria," growing on the surface. Cores taken near the methane hydrate patches contained up to 50 percent hydrate; hydrate lumps, up to the size of large radishes, were dug from the mud surface. Vogt noted that the discovery of hydrate actually ***on*** the seafloor is evidence of a very dynamic system.

))) **NOAA Releases Habitat Plan to Enhance Living Marine Resources.** The National Marine Fisheries Service will begin the process of identifying, conserving, and enhancing imperiled aquatic habitats in coordination with regional fishery management councils. Loss of essential aquatic habitat is one of the greatest long-term threats to many of the nation's fish and shellfish, such as salmon, summer flounder and shrimp. From Alaska and Maine to the Gulf of Mexico, many fish population declines can be attributed to lost wetlands and seagrass beds, dammed rivers, contaminated sediments, polluted coastal bays, and other habitat loss or degradation. /st/

Deep Ocean Data Recovery Module

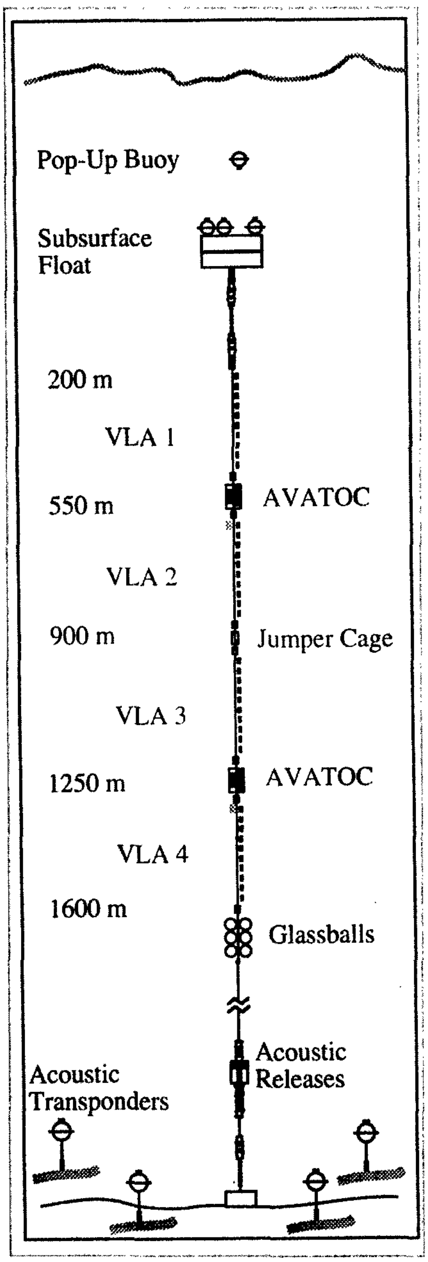
Pop-Up Buoy Enables Recovery of 2.1 Gigabytes of Data Without Interruption From Deep Ocean Instrumentation

By Dr. Peter F. Worcester
Research Oceanographer
Kevin R. Hardy
Senior Development Engineer
David D. Horwitt
Programmer/Analyst
and
Douglas A. Peckham
Senior Development Engineer
University of California-San Diego/Scripps Institution of Oceanography
La Jolla, California

A pop-up buoy has been developed to allow the recovery of 2.1 gigabyte (Gb) data sets at convenient intervals from a deep-ocean seafloor or moored instrument, while leaving the primary instrument undisturbed for periods of time up to or exceeding a year. This capability provides for the early return of data for analysis without interrupting the collection of long time series. The technique offers an alternative to recovery of data by acoustic telemetry link, satellite link, or cable to shore.

Pop-up buoys were developed at the University of California-San Diego (UCSD)/Scripps Institution of Oceanography (SIO) in support of the Acoustic Thermometry of Ocean Climate (ATOC) project[1] and tested at sea for the first time in January 1994. They were used again in 1995-1996 to provide the multi-institutional team of scientists with data from autonomous receiver moorings off the "Big Island" of Hawaii and Kiritimati (Christmas) Island.

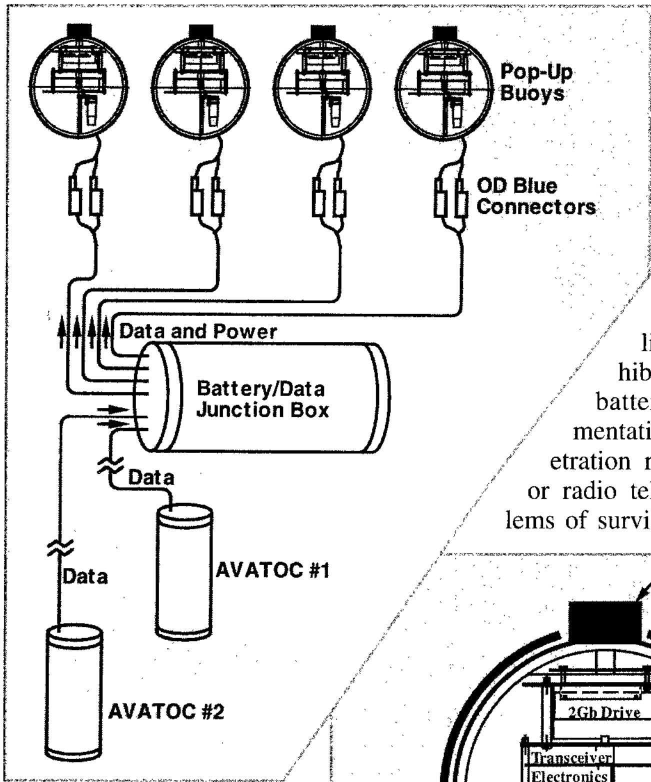
A pop-up buoy extends existing Benthos Inc. (North Falmouth, Massachusetts) TR-6000 releasable transponder technology by: (1) installation of a custom complementary metal oxide semiconductor (CMOS) 386/8 megabyte (Mb) RAM/2.1 Gb small computer system interface (SCSI) hard drive PC with high-speed serial interfaces, (2) adaptation of a pressure balanced, fluid-filled, underwater mateable connector, (3) use of a high-strength, corrosion-resistant burn-rod release assembly, (4) addition of radio and flashing-light recovery beacons internal to the 17-inch glass sphere, and other modifications.

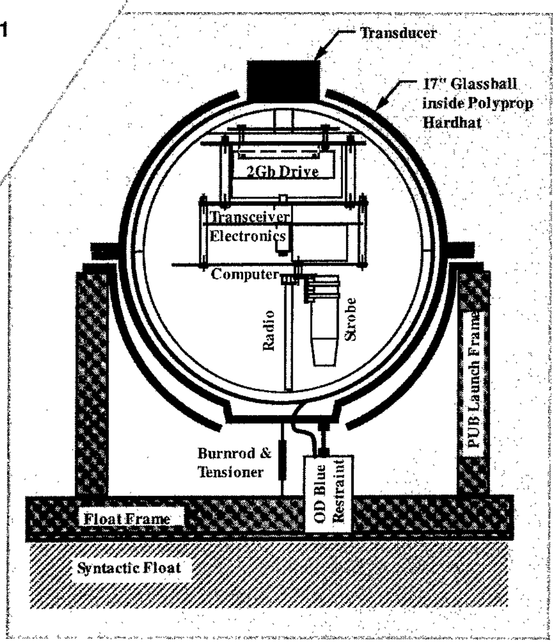


An AVLA showing three pop-up buoys remaining on the subsurface float and one on its way to the surface.

The present Scripps application uses a cluster of four pop-up buoys mounted on top of an Emerson-Cuming Composite Materials Inc. (Canton, Massachusetts) syntactic composite subsurface float connected to the instruments below by electrical cables [Sea Con®/Brantner (El Cajon, California)] which pass through the float. Two channels of data can be transferred from the subsea system to the pop-up at 125 kilobits per second (kbps) each.

The syntactic float supports a string of four 10-element hydrophone arrays [SAIC/MariPro (Goleta, California)], with two 10-element arrays connected to each of two Scripps' data acquisition systems (acronym AVATOC) to form twin 20-element receiver arrays. Kevlar line [Whitehill Manufacturing Corp.(Philadelphia, Pennsylvania)], jacketed "nilspin" wire rope [Macwhyte Wire Rope Co. (Kenosha, Wisconsin)], terminating hardware [Crosby Group (Tulsa, Oklahoma)], Benthos 17-inch glassballs, "dualed" Benthos 865A-DB3 two-year releases, and a stacked railroad-wheel anchor complete the lower half of the mooring, centering the array approximately on





The connections between the two AVATOCs, the battery/data junction box, and four pop-up buoys. At right, pop-up buoy interior and mounting arrangement.

the acoustic sound channel axis.

Each subarray acquires acoustic data at prescheduled reception times. After a reception, each AVATOC writes the data to disk internally, and transmits the data up twisted pairs in the center of the array cable to the pop-up data-recovery modules on the subsurface float. This arrangement allows the recovery of data at approximately quarterly intervals during the designed one-year deployment.

An individual pop-up buoy may be commanded to release using a standard Benthos DS-7000 deck unit and recovered by one person from a charter vessel of modest size. In order to enhance opportunities to recover one of the data recorders, a limited-function deck unit has also been developed and successfully used which allows a collaborating ship-of-opportunity and its trained crew to recover a pop-up buoy without danger of releasing the primary instrument.

Alternatives to the pop-up buoy were considered. Undersea acoustic telemetry makes it feasible to communicate and control a subsea instrument and to periodically read moderate amounts of data from the instrument to shipboard[2]. However, when it is necessary to recover gigabytes of data, the time and energy required by an acoustic telemetry link can become prohibitive, particularly for battery powered instrumentation. The surface penetration required for satellite or radio telemetry poses problems of survivability. The limited data rates through currently available satellites and limited line-of-sight ranges for radio further constrain the use of these approaches. Cable-to-shore solutions are costly to install, require robust sea-land interfaces, land-station terminals, and may be damaged by bottom-fishing or small boat anchors. However, cables do provide the possibility of supplying power to the instrument and receiving broadband data in real-time.

The Scripps' pop-up buoy data recovery modules are in many respects similar to the MYRTLE releasable data capsules previously developed by Foden and Spencer[3] [Proudman Oceanographic Laboratory, Bidston Observatory (Merseyside, England)] (*Sea Technology*, February 1996). Their development was stimulated by the desire to make multiyear deployments of instruments for measuring pressure and temperature and to recover the data at yearly intervals. This approach minimizes disturbances to the pressure sensor, improving the ability to measure low-frequency oceanographic signals[4]. The differences between the two pop-up data recovery modules are principally due to the much larger data volumes generated by the autonomous vertical line arrays (AVLAs) developed for the ATOC project. A complete description of the system is provided by Worcester *et al.*[5].

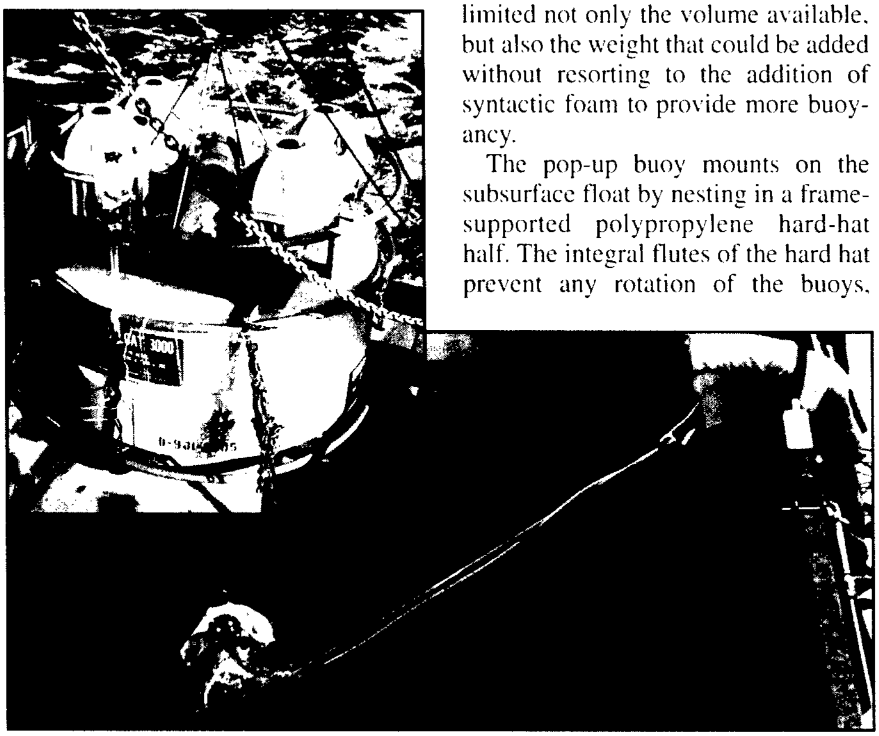
Architecture

The Benthos TR-6000 releasable acoustic transponders, which are used for underwater positioning and navigation, reply when acoustically interrogated and release upon acoustic command. For the pop-up buoy, the transponders are modified by:

- Installation of a custom 80386SL single board computer, with dual 125 kbps serial interfaces, and a 2.1 gigabyte Winchester disk drive
- Addition of modified "OD Blue" pressure-balanced, oil-filled, underwater-mateable connectors [Ocean Design Inc.(OD) (Ormond Beach, Florida)] for external power and signal connections
- Installation of recovery aides consisting of a Novatech Designs Ltd. (Vancouver, B.C., Canada) radio beacon and a modified Tandy Corp. (Fort Worth, Texas) personal strobe inside the glass pressure housing
- Replacement of the standard stainless-steel burn wire with a high-strength, corrosion-resistant Inconel 625 rod to increase mechanical strength and lengthen operating life
- Reduction of transponder battery size including isolation of the transmit/receive and burn-wire batteries
- Modification of the internal mechanical mounting arrangement to make it more robust and to accommodate additional components
- Installation of a deck connector to provide communications with the internal computer components enabling testing of the instrument and read out of the data (at 167 kbps) with the glass pressure housing sealed
- Addition of two titanium recovery bales to the sides of the protective hard hat.

In the ATOC AVLA application, four pop-up data recovery modules receive data from two sets of AVATOC electronics at 125 kbps per channel. Data from the two AVATOCs are routed through a junction box mounted on the subsurface float and fed in parallel to all four pop-up modules through underwater mateable "OD Blue" connectors. All four pop-ups therefore record exactly the same information. Once the disks are full, the oldest data are overwritten on each record cycle. Any one of the four pop-ups can therefore be recovered at any time to provide the most recent 2.1 gigabytes of data. All four pop-ups transpond using the same interrogate and reply frequencies, but have distinct release codes so that each pop-up can be individually recalled. When one of the pop-up modules is released, the module buoyancy force is adequate to separate the connectors.

Alkaline batteries for the transpond and release functions, and for the flashing light and radio beacon, are housed inside the glass pressure housing. The junction box houses alkaline batteries to power the single-board computers and disk drives.



Pop-up buoys, deep-ocean recovery modules encircle the battery junction box on the syntactic subsurface float in inset photo. The instrument platform awaits deployment off UCSD/SIO's R/V **New Horizon**. *Above, pop-up buoy recovery by John Kemp (Woods Hole Oceanographic Institution) from the UCSD/SIO's R/V* **New Horizon** *during the ATOC acoustic-engineering-test deployment cruise in September 1994. (Photographs by K. Hardy)*

Mechanical Design

The transponders are housed in the 17-inch glass spheres, which are placed in polypropylene hard hats for mechanical protection during handling. The mechanical design of the pop-up buoy was constrained by a desire to retain the basic simplicity of this packaging, while adding the single-board computer, disk drive, and recovery aides to the standard Benthos TR-6000 releasable transponder. This limited not only the volume available, but also the weight that could be added without resorting to the addition of syntactic foam to provide more buoyancy.

The pop-up buoy mounts on the subsurface float by nesting in a frame-supported polypropylene hard-hat half. The integral flutes of the hard hat prevent any rotation of the buoys, making a single-point, burn-rod restraint effective.

The pop-up buoy mounts on the subsurface float with the transponder up for optimum acoustic performance, but the interior weight distribution is arranged so that the transponder will float with the transducer down once released. This orientation makes it possible to acoustically range on the pop-up when it is on the surface if the acoustic conditions are suitable. The strobe light and radio beacon are turned on by mercury switches when the pop-up flips over after release.

Electronics

In addition to the 2.1 gigabyte disk drive, three circuit cards are installed in each pop-up: (1) the 80386SL single-board computer, (2) a computer power switching and regulator board, and (3) SCSI drive power-switching and regulator board.

The 80386SL single-board computer, identical to that used in the AVLA AVATOC electronics[1], is configured around two computer busses—a high-

"Pop-up buoys provided the early return of important information during the recent ATOC mooring experiment, August 1995-September 1996."

speed bus that is electrically, but not mechanically, ISA compatible and a low-speed interprocessor bus designed to connect a number of microcontroller units. Eight megabytes of CMOS static RAM are provided to buffer the incoming data before they are written to disk.

The telemetry channels use balanced drivers and receivers to reduce the induction of electrical noise from the 125 kbps data streams into the hydrophone channels. The receivers are optically isolated.

The 80386SL computer is turned "on" by the appearance of data on either telemetry channel. It is turned "off" under firmware control. The single-board computer and Winchester disk are completely powered "off" between reception cycles to conserve batteries. CMOS static RAM that is included in the real-time clock function of the 82360SL peripheral control unit is battery backed-up to retain essential parameters between power-ups of the main processor.

Consideration is being given to the addition of a second hard drive or substitution of one of larger capacity.

Software/Firmware

The firmware receives data from both serial lines simultaneously, buffers the data in RAM, and writes the data to disk after data transfer is complete. When the pop-up is powered "on," three independent processes are started: two identical telemetry channel reading tasks (one task per data channel) and a disk writing task.

The data received on the serial channels are written to disk exactly as received, except for the addition of a short header and footer. The header (preappended to the beginning of the data received on each channel) contains the current power cycle, the channel from which the data originated, and the number of bytes received. A one-sector footer, written after all valid data have been written, is a logical end-of-data marker which is overwritten by the data of the immediately subsequent power cycle.

At deployment, the disk-sector counter is initialized to zero. If the disk fills up, the software reinitializes the counter to zero, allowing the oldest data on the pop-up to be overwritten with newer data.

Testing

Initial testing of the Scripps's Inconel 625 burn-rod release and the "OD Blue" connectors was performed in a deep saltwater tank located on the Scripps' campus during mid-1993. The first at-sea test occurred during January-February 1994, in conjunction with the first moored test of the ATOC AVLA. The first scientific use of the pop-up buoy data-recovery modules occurred during the ATOC acoustic-engineering test in November 1994. We encountered some initial problems with the reliability of the "OD Blue" connectors during that experiment, though data were successfully recovered from both deployed AVLAs. With cooperation from the manufacturer, we believe those problems have been resolved.

Pop-up buoys provided the early return of important information during the recent ATOC mooring experiment, August 1995-September 1996. For the ATOC deployments, a shipment of improperly soldered burn-rod-release battery packs caused two pop-ups on each mooring to fail to release. (They were recovered with the main instrument at the conclusion of the experiment.) Revisions in our acceptance testing procedures and increased scrutiny by the battery module manufacturer's production and quality control have been implemented. We now believe the pop-up buoy data-recovery modules are ready for routine use. /st/

Acknowledgments

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Dr. Peter F. Worcester, at the UCSD/SIO's Institute of Geophysics and Planetary Physics, is presently the principle investigator of the ATOC research program. He received his bachelor of science degree in engineering physics from the University of Illinois in 1968, his master of science in physics from Stanford University in 1969, and his doctorate in oceanography from UCSD/SIO in 1977.

Kevin R. Hardy, at the UCSD/SIO's Institute of Geophysics and Planetary Physics, is a fellow of the Marine Technology Society. He received his bachelor of science degree in industrial technology/manufacturing from San Diego State University in 1980.

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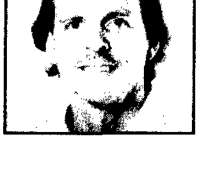

Douglas A. Peckham, at the UCSD/SIO's Institute of Geophysics and Planetary Physics, received his bachelor of science in physics from UCSD in 1977.

Special-Purpose Samplers at HBOI

Benthic, Geochemical, Biological Sampler Development: Suction Systems, Detritus Traps, Isobaric & Isothermal Properties, Sediment Probes & Samplers, Drills & Worm Taggers

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Investigators often find that standard methods or commercially available tools are inadequate or unsuited for use underwater. In response to specific problems for which a standard approach had not been developed or the previously employed methods and hardware did not provide sufficiently quantitative results, a number of custom, underwater sampling and measurement systems have been designed at the Harbor Branch Oceanographic Institution Inc. (HBOI) over the past several years. Some of the designs are improvements or simplifications of prior systems while others provide somewhat novel solutions to marine and limnological sampling problems.

Several specialized mechanical sampling systems have been are widely used by the underwater research community[1,2,3,4]. The earliest is the "Critter-Gitter"—a suction sampler developed for use on the *Johnson-Sea-Link* (JSL) manned research submersibles. Similar suction samplers have been designed for use on other manned submersibles, a one-atmosphere-diving suit, and several ROVs.

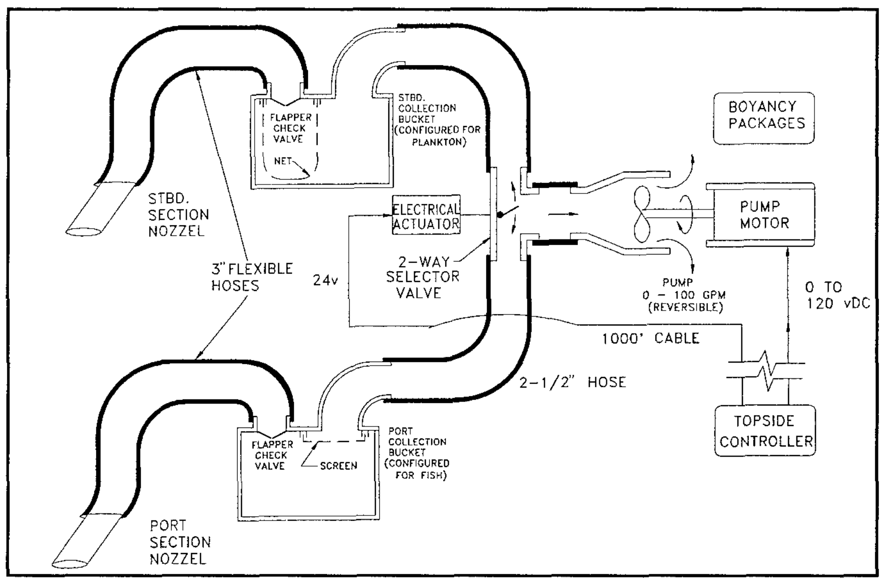
The collection of fragile midwater animals and objects, such as jellyfish and larvacean houses, has been accomplished with specialized collectors carried on manned, research submersibles and ROVs. These traps allow the specimen of interest and the surrounding water mass to be captured and transported to the surface with a minimum of mechanical disturbance or thermal stress.

The concentration and collection of particulate material from large volumes of water *in situ*, so that it can be later analyzed in topside or on-shore laboratories, are accomplished with a custom pump and filter system. This design allows geochemists to accurately measure low concentrations of organic and inorganic pollutants as a function of location (three dimensionally) and time.

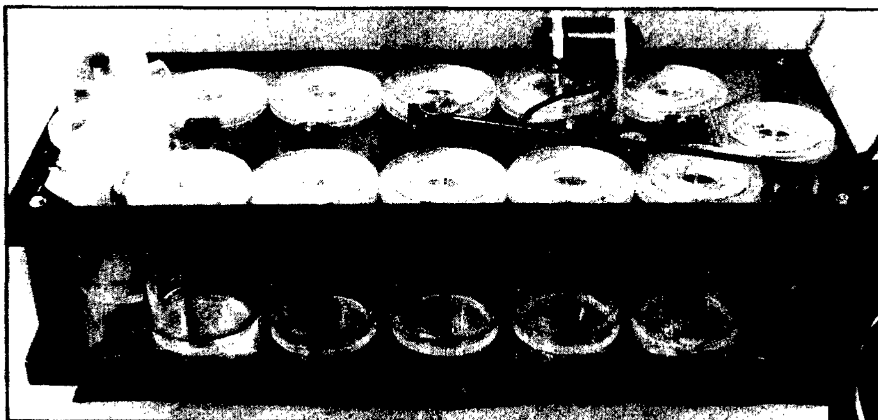
Multiple punch cores have been collected during a single dive of a work ROV using a custom sediment sampling system. Although designed for a survey of the seafloor for structural purposes, this apparatus should also be useful for obtaining scientific samples of the bottom for geological, chemical, and biological studies.

Another submersible-based sampler allows a physical specimen to be collected, deposited in a heavy-walled container, enclosed at great depth, and brought to the surface under isobaric and isothermal conditions. This system was developed to allow collection and analysis of methane-hydrate crystalline samples found in extensive deposits in deep-ocean sediments, which may be important economically as well as scientifically.

The growth rate of benthic tube worms is being studied by a couple of innovative, submersible-based methods. With one approach, numbered



Two-chamber suction sampler sketch.



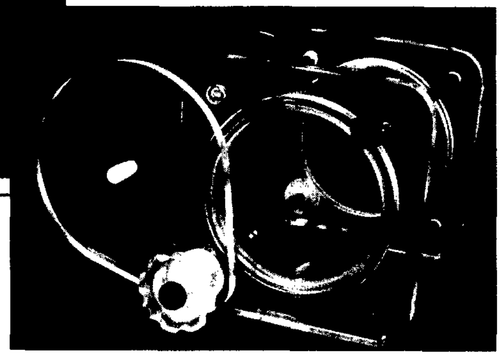
tags are attached to individual specimens while with the other, small groups are coated with a harmless dye and later observed to determine growth from the length of the non-stained part of the tube.

Suction Samplers, Detritus Traps

Suction samplers are basically "slurp guns" which use a high flow-rate pump to suck up the samples to be collected along with the surrounding water[1]. The object or material to be sampled is transported into a transparent chamber through a nozzle and large-diameter flexible hose by a high-volume, variable-speed pump. The chamber has a screen or mesh on the outlet side to prevent the sample from passing on into the pump and, if required, a flow actuated valve on the inlet side to prevent highly mobile specimens from escaping.

The pump is positioned downstream of the collection chamber to reduce contamination and mechanical damage of the sample collected. Good operator control of the flow rate is essential—slow, gentle flow for delicate samples and high flow rate for collecting mobile fish and high-density geological specimens. Hydraulically powered and electrically driven pumps are used, depending on the capabilities of the vehicle or platform on which the sampler is used.

For multiple chamber samplers, a conveyor mechanism which advances the chambers and sequentially positions them with respect to the inlet and output hoses is used rather than a simple two-position selector valve. With the multiple-sample approach, both inlet and outlet parts of the chambers



Above left is a 12-chamber suction sampler. A motorized sequencing mechanism allows any of the chambers to be positioned under the suction head (left). Above is a detritus trap for midwater delicate specimens.

are switched coincidentally.

A 12-chamber sampler (seven-liter chambers) was designed to be easily installed in the tool sled of Monterey Bay Aquarium Research Institute's *Ventana* and *Tiburon* research ROVs. Earlier versions have been installed on the *Johnson-Sea-Link I, Johnson-Sea-Link II,* and *Clelia* for several years. The design can be scaled up or down to satisfy the requirements of other vehicles. A compact five-chamber sampler has been in use for over 10 years on a variety of vehicles. Although it has not yet been done, these samplers could easily be deployed over-the-side or on a fixed-position-mooring to collect samples for time-series studies as is commonly done with benthic landers.

Detritus traps are primarily used by mid-water biologists to collect slow-moving, delicate specimens that cannot be obtained undamaged with other collection equipments[4]. The sampler consists of a transparent vertical tube with end closures which are remotely actuated. To close the sampler, both lids are rotated horizontally about a vertical pivot axis (with a sliding motion); this minimizes the disturbance of the water mass around the sample.

In operation, the open sampler is carefully maneuvered until the specimen is inside the tube. Then the top and bottom lids are quickly closed. The nominal samplers have internal volumes of 6.5 liters (16.5 centimeters in diameter by 30.5 centimeters long). Longer samplers with an internal volume of 12 liters have also been built and successfully used.

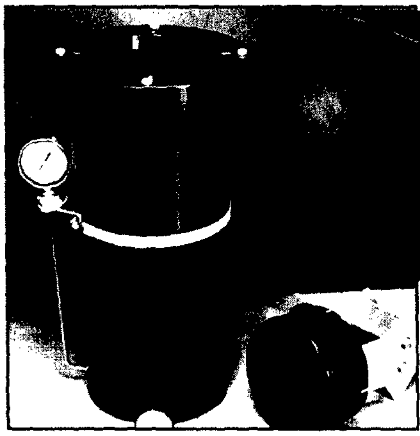
Geochemical Sampler

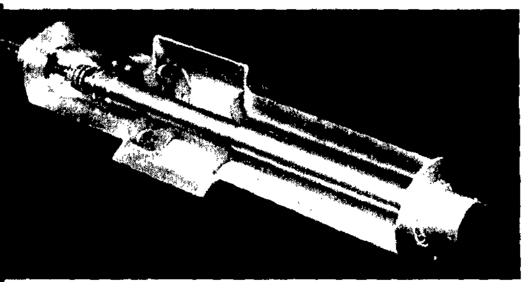
The collection of low-concentration pollutants associated with particles suspended in large water bodies required specialized sampling equipment. One approach is to collect numerous water samples using Niskin or other water samplers, transport the samples to the laboratory without contaminating them, extract the particulate matter, and complete the appropriate analyses. For quantitative measurement of low-concentration compounds, impractical large volumes of water may be required.

Another approach is to filter the particulates out of the water, *in situ,* and transport only the particulate matter and filter material to the laboratory for later study. Early attempts to do this with filter holders mounted within the HBOI suction samplers were only marginally successful because • the amount of water flowing through the filter could not be accurately measured, • insufficient pressure was available from the high-flow-rate pump, and • there was contamination of the samples by the filter holder materials.

Therefore, a sampler was developed to allow four independent samples of water to be filtered under highly controlled conditions during a manned-submersible dive. The filter holders allow a negligible amount of water to bypass the filter so that accurate measurements of water volume can be made. An electromagnetic-coupled, paddle-wheel flow-meter allows the instantaneous flow rate to be monitored, and in its integrating mode provides a measure of water-volume filtered. A mechanical volume-flow meter is connected in series with one of the filters to provide a simple calibration check of the electronic meter.

A five-position selector valve selects one of the four filters. The fifth





Left photo shows pressurized hydrate collector. At right is sediment coring device.

(bypass) position allows complete flushing of the inlet manifold between samples. A controlled-speed, high-pressure pump, with a progressive-cavity type impeller, provides sufficient suction to draw water through the filters even after they have become partially clogged with particulates. A differential pressure gauge allows the pressure drop across the filter to be monitored, and a pressure-relief valve, set at 30 pounds per square inch, limits the maximum pressure that can be applied to a filter. In shallow water the pump can easily develop sufficient vacuum to cause cavitation—at depths greater than 20 meters this is not a problem.

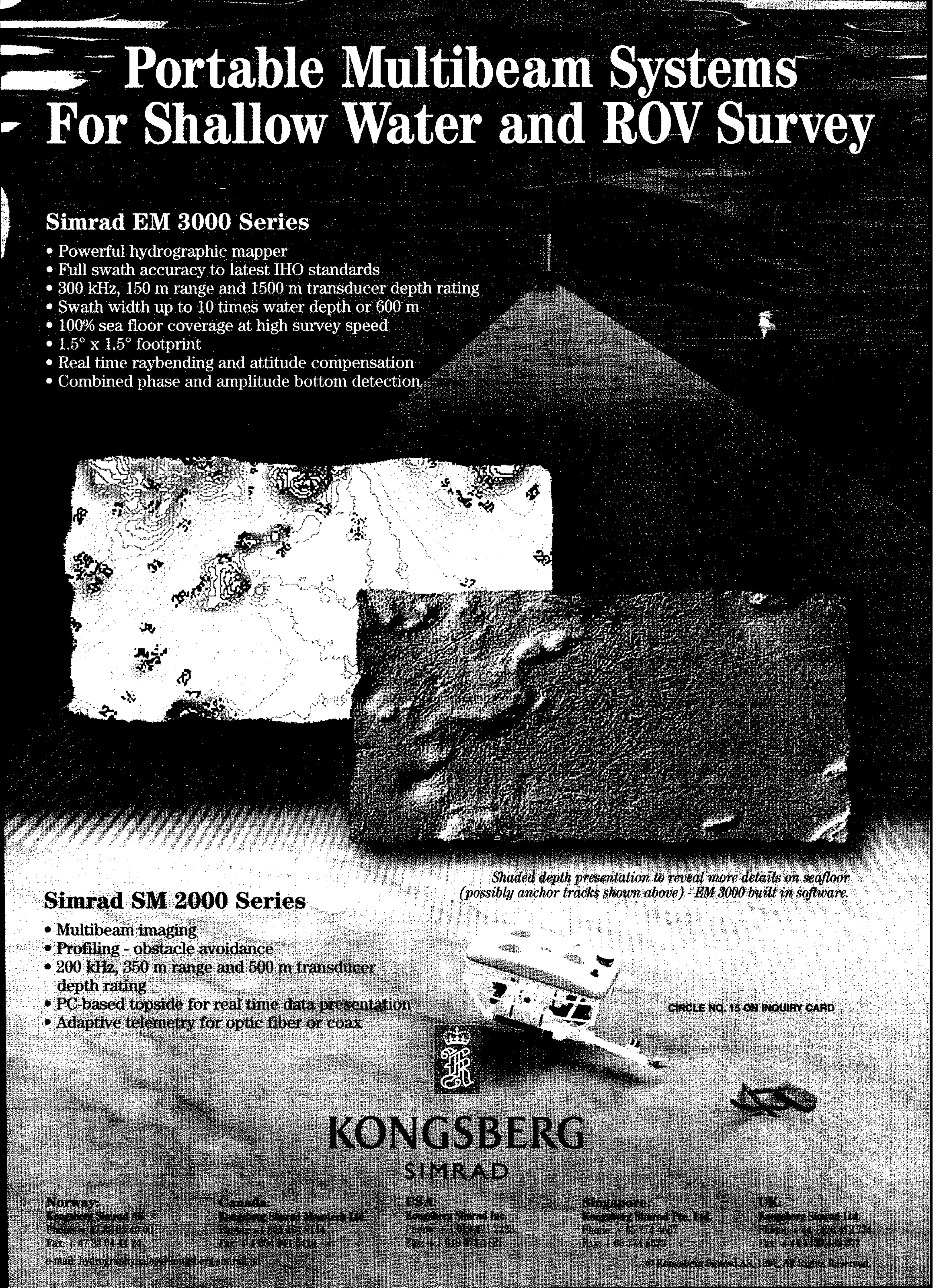
The check valves is oriented so that gravity will cause particles in the inlet line to be deposited in the manifold tube (where they can be easily flushed) rather than on the check valves. Each sample must be isolated from the surrounding water after it is extracted and from the other samples. The inlet manifold and check valves are PFA Teflon.

To minimize contamination by the sampler, the type of materials for components must be carefully selected. For collecting organic compounds, the filter holder materials are stainless steel with Teflon-encapsulated rubber seals (these have greater compliance than pure Teflon seals). For inorganic (trace metals) studies, the filter holders are constructed of selected plastics which are highly resistant to the cleaning acids and which exhibit low contamination. (The plastics chosen are primarily polycarbonate for its mechanical strength and ease of machining and polypropylene for its availability as a component material.)

Two sizes of filter holders which accept standard 90-millimeter and 293-millimeter filters have been fabricated. Any combination of filter-holder materials and sizes can be deployed during a dive of the host submersible. This particular system is configured for four filter holders due to payload and space restrictions. Other configurations are feasible.

Pressurized Hydrate Collector

Methane hydrate (clathrate) deposits have been recently discovered in many deep-ocean locations. Potentially important as a source of fuel, this naturally occurring crystal is the subject of considerable research[5]. The collection of this material and its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Shaded depth presentation to reveal more details on seafloor (possibly anchor tracks shown above) - EM 3000 built in software.
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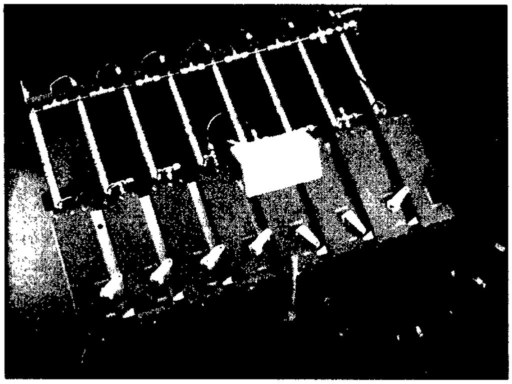
transportation to the laboratory for study are complicated by the facts that it is hard, lighter than water, and because it rapidly decomposes with decreased pressure and increased temperature.

A special pressure vessel has been built to facilitate the recovery of samples collected on the seafloor using a manned submersible. The collector is constructed of a 15-centimeter inside diameter (2.5 centimeter wall thickness) aluminum tubing with a fixed bottom and a removable lid. The lid mates to the tube with a one-eighth-turn bayonet closure which is self aligning so that it can be easily removed and reinserted by the submersible's manipulator.

A pressure gauge allows the internal pressure to be monitored, and a pressure-relief valve ensures that the internal pressure does not exceed the working pressure of the chamber. The housing wall has excess thickness to reduce the compliance of the chamber. This helps to maintain the internal pressure at close to the collection pressure as the sample is brought to the surface.

This sampler is designed for use to 3,000 feet with a large safety factor. In the future, an improved insulation jacket will be installed on the sampler to maintain the sample temperature close to the temperature at which it was collected.



Tube-worm tagging system for attaching tie-wraps to eight individual worms.

Sediment Sampler, Probe

A survey of a potential deep-water pipeline route required that numerous bottom core samples be collected by a hydraulically powered work ROV along the proposed track. A coring system[6] was developed at HBOI within a six-week period during 1995, delivered to the customer, and successfully used on the survey.

The mechanism consisted of a corer with an aluminum holder that was pushed into the sediment by a hydraulic cylinder mounted on top of the device. The holder provided alignment and guided the corer into the seafloor. The tube was open and flared down the side to allow access of the corer. A large entry area is provided to allow the manipulator jaw to enter the tube. In this area were two polyurethane grips which hold the corer in the device. The coring tube consists of a 24-inch long by 1.5-inch diameter aluminum tube fitted with a stainless steel core-cutting blade and a 24-inch long transparent plastic liner. The liner is fitted with a stainless steel, multiple overlapping-leaf type core catcher.

A unique passive latching and unlatching mechanism, which holds the top of the corer, automatically attaches and releases during the operation. The mechanism attached to the rod end of the hydraulic cylinder consists of many radial latches held together by rubber rings. The latches then attach to a special valve mechanism on the top of the corer when the hydraulic cylinder is extended. The valve allows water to exit the core tube while it is being pushed into the seafloor and then closes when the hydraulic cylinder is reversed by pulling up on the valve.

All functions are therefore performed passively except for the "extend" and "retract" functions of the hydraulic cylinder.

With this system, a core holder is selected from several stored in an on-board basket by using the vehicle's manipulator. A bottom sample is collected, and the sealed core holder returned to the storage basket.

The sediment overlying hydrocarbon deposits develops internal electric fields as a result of bacterial action. Measurements of the variations of *in-situ* electrical potential as a function of distance below the sediment surface provide reliable evidence of petroleum seepage. A ***multi-electrode probe*** and data logger has been successfully designed and tested at HBOI and deployed in the Gulf of Mexico during 1996.

Rock Drill, Tube-Worm Taggers

A dual, hydraulically actuated rock drill based on the design of Stakes and

> ***"Tube-worm growth has been measured from* Johnson-Sea-Link *submersibles using two innovative systems. The first system allows . . . numbered plastic tie-wraps to be slipped over the tube of the worm, tightened, and the tie-wrap released. "***

Holloway[7] has been developed for use on the JSLs to a depth of 3,000 feet. The two-drill mechanisms are mounted on a detachable frame on the front of the vehicle to facilitate operation and visual monitoring by the scientist within the submersibles acrylic sphere. Hydraulically driven motors running at 700 revolutions per minute power the drills and hydraulic pistons and springs provide the necessary thrust force. Cores up to 18 inches in length can be obtained in soft rock such as coral or sedimentary layers using standard diamond coring bits and core holders.

Only one drill is operated at a time. The support frame can be rotated to allow drilling at an angle of up to 80° from the axis of the submersible. The design could be adapted to mount more than two drills, allowing several samples to be obtained during a single dive.

Vestimetiseran ***tube worms*** are the primary ecosystem-structuring animal at many deep-water hydrothermal vents and cold seeps. Measurements of their growth rate provide information on energy transfer processes at these sites. Tube-worm growth has been measured from *Johnson-Sea-Link* submersibles using two innovative systems. The first system allows individually numbered plastic tie-wraps to be slipped over the tube of the worm, tightened, and the tie-wrap released. At a later revisit to the site, the growth of the individual worm above the tie-wrap is measured with a quantitative photographic method[8].

A hydraulically actuated sequencing mechanism allows the operator inside the submersible to attach tie-wraps on up to eight individual tube worms during a single dive. This system has been successfully utilized by the *Johnson-Sea-Link* in the Gulf of Mexico during research cruises in 1991-1995 and *Alvin* and *Nautile* on the East Pacific Rise to a depth of 2,500 meters.

A second, less-invasive, method allows tube-worm tubes to be marked with a harmless dye—the subsequent growth is determined by the length of the naturally-colored portion of the tube. In order to dye the specimens, a plastic "Bell-Jar" is placed over a group of tube worms, dye is injected into the jar from the top, and allowed to stand for three minutes. The dye is then pumped back into the reservoir and the bell jar removed. Many groups of worms can be stained during a single dive. All exposed surfaces of the tubes are dyed, and the growth is measured during a later visit to the study site. The dye color is changed during subsequent visits to the same community so that the incremental growth can be easily measured. All manipulations are performed remotely by the operator in the submersible. This device has also been used on *Nautile* and the ROV *Ropos*. /st/

Acknowledgments

Dr. Douglas S. Lee, the principal at DSL and Associates Inc. (Norwich, Connecticut) and former freshwater program director for the National Undersea Research Center (University of Connecticut); Dr. Ian R. McDonald, biological oceanographer with the Geochemical and Environmental Research Group of Texas A&M University, program director for the Stability and Change in the Gulf of Mexico Chemosynthetic Communities Program; and Dr. Charles R. Fisher, associate professor of biology at Pennsylvania State University, whose equipment has been used on over 50 dives of submersibles and ROVs. All are essentially co-authors of this article.

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R. Chris Tietze has been with HBOI since its inception in 1972. He has developed numerous scientific samplers and other systems for all of the HBOI-developed undersea vehicles. Tietze attended Florida Atlantic University and has been granted three patents for underwater devices and equipment.

Kim R. Reisenbichler has specialized in development and integration of scientific research tools into undersea since Monterey Bay Aquarium Research Institute was founded in 1987. He holds a master's degree in aquatic biology from the University of California, Santa Barbara.

Deep Flight: Technology Demonstrator or 'The Answer'

Eight Years Abuilding, Newest Submersible Frees Researcher From Support Ships but Begs Question—Is There a Future?

By Graham S. Hawkes
President
Hawkes Ocean Technologies
Oakland, California

Real issues with *Deep Flight* lie not in its obvious media appeal but in the question of whether *Deep Flight* is ultimately successful in its mission to preserve a viable manned option for the future, a future where conventional manned submersibles will not be built, having been made obsolete by the ROV and the AUV.

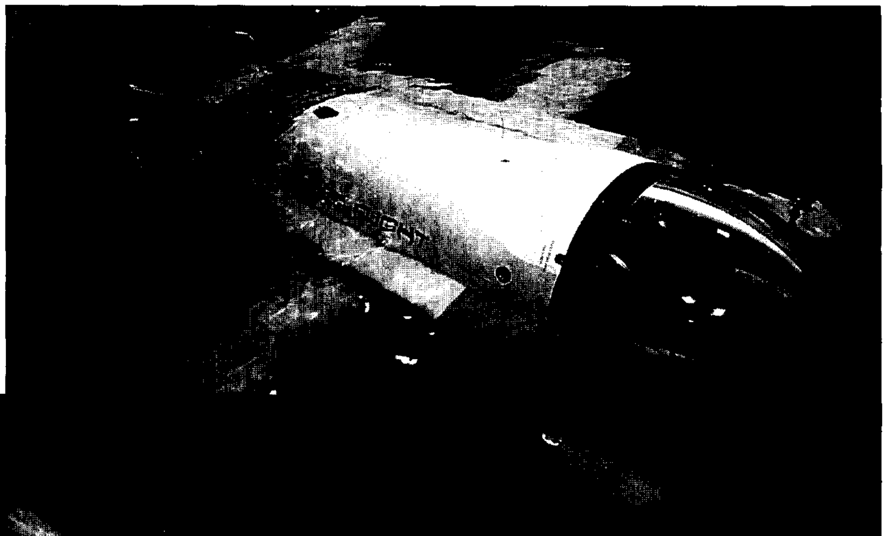
To begin with, the basics are unavoidable: *Deep Flight* is a manned craft that is way out of step with the mainstream and, therefore, no sensible discussion of *Deep Flight's* purpose or potential can be undertaken without getting the manned vs. unmanned issue on logical ground.

Consider the lessons learned from the North Sea oil field experience.

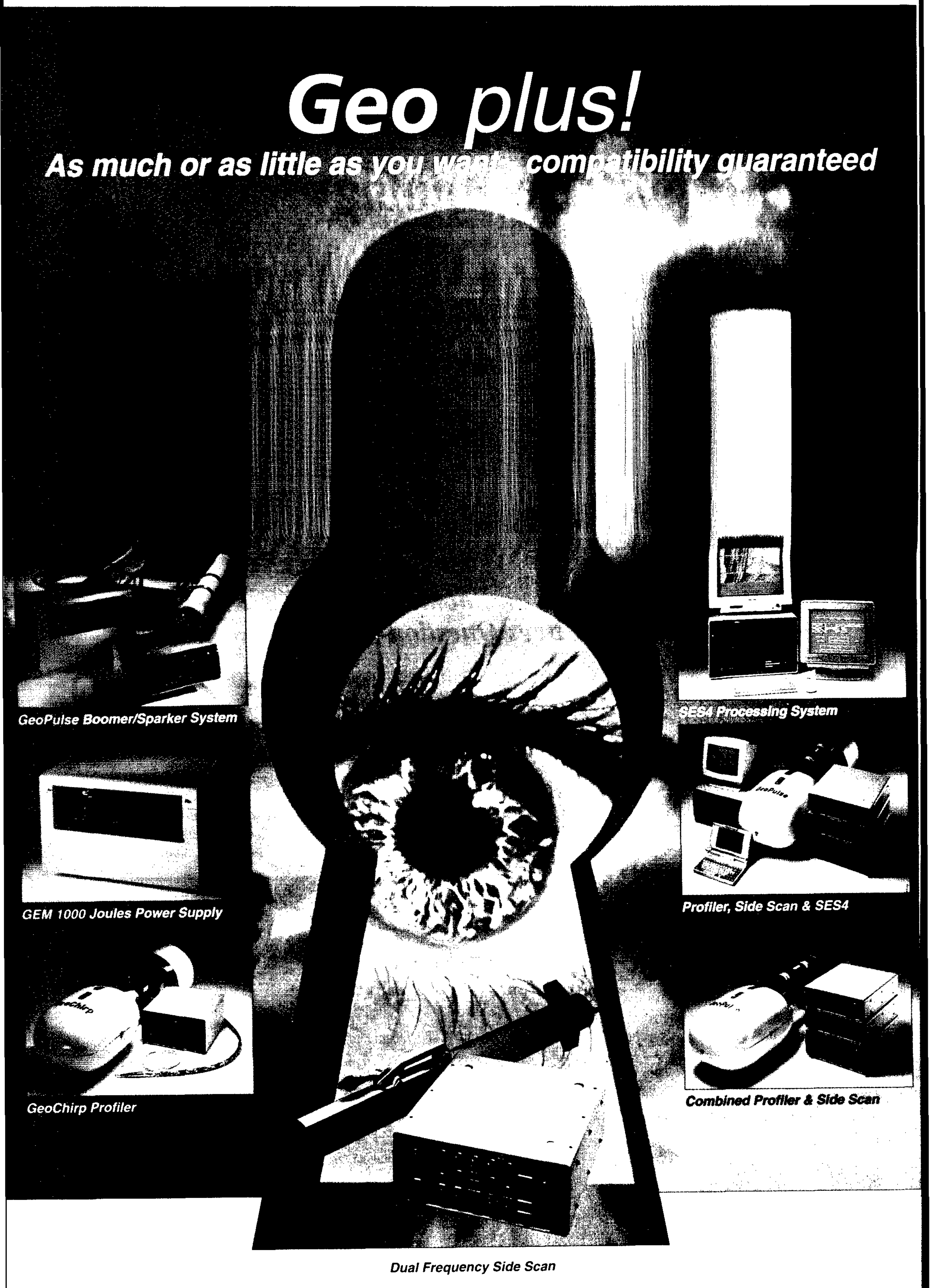
Counter-intuitive though it may be, but insurance costs for manned systems (the ADS—Jim/*Wasp*/*Mantis*) eventually became lower than those for comparable ROVs. The lower costs were due to the actual track record (there proved to be many expensive ROV insurance claims, but no manned vehicle claims) and therefore these costs became based on reality rather than perceived risk.

In fact, the ADS systems came to represent a huge, statistically significant body of (accident-free) deep manned experience in what were very difficult and unfriendly conditions. For those of us involved, a comfort level with manned vehicle operations had therefore developed way beyond the cumulative experience (of manned operations) inside the United States. For example, over the principle ADS years (early 1980s) at any one time, 24 hours per day, 365 days per year, there were approximately 40 units on active diving service—and perhaps five in the water at any given time for which I as designer and builder was somewhat responsible.

What I have in mind then for future manned vehicles is significantly lower



In this series of photos, author Graham Hawkes prepares for his historic test dive in **Deep Flight I** ***last October in Monterey, California. Submersible is designed for 3,300-foot depths. (Photographs by Amos Nachoum.)***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risk than this known data set; it is also far friendlier and vastly more comfortable (to absolute wimp levels of luxury and safety for the many ex-*Wasp/Mantis* pilots around). The reality is that the incremental additional risk of man in the machine is literally way down in the noise level of general shipboard risk (lower than cars, recreational diving, aviation, etc.). In fact, I consider the lethal line transmission voltages (1,000 volts) necessary for deep ROVs as being a risk factor in the same ballpark as manned vehicle operations. Moreover, the subs I am talking about will probably be operated primarily in the more cautious (less pressured) environment of science/exploration.

In the end I believe, however, that the fundamental difference between manned and remote vehicles lies not in the risk issues but in the relative cost and consequential limitations of pilot placement. I am not missing the point that the perceived risk is a political reality (that has to be dealt with); however, in looking this far ahead, I think it is valid to deal only with real issues.

Performance Advantages

For the next 10 years or so, a manned vehicle will have certain performance advantages (better visual, spatial, and motion sensory hook up). However, future advances in remote sensory feedback will cancel those advantages—after all, the crew of a manned vehicle is separated from the environment by a thick pressure hull anyway and so if you believe in the potential of telepresence (I certainly do) you can argue that you may as well be at the surface.

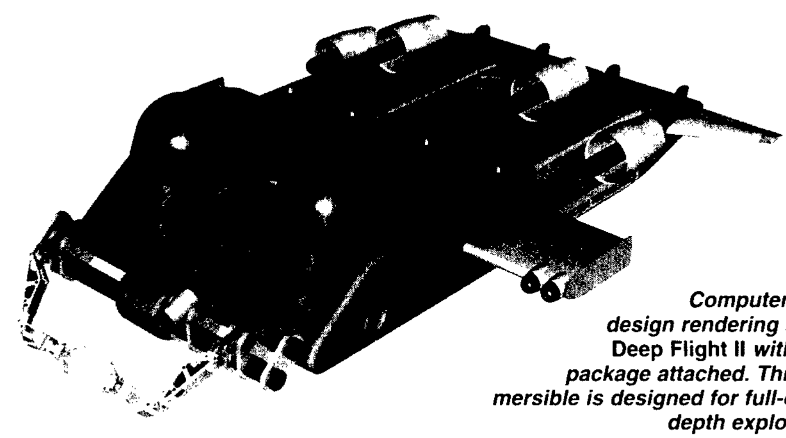
So for argument's sake, consider a theoretical future manned craft where the crew are inside an ***opaque*** ceramic hull (windows are no longer needed), using the latest in telepresent techniques, to "look/be" outside the hull in exactly the same way that the ROV crew will be hooked via their craft into the environment. Functionally then, there would be no fundamental performance difference or advantage to either craft. If you accept my point that either craft can kill, but risk can readily be reduced to normal levels, then the irreducible difference is highlighted and inescapable: manned craft are autonomous and remote craft are tethered.

This then is the essence of the issue: to tether or not to tether.

The manned craft is seriously time-restrained by the endurance of its crew, but is wholly unrestrained in movement. The ROV is seriously restrained in movement, limited by the drag constraints of its tether, but unlimited in endurance. That combination of contrasting strengths and weaknesses means there will be a role for both, providing other factors—particularly costs—are in the same ballpark.

Moreover, since it is the autonomy of the manned vehicle that is its future strength, it is the autonomous underwater vehicle (AUV) that is its theoretical competition. However, I still believe that the gulf between artificial intelligence and the real thing will ensure a rationale for humans *in situ* for the foreseeable future.

Hence, the *Deep Flight* competitive rationale is predicated on the simple assumption that a tether to the surface will always be necessary for unmanned vehicles whose mission requires real-time human control (everything else should be conceded to the AUV anyway). Since the cost and



Computer-aided design rendering shows **Deep Flight II** *with work package attached. This submersible is designed for full-ocean-depth exploration.*

freedom-of-movement limitations caused by that surface tether increase with depth/separation from the ship (unlikely to improve with technology), this creates an opportunity that begins to favor an autonomous vehicle as the depth/freedom requirement increases.

This window of opportunity for future manned craft is significant but not sufficiently overpowering to carry new build costs of existing generation design submersibles (or to avoid extinction of the current class). In fact, if the sub (or the ROV package of tether management/winch and cable) grows so large as to need a dedicated mother ship, the system costs are automatically noncompetitive.

Looking for Lessons

If you again look at the North Sea for lessons in real world free markets, the conventional submersible—once the star of the show operated by Vickers Oceanics and Intersub—was actually made thoroughly obsolete 15 years ago. This was pure economics because once the ADS and ROV started to operate from ships of opportunity, anything requiring a dedicated mother ship was suddenly stone dead in the water overnight. Only for science—where the limitations of a cruise itinerary are tolerated (science is conducted along the path of the ship which is scheduled three years in advance)—does the manned submersible remain in service. But for how long? And does anyone seriously see replacements being built when costs for new deeper conventional subs are thought to cost upwards of $50 million?

Hawkes Ocean Technologies (HOT) sees a strong competitive future for manned craft built on its unique advantages, including intelligent autonomy (IA), but only if costs are dramatically lowered—which means bluntly that the dedicated mother ship has to be eliminated. So, if you follow that line of reasoning, the classic submersible is already obsolete and the only chance to maintain the manned option in a competitive environment is a new generation, a micro-submersible—a manned craft limited to a maximum launch weight of say 12,000 pounds (with work package).

If you start with a *Mantis* (arguably the most successful manned sub-

mersible built with 26 in service), then "all you need to do" is throw away its tether, making it autonomous, increase its operational depth from 2,000 feet to full depth (why not deal with depth once and for all), and drastically increase its speed to take advantage of its autonomy and distance itself from the performance curve of the ROV.

Finally, to plan for the political world, you would be well advised to demonstrate bullet-proof safety.

Without a doubt, the biggest single step would be to make the craft "unsinkable," i.e., never allow it to be negatively buoyant, but rather keep the sub in a fail safe mode of being positively buoyant. Secondly, and probably the next biggest step, would be to adopt a buddy pair dive philosophy and dive multiple units, able to assist each other, rather than put multiple bodies in a single unit. Beyond that there are a myriad of incremental improvements to be made.

About ten years ago, Sylvia Earle and I took two *Mantis* subs in Stony Cove, England, unhooked the tethers, operating each from emergency batteries, and dove as a buddy pair. What we had in mind was to test exactly the above. Ten years later, those concepts have aged rather well. In fact, it is no coincidence that *Deep Flight* could be accurately described as a streamlined, self-powered *Mantis* (with aspirations of full depth capability). One difference, however is that the *Deep Flight I* design is fully preoccupied with demonstrating and proving the technology, rather than the very clear work purpose of a *Mantis* (which bristles with seawater manipulators, etc.).

Pushing to a New Level

When I first began thinking about *Deep Flight* eight years ago, as hard as we may try, we could not build an autonomous manned vehicle small enough to be free of a mother ship and useful enough to compete with future ROVs and AUVs. What I felt was needed was to follow the example of the aviation industry; to stretch and, through an act of faith (or unlimited funding), build a proof-of-concept craft—one that was not required to be useful or intended to enter service but one that could perhaps push technology through to a new level. I knew that it would need to be light, powerful, deep, and fast; and if we succeeded in building such a baseline beast, perhaps it would be the bridge to the future. Implicit in this concept was the belief that humans *in situ* is an option well worth preserving.

So trusting seawater aluminum batteries to supply the necessary higher power levels, we set about and have succeeded in building *Deep Flight I*. Whether the project is ultimately successful or not depends quite simply on whether we learn or have learned enough from it to break through to the next generation of practical, useful, autonomous micro subs.

With *Deep Flight I's* first test dives behind us, we know that Hawkes Ocean Technologies has a successful experimental craft, significantly more complex under the hood but outwardly more simple. In theory, *Deep Flight I* has already succeeded simply because HOT has now published the basic concepts for *Deep Flight II*—a no-compromise, manned modular work system (aimed at full depth), suitable for ship of opportunity deployment. This sub meets all existing certification requirements and fully achieves the user-friendly safety goals of original concepts.

The prototype *Deep Flight I* was made as small as possible in order to get future deep designs for two people (twinned pods) close to the self-imposed limit of 10,000 pounds (without work package). However, just where all the "insides" of working submersibles could be stowed, eight years ago we did not know.

In fact, the internal space is one problem that has been fully answered over the passage of time. The *Mantis* and *Deep Rover* subs (my designs and precursors to *Deep Flight*) provided a head start on miniaturizing all the basics. However, the effort for *Deep Flight I* was much bigger than anticipated as we set higher and more complex standards for control and instrumentation.

The initial approach was to use electronics to miniaturize the discreet systems. Since then, the microprocessor has saved us from endless iterations of incremental improvements, providing the definitive answer. The philosophy is now brutally simple: since a crew member only has two hands, we only need two control modules, one optimized for each hand. Software will adapt those controls to future tasks without limits. Instrumentation is the same with flat screen or CTR read out, and the control and instrument module has virtually unlimited expansion and adaptation capability.

As a backup, a full set of basic hard-wired control/instrumentation fully developed as the baseline system for *Deep Flight I* will be the back up redundant suite of control and instrumentation for *Deep Flight II*. This philosophy is ideal since it allows the crew pod to be physically defined in detail and remain unchanged from that proven (safe) standard while, at the same time, allowing no limits to the future adaptation and expansion of control and information possible. The days of ripping into the wiring to upgrade every few weeks are over; now you simply rip into the software. Also for the first time in our history, the control/command, life-support module for *Deep Flight I* is suitable for *Deep Flight II* as are the power control and running gear.

A Most Obvious Feature

The most obvious feature of *Deep Flight* that draws many comments is that the operator's position (crew) "looks uncomfortable." In fact, it is not so much that it looks uncomfortable, since it rather clearly is very comfortable, it's that the crew position seems unfamiliar and therefore looks worrisome. In the beginning, the whole challenge of how you might best hold a crew member in place in a craft that needs to change its attitude (so chairs don't work) seemed a huge problem. The "wild" solution is a molded body pan that supports the chest from the shoulders to hips in the position of head forward and face down for normal straight and level operation. A padded five-point harness, foot rest, and fixed hand holds (so that the controls are miniature force-input "J" sticks for the thumbs) take care of every position comfortably.

This position is ideal for *Deep Flight I*, and while the comfort limits of dive and climb attitude for *Deep Flight II* have yet to be defined, from static tests we feel that the ideal

"So there you have **Deep Flight I***—a thoroughly conventional and obvious approach to the problem of an autonomous manned craft able to operate from a ship of opportunity."*

might be to incline the horizontal position for the crew at about 30° up (for straight and level)—a working position that feels absolutely natural underwater and allows for a conservative (comfortable) dive at 30° nose down and climb out standing upright at up to 60° nose up. In practice, we expect that once the crew members become accustomed to the ride, they will be happy through a greater range.

The reasons for adopting this crew position are compelling: frontal area is drastically reduced, as is the displacement of the craft per crew member—the key to eliminating the mother ship. The eyeball-to-subject distance is importantly reduced to a few feet as opposed to about 8 feet for *Deep Rover*. The liability is that it forces a transition from a pressure hull that we reside inside, with thermos and note book, to one that is worn, requiring a change of attitude and use pattern to a powered diving suit or "space suit"-type mentality. The practical results are a much lighter, more agile, and dexterous working craft suitable for a ship of opportunity but with the limited endurance of a diving suit, (such that as a goal no more than 60 minutes should be spent getting to or from the work which may be 7 miles away). This goal alone drives the "need for speed," which in turn drives a streamlined body able to change its attitude and dive along the streamlined axis.

As for the novelty of the system, well, it is not entirely novel. *Mantis* used this configuration successfully. Having designed and piloted both, I can say that *Deep Flight I* is, however, much more refined and comfortable/secure. As for the position, if you think about it, it is simply the same position every mammal, including humans, instinctively adopts in water (no one tries to sit under water but swims head forward, face down, etc.).

Thoroughly Obvious Approach

So there you have *Deep Flight I*—a thoroughly conventional and obvious approach to the problem of an autonomous manned craft able to operate from a ship of opportunity. With *Deep Flight I* in the bag, the principle problems to be solved for a working vehicle *Deep Flight II* were:

• Certification requirements specify a surface "escape" (not designed into the experimental *Deep Flight I*) with sea state and fair water heights specified to prevent water taken on board with potentially dire consequences. With small subs, these requirements are onerous and worrisome and the risk is aggravated because of the limited sea state and risk of flooding. In fact, if you look at the few accidents with submersibles, flooding on the surface through crew *misuse* of the hatch is the dominant risk. *Deep Flight II* takes a different approach: a single large surface ballast tank will provide sufficient buoyancy in an emergency to open the dome and allow the pilot(s) to exit with the craft remaining afloat [even if the hull(s) flood completely]. This is the same philosophy used on the last *Deep Rovers* with submerged bottom hatches—in that the hatch cannot deliberately be used routinely (eliminating its misuse) but, if needed, can be accessed in any sea state.

• Batteries remain an Achilles heel, but with major R&D invested in this issue for zero-emission road vehicles there should be a solution soon.. Currently, *Deep Flight I's* performance potential is only available with silver-zinc batteries. However, as the performance envelope (except endurance) can be explored with lead-acid batteries, we have not felt the need to spend the money for silver-zinc. *Deep Flight II* is currently designed with a massive volume and corresponding buoyancy volume allowance for batteries so that the design will have a useful performance envelope to 20,000 feet with lead-acid batteries if necessary. Note: as with *Deep Flight I*, the cost and utility goals for this next generation do not allow silver-zinc batteries as a viable option.

• Perhaps one of the most difficult challenge with *Deep Flight II* is the conflicting mission requirements. Biologists want stealthy, agile critter-stalkers and catchers; geologists want massive rock-carrying machines. Additionally, my input is that we need to return to the last century notion that pure exploration is the first task when faced with such vast unknown territories (a task for which modern measurement-oriented science is no longer comfortable). Hence, we need streamlined, faster survey scout-type vehicles that would also be a good aggressive use of the autonomy edge of manned craft over the ROV.

Because of these conflicting requirements I had argued that we need to build many specialized types of vehicles, and the notion of heavily compromising any one design to try and be all things to everyone would be a crippling mistake. However the realities are that there may not be any more manned craft, let alone a fleet of specialized craft.

So, necessity being the mother of invention, *Deep Flight II* became *DF2-S*, a modular adaptive system (inspired by transformer toys). This design allows, for example, the undiluted efficiency of a one-place ultralight, fast scout/survey/search vehicle to be reconfigured with a second unit, a two-place craft as needed; and then by separating the two modules and fitting a maneuvering and work package, the craft is transformed into a full blown work system. These reconfigurations are designed to be achieved on ship as needed.

Finally, there is the issue of pressure-hull materials and certification/experimental status. *Deep Flight II* can be built today with friendly plastic hulls for 4,000 feet or with certified titanium hulls and conventional ports for 20,000 feet (with an experimental class ceramic/glass hull for full depths). Fortunately, as proposed, the choice between the options is not an either/or but simply a modular change option since the pressure issue is isolated to the pod hulls, buoyancy modules, and a few one-atmosphere housings. Hence, we would ideally have all three hulls available so that *Deep Flight II* could have greater payload and lower lease cost for 4,000 feet or be equipped for 20,000 feet as a certified lease vehicle. The full depth ceramic hulls would be uncertified but would enable a relatively inexpensive (since it is only the hulls, not the whole sub) campaign to reach full ocean depth in a very practical craft. Indeed, the major goal for this revolutionary craft is to "fly" her to the deepest point on the planet where only Don Walsh and Jacques Piccard have visited—the Marianas Trench, which lies at some 36,000 feet beneath the surface. */st/*

Graham Hawkes is internationally renown as an ocean engineer and explorer. He designed and built Deep Flight I, *an entirely new class of vehicle he calls hydro-acrobatic winged craft (HAWC). Hawkes has successfully founded and managed six high-tech ocean engineering companies, including Hawkes Ocean Technologies, which incubates creative engineering products for specialty markets. He is also vice chairman of Deep Ocean Engineering Inc., a company he founded in 1982 with Dr. Sylvia A. Earle, which produces a significant portion of robotic craft now in use—including the* Deep Rovers *and Phantom low-cost ROVs. Since 1970, Hawkes has been responsible for the design of more than 70 percent of all manned (plus more than 300 ROVs) submersibles. In 1987, he was named associate laureate for the Rolex Awards for Enterprise for his work on* Deep Flight *and was nominated for "Engineer of the Year" by* Design News *magazine in 1996 and 1997 for leading U.S. efforts to achieve deep ocean access.*

Location, Recovery of *Panache IV*

Salvage of 15-Ton Ocean Racing Yacht, in 270 Meters in Complex Coastal Flow Regime Abets Law Enforcement, Underwriting Agencies

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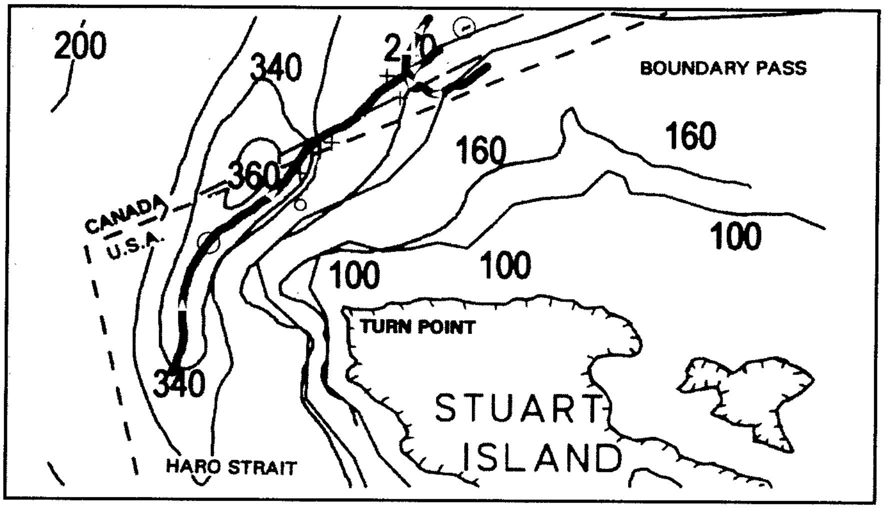
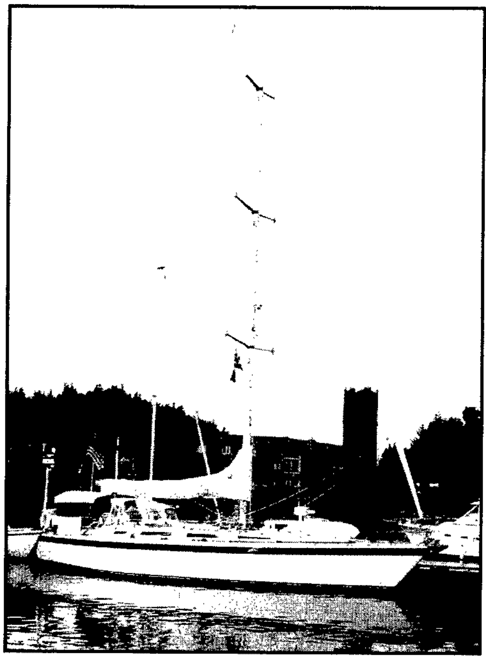
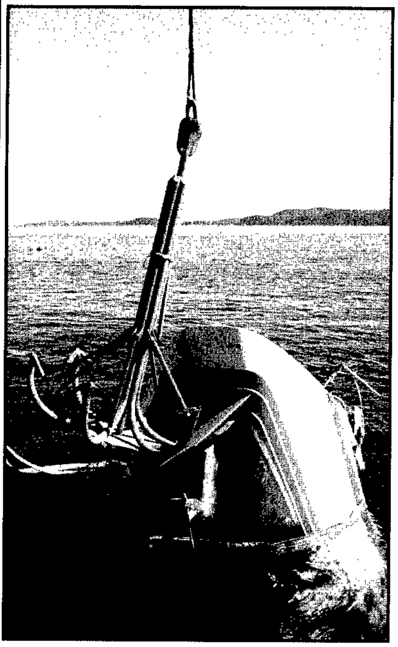


Photos below show a similar Centurion 47 (left) and* Panache IV *being retrieved from the seafloor. Above is turn point area showing northeasterly side-scan track through 360-meter hole towards point of discovery of vessel.

On the evening of February 23, 1995, the 14.5-meter ocean racing yacht *Panache IV* was proceeding southwest through Boundary Pass enroute from Crescent Beach (near Vancouver) to Victoria, British Columbia. The owner of the Centurion 47, a French-built luxury yacht, was the only one on board as the vessel worked against a strong flood tide on a dark, windless night. Its passage seemed routine. But at 11:09 p.m., "Seattle Traffic" received a "MAYDAY"; the owner reported that he was sinking off Turn Point (Stuart Island, Washington, United States) and was abandoning ship.

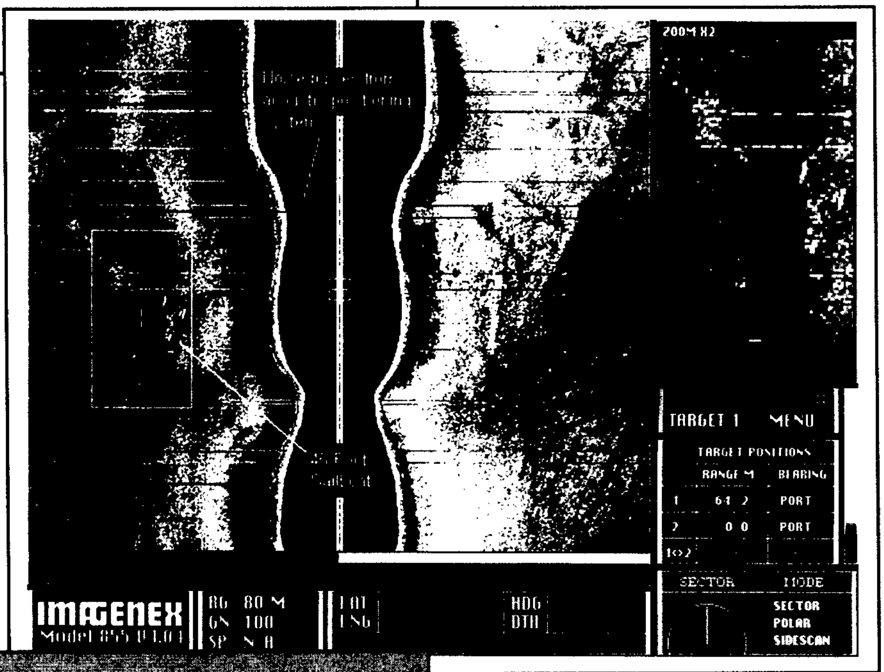




Within minutes, a military *Sea King* helicopter was dispatched to the scene. Vessel-traffic radar recorded the yacht's track as it sank. A lone occupant, found drifting in an eight-man inflatable life raft near a large upright sailboat with decks awash, shortly afterward was hoisted from the water.

The next morning in a routine statement taken from the survivor by the Royal Canadian Mounted Police (RCMP), it was ascertained that he owned the vessel, was the only one on board, and had no idea what had caused his boat to take on water and sink. He stated that his engine stop-

ROV identifies sonar image at 270 meters depth. At right is yacht as seen on side-scan screen.



ping was the first sign of trouble, and that upon investigation he found the vessel's cabin was half full of water. In a later statement to his insurance underwriter, he stated that he had seen a light glowing on the switch panel, indicating that the automatic bilge pump was operating.

Turbulence, Turn Point, Mobilization

Panache IV sank off Turn Point at the intersection of Boundary Pass and Haro Strait. This international waterway is the main channel for deep-sea vessels traveling to and from Vancouver and an alternate route for oil tankers enroute to the oil refinery at Cherry Point, Washington. It is not uncommon to have up to four major vessels approaching Turn Point at a time. Just off the point is located a 360-meter hole that is the deepest depression to be found between Vancouver and the Pacific Ocean.

Tidal ingress and egress of water from the southern end of Georgia Strait, the large inland "sea" bounded by Vancouver Island and the mainland, is through Boundary Pass and a few other nearby channels. In Boundary Pass, currents reach speeds of 4 knots during spring tides with volumetric flows exceeding 100,000 cubic meters/second. As a result of a 90° change of current direction and very upthrust bottom topography off Turn Point, large scale turbulence and a very complex flow regime exists in the local area. Acoustic doppler current profile data show vertical current velocities to be approximately 40 percent of the horizontal velocity component. Therefore, the search and ultimate recovery of *Panache IV* was a technically difficult task.

Coast Underwriters Ltd. had concerns about the loss and wanted to find and raise Panache IV. A contract was let with Western Subsea to find the vessel.

Western Subsea stated that it would be very difficult to complete a side-scan-sonar search in the area of the sinking due to the extreme current regime and the water depth (250 to 360 meters). In addition, the poor

Survey Equipment

[illegible]:
- [illegible] sonar system with [illegible]
- [illegible] meter armored sidescan [illegible]
- [illegible] weight

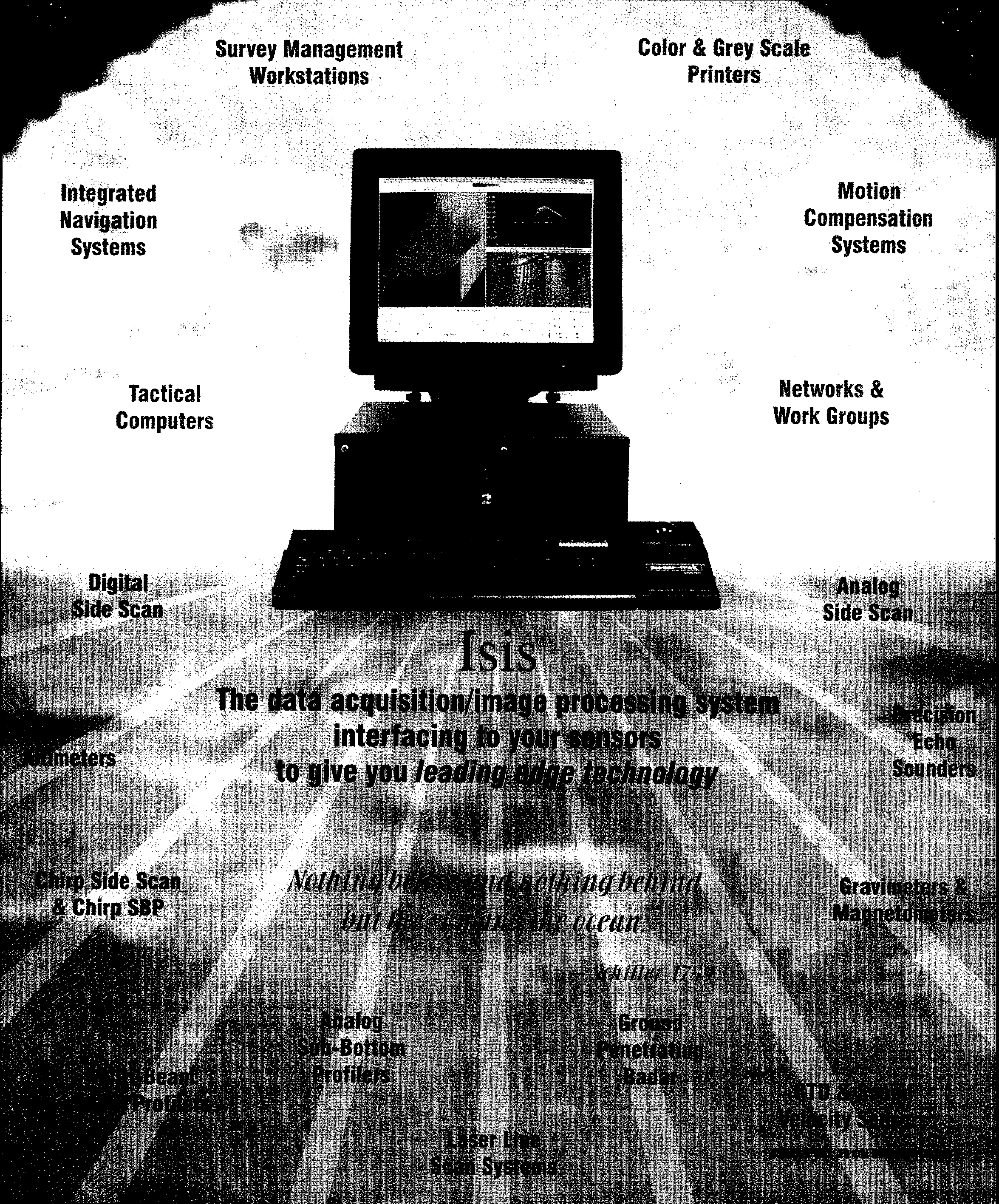
GPS [illegible]:
- [illegible] NavTrac GPS receiver
- CSI MBX-1 Differential GPS Radiobeacon receiver

Underwater Positioning:
- ORE Trackpoint II USB Acoustic Positioning with multibeacon transponder and depth reporting
- Ritchie Digital Compass

Electronic Charting Systems:
- [illegible] Subsea Technology's Fishchart (strategic [illegible])
- [illegible] Associates' Workboat ([illegible])

[illegible]:
- [illegible] w/Hi-Fi audio
- [illegible] A/D converter

[illegible]:
- [illegible]


Survey Management Workstations
Color & Grey Scale Printers
Integrated Navigation Systems
Motion Compensation Systems
Tactical Computers
Networks & Work Groups
Digital Side Scan
Analog Side Scan
Isis
The data acquisition/image processing system interfacing to your sensors to give you *leading edge technology*
Echo Sounders
Chirp Side Scan & Chirp SBP
Gravimeters & Magnetometers
Analog Sub-Bottom Profilers
Ground Penetrating Radar
Laser Line Scan Systems

quality of sonar return anticipated from the smooth curved hull of a recently sunk yacht (i.e. specular reflector) would be hard to detect. However, the insurance company was not deterred. Mobilization commenced on March 10, 1995 from Western Subsea's deepwater jetty.

Fundamental to search efforts was the identification of a good platform on which to install a heavy hydraulic winch. The 20-meter *Richardson Point,* a former fisheries/oceanographic research vessel, came equipped with a large A-frame aft. A large winch with 1,000 meters of double-armored cable was then installed. This 1,250-kilogram unit, on loan from the Esquimalt Defence Research Detachment, was custom designed for sonar surveys and provided the control necessary to fly a sidescan-sonar fish at a constant altitude over the bottom.

Equipment, Planning, Intelligence

An integrated suite of survey equipment was installed on *Richardson Point.* An Imagenex 330 kHz sidescan sonar with approximately 200-meter swath width on bottom was mounted in a 2-meter-long weighted towfish that provided the stable platform necessary for good sonar imagery.

Due to turbulent currents, it was essential to have precise positioning. Real-time differential GPS was used to fix the location of the survey vessel, and a Trackpoint II ultra-short-baseline system (along with a digital compass) were used to fix the towfish location with respect to the vessel. The subsea transponder contained a depth telemetry unit to ascertain the towfish's depth. Track and position data were displayed on two different electronic charting systems. All data was logged for post processing. Shallow water trials with the equipment were held off Victoria.

Preliminary planning focused on three major factors: • the strong, turbulent tidal flow in the area, • the depth of water and rugged bottom topography, and • the large number of ocean-going vessels that use the channel.

The bottom topography, the tides, and the presence of shipping meant that the survey track would have to be along the axis of the channel.

The depth of water meant that the speed through the water would have to be kept under 2.5 knots to avoid excessive layback; therefore, it would not be possible to do good survey work when the tide was 2 knots or more. With faster tides, going up-tide would obviously mean not progressing over the bottom, and going down-tide would mean traveling much too fast over the bottom.

Thus, the survey work could only be done when the tides were relatively weak. Slack tide was never really slack, and the 40 minutes or so available was also a period of tremendous variability, both in strength, direction, and depth. However, these tides have a strong semidiurnal element, so that during parts of each tidal month one tide (from high to high) can be much weaker than the others—the survey needed to be done during this period.

Close cooperation with "Vancouver Traffic" was required to ensure that all shipping in the area was aware of the search and recovery operation as it proceeded.

Fortunately, good information was available as to where the vessel had sunk. Vessel-traffic radar in the area had recorded radar fixes at five-minute intervals from receipt of "MAYDAY."

These series of positions agreed well with the expected direction and strength of the tide on the night of the sinking and were in general agreement with the estimates given by the survivor and the helicopter crew. As a result, it was decided to make the initial survey along the track of the radar plot and subsequent tracks parallel to and centered around the last recorded position of the sinking vessel.

The Survey

The sidescan survey started on March 14—tide tables indicated a weak flood from 11:00 a.m. to 3:30 p.m. with a maximum of about 1 knot. Traveling with the tide, over-the-bottom speed would be kept to approximately 2 knots, an ideal speed with which to keep both the length of the tow-cable and the acoustic baseline short. In addition, it would be important to complete the survey prior to March 16 when time tidal currents would increase significantly.

After solving problems with the newly installed hydraulics for the sidescan-sonar winch the morning of March 14, the deepwater sidescan survey began. Increasing winds reached 50 knots by mid-afternoon—launch and recovery of the towfish and depressor weight was slow as *Richardson Point* pitched and twisted. All systems functioned satisfactorily and it was possible to fly the towfish 20 meters off the bottom in 300 meters of water while moving through the water at 1.5 knots. A section of the bottom along the track that the sinking *Panache IV* had drifted was surveyed and sonar images obtained. However, the pitching of the *Richardson Point* was violently yanking the sonar towfish up and down, degrading the sonar images so badly that they became useless as search information. In late afternoon it was decided to terminate operations and to hope for better weather conditions the following day.

On March 15, winds were light, all equipment was working, and by 10:00 a.m. the towfish was flying close to the bottom as the survey vessel moved slowly northeastward against the last of an ebb tide. The crew was augmented by Imagenex's Alan Mulvenna, an experienced designer of sonar systems and analyst of sidescan sonar imagery.

During the survey, the strategic electronic chart display was used by the helmsman to follow a predetermined survey track over the bottom. The tactical electronic charting system was used to correlate the survey vessel's DGPS position with the towfish's acoustic position from TrackPoint II and the digital compass.

Upthrust bottom topography required constant attention at the winch to ensure that the towfish did not plow into the seafloor. It also produced a wealth of "ship-like" targets on the sonar monitor. However, a valid target would require the correct dimensions, and, most importantly, an acoustic shadow that corresponded to what the *Panache IV* would be expected to produce.

As the hours passed a sense of routine set in. However, interest increased as the position of the last vessel-traffic radar plot of the sinking vessel was approached. Suddenly, an unusual "non-target" appeared on the sidescan's port channel; it was a large shadow without the usual bright highlights on the near side. Alan Mulvenna put his finger on the screen and said "That's the boat!" The target was quickly marked on the tactical screen.

To most observers that crowded in

front of the sonar screen, the image did not appear boat-like. Alan explained that the lack of highlights was to be expected; the hull was still smooth and clean, and appeared mirror-like at the 0.45 centimeter wavelength of the sonar, and little sound would be reflected back directly to the towfish. He also noted the shadow of the mast that extended towards the edge of the display, as well as the shadow of the boom. He pointed out three small highlights; the radar reflector tied to the backstay (aft), a specular reflection from the hull (amidships), and a reflection from the vessel's pulpit (forward).

Four hours and six passes later, sufficient sidescan imagery had been obtained to confirm the presence and precise location of a large sailing vessel. Each time an image was obtained, a mark was entered at that location on the electronic chart display. At the end of the survey, six marks had been entered on the tactical display screen, all within a 50-meter circle. Each mark represented the same target as seen from different sidescan passes.

Coast Underwriters in Vancouver were then notified that a high probability target had been found two kilometers north of Turn Point in approximately 270 meters of water.

Confirmation, Wreck Recovery

The following day, after several attempts under difficult conditions, a Phantom DHD2 ROV was able to positively identify the vessel as *Panache IV*. It was standing upright with its keel partially buried and appeared to be in excellent condition. The ROV was unable to find any evidence of external damage that could have accounted for the vessels sinking, although it was not possible to inspect the buried parts of its hull.

Panache IV sunk on February 23, was found on March 15, and positively identified on March 16. On March 17, agreement was obtained from Coast Underwriters to proceed with salvage. Now all there was to do was the simple job of raising the vessel...

Salvage of the 15-ton vessel, especially the attaching of a lifting line, was impeded by the 270-meter water depth and the strong tidal currents. Using divers or an ROV to attach lifting lines were both low probability options. Rough calculations indicated that in a 2-knot current, a 3-centimeter diameter umbilical from the surface to the bottom will generate a drag force of about 360 kilograms. Assuming that the umbilical approaches the bottom at 45°, there would be 180-kilogram drag and a 180-kilogram lifting force on an ROV or tethered diver—large compared to the forces available to an ROV or diver. Both the March 18-19 attempt (using an ROV) and the March 25-26 attempt (using the Newtsuit) failed even though down lines were rigged in each attempt.

Approximately six weeks later, on May 16, the salvage team mobilized at Lamina Drydock's yard in New Westminster. The salvage vessel this time was a 1948 tug, *Magellan*, and the *Northwest Rigger*, a 60-meter-long salvage barge with a crane mounted on a 12-meter tower and a 250-ton-lift A-frame at the stern.

On May 17, the tug and barge proceeded to the Boundary Pass location. A single-point moor was established by paying out an 8-ton anchor with approximately 1,000 meters of wire rope up current (for the ebb tide) so that the barge could be adjusted to sit over the wreck's position. It was then possible to pull the anchor line taut and move laterally back and forth over the salvage site. In practice, the operation was conducted during a weak flood, in such a manner that the tug was able to hold the barge against the tide to keep the anchor line tight.

Initially, it appeared that the system would be too unwieldy to provide satisfactory results. However, with excellent positioning using Western Subsea's integrating position system, it was possible to work out a methodology which enabled the barge to maintain fairly good station over the target site. The salvage tool on this occasion was a large, custom-fabricated, 3-meter, 2,000-kilogram grappling hook. Six 8-centimeter-diameter steel bars were welded together to form the shank of the hook, then each bar was bent at a 0.5-meter radius to form six prongs. One single tang could by itself support the weight of the yacht.

The first slack water was at 2:00 a.m., and the next at 5:30 a.m.; in between there was a weak flood with currents that were not expected to exceed 1.5 knots. With the grapple deployed, a series of northwest-southeast (NW-SE) swaths were made traversing the 50-meter-diameter target circle.

At 2:50 a.m., the 50-millimeter lifting line drew taught. A very heavy object had been snagged. After consultation with the salvage master, Dave Turner, and personnel in the control shack, it was decided to lift the object slightly. Moments later, the weight suddenly released—whatever was on the hook was there no more. Hopes had been dashed again! After several other passes with the grapple and the end of the tide, the hook was brought to the surface. Luck seemed to be running out.

However, a routine examination of the grappling hook on deck, brought a surprise. First of all, the base plate was covered in clay—for the first time, we fully understood the nature of the substrate in which the yacht was sitting. Secondly, one of the tangs had cable burns along its inside edge. Measurement of the cable striations clearly indicated that the grapple had come in contact with 12-millimeter 1x19 cable, probably the back stay of the yacht, and had either slipped off or broken the stay.

Spirits were revived. In case the wire had slipped off the tang, it was decided to add barbs to each prong. Eight hours of cutting and welding later, each prong had a sturdy barb attached. After several unsuccessful passes over the target area with the grapple, it was suggested that the hook be lowered from 255 to 270 meters, based on the logic that the sailboat might be in a slight hole or depression. This was consistent with previously obtained sidescan data.

The subsea positioning blip on the computer screen bounced back and forth ±5 meters as it traversed the bottom in a NW-SE direction for a final pass. The mean path of the grapple appeared to be moving in a direction which would run over the top of the yacht's position. Again, all eyes were on the track of the grapple as it "inched" its way diagonally across the computer screen.

At 2:00 a.m., the lift cable tightened under heavy load. Was this the wreck or merely a boulder or rock ledge? Wireline was "inched in" until it was estimated that it was supporting more than half the weight of the sunken vessel. It was then agreed not to lift the object further for several hours; this would give the wreck time to break out of the bottom-clay suction as the tide came in.

At 4:45 a.m., the positioning system showed that the object on the bottom was starting to move. Daylight was breaking with a slight increase in a wind from the northwest. It was time to commence the long haul to the surface. After 90 minutes of extremely slow pulling at a constant rate, the first telltale signs as to the nature of our lift appeared. With about 35 meters left to go, small drops of oil started to appear on the surface....at 25 meters, an eruption of gas bubbles...at 10 meters, the eerie whiteness of a roundish subsea object in the gray-green gloom...at zero meters the transom of *Panache IV* broke surface with one tang of the grapple snagged around the rudder post! The vessel had come up stern first...

Excitement on deck was tempered by the realization that the grapple was barely holding the 15-ton yacht and that the rudder post was never designed for such a load. All efforts quickly concentrated on securing the prize. The barge and its suspended load were then towed towards Bedwell Harbor, about two miles distant, at a cautious speed of 1.0 knot.

Once in harbor, *Panache IV* was lowered to the bottom, righted, and unhooked from the grapple. It was then raised until its main deck was awash and dewatered. The vessel's mast was broken and its deck a mess of rigging and sails, but *Panache IV* was again floating after more than three months on the bottom. An inspection of the yacht's interior discovered that several through hull fittings had been removed and one toilet hose cut. As a result, the vessel was seized by the RCMP. Holes were plugged and the vessel towed to Sidney for further examination.

A few weeks later, a warrant was issued for the arrest of the vessel's owner.

Aftermath

On October 17, 1996, a 12 person jury in the Supreme Court of British Columbia found that the yacht's owner had deliberately sunk his boat and was guilty on two counts relating to fraud. He was sentenced to a one-year conditional sentence which included 200 hours of community service. The bank which held a $213,000 marine mortgage may be pursuing the owner for payment. In addition, the underwriters could also seek restitution for salvage and other costs. The owner is currently appealing his convictions.

Cost-effective subsea technologies are now available to assist the insurance industry in obtaining data with which to verify marine claims. However, due to the litigious nature of claims, it is essential that all parties involved in the recovery of marine artifacts operate in an integrated manner in order to preserve evidence and follow predetermined operating procedures prior to the commencement of court actions. The successful outcome of this marine operation was due largely to the collaborative efforts of all parties. /st/

Mike Muirhead, an ocean engineer (graduate of Florida Atlantic University, 1974), has experience in a number of offshore sectors. He trained with National Oceanic & Atmospheric Administration-U.S. Navy as an aquanaut in the Scientist-in-the-Sea program, worked in the North Sea as a subsea engineer aboard semisubmersibles, was a systems engineer for Sedco Inc. during the successful 1977 mining of manganese nodules from the floor of the Pacific Ocean, and was manager of the 30-meter research submarine Auguste Piccard *for Horton Explorations Ltd. He founded Western Subsea Technology Ltd. in 1984.*

Dr. Bill Vogel graduated from the University of British Columbia in 1960 with a bachelors in physics and in 1962 with a masters degree and McGill University with a doctorate in engineering in 1974. He worked as a defense scientist for 32 years, with the last 12 in the field of mine countermeasures. He is experienced in sidescan-sonar analysis and accurate navigation, both on the surface and underwater. In 1995 he became a consultant in underwater surveys and precise marine positioning.

Paul Mendham, after completing the certificate program in shipping and marine operations at the Pacific Marine Training Institute (North Vancouver), he became a marine claims adjuster for Coast Underwriters Ltd. in 1989. Prior to that time, he had a broad background in the marine industry, having worked with Sealink Marine Services and as a member of the Canadian Coast Guard Auxiliary.

Dr. Ann Gargett graduated from the University of Manitoba 1966 then the University of British Columbia with a doctorate in oceanograpy in 1971. After a post doctoral at the National Institute of Oceanography in the United Kingdom, she joined the Institute of Ocean Sciences in 1972. She has done extensive research in coastal and open ocean waters, and is an authority on ocean mixing processes. The mapping of currents and turbulence in Boundary Pass/Haro Strait was part of this research.

Phillips Petroleum's Seastar Project

All-ROV/Drill Ship Installed, Maintained Subsea Completion In 750 feet of Water, 13 Miles from GOM Production Platform

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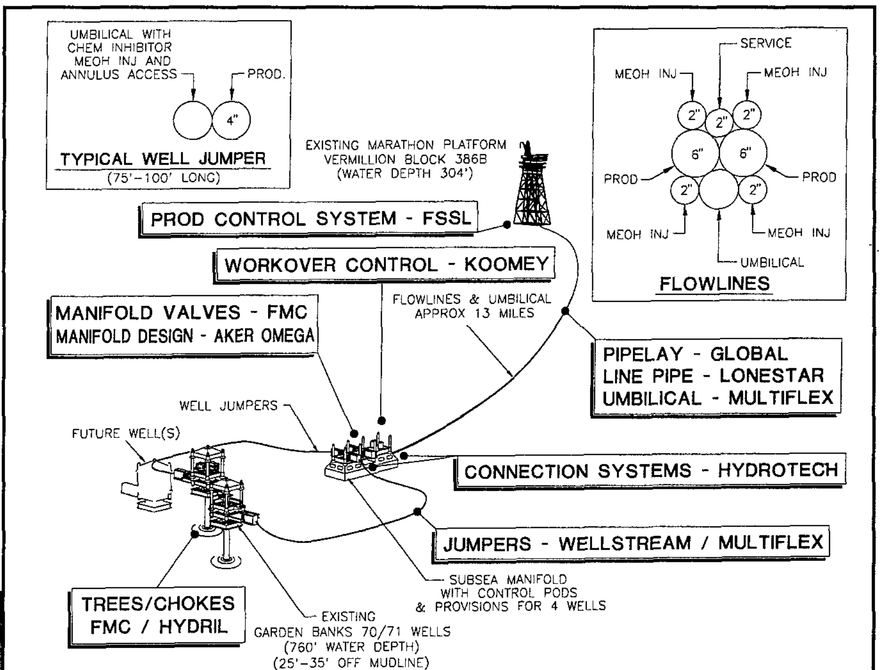
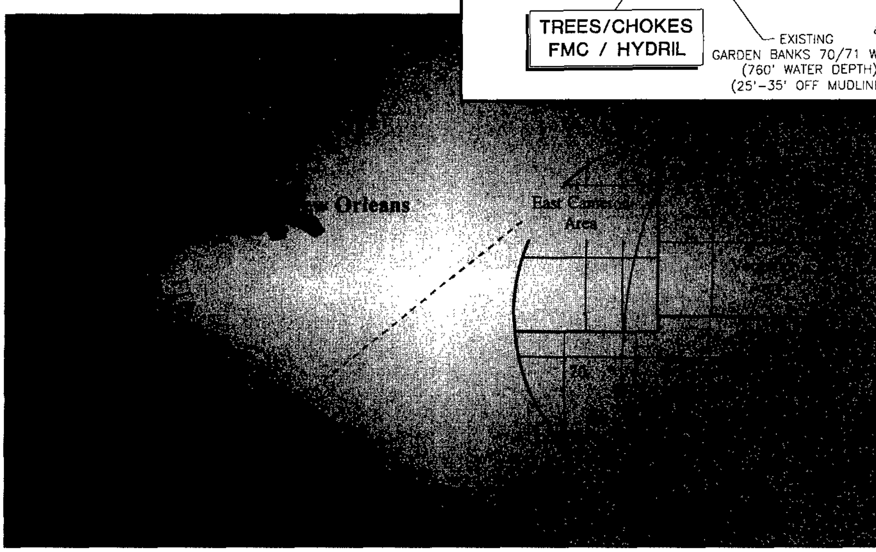
On May 1, 1995 Phillips Petroleum's Seastar Project began production as the first cluster-type subsea development in the Gulf of Mexico. Seastar production reached approximately 60 million cubic feet of gas per day (mmscfd) in November 1995 with the completion of a second "sales" line (a pipeline that transports the petroleum to shore) at the Vermilion Block 386-B host platform. Currently, the field is producing 40 to 50 mmscfd and plans are on schedule for the addition of a third producing well during the first quarter of 1997. All of the subsea equipment was installed using a drilling vessel and onboard ROV support.

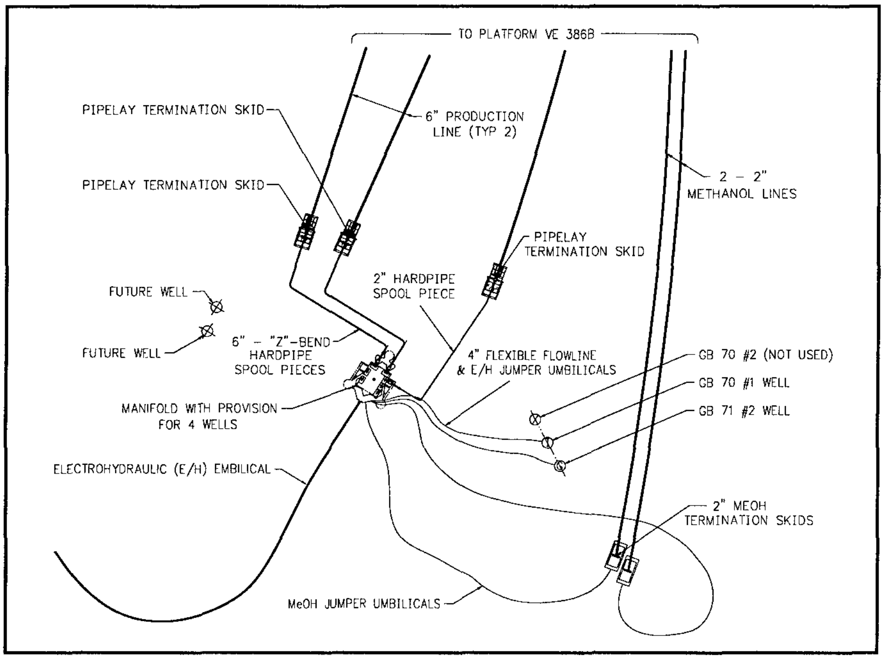
The Seastar project began in 1987 when Phillips and its partners leased Garden Banks Blocks 70 and 71, located 110 miles south of Cameron Louisiana. The partnership drilled two wells in 1990 that discovered non-commercial hydrocarbon reserves. Following a reevaluation of the seismic data, Phillips assumed 100 percent ownership in the leases and drilled Garden Banks 71 #2, which discovered 350 feet of "pay" sand (oil resource) in March 1993.



Phillips Garden Banks four-well manifold subsea development project. Vendors names are indicated in dash after component name.



The initial phase of the project consisted of two satellite subsea trees tied back to a four-slot retrievable subsea manifold in 760 feet of water. Commingled gas production is delivered via dual subsea pipelines to a host platform processing facility in 300 feet



Layout of subsea completion manifold, various connections to production platform and position of three wells.

of water 13 miles away in Vermilion Block 386-B, thence via sales lines to shore.

In addition to the two 6-inch production flowlines, four 2-inch methanol lines and a single 2-inch service line run from the platform to the manifold. The production flowlines and the service line are connected at the manifold end utilizing a unique hard-pipe spool piece connection system. Additionally, an electro-hydraulic (E/H) control umbilical was installed to provide functional commands to both the manifold and tree control modules.The subsea trees are 4 inches x 2 inches, 10,000 psi layaway-style trees supplied with 150-foot flexible "pigtail" jumpers for tie-in of each well to the manifold.

Although the field is diver accessible, Phillips decided to pursue a diverless development with primary intervention designed for ROV operation. Therefore, all of the equipment used for Seastar could be installed in water depths of 2000 feet or more with minimal modification. Seastar project equipment included a diverse set of ROV tooling for the diverless subsea trees and manifold, including specialty ROV tooling for attachment of flexible E/H and methanol jumper hoses, valve override, hot-stab operations, and functioning of the flowline connection system. Other ROV tools were included as contingency items for future intervention on the subsea completion equipment if necessary.

Phillips' ROV contractor was required to supply a standard spread of ROV tooling which included hard and soft line-cutting tools, a jetting tool, and ROV-removable spring shackles and floats.

The task-specific tools requiring ROV intervention procured for the project consisted of:

- Premeasurement tool (PMT) for hard-pipe spool piece measurements
- Flowline connection-system actuator (stroking tool)
- Hydraulic reservoir skid for water-based control fluid
- "Flying lead deployment skid" and ROV tool for methanol and E/H jumpers
- Valve override tools for subsea gate valves
- Subsea grouting system for manifold piles

The contingency tooling requiring ROV intervention on the project includes:

- Subsea choke retrieval/installation tool
- Subsea choke override tool
- Sealant injection system for subsea gate valves
- Seal replacement tools for flowline connection system.

Connecting Components

All of the lines between the manifold and the platform were installed in August of 1994 using the dynamically positioned reel barge *Chickasaw*—the flowlines were installed early to take advantage of the more favorable late summer weather. Each flowline terminates with a flowline termination skid to allow for remote connection to the manifold. The dual 6-inch and 2-inch flowlines each connect to the manifold end using an innovative "Z"-shaped hard-pipe spool piece connection system with horizontally oriented collet connectors.

Following the manifold installation, an ROV-operated taught-wire measurement system was used to obtain the measurements for fabrication of the hard-pipe spool pieces (6-inch and 2-inch). The PMT was lowered to the seafloor and positioned by the ROV on the manifold support foundation. The ROV pulled a cable and hook from the PMT and attached it to the flowline termination skid.

Hydraulic power from the ROV pulled the cable to a predetermined tension, and the cable-length counter and the horizontal- and vertical-angle measurements at each end were recorded using the ROV cameras. These measurements were recreated on the deck of the drilling rig using manufacturing jigs to mimic the seafloor configuration and the hard-pipe spool pieces were fabricated to fit.

Once fabricated and tested, an ROV-operated actuator stroking tool was attached to the collet connector on each end of the spool piece. Each spool piece was keelhauled under the drilling rig and lowered to the seafloor with a spreader bar assembly on drill pipe and guideline assistance. Once the spool piece was lowered into position, the ROV inserted a hydraulic hot stab into the actuator panel to stroke the connector towards the mating hub on the manifold. The collet connector was locked on the hub of the manifold with a similar hot-stab operation. A third hot-stab receptacle and pressure gauge on the panel allowed the ROV to perform an external test of the metal-to-metal seal. The stroking, locking, and testing operations were then repeated on the flowline-termination skid end of the spool piece. The "Z-Bend" in the spool piece allowed for up to 12 inches of stroke on each end. The stroking tools and spreader bar were retrieved to the surface leaving no flowline-connection hydraulics subsea.

The subsea trees were installed with 150-foot flexible flowlines already attached. The free end of the flexible flowline was run with a stroking tool in place. Once the tree was connected to the wellhead, the ROV was again used to connect the flowline to the manifold.

Hydraulics for the flowline connection system operations are provided by a dedicated hydraulic-reservoir skid mounted to the bottom of the ROV and connected to the ROV control system. The ROV uses conventional oil-based hydraulic fluid, which could not be used for hot-stab operations for environmental reasons. This skid was designed to provide hydraulic power to the flowline connector stroking tool using environmentally safe, water-based control fluid. The skid has independent 3,000- and 10,000-psi pressure circuits and dual five-gallon reservoirs.

The subsea wells and manifold are controlled from the Vermilion Block 386-B platform through the use of an E/H control system. Hydraulic fluid and electric signal and power are carried from the platform to the field via an armored umbilical—a combination of thermoplastic hoses, electric cables, and armor wires. Hydraulic fluid is delivered to subsea control pods (one per well) which contain E/H controls and solenoid valves. Electronic commands from the control computer on the platform cause the solenoid valves to route hydraulic fluid to open and close valves on the subsea trees and manifold. Via a microwave link to shore, real-time well conditions can be monitored and the subsea equipment can actually be operated from Phillips' Lafayette, Louisiana office.

The armored umbilical terminates in an umbilical termination assembly (UTA) at the subsea manifold. The control pods on the trees and manifold are connected to the UTA with unarmored "flying lead" umbilicals. Flying leads were also used to connect the four methanol supply lines to the UTA—both were installed using a "flying lead deployment skid" and ROV connection tool. Each umbilical was wrapped onto a deployment skid in a "figure eight" configuration to allow the ROV to pull the umbilical off in a controlled manner. Each end of the umbilical terminates in a connection plate that attaches to a docking porch on the deployment skid for easy ROV access. The entire skid was then lowered to the seafloor through the moonpool of the drilling vessel to a spot between the manifold and subsea trees. The ROV connection tool mounts to the bottom of the ROV and connects to its control system.

The system was designed to allow the ROV to dock the connection tool on the deployment skid and remove one end of the flying lead at a time. The vehicle then maneuvers to the designated docking porch on the tree or manifold and attaches the umbilical. The connection operation is repeated for the other end of the flying lead, then the deployment skid is retrieved to the surface.

Contingency 'Preps' Pay-Off

The subsea trees are equipped with chokes to regulate production. Using an ROV and a dive support vessel, the choke can be manually overridden or the entire assembly can be retrieved. A retrieval/installation tool was designed for this purpose if it became necessary to replace the choke. The tool is capable of unlocking, retrieving, and reinstalling the choke in a controlled manner using soft-landing cylinders which are integral to the tool. The retrieval/installation tool is run on a "down" line from a support vessel along with an umbilical to provide hydraulic power to the tool.

Due to the multiple steps involved in the retraction/installation process, the tool is designed to be controlled by a portable computer with dedicated software and an associated solenoid valve module.

The retrieval/installation system was to be used in mid-November 1995. Phillips mobilized the dynamically positioned vessel *Witch Queen* with an ROV spread for choke retrieval operations on the Garden Banks 70 #1 well to repair a failed choke. The vessel was equipped with the dedicated retrieval equipment, utility umbilical reel, and ancillary hardware. The entire operation including retrieval, repair, and reinstallation was completed in 37 hours from the time the project team was picked up from the host platform (Vermilion 386 B) until completion at the work site, 13 miles away. This operation marked the first remote subsea-choke retrieval in the Gulf of Mexico.

A choke override tool was designed to allow the operator to reposition the choke trim in the event of choke actuator failure. The tool includes a rotary torque motor and is configured for mounting to the bottom of the ROV and being flown into position on top of the choke. The ROV operator monitors the visual position indicator on the top of the choke via the remote camera and light which are integral to the tool. The override tool was successfully used in September 1996 to override the choke on Garden Banks 70 #1.

Rotary gate-valve override tools for operating valves on the manifold and subsea trees were also included. Standard API RP 17D docking receptacles were utilized for valve intervention. Unique end effectors are included on each different valve size to prevent the ROV from operating the wrong valve or over torquing a valve. The tools and ancillary hardware were stored in a purpose-built toolbox which proved to be invaluable for keeping the equipment intact and protected during the multiple shipping operations involved in factory acceptance/system integration testing and offshore installation.

A sealant injection system was designed that could be easily handled and operated by an ROV in the event of a stem leak on a manual gate valve. The manual valves used on the project did not include a metal-to-metal back seat on the stem; therefore, an injection port and hot-stab receptacles were included in each valve to allow for injection of sealant into the stem packing cavity. The system includes a position indicator to allow the ROV operator to visually monitor injection quantity and reservoir supply. To date this equipment has only been used during pre-installation testing.

The subsea manifold was secured to the seafloor using three 90 foot piles. The piles were jetted into place by the drilling rig and the manifold was installed over them. A subsea grouting system was designed to secure the manifold support foundation (MSF) to the piles. The simple grouting system consisted of a 150-foot hose assembly connected to a string of drill pipe and included an ROV-operated isolation valve. The hose assembly terminated with an ROV operated stab that was inserted into a receptacle on the MSF. Grout from the rig cementing unit was pumped to simultaneously fill the annular cavities between each pile and the MSF. Following grouting the ROV disconnected the hose assembly from the manifold, and the system was retrieved to the surface.

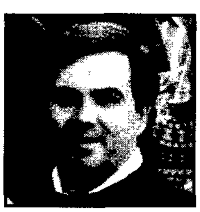
The 6-inch hard-pipe spool pieces

each contained an isolation valve, and, following installation, the ROV identified a minor leak in one of the valve connectors. Since the spool pieces were not designed to be retrievable, a subsea cutting system was required to remove the spool. Also, one of the guidebases from the original drilling program in 1990 was determined to be unremovable from the wellhead with conventional subsea drilling tools. After evaluating several alternatives, the ROV contractor provided an underwater hydraulic saw that was capable of making multiple cuts through the 16-inch wide flange beams on the guidebase. The cuts were required to allow clearance for departure of the flexible flowline from the subsea tree. An ROV-operated hydraulic saw originally designed for cutting wire rope was adapted for the operation. The saw relies on the centrifugal force created from the rotation of the carbide blade in water to translate the blade through the cut. /st/

Acknowledgments

Phillips Petroleum Co. for permission to publish the results of this highly successful venture with special thanks to the many manufacturers and service companies that participated in this outstanding team effort.

John L. Upchurch has been working for Phillips Petroleum Co. since graduating from the University of Missouri-Rolla with a bachelor of science degree in petroleum engineering in 1980. He was one of two project managers for Phillip's Seastar Subsea Development Project and was responsible for the overall design, fabrication, and installation of the subsea trees and manifolds.



Robert P. Money's project manager responsibilities for subsea development projects include design and coordination related to subsea trees, manifolds, chokes, flowline connections systems and subsea control interfaces. Currently he is assisting at Conoco-Houston in the Deepwater Technical Solutions group for field development in up to 8,000 feet of water. Money was lead engineer in the Seastar project and is Aker Engineering's project manager for phase 2 of the project. He has a bachelor of science degree in mechanical engineering from the University of Houston.

UUVs for Underwater Work—Innovation or High Tech Toy?

Defining Solutions to Problems, Not Finding Problems for Solutions; Using the Decision Roadmap, Oceaneering Makes An Odyssey *Connection*

By John R. Kreider
Vice President, Engineering and Programs
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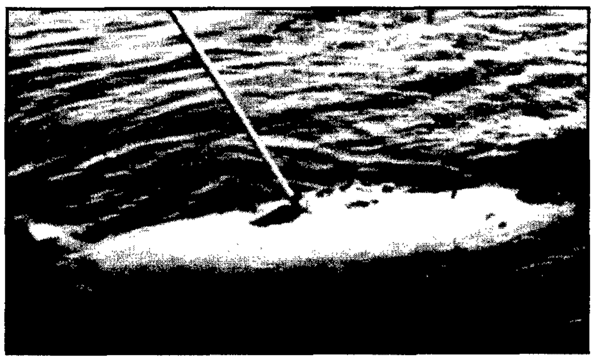
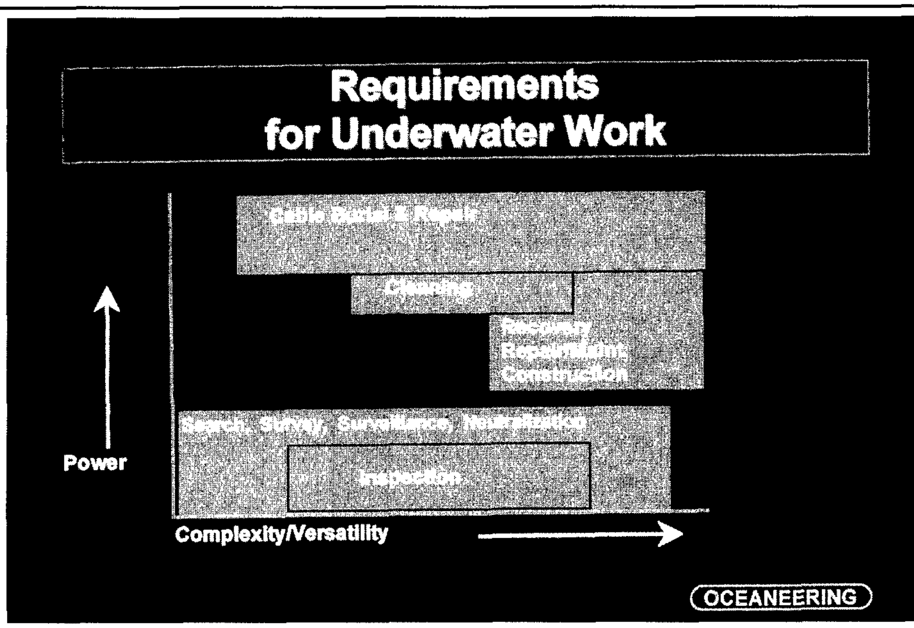
Upper Marlboro, Maryland



Odyssey, ***a small, cost-effective UUV developed at the MIT Sea Grant Laboratory, departs ship for one of its 300-plus dives. Typical underwater work tasks require wide ranges of power and complexity/versatility.***



While a wide variety of unmanned underwater vehicles have been developed, very few have found successful application in the underwater industry beyond developmental roles as test platforms where "technical sizzle" alone can be adequate justification to try a new innovation. At Oceaneering, we believe there are several valid reasons for the limited acceptability of UUVs, and we have developed a targeted approach to use UUVs for specific applications where they offer major advantages over other solutions.

UUVs have existed for more than 100 years—torpedoes, one of the simplest forms of UUVs, date to the Civil War. Beginning in the 1960s, UUV development has received significant technical interest. About 40 to 50 vehicles have been built since that time, most within the last 15 years. These UUVs have ranged in size from a few pounds to more than 8 tons, with a wide variety of sensors and intended applications. They have been marketed as technical innovations capable of meeting many needs of the offshore industry and military. Nevertheless, they have received limited acceptance, particularly from commercial users. Why is this the case?

It is first helpful to review the requirements for a successful innovation. While academic innovations can be successful if they employ a new technology, this fact alone is not sufficient for a successful commercial innovation. *Successful commercial innovations must offer customers a real benefit over the current way of doing things. In addition, that benefit must come at a price that customers are willing to pay and at a level of risk that customers are willing to accept.* The benefit to the customer could be an improved way of performing a task, usually meaning less cost or lower risk. It could also be the ability to perform a task that they could not previously accomplish, although it must be clearly established that the customer really needs to perform the task at all. Price is of primary concern for all commercial applications and many government/military operations. The benefit must also be at a level of risk acceptable to the customer—the offshore industry is a very risk averse industry. Many of the approaches in use offshore today are relatively simple and have been proven over a long period of time. The industry does not leap at new technological solutions because the perceived downside risk and high cost of problems offshore far outweigh the potential advantages of a new, unproven solution.

In summary, successful innovations in the offshore industry demand careful evaluation of fundamental questions about the market, not the technology. The key issues are cost effectiveness and risk aversion, not technology. Because of the risk averse nature of the industry, UUVs must overcome a significant hurdle.

> ***"Thus based on 'being able to do the job,' potential UUV applications are immediately limited to inspection, survey, surveillance, mine neutralization, and search and reconnaissance activities."***

Innovations are generally either evolutionary (continuous or incremental improvements) or revolutionary (a quantum leap). The offshore industry readily accepts and implements the first type of innovation. Companies frequently come up with approaches that are "a little bit better," involving incremental steps in technology and risk. These innovations are readily accepted because they offer potential cost savings with relatively low risk.

However, most UUVs are revolutionary—quantum leaps from the way work is typically performed offshore. As a result, there is a natural resistance by most customers, even if the UUV is potentially more cost effective. As a result, the successful UUV innovator must find true needs that cannot be satisfied by alternative, proven approaches, or find ways of reducing risk while still offering significant cost advantages.

In summary, the successful innovation must demonstrate three things to the customer's satisfaction: • it can do the job, • it is low risk, and • it is a cost-effective solution.

Applying the Criteria

The first criterion is always the most important. The relative importance of risk and cost effectiveness will vary depending on the customer and the job.

Ten typical jobs performed underwater by commercial and government users—missions for underwater work systems—include: inspection of manmade systems, survey, surveillance, mine neutralization, search/reconnaissance, recovery, repair and maintenance, construction, cleaning, and cable burial and repair.

In regard to requirements for power and versatility, inspection tasks typically require relatively low power and medium versatility. On the other hand, cable burial and repair require significant power. The range of complexity varies considerably from simple straight-line cable installations, best performed with a plow towed behind a ship, to more complex cable repairs involving finding, uncovering, repairing, and burying the cable.

To perform these underwater tasks, wide ranges of proven, alternative solutions are frequently available. Typical approaches include divers with tools, atmospheric dive

> ***"Therefore, to satisfy the risk criterion for UUV applications, we should look for simple tasks and try to employ simple equipment."***

suits, manned submersibles, ROVs, and towbodies—all proven solutions in 1996. Two innovative approaches are a UUV with supervisory control and a truly autonomous UUV. (For this article, an ROV has an umbilical providing power and vehicle control.) The supervisory controlled UUV is self-powered, but has communication with the operator via a fiber optic or acoustic link to provide operator input, generally at a high (supervisory) level. The truly autonomous UUV has no direct link with the operator. It is self-contained with power and intelligence in the form of preprogrammed logic.

The first question a customer considers before evaluating cost effectiveness or risk is whether the proposed approach can do the job. In looking for successful applications for UUVs, we must recognize that current technology imposes severe limitations on both power and versatility. For example, a typical UUV cannot bury cable one meter deep because it cannot carry sufficient power. In fact, UUVs generally cannot perform the last five of the 10 foregoing tasks (and shown at the top of the graph) because of power restrictions. *Thus based on "being able to do the job," potential UUV applications are immediately limited to inspection, survey, surveillance, mine neutralization, and search and reconnaissance activities.*

For selected applications in these categories, UUVs offer a unique solution. ROVs and towbodies require a support vessel close to the underwater task. For selected military applications, the customer wants to perform tasks in areas a significant distance away from the support vessel. UUVs are one of the few solutions for this type of job. However, for most other applications, UUVs must compete with alternative solutions. They will then be selected on the basis of their ability to reduce risk or cost effectiveness (second and third criteria).

First Consider Risk

In comparing UUVs to alternative solutions, such as ROVs, UUVs are typically limited by versatility/complexity of the task. For truly autonomous UUVs, the operator is out of contact with the vehicle—the mission is programmed ahead of time, and the vehicle is sent off to perform the task. The operator cannot monitor progress and change the operation once the vehicle has departed. The probability of mission success depends entirely on the foresight of the developers in being able to anticipate every contingency and in the ability of the on-scene operator to correctly program the UUV for the intended mission. In general with current technology, they will not be successful at the more complex tasks where it is difficult to define the task and to predict exactly what will happen in all circumstances. Artificial intelligence is a hot research topic, but it is not close to a real-world solution to enable UUVs to perform complex operations at sea.

Even simple underwater tasks, such as running a search pattern at constant altitude, become difficult if conditions such as high currents, unknown terrain, and obstacle avoidance are imposed. Thus, the risk increases significantly, and the only reason for selecting a UUV would be correspondingly significant cost savings.

Another aspect of risk is concern about equipment downtime at sea. For commercial operators, the cost of downtime can be more than $100,000/day when large equipment spreads are involved.

Most offshore government operations are also cost sensitive. Budgets cannot accommodate significant downtime, so if a system is down, the mission may have to be terminated early before it is completed. For military applications, people's lives could be at risk if essential equipment is down.

Since UUVs are developmental systems, they frequently employ new, sophisticated technology that is not the most proven, reliable, or maintainable at sea. New technology that works well in the lab may not stand up to the rigors of smashing into the hull during a recovery in sea state 5. Systems that require high level engineers to troubleshoot and maintain will not succeed offshore where they must be maintained by technicians and sailors. *Therefore, to satisfy the risk criterion for UUV applications, we should look for simple tasks and try to employ simple equipment.*

KISS—"Keep it simple stupid"—is essential. For this reason, UUVs under supervisory control offer several advantages over those purely autonomous. First, the operator can immediately take control of the vehicle if unforeseen circumstances arise during the mission. In addition, onboard control can be less sophisticated since it is not required that the vehicle be able to handle every imaginable contingency on its own. Therefore to offshore customers, supervisory controlled UUVs provide a potential intermediate step between well accepted ROVs (low risk) and autonomous UUVs (perceived high risk).

Cost Factors

If a UUV can do the job, and it has an acceptable risk, it still must meet the third criterion of demonstrating cost effectiveness. In most potential applications (inspection, survey, surveillance, neutralization, and search/-reconnaissance), the primary competition for UUVs is from ROVs and towbodies. In general, UUVs offer a potential advantage over these only where the umbilical becomes a problem. Potential UUV applications include jobs to be performed at a large horizontal offset from the support vessel (e.g., more than one mile), jobs where speed is critical, selected deep water tasks, and tasks where it is critical to decouple the vehicle from surface motions.

For applications at large horizontal offsets, a UUV truly offers many unique capabilities so that risk and cost are less important. For tasks such as cable/pipeline inspections, route surveys, and search, speed is important for cost effectiveness and is frequently limited by the umbilical—the speed of conducting a pipeline inspection may be limited by the speed of the ROV, not by the speed at which data can be collected. The speed at which deep-water searches can be performed is severely limited by drag on the tow

> ***"In most potential applications (inspection, survey, surveillance, neutralization, and search/reconnaissance), the primary competition for UUVs is from ROVs and towbodies."***

cable. Searches in 20,000 feet of salt water (FSW) are limited to 1 to 2 knots because of the drag on a 30,000-foot tow cable. In addition, making a turn with a towbody in 20,000 FSW can take more than eight hours. Eliminating this lost time will clearly provide a more cost-effective search pattern.

UUVs can offer advantages over towbodies even in shallow water because the UUV is decoupled from surface motions, while a towbody is subjected to vessel motions unless a depressor/weight is used as a second body in front of the sensor platform—but with an associated increase in system complexity and handling difficulty.

In evaluating cost effectiveness, we must consider the overall cost of performing the job. The ROV or UUV day rate is generally determined by the capital cost of building the vehicle. In most cases, these numbers will be comparable, or the UUV will be at a disadvantage. However, this day rate is only a small portion of the overall cost of doing an offshore job. Other key costs include vessel day rates, crew costs, spares, and associated equipment costs, such as handling systems, winches, generators, umbilicals, etc. Potential savings in these areas are where UUVs can demonstrate cost effectiveness. For example, if an ROV system requires a large handling system because of the umbilical, the surface support vessel must also be large (expensive). Using a UUV would eliminate the costly umbilical, decrease the size of the required handling system, and potentially allow a less capable, less expensive vessel to be used. In particular, decreasing requirements of the support vessel can result in significant cost savings. The savings may result from simply going to a smaller vessel, or it may be because the UUV can eliminate required vessel capability such as dynamic positioning.

KISS, a UUV risk reduction technique, also provides cost advantages. Using simple, readily available, commercial off-the-shelf (COTS) equipment in the UUV results in a cheaper vehicle that is less expensive to maintain. In addition, the skill level of the crew operating and maintaining the vehicle can be lower, so crew costs are less.

In summary, UUV cost effectiveness results from keeping the vehicle simple and from selecting applications where eliminating an umbilical provides significant reductions in associated equipment requirements and capability of the required support vessel.

Course of Action

Evaluating UUVs in the context of the three criteria of capability, low risk and cost effectiveness, define how UUVs can become a successful innovation for performing meaningful work. ***First,*** UUVs cannot perform all underwater tasks. It does not make sense to try to sell the concept as a solution to a task it is not well suited to perform. This sounds obvious, but it is frequently forgotten by innovators looking for a problem to fit their solution. Recognize the current limitations of power and versatility of UUVS, and look for selected applications in the areas of inspection, survey, surveillance, neutralization, and search/re-connaissance. ***Second,*** recognize the risk-averse nature of the industry and look for initial applications involving simple tasks and simple pieces of equipment. UUVs must walk before running. Customers in the offshore industry do not generally buy a solution because it is the newest technology; in fact, they usually avoid it because it equates to high risk. Trying to take on difficult tasks too soon results in failure, which only reinforces customers' aversion to accepting a new approach. ***Finally,*** look for applications in which the associated equipment for the vehicle and the surface vessel requirements can be reduced. These applications will provide the largest cost benefits over alternative solutions, so that customers will be willing to try the "new, innovative solution."

> ***"Oceaneering believes Odyssey technology provides a significant opportunity for a successful commercial innovation."***

Oceaneering's View

With these factors in mind, Oceaneering has looked at potential market opportunities for UUVs. We have avoided large complex vehicles as too costly to develop, operate, and maintain. In addition, there is the natural reluctance of customers to employ UUVs because of perceived risk. Thus, we have focused on looking for a simple vehicle, employing COTS equipment, that has the potential of performing selected, simple tasks at significant cost savings over ROVs or other existing solutions, such as divers or manned submersibles. After careful evaluation of several alternatives, we selected the *Odyssey* vehicle (*Sea Technology*, December 1995), developed at the MIT Sea Grant Laboratory, as an attractive UUV solution.

Odyssey's significant advantages include: • it is based almost exclusively on COTS equipment—it is reliable and cost effective to build. Maintenance is also cost effective since parts are readily obtained, and technicians are familiar with the technology, • it is a simple vehicle—designed and built with the express purpose of maintaining simplicity and low cost, and • it has been proven on more than 300 successful operations under a wide variety of conditions. It has evolved over the past five years and performed successful dives in environments ranging from under-the-ice in the Arctic, to 4,500 FSW in the Juan de Fuca Strait, to coastal waters off Florida.

As the next step in developing *Odyssey* technology, Oceaneering is cooperating with MIT to provide operator experience to make the vehicle more user friendly and easier to manufacture. Our experience with a wide variety of underwater systems, including diver tools, atmospheric dive suits, and ROVs, dictates that operator experience is an essential input to ensure system success. Obtaining this early input becomes even more critical for systems like UUVs where the operator in the field is not close at hand to the actual task being performed.

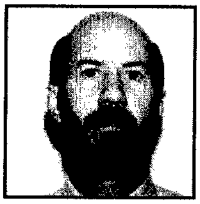
Experienced operators understand what it truly takes to accomplish a mission in the field. They know equipment limitations and understand task requirements. Manufacturing personnel provide valuable insight into manufacturability of a new system. Yet many "sophisticated" systems are designed without input of operations and manufacturing. Maintainability and repairability are frequently neglected or ignored by design engineers. Millions of dollars have been spent on training and simulation programs for underwater systems designed by engineers who have never been to sea with an ROV or UUV. It is no wonder hardware frequently misses the mission objective and fails in the field.

Unfortunately, many UUVs are headed in the same direction. They have been designed by technically skilled engineers, but lack the real-world input of operators who have spent years at sea and fabricators who have built underwater systems. The ability to use the latest generation of computer hardware for a sophisticated control system does not ensure a successful UUV system. All subsystems must work together to accomplish the entire mission from prelaunch planning to recovery and repair.

In summary, we believe the primary reason limiting widespread UUV application has been the same reason new innovations in other industries frequently fail. The new innovation starts out being technology-driven rather than market-driven. Developers make unsupportable claims and try to apply the innovation to applications for which it is not suited. As a result, customers become disappointed, and further sales are even more difficult. This is particularly true in the offshore industry where risk is avoided. Most customers would rather use the tried and proven solution and make incremental improvements rather than risk a revolutionary approach. Fishing nets are more accepted than neural nets!

We challenge organizations funding equipment development to recognize these realities and insist on "reality-based engineering" during development of new systems.

Oceaneering believes *Odyssey* technology provides a significant opportunity for a successful commercial innovation. We arrived at this solution after evaluating market needs, not by developing a new technical solution without a particular application in mind. *Odyssey* is capable of performing the targeted applications—it avoids the "technological wonder" by employing easily supportable, COTS technology. And finally, it offers an attractive cost-effective alternative over more conventional solutions. /st/



John R. Kreider has more than 20 years experience in a wide range of offshore projects, from the Arctic to ROVs that have dived to more than 20,000 FSW. After receiving graduate degrees in ocean engineering from MIT and Woods Hole Oceanographic Institution, Kreider worked at Shell Oil Co. involved in frontier area development offshore California and Alaska. He then directed numerous theoretical and field programs involving ice mechanics, characterization of sea ice, and ice loads on offshore structures. Most recently, he has managed hardware development programs for advanced underwater systems capable of search, recovery, survey, inspection, and cable burial at Oceaneering.

NR-1: Deep-Ocean Introduction Of New Laser Line Scanner

New Optical Imaging Instrument Promises High Resolution Seafloor Pictures for Benthic Ecology, Geology, Nautical Archeology

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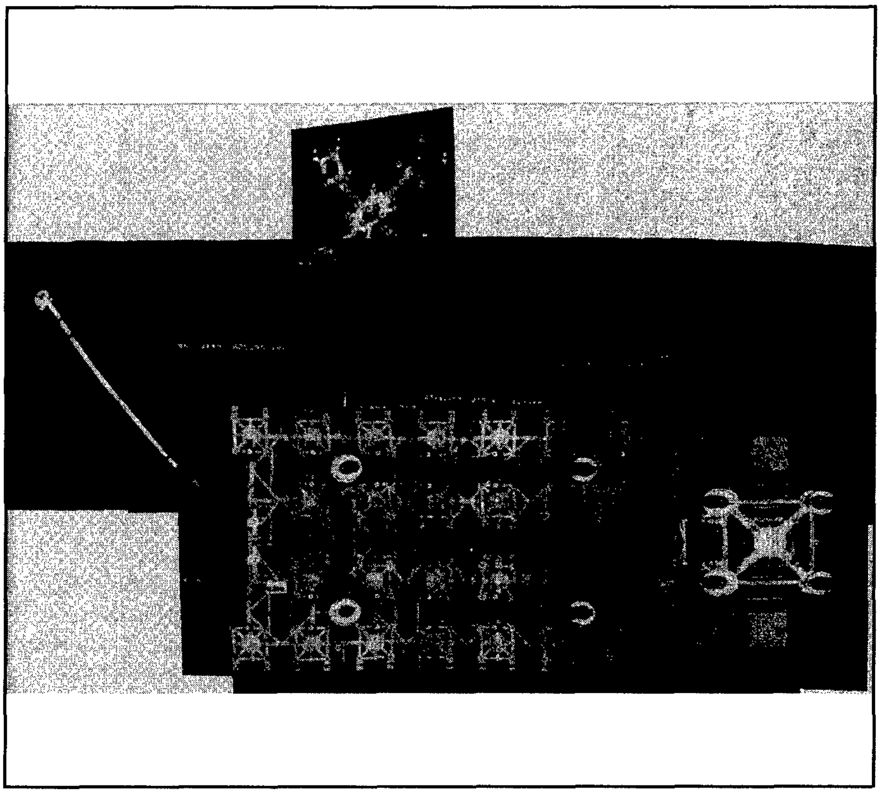


This mosaic was assembled from several passes over a drilling template. The structure and its satellite measure 20 x 15 meters. The cone-shaped units down each side are reentry ports for risers to the Enserch platform that will be installed on this site.

If we could image the seafloor the way aerial photographs have been able to image the land for the past 50+ years, it would radically change the way we now think about—and work in—the submarine environment. Here we describes use of the SM2000 laser line scanner mounted on the U.S. Navy's Submarine *NR-1*, and subsequent processing of the images, to produce large area mosaics for application in basic science and seafloor engineering.

At present there are two means for seafloor imaging: seismic and optical. Seismic imaging, such as side-scan sonar, is limited in resolution. Optical imaging such as underwater photography has been limited in scope because of backscatter.

The laser line scan system (LLSS) is a new optical imaging instrument that overcomes the back-scatter problems plaguing underwater photography (Boston 1993; Gordon 1993). Recent design improvements have produced a new LLSS, model SM2000, that reduces power requirements to under 200 watts and size and weight by roughly half.

These improvements make this LLSS a potential tool for much of the U.S. submersible fleet—including ROVs and towed fish—for Navy submarines and for *Alvin*; but as yet, the submarine user community has not undertaken any detailed scientific or engineering tasks with the system. In its current configuration, the LLSS provides high-resolution pictures of the seafloor along swaths up to 40 meters wide. These are either recorded on videotape or selectively recorded as digital "snapshots." These products have potential application for a variety of survey tasks without any enhancement; however, scientific applications such as benthic ecology, marine geology, marine engineering, and nautical archeology would benefit if the swath data could be mosaicked as digital images that cover contiguous areas on the order of 1 square kilometer.

Research Questions

Hydrocarbon seepage in Gulf of Mexico profoundly affects the geology and ecology of the region's seafloor (Behrens 1988). Widespread occurrences of massive carbonate outcrops (Roberts and Aharons 1993), mud volcanoes, brine pools (MacDonald *et al.* 1990), shallow gas hydrates (MacDonald *et al.* 1994) and dense communities of chemosynthetic fauna (MacDonald *et al.* 1989, 1990) all originate from the "leaky" nature of the slope and have been the focus of intense scientific interest in recent years. Also, the United States has increasingly turned to offshore reserves to meet energy needs, but the economic significance of the region must be evaluated both in terms of the value of the reserves and the enormous costs associated with production in deep water. Management regulations designed to protect important biological communities (MMS 1988), to inspect seafloor installations (MMS 1991), and to remove debris at the end of the production cycle (MMS 1992) have become components of these costs.

Laser line scan technology has the potential to provide quantifiable information concerning seafloor features at the appropriate spatial scale and level of resolution. The mission described here was designed to develop methods and procedures for use of a LLSS in deep sea science and technology.

From a technical standpoint, we needed to determine the optimal methods for collecting and processing LLSS data into geo-referenced products. This means moving from the current display-mode storage of data on videotape to digital products that are comparable to standard geophysical survey files. We also needed to select sites for imaging that contain reproducible benchmarks in order to evaluate the validity of our geo-rectification and mosaicking procedures.

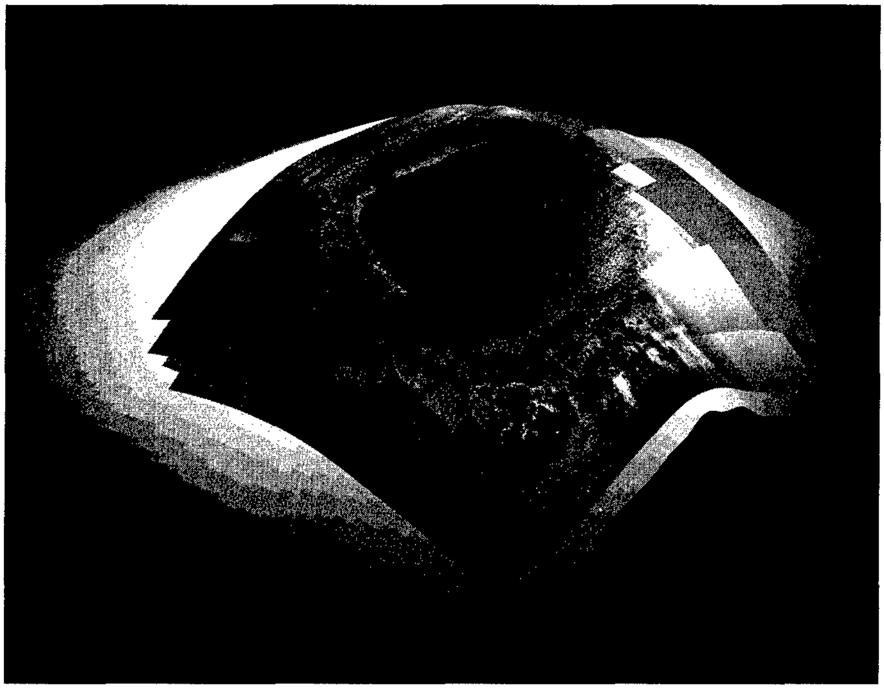
From a research standpoint, we selected study sites in which large-area digital images could contribute significantly to scientific understanding or the state of engineering art.

Materials: Instrument & Vehicle

Submarine *NR-1* is a 44.5-meter nuclear-powered vessel with four conventional berths and two to three auxiliary berths. She commonly carries a crew of 10 sailors and officers and, during scientific missions, two scientist/observers (Babb *et al.* 1994). Rated for non-classified dives to depths of 740 meters, *NR-1* can remain submerged for periods in excess of 20 days. Features of special note for the LLSS application included an onboard computer that logs ship's heading, depth, altitude above bottom, and position. *NR-1* is also fitted with a box keel—an open enclosure extending most of the length of the ship—that houses two wheels used for landing the submarine on the seafloor. A doppler transponder system is used to estimate the ship's acceleration in north-south and east-west directions. These accelerations are processed to provide a dead-reckoning position.

The SM2000 utilizes a solid-state green laser and a rotating prism to project a beam of laser light onto a swath of the seafloor. A photo-multiplier processes the reflected return of this beam into a single optical scan. By translating the instrument in a direction perpendicular to the scan, and by maintaining the prism rotation proportional to translation speed, the LLSS builds up an optical image of the seafloor. Adjustments to scan angle and depth of field can optimize the image for specific requirements.

Maximum scan angle is 70°, which provides a potential swath-width equal to 1.4 times instrument altitude; mini-



Mosaic of Brine Pool* NR-1 *"draped" over local bathymetry. Vertical exaggeration is about 8:1. Subtle differences in the topography account for the abrupt northern boundary to the mussel bed, where a partial dike tends to retain the brine, and the meandering stringers of mussels on the southern edge where brine tends to overflow.

mum scan-angle is 15°. Each scan is digitized as 1,280 pixels. It is possible to pan field of view so that scanner is looking at objects between 35° and 15° off the instrument's nadir. Depth of field in the SM2000 is controlled by a mechanical shutter that determines what vertical portion of the reflected signal reaches the photo-multiplier for processing.

The SM2000 pressure housing was mounted on *NR-1* with a simple pair of cradle brackets on the starboard side of the box keel, 1.2 meters above the bottom of the keel and about 12 meters aft of the bow section. The pressure housing and internal control and recording equipment were dry-fitted on *NR-1* during a scheduled dry dock, then removed until immediately prior to the mission. To deploy the LLSS for the mission, the pressure housing was dry-mated to the connectors on deck, lowered with a crane into the water, and bolted in position by Navy divers.

Because of the limited interior space available in *NR-1*, we designed an optimized control and recording system. This comprised an A-to-D board driven with a 386 PC, controls for prism rotation and depth of field that were interfaced to the altitude and acceleration data stream from *NR-1's* computer, and an annotation card that copied the attitude data onto the output video signal. For this mission, the image data were recorded in analog format on high-band 8mm videotape.

"Laser line scan technology has the potential to provide quantifiable information concerning seafloor features at the appropriate spatial scale and level of resolution."

Field Methods

NR-1 mobilized from Pensacola and was transferred under tow by the M/V *Caroline Chouest* to the operations area in the Green Canyon and Garden Banks regions of the Gulf of Mexico continental slope. *NR-1* collected LLSS images from a variety of deep water targets during an 11-day mission. The sites included the following: two drilling templates (owned by Enserch Exploration Inc.) located in 450- and 650-meter water depths; two large communities of chemosynthetic tube worms located at natural oil seeps in ≈550-meter water depths; a seafloor brine pool surrounded by methanotrophic mussels; an active mud volcano; and a 50-kilometer length of an oil and gas pipeline (also owned by Enserch).

The mission had two complementary tasks. The first was collection of contiguous images that could be assembled into a mosaic of a seafloor feature or an engineering installation. The second was detailed survey of the seafloor over an extended transit. Two modes of operation proved effective for these respective tasks.

For collection of mosaic images, *NR-1* crossed the target area along a series of parallel tracks. Altitude of the submarine and scan angle of the SM2000 were adjusted to optimize areal coverage and image resolution and to allow sufficient overlap between image swaths. Depth of field was set manually to a fixed altitude (e.g., 10 meters); actual submarine altitude tended to vary ±1-2 meters along track. Image overlap between swaths was generally targeted at 25-40 percent. Pan was set to zero. Records of submarine altitude, heading, and position were logged at a 10-second or 1-second rate.

For collection of extended survey data along the recently installed oil and gas flowline, *NR-1* steered a course to one side of the flowline. Scan-angle was reduced to 15° and the image was panned to the maximum extent. This combination was intended to optimize resolution of pipe detail and to provided a view of the portion of the pipe that was resting on the sediments. The latter adjustment is critical for detection of pipeline "spans"—i.e., sections of the pipe not in contact with the bottom and therefore subject to potential undercutting by currents.

Image Processing Methods

Because all data were recorded on high-band 8mm videotape, video capture was the first step in processing the SM2000 images. A Targa-64 video capture card, driven by a 486 PC, was used to capture frames for construction of mosaics. A DEC J300 multimedia card, driven by a DEC Alpha 3000-

600 UNIX workstation, was used for automated capture of frames from the pipeline survey.

The individual mosaic frames comprised sections of a continuous waterfall of scan data. Reassembling the frames into a single, contiguous swath was the second step in mosaic construction. Because the frames were captured with 10 to 15 percent along-track overlap, there was always a potential "perfect fit" between frames and there was usually enough texture in the images-from burrows, shells, and other seafloor material-to provide visual match-points between frames. It proved straightforward but tedious to digitally assemble 20 to 40 frames into seamless swaths with use of Photostyler, a Windows®-based image processing program.

The reassembled swaths of SM2000 imagery had a regular, rectangular geometry, 640 pixels wide and 5,000 to 10,000 pixels long. However, the actual geometry of the bottom features recorded in these swaths was distorted because *NR-1's* altitude, heading, and course over ground was not constant. To correct this distortion, the image swaths had to be warped to their true geometry.

When working with engineering installations such as drilling templates, we could use scaled construction drawings as a guide to this warp correction. For unmapped bottom areas, we calculated the end-points of a series of scan lines distributed along the swath. The calculation was based on the scan-angle, submarine altitude, and submarine heading, matched to the image swath on the basis of the video time-tags and the submarine's recorded position.

Warping was carried out with use of Earth Resource Mapper and utilized a fourth-order polynomial fit of the image to the control points. (ER-Mapper™ is a UNIX-based software environment used primarily for satellite and geophysical image processing.)

We used ER-Mapper to assemble the warped swaths into contiguous mosaics, adjusting brightness and contrast to minimize tonal differences at the overlaps. To overlay the images onto a digital elevation model (DEM), we used routines in the PV-Wave data visualization package. PV-Wave routines were also used to calculate the DEM from the *NR-1* depth and position data. All images were re-imported to Photostyler for global cropping, tonal adjustment, and annotations.

The objective of video capture for the pipeline survey was to reduce some 40 hours of videotaped data into a compact format and to provide ready access to the geographic, depth, and interpretive information associated with any particular laser image. With use of the J300 board, it was possible to automate capture of one video frame every three seconds. This was a sampling rate that we determined would assure 100 percent coverage of the survey route, given the speed of *NR-1* along-track and the areal coverage of the laser images. Frames were stored in JPEG compressed format; each frame required about 35 kilobytes of disk space. Each image was time-tagged so that it could be subsequently matched to navigation data. Thus it was possible to reduce the 40 hours of video data (occupying 25 videotape cassettes) to about 43,000 usable images, which together could be copied onto three CD-ROM disks. The images were indexed by use of a geographic information system (GIS).

Despite difficulties, the mission was highly successful. A total of approximately 80 hours of laser line scan data were recorded on video tape, and the *NR-1* navigation information was recorded on computer disks. All of the scheduled sites were visited and successfully surveyed. Subsequent processing of the image data was time-consuming, but productive.

Conclusions

The SM2000 provides a new way of working with subsea survey problems. Images collected by the system have proved applicable to mosaicking and to long range survey. Collection of images on video poses a considerable constraint on post-mission processing. Perfection of digital data logging techniques on future applications will ease this difficulty. *NR-1*, with its abundant power, on-board computer system, and above all its human presence proved an optimal platform for SM2000 deployment. With the reduced power requirements of the SM2000, there is no reason why techniques developed during this mission could not be applied to deployment on towed vehicles in the deep sea. In all cases, whether the images are mosaicked, displayed in a database, or simply kept on videotape, laser line scan technology increases the scale and the resolution by which we can view the bottom of the sea. /st/

Acknowledgments

Use of Submarine *NR-1* was made possible through a grant from the NOAA National Undersea Research Program (NURP). We also acknowledge the generous support from Enserch Exploration Inc. Garden Banks Block 388 project team. Use of the SM2000 was additionally supported by the Westinghouse Electric Co., Oceanic Division. We thank R. Theisen from SAIC for critical technical consultation.

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Dr. James F. Reilly II was formerly a petroleum geologist but has since answered to a higher calling as a mission specialist with NASA. He earned his doctorate from the University of Texas at Dallas in 1995 and remains interested in Gulf of Mexico science.

Jeffrey S. Chu is an electrical engineer with a master of science degree from the University of Michigan. He is project leader for laser line scan technology at Northrop Grumman, formerly the Ocean Systems Division of Westinghouse Corp.

Cdr. David Olivier is currently assigned as officer-in-charge of the submarine USS Boston. *He holds a master of science degree in meteorology and oceanography from the U.S. Naval Postgraduate School in Monterey, California.*

RN Ocean Atmosphere Model

3-D Forecasting Model—FOAM—For Royal Navy Strategic, Theater, Tactical Operational Use; Dual-Use Application

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Lt.Cmdr. Roland Rogers, RN
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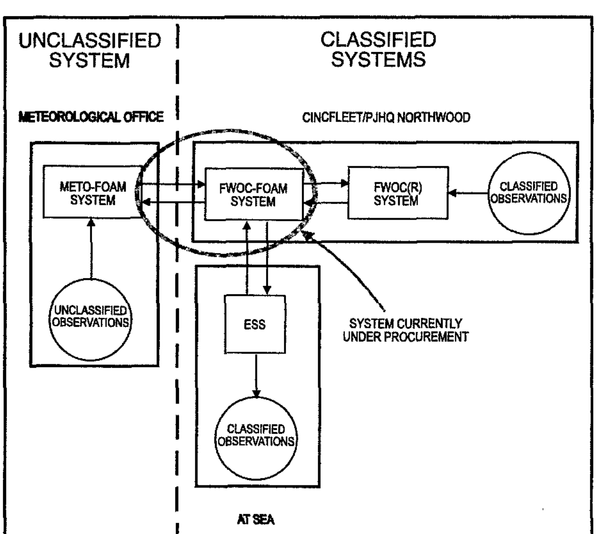
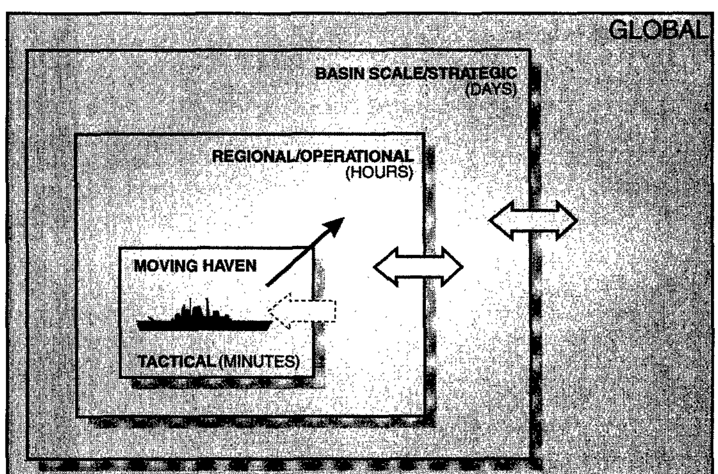
FOAM, a 3-D forecasting ocean atmosphere model, will enter service with the Royal Navy during 1997 at the U.K. Fleet Weather and Oceanographic Centre (FWOC), Northwood. In conjunction with a new integrated Command and Environmental Support System (CSS/ESS), the 3-D FOAM is expected to significantly enhance RN capabilities, ashore and afloat, to predict the undersea environment in support of ASW operations worldwide. In common with other western navies, RN military maritime strategy has been refocused towards rapid deployment and out of area operations, especially in shallow water. Future developments of FOAM and the inclusion of an organic modelling capability in ESS will therefore address nested high-resolution regional models, feature models, and littoral zone wave and current prediction models to support shallow-water ASW, mine warfare and mine countermeasures, amphibious, and special forces needs.

FOAM is the culmination of a research program that began in the mid-1980s when the Royal Navy introduced ocean modelling into the DERA's research program. A fundamental requirement was to establish and quantify improvements in operational effectiveness that would result from the introduction of numerical ocean forecast models. DERA research was directed initially towards developing objective methods of assessing improvements in ASW capabilities using sonar and other operationally related criteria. Techniques were developed for running numerical ocean models and acoustic models together so as to address the many issues surrounding the design of a future oceanographic prediction system that would include both shore-support and at-sea elements.

Working with U.K. defense contractors, DERA researchers investigated a wide range of topics including ocean model spatial and temporal resolution requirements[1], data fusion including data assimilation, compression and communication as well as data presen-





The FWOC-FOAM system. The vertical broken line separates those parts of the system dealing with classified and unclassified data respectively. The hatched line indicates the FWOC-FOAM system currently under procurement. At right, it is envisaged that the FWOC-FOAM system will provide access to a hierarchy of ocean models extending from global through regional (or theater) models to moving haven/tactical models. The times relate the timescales on which it might be required to prepare a response to a request for environmental data. The arrows across model boundaries indicate dynamic coupling between regions or in the case of the moving haven model (broken arrow) transfer through forecast data along the projected route of a task force.

tation, visualization, and human intervention. Of particular importance were studies relating to the use of FOAM products at sea, shipboard computer processing, and data storage requirements[2].

In parallel with these developments, DERA undertook a comprehensive research program with U.K. universities and government agencies to investigate future ocean modelling requirements. In particular, work was begun on prototype shallow-water models to provide two types of operational capability, viz.:

• UKOPMOD, a regional high resolution tide, surge, and temperature prediction model of the waters around the Northwestern European Shelf, developed jointly with the U.K. Natural Environment Research Council's (NERC) Proudman Oceanographic Laboratory, and

• A coastal ocean model prediction and simulation system (COMPASS) for global rapid-response modelling using generic shallow-water models and global databases, developed jointly with the Unit for Coastal and Estuarine Studies (University of Wales Bangor).

UKOPMOD and COMPASS were developed as technology demonstrators to illustrate the type of capability that might eventually be made available to FWOC and at-sea units equipped with ESS. These and other activities resulting from MoD-funded research at DERA, the Hydrographic Office, and the Meteorological Office (METO) have resulted in several key developments for military oceanographic capabilities. Topics studied included:

• Process studies: vertical current structure and stratification in shallow water; shelf-edge studies/internal waves and internal tides; and air/sea interaction studies

• Modelling techniques: free surface version of Cox 3-D code; quasi-geostrophic modelling techniques; isopycnic coordinate models; models of the upper ocean mixed layer; nested ocean models with two-way interactive boundary conditions; ocean feature modelling techniques; turbulence-closure modelling; sea-ice modelling and trajectory modelling (for search and rescue, oil spill, and mine/-sonobuoy drift prediction)

• Observation methods: objective mapping of dynamic sea-height variations (TOPEX/Poseidon satellite); optimum sampling strategies for oceanographic data gathering; deep-sea tide gauges; air-sea flux measurements; neutrally buoyant floats; and adaptive sampling techniques

• Applications: computer-based ocean-acoustic forecast aids (e.g. OCIDAS-1); data compression techniques; database methodologies; object-oriented databases; ocean-feature databases; data-assimilation techniques; and data visualization and display

Throughout the late 1980s, DERA and METO undertook trials of an upper-ocean mixed-layer model (MLM)—similar to the U.S. Navy's thermal ocean prediction system—which was driven by atmospheric fluxes from the METO's numerical weather prediction model. Tests of the MLM at the FWOC established the operational feasibility of the model. The model was not only able to improve on the historical data used by the Royal Navy to produce ocean nowcasts—but could also generate quantifiable improvements in operational effectiveness using objective skill-assessment criteria.

Later developments included the integration of ocean modelling capabilities with acoustic models and other predictive models into the RN OCIDAS-1 system—an Ocean Intervention and Data Assimilation System developed jointly for MoD by DERA and EASAMS Ltd. OCIDAS-1 was

Abbreviations

AIM	Atlantic Isopycnic Coordinate Model
CINCFLEET	Commander-in-Chief Fleet
COMPASS	Coastal Ocean Model Prediction and Simulation System
CSS	Command Support System
DERA	Defence Evaluation & Research Agency
ESS	Environmental Support System
FOAM	Forecasting Ocean Atmosphere Model
FWOC	Fleet Weather and Oceanographic Centre
FWOC(R)	FWOC Computer System Replacement
METO	Meteorological Office
METO-FOAM	Meteorological Office component of FOAM system
METOC	Meteorological and oceanographic
MICOM	Miami Isopycnic Coordinate Model
MLM	Mixed Layer Model
MoD	Ministry of Defence
NERC	Natural Environment Research Council
PJHQ	Principal Joint Headquarters
OCIDAS-1	Ocean Intervention and Data Assimilation System (Phase 1)
RN	Royal Navy
SOC	Southampton Oceanography Centre
UKOPMOD	U.K.-waters operational shallow-water model

subsequently integrated into the FWOC replacement computer system [FWOC(R)] by Data Sciences Ltd. in 1995[3].

The mixed layer model is the Royal Navy's first computer-based ocean prediction model. Used in conjunction with the U.S. Navy's acoustic sensor range and prediction domain climatology—which has been maintained and enhanced on behalf of the Royal Navy by the U.K. Hydrographic Office—the MLM gives an effective coverage over the North Atlantic and is particularly useful for predicting changes in the strength of the surface sonar duct and the deep-sound channel. The MLM is believed to be the first operational ocean thermal structure prediction model be developed in the United Kingdom.

At the same time that these developments were taking place, research was also underway at METO on a more ambitious scheme to develop an advective 3-D numerical ocean model capable of assimilating *in-situ* observations and remotely sensed data from satellites. The outcome of this research was FOAM, developed in a joint program by METO and DERA.

While METO was tasked with developing the general operational model, DERA research concentrated on the more specific RN operational needs and in particular the manner in which METO generated FOAM fields would be used at FWOC and in future at-sea systems such as CSS/ESS. Research undertaken by DERA in conjunction with other U.K. defense contractors, in particular BAeSEMA and Smith System Engineering Ltd., addressed computer processing and data storage requirements, data assimilation, compression, and communications. DERA, in conjunction with the Centre for Defence Analysis, also undertook research to further quantify improvements in ASW operational effectiveness using sonar related criteria (e.g. impact of 3-D ocean features on sonar contact holding patterns). This was done for a range of high- and low-frequency sonar types and for a number of strategically and operationally significant areas worldwide. DERA research has also addressed non-acoustic sensor performance.

Concept of Use

The implementation of FOAM to meet RN operational needs has required the development of a combined concept of use and user requirement strategy, thus enabling the FOAM capabilities to be transitioned into operational use by industry and to facilitate technology transfer.

FOAM will be run operationally at the Met Office (the METO-FOAM system) with its output made available—via a high bandwidth communications bearer—to the FWOC-FOAM system at Commander-in-Chief Fleet (CINCFLEET) Northwood, a national NATO and RN command center. The principal aim of FWOC-FOAM will be to support the four-star RN command, the Principal Joint Headquarters (PJHQ) and—via the CSS/ESS—the operational commanders at sea. Central to this will be the provision of a timely supply of oceanographic data and products at strategic, operational, and tactical levels so as to facilitate optimum deployment of assets and to maximize platform, weapon, and sensor performance.

Specifically, the requirement to be placed on the FWOC-FOAM system is that it shall be capable of producing analyses (i.e. "nowcasts") and forecasts of global oceanographic conditions—including shallow water—using the data which are available to it from the 3-D FOAM model and models such as UKOPMOD.

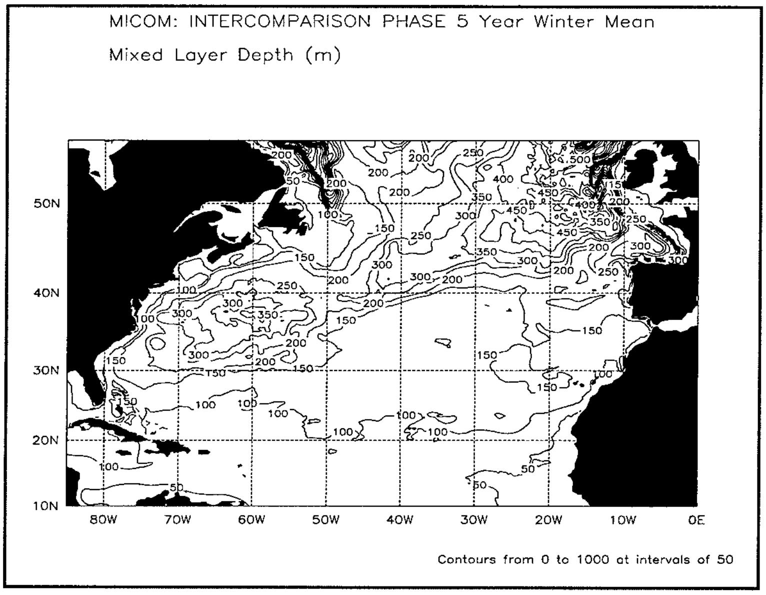
Data shall be representative of the true dynamical state of the ocean and be statistically validated. The data shall include sea-surface temperature, profiles of temperature, salinity and density, sound-speed profiles, surface currents and the currents at prescribed depths, the locations of ocean fronts and eddies, the position of the ice edge and ice thickness plus observed and derived acoustic fields (e.g. ambient noise, propagation loss) taking account of all FWOC-FOAM system inputs. The outputs from the system will be a fusion of METO-FOAM fields, observations, climatology, and other data (e.g. satellite remote sensing data) that are available to forecasters at FWOC. After interpretation and validation, FWOC-FOAM fields shall be transmitted to RN units equipped with ESS.

It is planned to meet the above requirement in two phases. Phase 1, a global version of FOAM running at 1° resolution (approximately 100 kilometers), will go operational at FWOC in late 1997 while Phase 2, delivering sub-degree resolution capabilities in nested regional models, will come into service in late 1999. Increases in horizontal resolution will be matched by increases in vertical resolution. To fulfill these requirements FWOC will be equipped with powerful computers to process FOAM data, run models, assimilate classified data, and generate oceanographic and acoustic products suitable for transmission to RN and Royal Air Force maritime users.

METOC (meteorological and oceanographic) data may require to be communicated to at-sea users in a number of ways amongst which could be a high-capacity satellite communication link. RN ships will be equipped with powerful onboard computers (ESS) to ingest FOAM forecasts in compressed format, decompress, and fuse ocean analysis and forecast fields with historical, *in situ*, and remotely sensed satellite data. ESS will also provide an organic modelling capability to provide robustness against loss of communication. Such models will include limited area regional models, mixed layer (i.e. surface duct) models, trajectory models and sea, surf, and swell models, amongst others. At sea, fused METOC data plus information from sonar and other sensors will be integrated to generate tactical advice for input to CSS.

A hierarchy of ocean models is envisaged within the FWOC-FOAM system, each with a geographical extent and timescale pertaining to its military role. The timescales of these models relate to the time in which an operator might be required to generate a response using modelled data and other information. Thus for strategic planning purposes—for which forecasts might be required at basin or half-basin scale—this will be *in the order of days*. This could, for example, include the planning for the deployment of a task force through the Mediterranean in support of allied forces operations in the Adriatic. Within the basin or half-basin scale model it might be necessary to have regional models located on strategic choke points, e.g. the Greenland-Iceland-Faeroes Gap. Such models need to be capable of generating responses within a timescale *in the order of hours*. At an even smaller scale it might be necessary to construct a moving haven model which describes the environment in the immediate vicinity of the task force and which tracks with it. While basin-scale and regional models will be capable of being dynamically linked[4], the moving haven model requires some combination of analyzed and forecast environments along the projected track with *in-situ* and remotely sensed data assimilated using optimum interpolation and feature modelling techniques. Such models need to be capable of providing tactically useful information on a timescale *in the order of minutes*.

It should be noted that the concept of use and user requirement specification is not necessarily constrained to a



A simulation of mixed layer depth (in meters) in the North Atlantic using an isopycnic coordinate model5. Mixed layer depth predictions are required for forecasting acoustic surface duct conditions and assessing the performance of RN sonars.

particular type of ocean-model code. Thus while the initial implementation of FOAM for operational use, will utilize the Cox 3-D code, later developments may take advantage of new techniques that have been researched with MoD funding. The figure shows a simulation of mixed layer depth in the North Atlantic from an isopycnic coordinate model[5]. Models such as this may significantly enhance RN capabilities to predict surface duct conditions—improving on the MLM capability described previously and eventually replacing the Cox 3-D formulation within FOAM.

Civilian Applications

The Royal Navy has for many years run an operational weather and oceanographic prediction service at FWOC (Northwood). This is believed to be the only operational oceanographic prediction facility of its kind in the United Kingdom and although FWOC forecast products are not available to the civilian oceanographic research community, existing and future oceanographic prediction models are expected to have considerable "dual use" potential.

The need over the past decade to improve military capabilities has played a significant role in focusing the thoughts of the civilian R&D community on RN requirements and been a key factor in stimulating the growth of operational oceanography in the United Kingdom. Global and regional models such as FOAM and UKOPMOD could play a key role at the center of any future operational observing or marine forecasting network [e.g. GOOS or European Global Ocean Observing System (EuroGOOS)[6,7]]. The need for such a network has been identified in a recent report by the U.K. Inter-Agency Committee on Marine Science and Technology on operational marine environmental networks[8]. In keeping with developments in the United States, such models are likely to be able to generate a range of products with potential civilian applications without compromising their integrity or suitability for military purposes. (Much of what is important in a military sense comes from "value added" services provided by central or regional forecast centers—e.g. U.S. Navy Oceanographic Office and FWOC in United Kingdom—with access to classified data).

"Dual use" makes sense in terms of being able to offer the same service to the military customer at reduced cost. Dual use also provides the military with access to larger databases and global ocean observation networks that are being developed for climate modelling and other purposes.

Shallow-water models in particular are likely to have commercial applications and DERA, NERC, and METO are jointly investigating the commercial exploitation of UKOPMOD. MoD interest has been instrumental in establishing a strategy for developing predictive shallow-water models in the United Kingdom, models which are likely to have considerable dual-use potential over the next 10 to 15 years, with the offshore oil and gas industry, environmental protection agencies, and authorities responsible for sea defenses and flood prevention.

MoD has also invested significantly in research programs which, although ostensibly directed towards civilian applications, e.g. climate modelling, were perceived to have synergy with military requirements by providing improvements in numerical ocean modelling methods, a better understanding of ocean processes or improved measurement and observation techniques. Examples of this have included the World Ocean Circulation Experiment (WOCE); Fine Resolution Antarctic Model (FRAM)—a model of the Southern Ocean; the Atlantic Isopycnic Model (AIM), and AUTOSUB—Southampton Oceanography Centre's (SOC) AUV—amongst others.

Ocean modelling research in particular—often involving international groupings of scientists—provides a good example of this synergy and the potential for dual use. MoD-funded research on AIM has been instrumental in enabling U.K. scientists to undertake comparisons with other isopycnic models, e.g. Miami Isopycnic Coordinate Ocean Model (MICOM), to support climate modeling research. The figure shows the results of a simulation of surface currents in the North Atlantic using MICOM[5]. These studies are not only contributing to our knowledge of climate driven ocean circulation—but also providing improved representation of acoustically significant oceanographic features and processes—capabilities that may later be incorporated in the RN FWOC-FOAM system.

Collaboration has been an important feature of this work and MoD has invested in research on operational oceanography in universities, other government agencies, and in industry. The result of this activity over the last decade has been the creation of a significant operational oceanography capability which, at its heart, has numerical ocean forecast models such as FOAM and UKOPMOD. DERA and METO research programs have also provided an important underpinning capability with concepts and technologies that are likely to mature over the next 10 to 15 years. /st/

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Dr. Tony Heathershaw, prior to joining DERA in 1985, was employed at the U.K. Institute of Oceanographic Sciences. During this period he also worked in United States for the U.S. Army Corps of Engineers. At DERA Heathershaw has been responsible for researching the naval applications of numerical ocean forecast model products and systems, in particular FOAM. He is the author of numerous articles and is an editor of the journal Continental Shelf Research. *Heathershaw, who has served on various national advisory groups and panels, holds a bachelor's degree in physics and a doctorate in physical oceanography. In February 1997, He will relocate to SOC as head of the DERA Unit located within SOC.*

Lt.Cdr. Roland Rogers, RN, holds bachelor's and master's degrees in fishery science and marine law and policy respectively and is currently studying for a doctorate in military oceanographic policy at the University of Wales Cardiff. Rogers's previous RN appointments have been as the senior METOC with the Seventh Frigate Squadron, teaching military oceanography at the School of Maritime Operations HMS DRYAD and as the METOC underwater warfare specialist in the Royal Navy's Directorate of Surveying, Oceanography, and Meteorology.

Lt.Cdr. Chris Durbin, RN, is the naval liaison officer responsible for underwater environment research. He has served as MoD staff officer for oceanography and remote sensing and also with the U.S. Navy as head of the satellite and oceanographic and meteorological modelling department at Fleet Numerical Meteorology and Oceanography Center (Monterey). Durbin holds master's degrees in oceanography and space physics.

Real-Time Satellite Imagery Changes Icebreaker Operations

Productivity, Effectiveness of Polar-Class Vessels Has Changed Markedly Since Advent of Satellite Imagery

By Capt. Robert Parsons
U.S. Coast Guard (Retired)
Bellevue, Washington

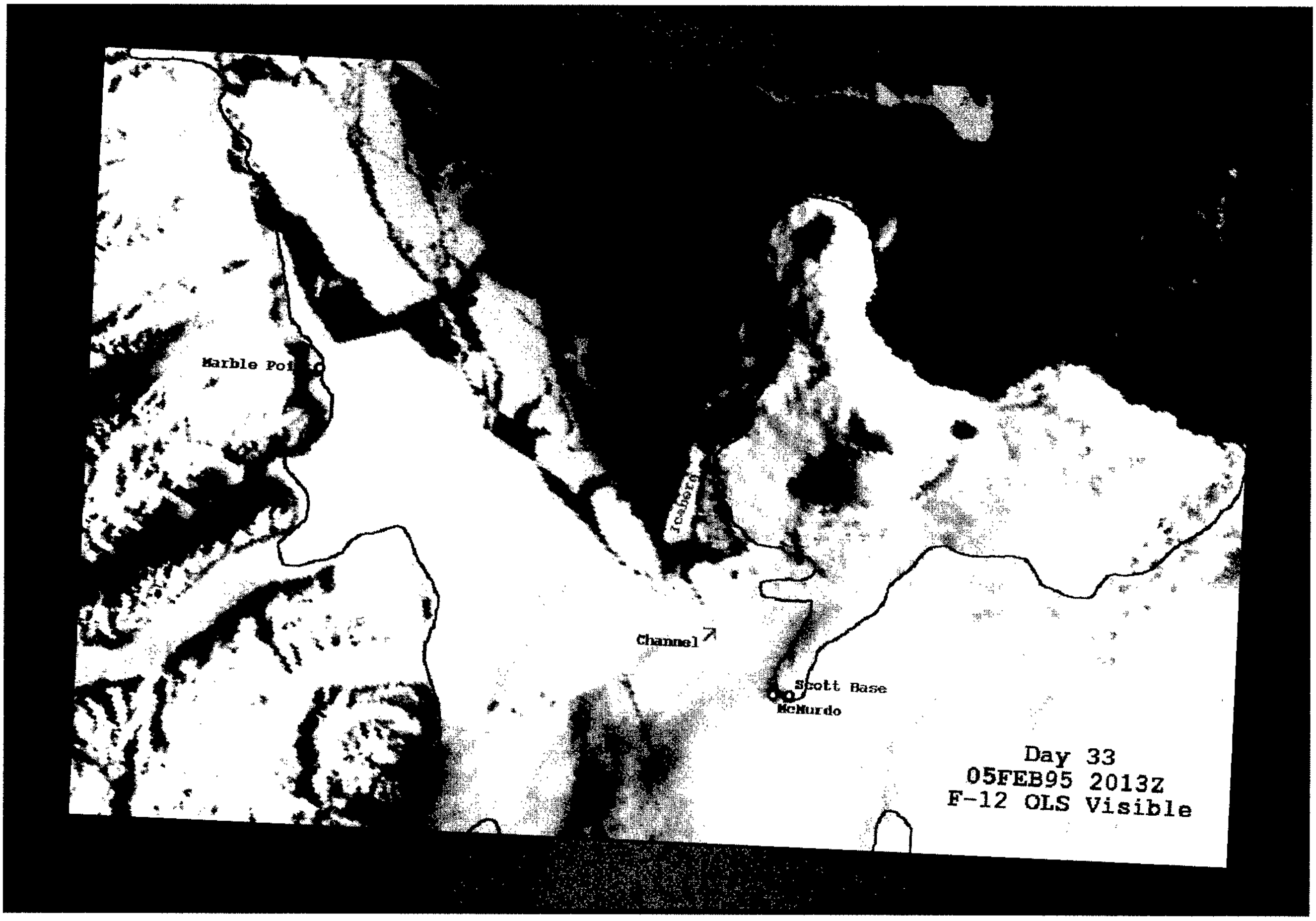
Each year American icebreakers are deployed to the harsh polar regions for up to six months to conduct logistic and scientific research support. Down to two polar icebreakers (*Polar Star* and *Polar Sea*) in the U.S. inventory, the demands for their time requires innovative planning and use of the latest technologies to meet the aggressive operating schedule.

To enhance the opportunities to conduct research in Antarctica, in 1992 the National Science Foundation contracted the services of the newly constructed R/V *Nathaniel B. Palmer*, an ice-class A2 vessel.

The two-decade-old *Polar Star* and *Polar Sea,* identical sister-ships, are unique unto themselves. At 400 feet and 13,200 gross tons, with more than 60,000 shaft horsepower, they are the most powerful non-nuclear-powered icebreakers in the world. They are capable of breaking 6 feet of new hard ice at a continuous speed of 3 knots, and up to 21 feet of ice at 1 knot (backing and ramming).

Although the "business" of icebreaking has not changed significantly over the past 20 years, the recent technological improvements in obtaining

Imagery from the Defense Department's DMSP satellite picked up* Polar Star's *channel through the ice to McMurdo Station in Antarctica.



> ***"The problem remains that there are few . . . observing stations in the polar regions for forecasters to base their predictions and frequently the icebreaker crews would simply receive forecasts and condition reports based on their own input. "***

"real-time" satellite imagery on board ship has made a marked difference in the productivity and effectiveness of the polar-class icebreakers. For many years the goal was to simply construct a vessel with inordinate power and a unique hull design to muscle through the ice. However, it is a long held maxim among knowledgeable icebreaker deck officers (ice pilots) to "never break ice unless absolutely necessary." Even though the vessels are built to endure the extraordinary forces associated with ice breaking, it is ***always*** safer for the vessel to go around ice rather than through it.

To avoid ice is to avoid possible damage to the propellers, shafts, and rudders; is more fuel-efficient (probably saves time, too); and is less stressful for the crew members (limiting the fatigue associated with the constant movement and noise as the ship works through ice). The main reason helicopters were assigned to the icebreakers was to routinely (weather permitting) fly out ahead of the vessel with an "ice observer" on board to scout out the best path through the ice.

With the advent and installation of the TeraScan system by SeaSpace Corp. of San Diego, California, on polar-class icebreakers, the business of icebreaking significantly changed. Providing high resolution "pictures" of the ice and microwave imagery of the percentage of ice coverage, today's ice pilot has the ability to plan on both the strategic (long range) and tactical (short range) basis. Installed prior to *Polar Star's* deployment to the western arctic in the summer of 1993, the deck officers and science parties discovered that they could plan vessel operations with a high degrees of reliability.

For example, one science party desired to work in an ice covered area but not so densely covered as to impede vessel progress. The vessel was required to maintain 4 knots while towing a large seismic array. Avoidance of large multiyear floes was of paramount importance. Being able to see the larger floes and plan a course through the ice made the mission a success.

In another application, a science party was seeking a "medium sized floe, 1-2 miles across" at a specific northern latitude to construct its ice camp. All the preliminary searching was conducted using ice images and in the final selection of a site the ship's helo was deployed with the science party to actually test the floe and conduct ice coring to ensure the floe was strong enough to support the camp for the next six months. Less than eight flight hours were required to accomplish the task, wherein the planning stages' several days were allotted to seeking a floe. Prior to TeraScan, the search would have required numerous flights and many flight hours by the two helos.

For many years the polar class icebreakers have had the ability to receive prepared images and faxes from the National Ice Center (formerly called the Navy-NOAA Joint Ice Center) in Suitland, Maryland; however, the images covered broad geographic areas and lacked a "real time quality." A most typical product was a faxed hand drawing (called an "egg chart") depicting the estimated ice coverage, age, and areas of open water in little symbols that resembled eggs. Images were analyzed and enhanced before delivery to the vessel, which mitigated their usefulness and cost time.

Routinely, the images were several days old before the ships received them.

Thus, the helos and ice observers were still the mainstay for ice information. Consider also that the helos can only fly in reasonable weather and are grounded by snow, fog, high winds, and whiteouts (which is not uncommon in the harsh polar regions). Commanding officers were frequently left to depend on their experience, judgment, and—all too often—good fortune to decide the course of action.

For today's vessel operators, it is a new and different world. For discussion, let's examine a couple of additional recent examples of icebreaker operations. During *Polar Star's* recent antarctic circumnavigation, TeraScan provided real-time images from both the NOAA polar-orbiting satellite and the Defense Meteorological Satellite Program (DMSP) special sensor microwave imager (SSMI) of total ice concentrations. New information was received several times a day, in a variety of forms (visual, infrared, and microwave). With a voyage of approximately 8,000 miles, one of the goals was to avoid using additional fuel to break ice; however, we needed to be close to the ice to conduct a science project involving the seal population using the ship's helicopters. Each day of the trip was planned, based on the imagery showing ice coverage and the weather systems in the area. Early in 1993, after the TeraScan installation, it became evident that NOAA and DMSP satellite images provided us with a new tool to "ground truth" weather forecasts and predict our local weather.

As one might imagine, polar-class icebreakers have access to all forms of prepared weather forecasts, from sources worldwide, both military and civilian. The problem remains that there are few weather observing stations in the polar regions for forecasters to base their predictions and frequently the icebreaker crews would simply receive forecasts and condition reports based on their own input. TeraScan gave the vessels the ability to "see" the cloud formations and developed weather system patterns. Augmented with upper level wind conditions, sea surface temperatures, and atmospheric moisture profiling, the vessel's weather personnel and deck officers could make their own local forecasts...based on the facts.

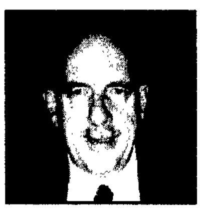
TeraScan images were the founda-

Satellite image from NOAA was received as* Polar Star *departed Unimak Pass in the Aleutian Islands for Seattle, across the Gulf of Alaska. With a 964 millibar low pressure system directly on the great circle trackline, the vessel was able to monitor the storm's progress as it moved northwest toward Kodiak Island.

tion of every weather briefing, whether for transit through ice, planning the next day's science operations, or for the more immediate "flight brief" prior to dispatching a helo. With new information every few hours, the ship was able to adjust its trackline for the safest and most direct route, eliminating the guess work known to sailors throughout the ages.

In June 1995, *Polar Star* visited the Arctic Ocean in the Chukchi Sea, directly north of the Bering Strait, to conduct testing on the vessel's newly installed, computerized machinery control and monitoring system. A short one-month trip, the goal was to visit the ice, test the system, and document performance. The problem at hand was locating significant ice (10/10 coverage) as quickly as possible without proceeding deep into the Arctic Ocean. Using TeraScan's real-time SSMI imagery, the vessel was able to steam directly to the most southerly ice edge and locate the desired coverage without extra days spent searching.

It was the first deployment to the arctic region without a helicopter assigned. Searching for ice or finding the way in ice-covered waters has been. made safer, easier, and more efficient with the technology of today. /st/



Capt. Robert Parsons is past commanding officer of Polar Star. *He is currently writing and consulting on polar marine issues from his home in Bellevue.*

Budget to Seek 'Operational' Status for TOGA, NURP

According to a source at the National Oceanic & Atmospheric Administration, that ocean agency is prepared to support a program now that it once decried because it lacked "budgetary priority." Another program gets support because "research" funding ran out and "operational" funding was deemed critical.

As of press time, the NOAA budget request for fiscal year 1998—due to be presented along with other administration requests early in February—contained a line item for nearly $5 million through the Office of Global Programs to make the Tropical Oceans & Global Atmosphere program operational. In addition, funding is also requested by NOAA for its other perennial soccer ball, the National Undersea Research Program (NURP).

Zeroed out in the FY 96 and 97 budgets by the administration and NOAA head Dr. Jim Baker because of "low priority," NURP was saved last year again by Congress with a $12 million bailout. The FY 98 budget, according to the source, is different because the line item is in—not out—and it continues NURP with a $5.4 million request.

The National Research Council's earlier report on the accomplishments and legacies of TOGA called it a "model for how to do Earth sciences." The program—which began in January 1985 and ended in December 1994—has allowed major advances in the understanding of the strongest climate variation on seasonal-to-interannual time-scales, El Niño and Southern Oscillation.

According to the NRC report "TOGA opened the way to the future of seasonal-to-interannual climate predictions. The follow-on programs will further develop the means of predicting the climate for the ultimate benefit of humankind."

TOGA achieved much of its success in part because the program concentrated on a piece of the climate puzzle where the pieces looked like they might fit together. Additional research is still required to develop the skill for predicting short-term climate variations caused by other processes or in other parts of the world. The NRC report called for further efforts to maintain the observing system, creation of an institute for developing applications of short-term climate forecasts, and suggested a program for continued research on seasonal-to-interannual climate variations as well as the influences of longer time-scales and their predictability.

McCain Named Chairman of Senate Commerce Committee

Following a vote taken by his Republican colleagues on the Senate Commerce, Science & Transportation Committee, Senator John McCain was unanimously elected committee chair. Subcommittee chairs were to be named at an organizational meeting scheduled to be held the week of January 20.

The Committee's first hearing will examine air bags and explore the best means to prevent them from causing future deaths while increasing their effectiveness in saving lives. With President Clinton expected to send his budget to Congress in early February, McCain said he is increasingly hopeful that his colleagues will consider auctioning the remaining digital spectrum and raising millions of dollars that could be used to balance the budget.

"I remain firmly committed to the government auctioning portions of the remaining spectrum to broadcasters. While I realize it's an uphill battle, I'm prepared to fight for the American taxpayers' rights to these profits," said McCain. Other issues McCain plans to address as newly appointed chairman include reforming product liability and cleaning up waste and duplication in the departments of Commerce and Transportation and examine trade issues.

McCain has been a member of the Commerce Committee since 1986, his first year in the Senate. He most recently chaired the Aviation Subcommittee, a post he relinquished once he was named chairman of the full committee.-

NAS Report Focuses Again on FY 97 S&T Budget Trends

The follow-up report, *The Federal Science & Technology Budget, FY 1997*, from the National Academy of Sciences focuses on the federal science and technology (FS&T) budget as well as trends in it since 1994. The FS&T budget was proposed in a 1995 NAS report as a more precise measure of the federal investment in new knowledge and new technologies. It excludes funding traditionally counted in the federal R&D budget for activities such as production engineering, testing and evaluation, and upgrading of large weapons and related systems. Panel chair and member, respectively, are Dr. Frank Press and Dr. H. Guyford Stever.

The main findings of the report, expressed in constant or inflation-adjusted dollars, are as follows:

- The final FS&T appropriation for FY 97 is approximately $43.4 billion, which is a slight increase (0.7 percent) over the FY 96 appropriation for FS&T.
- The upturn in FS&T funding follows but does not offset several years of shrinkage. The new FS&T budget is 5.0 percent less than it was in FY 94.
- Only two of the 10 major S&T agencies and departments—the National Science Foundation and Department of Health & Human Services (DHHS)—have more FS&T funding in FY 97 than they had in 1994. If the FS&T budget at DHHS (which is mostly for the National Institutes of Health) were not included, the same budget for FY 97 would be nearly 10 percent less than it was in 1994.

Press noted that one can argue about what should be or should not be included in the FS&T budget; for example, some might dispute the inclusion of the Space Station. However, while excluding it would change the amount, it would not affect the trend. It would still show, for example, a substantial decline in funding for the physical and other non-biomedical sciences. /st/

Ocean Research

European Team Getting Deep into Hot Water

University of Southampton (U.K.) scientists are co-cordinating a huge deep sea research project to explore the largest, most powerful hydrothermal vent site ever found in the Atlantic Ocean. The Rainbow vent field lies 2,300 meters below the ocean's surface along a segment of the Mid-Atlantic Ridge near the Azores where the tectonic plates that form the Earth's surface fracture and separate, allowing new seafloor to be created.

At hydrothermal vent sites, sea water percolates down through these fractures and, where it passes close to molten magma, it is heated to temperatures up to 400°C. The Southampton scientists believe the site could provide an "ideal laboratory" to study how biology adapts to cope with a harsh, hostile, and inhospitable environment. "Despite the high pressure, temperature, and toxicity, the site supports an abundant and exotic ecosystem. Studying the site's biology will help us understand how biology copes with extreme pollution and could provide invaluable in predicting the affect of man-made pollutants on marine environments," says Southampton researcher Dr. Chris German.

The researchers will also be mapping the seafloor to find new sites and work out how far apart the sites are. Using this information, they will be able to test the hypothesis that some larval fauna carry enough food to survive the journey. "Hydrothermal plumes rise up from the vent for maybe several 100 meters before cooling down to be carried along by deep ocean currents. They may provide a "larval highway" which transports young fauna to new sites," says Dr. Lindsay Parson.

UW Oceanography School Names New Acting Director

Professor Richard Sternberg has been named acting director of the University of Washington's School of Oceanography, one of the three best programs in the United States, according to the National Research Council's rankings last year.

Sternberg is a marine geologist who studies how the world's rivers and oceans transport sediment. The work is important in understanding such things as beach erosion, siltation that can affect harbors and estuaries, and the fate of sediments loaded with chemicals and toxic materials.

The professor was part of a team investigating soil erosion surrounding the burning and clearing away of the Amazon rain forests and how it could eventually change the whole nature of the waterway. Sediments were found becoming part of the Amazon delta, building up muddy capes and headlands, or carried out by ocean currents northward along the coast of South America. These are important considerations for the future, especially if the sediments carry agricultural or industrial contaminants.

In recent years, Sternberg has served on research and scientific committees for the National Science Foundation, National Academy of

Sciences/National Research Council, and the Department of the Interior. He is currently a member of the NSF's steering committee on coastal ocean processes.

Researchers Sift Evidence About Plate Boundaries

A series of papers presented at the annual conference of the American Geophysical Union in San Francisco could shed new light on the geological processes by which continents grow, as well as on the nature of faults that lie along plate boundaries, according to a spokesman.

For the past two years, a team of National Science Foundation (NSF)-supported scientists has used seismic techniques along a network of deep mountain fjords near the border of British Columbia and southeast Alaska. The team has been studying what may be part of an ancient boundary between two tectonic plates: the Kula plate, which disappeared under Alaska about 50 million years ago, and the North American plate.

"Scientists from various Earth-science disciplines have assembled evidence on the nature of the rocks and rock formations found deep beneath the surface of the earth," says Leonard Johnson, director of NSF's continental dynamics program. "As they present and discuss their findings, they will be attempting to draw some conclusions about whether they have, in fact, located the exhumed portion of a major ancient strike-slip fault."

Aboard the research vessel *Maurice Ewing* in 1994, Earth scientists used ultrasound techniques to create a three-dimensional image of British Columbia and southeast Alaska along a network of fjords that crosses the mountains along the northwestern continental margin. The ship navigated the fjords Portland Canal, Dixon Entrance, and Clarence Strait, towing a 2.5-mile cable of hydrophones and an array of air guns. The project was coordinated by Lincoln Hollister, a geoscientist at Princeton University in New Jersey.

Link Between Tropics & North Atlantic Climates Revealed

Scientists working under a grant from the National Science Foundation have unveiled a new theory that winds in the tropics caused vast iceberg armadas to surge across the North Atlantic.

In the December 13 issue of *Science*, Andrew McIntyre and Barbara Molfino, paleoclimatologists at the Lamont-Doherty Earth Observatory in Palisades, New York, report evidence that strong westward-blowing trade winds died down along the equator at about the same time that iceberg flotillas sailed across the North Atlantic during the last ice age—in approximately the same 7,000 to 10,000 year cycles.

"Ever since these cyclic iceberg pulses were first discovered in the early 1990s, scientists have tried to understand what caused them and have wondered whether Earth's climate system could shift so dramatically again in modern times," says Connie Sancetta, program director in NSF's marine geology and geophysics program, which funded the research.

The Lamont-Doherty scientists theorize that the equatorial winds relaxed periodically, allowing a large reservoir of warm tropical waters—which had been pushed into the Caribbean Sea and the Gulf of Mexico by the winds—to flow back eastward. The waters went north with the Gulf Stream, where they warmed the North Atlantic region and triggered melting along the edges of the massive ice sheets that covered the Northern Hemisphere.

According to McIntyre and Molfino's theory, the strength of Atlantic equatorial trade winds over long intervals of time is governed by Earths's orbital cycle, which alters the seasonal intensity of solar radiation reaching the planet. The researchers found that over the past 45,000 years, a suborbital rhythm of 8,400 years has produced variations in the strength of the tropical winds.

New Map of Lake Michigan Lakefloor Topography Released

The National Oceanic and Atmospheric Administration (NOAA) recently announced that a group of oceanographers have compiled a new poster and accompanying database on CD-ROM describing the physical features of the lakefloor of Lake Michigan.

The new poster more clearly delineates previously known features and reveals a number of features seen for the first time. More than 600,000 high-quality soundings collected over a 120-year period were used in the project. The data, collected by NOAA's National

Ocean Service, Coast Survey, and the Army Corps of Engineers, were originally collected for nautical charting, but fully assembled, they constitute the best data set available for compiling bathymetry or lake-floor topography.

Both the poster and the CD-ROM picture files may be viewed in 3-D using Chromadepth™ high-definition glasses, which will be distributed with the poster. The 3-D effect is particularly enhanced in custom plotter versions of the poster which are plotted using high-intensity color links.

Infrared Technology Reveals Breaking Waves in Open Ocean

Being able to discern the strength of breaking waves in the open ocean is crucial for those forecasting stormy seas and for scientists wrestling with questions of how the Earth's oceans absorb and release greenhouse gases and heat. A new infrared imaging system has given scientists a promising way to better understand these breaking waves, according to a report in a recent issue of *Nature*.

The techniques reveals the area of the wake following individual breaking waves in the open ocean—something scientists have not been able to measure before, according to Andrew Jessup, lead author and a senior oceanographer at the Applied Physics Laboratory of the University of Washington. The new technique also has made it possible to remotely measure the energy dissipated by breaking waves, something that has long eluded oceanographers.

In this case, Jessup and his collaborators from the university and the University of Toronto are taking advantage of infrared imagery's ability to detect temperature changes in the "skin-layer" of the ocean, the top millimeter. This layer is generally a few tenths of a degree cooler than the water below. When the skin is disturbed by a breaking wave, the slightly warmer water mixed up to the surface can be detected by infrared technology. Until the skin-layer re-establishes itself, differences in temperature provide information about the strength of the breaking wave and the area of the ocean surface that is being disturbed.

"Scientists have studied waves going back to the time of Ben Franklin trying to predict how rough the sea will be in stormy weather," Jessup says. Those involved in shipping and transportation, already use measurements from satellites—primarily radar data—to estimate wind speed and the height of waves. /st/

Experts Plan Global Locator Service for Environmental Info

Experts from around the world have agreed on a standard for locating information, whether held in libraries, data centers, or published on the Internet. This will lay the foundation for a virtual library of environmental information and data that will be easily accessible on global networks.

"An information locator service is useful wherever people communicate, but there is a special urgency to worldwide sharing of environmental information," says U.S. Vice President Al Gore. "Every year, governments and other spend billions of dollars collecting and processing environmental data and related technical information."

The experts are representatives to the Global Information Society initiative, which was convened at the suggestion of Gore and organized by the G7 (Canada, France, Germany, Italy, Japan, United Kingdom, and United States) and European Commission. The leaders of the Environment and Natural Resources Management project, which includes several other nations and organizations, are Larry Enomoto of NOAA and Eliot Christian of the U.S. Geological Survey.

The standard adopted for this service is ISO 10163, known in the U.S. as ANSI Z39.50. This standard specifies how electronic network searches should be expressed and how results are returned. It is adaptable to all languages and supports full-text search of documents as well as very large and complex bibliographic collections. The standard does not require a central authority or master index. Just as catalogs provide a common way to search separate libraries, anyone can create information locators independently.

By applying a standard that has been widely used for many years, this initiative takes advantage of existing networks and software to access a vast array of valuable resources, including hundreds of libraries, museums, and archives worldwide—some containing as many as 35 million locator records. It also fits in with many other international and national programs focused on improved access to information, including the Government Information Locator Service being implemented in the United States and elsewhere.

Japan Still Battling One of Largest Oil Spills

In Mikuni, Japan, the battle against one of Japan's worst oil spill disasters continued as massive new slicks pushed by heavy winds hit a stretch of coastline already affected by the spill previously. In the morning of January 2, 1997, the 13,157-ton tanker *Nakhodka* ran aground about 100 miles from the Hyogo Prefecture. The ship was carrying 133,000 barrels of heavy fuel oil. The authorities initially estimated that 26,000 barrels of oil leaked out but now say that the figure appeared too low.

RADARSAT International (RSI) (Richmond, B.C., Canada) electronically delivered a RADARSAT image on January 11 to the Remote Sensing Technology Centre (RESTEC) of Japan. As RSI's distributor of RADARSAT data, RESTEC will be providing data to local agencies involved in assessing the oil spill.

A 190-mile stretch of coastline spanning four prefectures facing the Sea of Japan around Kyoto has been affected in the spill and was expected to grow wider, according to the Japanese Fisheries Agency. "It is highly probable that heavy oil released immediately after the accident will expand the area hit by oil slicks," the agency said in a statement.

Some of Japan's richest fishing areas have been affected as well as small ports and tourist resorts. Some fishing markets were either shut down or just had frozen or processed seafood for sale due to the oil spill. Shellfish-gathering operations were damaged and it is feared that the oil could damage offshore net and bottom fishing of shrimp and crabs. Wildlife authorities have had few reports of harm to wildlife except for several cases of seagulls and other birds covered by the oil. Experts warn that the toll will rise as the oil disperses.

The worst oil spill for Japan happened in 1971 when 50,400 barrels of oil were spilled from a tanker that ran aground near the port city of Niigata on the Japan Sea. /st/

Contracts

Advanced Communications Systems Inc., Fairfax, Va., $8 million contract modification for management services for the Joint Maritime Communications System program office. (Space & Naval Warfare Command)

Lockheed Martin Federal Systems, Manassas, Va., $16.7 million contract modification for Acoustic Rapid Commercial Off-the-Shelf (COTS) Insertion systems for installation on SSN 688, SSN 688I, and SSBN 726 class submarines. (Naval Sea Systems Command)

Science Applications International Inc., San Diego, Calif., $6.3 million indefinite quantity/indefinite delivery award for engineering support services for surveillance and security systems at the customer's site. (Naval Command, Control & Ocean Surveillance Center, RDT&E Div., San Diego)

Hughes Aircraft Mississippi Inc., Middletown, R.I., $24.8 million indefinite delivery/indefinite quantity contract to provide technical and engineering services in support of the Mk 48 Heavyweight Torpedo Program, including the Mk 48 ADCAP. (Naval Undersea Warfare Center Division Newport, Newport, R.I.)

Bender Shipbuilding, Mobile, Ala., contract (terms not disclosed) to repair the submersible drilling rig Falrig 77. The rig's drilling contract will continue through April 1997. (Falcon Drilling, Houston)

Consafe Engineering, Oslo, in a joint venture with Hopeman Brothers, contract (terms not disclosed) for detailed design and outfitting of the 120-man quarters for the jackup Rowan-Gorilla 5, under construction at the LeTourneau yard in Vicksburg, Miss. The $170 million ultra harsh environment jackup is scheduled for delivery in May 1998. (Rowan Companies, Houston, Texas.)

GrayStar, Houston, contract (terms not disclosed) to operate and maintain production facilities in Eugene Island Block 208 in the Gulf of Mexico. Facilities include a central processing platform and tow satellite platforms. (Greenhill Petroleum Corp., Houston) /st/

Letters

'Lighting the Littoral'...Yet Again

The article "Laser Airborne Bathymetry—Lighting the Littoral" in the August 1996 issue contains many errors not corrected by the author in the October "Letter." Airborne laser hydrography (ALH) was not discovered by accident. The concept arose as an offshoot of theoretical sub-hunting work by the U.S. Navy in the early 60s. The first successful airborne experiments were conducted by Dan Hickman at Syracuse University. The first focused U.S. effort was not "DMA's HALS in the early 1980s" but rather NASA's airborne oceanographic lidar (AOL) which was successfully tested for hydrography by NASA and NOAA in 1977.

Much of our current understanding of the performance characteristics of ALH systems comes from this project. The AOL, which was the most sophisticated ALH system in the world at the time, is still flying productively today, albeit much modified and rarely for hydrography. As the article states, "HALS never fielded a fully operational system...." HALS did not fly until 1986; the hardware failed in 1988, and the project was canceled shortly thereafter. The article states that an early version of the Australian LADS system was fielded in 1986. In fact, the testing of the WRELADS II system ended in 1984. It was unfortunately dismantled, having served its purpose with over 550 hours of flight testing. Due to contracting problems, no ALH system flew again in Australia until LADS in 1993.

Many of the values in the modified table are still incorrect. The U.S. Army Corps of Engineers' SHOALS and much of the Swedish Hawk Eye were designed and built by Optech Inc. of Toronto (who also built the earlier Larsen-500 system), and they share much of the same hardware and software. The table values for both should be basically the same, except that the nominal SHOALS altitude is 200 meters, not 300 meters, while the customary Hawk Eye operational altitude is 300 meters. The speed depends on which aircraft is in use. Both values in the "depth accuracy" row are wrong. For SHOALS and Hawk Eye, these should read either "0.18 (1σ)" or "0.30 (90%)," not 0.30 (1σ). It is doubly incorrect to state that "Today's operational systems are yielding 3σ depth accuracies on the order of ±0.3 meter which meet IHO standards in most cases." First, the current IHO depth accuracy standard for depths under 30 meters is 0.3 meter 90 percent of the time, not including errors in tide corrections. This is equivalent to 18 centimeters (1σ) assuming a normal distribution, so a sigma of 10 centimeters would always more than meet the requirement. Second, today's systems are not yielding 10-centimeter accuracy under any circumstances, both because there is no requirement and because of the number of error sources dictated by the physics of light propagation and practical hardware limitations.

The accuracy of the SHOALS system was measured to be 14 centimeters (1σ) through intercomparison with a standard survey performed by NOAA's National Ocean Service. This is the best result one could practically hope to get. The accuracy requirement placed on the LADS system by the hydrographer of the Royal Australian Navy is 50 centimeters (1σ), but they report performance to be better than 20 centimeters (1σ) under many conditions.

With their 20° scanner nadir angle, SHOALS and Hawk Eye have maximum swath widths of 73 percent of the altitude, not 85 percent. The current hardware depth limit for SHOALS and Hawk Eye is 37 meters, not 50, although that can be doubled with appropriate firmware. LADS reports their horizontal accuracy as 7.5 meters, not 5 meters.

The article mentions only one Hawk Eye system, purchased by the Swedish Navy. Actually, two Hawk Eye systems were delivered to the Swedish government—one for the navy and the other for the Hydrographic Department of the Swedish Maritime Administration.

Eye safety does not, as stated, limit laser "power" to "about 5 mJ/pulse." Joules is a measure of energy, not power. Eye safety is based on energy density, which depends on altitude, laser pulse energy, and laser beam divergence. Depending on these parameters, pulse energies of significantly greater than 5 mJ could be used if available.

It is incorrect to state that "recent systems use a wider, fixed, near-infrared beam...to 'find' the surface." The two most recent systems, SHOALS and Hawk Eye, use scanning collinear green and infrared beams. The only system in the world using a broad, non-scanning IR beam is LADS. Contrary to Australian predictions, the collinear approach has demonstrated excellent success and provides greater flexibility.

The statement that accuracy requirements "in advance of a dredging...operation...are less demanding" is incorrect. There are several categories of dredging survey, each with its own requirements. "Condition" surveys have accuracy requirements similar to current IHO standards. Since dredging companies are paid for the volume of material moved, the bathymetric measurements made before and after dredging require even greater accuracy.

The article states that "Sounding density is more problematical if assurance is required that the entire bottom be illuminated to detect and identify potential obstructions." The full "illumination" of the bottom (not a well-defined concept) does not guarantee the detection of small objects on the bottom. For current systems and typical survey parameters, the detection probabilities for small objects, with heights off the bottom of less than 2 meters, are significantly less than 100 percent, even if they are "illuminated." Although ALH is a very effective technique for providing relatively high density bathymetry rapidly and efficiently, current systems are not viable substitutes for side-scan sonar, contrary to Australian claims.

I question the author's statement that "Probably the Royal Australian Navy's LADS system has achieved the most prominent operational role...." Although LADS became operational in 1993 and SHOALS in 1994, both systems are kept very busy and have been producing excellent results and successfully meeting the purposes for which they were designed.

In FY-96, SHOALS spent 330 days operating in the field. The statement about "NOAA, who were potentially interested in evaluating SHOALS..." is misleading. NOAA has successfully evaluated SHOALS and is currently interested in its use as evidenced by a recent contract survey at San Luis Obispo, California, about 40 percent of which was done by SHOALS.

Gary C. Guenther
NOAA, National Ocean Service

Legalizing Raster Charts?

I read with interest Mr. (Mortimer) Rogoff's [October 1996, pp. 55-60] article "Ahoy! Electronic Charts! Where Are You?" which amply explains the benefits and expected virtues of ECDIS. It is unfortunate then that the article gives such a misleading view of the work being done by the IHO and, in particular, the "delaying factor" of the British Admiralty's attempt to have raster electronic charts legalised.

It is true that there is no official ENC data available which conforms to the *ENC Product Specification*, but why not? Early experience with the creation of ENC data conforming to the IHO's S57 standard highlighted the need for a specification. The contents of this specification were agreed in outline by not just hydrographic offices but also regulatory authorities and equipment manufacturers and the task of producing the associated document began in January 1995. The results are contained in S57 Edition 3, which has only just been published. Irrespective of the number of "new techniques, inventions, and circuits" available to potential data producers, the availability of the product specification was a prerequisite to producing ENCS.

Mr. Rogoff also implies that we in the IHO member states have been constrained by legal problems. It is indeed true that legal considerations have played a part in the slow gestation of ECDIS and the clue to this lies at the end of the article where he explains the work NECSA is doing. It is not for me to enter into a debate about the quality of commercial data, though we are aware that it is of variable quality. Neither I nor my staff have seen the NECSA standard, which may or equally may not help to remedy this situation, but Mr. Rogoff is quick to dart around the liability issue.

The British Admiralty products are sold with the liability clearly understood. It is essential, indeed a prime mover that the product must conform to a specification that has been properly scrutinised by authorities that have the safety of the mariner as their prime motivation. The product, when sold, must be beyond reasonable doubt, safe. That, when put into a worldwide context, is not simple. I am, therefore, uncertain as to what mandate and level of scrutiny NECSA are operating, though I do not doubt their laudable intentions.

It is because of these legitimate technical and legal delays in the provision of ENC data that a number of hydrographic offices, not just the British, are providing, or intend to provide, an official raster data service and are of the opinion that the specific implementation of raster data in a raster chart display system (RCDS) should be awarded paper chart equivalency. Raster does not provide the extensive functionality of ECDIS and nobody here pretends that it does, which is why so much effort is being put into the ENC data base. However, as our many customers who have chosen to use the Admiralty raster chart service (ARCS) have made clear, raster is a significant improvement on the paper chart - I have yet to receive a complaint from sea of the system, rather the reverse. Incidentally, the *Queen Elizabeth II* mentioned in the article is now a RCDS user.

Let me stress that the RCDS initiative did not meet with terminal defeat at the IMO's Safety of Navigation Subcommittee meeting in July 1996 (NAV42). Rather, the appropriate body was asked to prepare an RCDS performance standard in recognition of the increasing use at sea of such equipment, to consider the role of RCDS further, and to report back matter to next year's meeting of the Safety of Navigation Subcommittee (NAV43).

Reports on the use of RCDS at sea were also requested by IMO to help inform the debate. What would certainly not be in the mariners' interest is a polarization of views into entrenched raster and vector camps.

In summary, many members of the IHO are working hard to bring a safe and efficient ENC service to the mariner. We may be approaching the brave new world with more caution than some would wish, but let nobody doubt our commitment and recognition of the benefits. In the meantime, official raster has a role to play; it can provide a significant advance in maritime safety now, may have a future in acting as the "glue" between parts of the world that have ENC (which is why the British Admiralty is conducting trials to test the hybrid concept), and has much to offer the small boat and leisure market. ECDIS—yes, please...but one has to question the motivation of those who denigrate official raster charts and seek to deny the user benefits that are available today, not least in ARCS and other national Hydrographic Office official raster products.

RAdm. J.P. Clarke
Hydrographer of the Navy
U.K. Hydrographic Office
Taunton, Somerset, U.K.

Marine Resources

Methane in Ocean Crust Could Feed Microorganisms

Evidence is surfacing that searing temperatures and crushing pressures are creating a storehouse of nutrients needed by microorganisms living at the seafloor and, possibly, deep within the earth's crust.

Microorganisms in the ocean depths thrive where there is no light and dine on chemicals toxic to other life. Deborah Kelley, a University of Washington oceanographer, presented a poster at the American Geological Society meeting in San Francisco saying that a significant reservoir of methane and hydrocarbons may be found in rock beneath the seafloor. Such a large food source bolsters speculation about how pervasive these life forms might be.

Kelley has been studying the source of these nutrients in what is called "layer three" of the oceanic crust. Located at a depth at about 2-1/2 miles, this layer consists of rock that was once part of molten magma chambers. Although the basalts found nearly everywhere on the seafloor come from the same submarine chambers, Kelley says that the fluids in layer-three rock are very different from those in basalts because of the environment in which they cooled and evolved.

This considerable reservoir of methane is unlikely to be exploited by humans. Most of the methane below the seafloor is trapped in rock as bubbles so tiny that they can only be seen clearly with a microscope.

It is more likely that the methane may be used by deep sea microorganisms. As rock ages it continues to fracture and admit seawater. It could be that the seawater carries microorganisms down into the rock where they mine the methane or it could be that the seawater leeches methane out of the rocks and carries it into the oceans, Kelley says. There is evidence that this happens at hydrothermal vent fields where the seafloor has fractured and emits hot water and dissolved minerals.

Reducing Pressure on Shrinking Atlantic Shark Populations

A proposal designed to protect sharks in the Atlantic Ocean, Gulf of Mexico, and Caribbean by limiting fishing pressure on all of the 39 federally managed species was announced recently by the National Marine Fisheries Service (NMFS), the NOAA agency charged with managing and scientifically monitoring marine life. The plan would implement a limited access system for commercial shark fisherman to reduce overcapitalization of shark fisheries and discourage derby fishing conditions where the "race for the fish" can cause overfishing and quota overruns.

"Overfishing of some shark species along with full use of others is a formula for too much fishing effort," said William Hogarth, chief of the fisheries service's Highly Migratory Species Division. "This proposal will halt future expansion of these fragile fisheries and create a more reasonable balance between harvesting capacity and quota." Hogarth added that strong action is needed now to reduce both landings and effort.

The NMFS proposal will implement a limited access system for sharks (proposed as Amendment 1 to the *Fishery Management Plan for Sharks of the Atlantic Ocean*) that would create permit categories as either "directed" or "incidental," would develop eligibility criteria for these permits based on historical participation, and would specify rules to allow for transfer permits.

The fisheries service has determined that the Atlantic shark fishery is severely overcapitalized. Among the 2,700 fisherman who currently hold commercial shark fishing permits, fewer than 140 target and land sharks on a regular basis. Therefore, the fisheries service intends to improve shark management by eliminating more than 2,300 shark permit holders from the fishery who rarely, if ever, land sharks. Under the proposal—of the remaining 413 permitted fisherman who land sharks—134 fisherman who regularly target sharks will be placed in a directed fishery and 279 fisherman who target other species, but catch sharks as bycatch, will be placed in an incidental fishery.

For a copy of the proposal or to send comments, write William Hogarth, Acting Chief, Highly Migratory Species Management Division, Office of Sustainable Fisheries (F/SF1), NOAA, 1315 East-West Hwy., Silver Spring, MD 20910.

Research Group Releases Documentary on Sea Turtles

Ocean Trust, an environmental research group based in Washington DC, announced the release of The Return of the Kemp's Ridley, a 13-minute documentary that chonicles the comeback of the endangered species of sea turtle. The video, produced in association with Texas A&M University's Sea Grant Program, focues on a number of very successful environmental protection and preservation measures that have been undertaken by government, industry, and environmentalists—all directed at bringing sea turtle populations back from historic lows during the decade of the 1970s.

"We spent a good deal of time in Rancho Nuevo, New Mexico, getting footage of the sea turtle nesting beach protection program," said Thor Lassen, president of Ocean Trust and director of the video production. "The administrators, biologists, and camp workers treated us like part of the team, letting us follow them around and get a true record of their day-to-day work protecting turtle nests and hatchlings."

The documentary also describes the efforts of the shrimp industry to safeguard sea turtle populations during shrimp operations, particularly their widespread use of turtle excluder devices, which allow turtles accidentally caught in trawl nets to swim free, unharmed.

The video is available from both the Ocean Trust and the Shrimp Council for $19, which includes shipping and handling. To order *The Return of the Kemp's Ridley* from Ocean Trust, write to Ocean Trust, 222 1/2 South Washington St., Alexandria, VA 22314 or fax at (703) 739-4622. To order from the Shrimp Council, write to the Shrimp Council, 1901 N. Ft. Myer Dr., Suite 700, Arlington, VA 22209 or fax at (703) 524-4619. /st/

Offshore Oil & Ocean Engineering

Oceaneering Board Approves Fourth Expansion of ROV Fleet

Oceaneering International Inc. (Houston) announced that its board of directors has authorized further expansion of the company's remotely operated vehicles (ROV) fleet with three new Hydra® Magnum work class vehicles. The units, manufactured in Morgan City, Louisiana, with delivery between April and June 1997, are being built to meet increased market demand around the world for ROVs capable of working in depths greater than 1,000 feet of seawater and in severe weather conditions, such as those encountered in the North Sea.

Jay Collins, executive v.p. of oilfield marine services, said, "These three vehicles raise the total number of new fleet expansion vehicles we have announced since last December to 25, a 50 percent increase in the size of our work class ROV fleet. This expansion underscores the company's commitment to maintain its worldwide leadership position in providing deep water work class ROVs to the oil and gas industry."

The Magnum ROVs are high-thrust, cage-deployed vehicles designed to accommodate a variety of sensor and work packages for performing a wide range of underwater intervention tasks that support oil and gas drilling, construction, and production activities. The new vehicles are 75-horsepower units capable of operating in 6,600 feet of seawater or more and are being manufactured using the latest technology in advanced control systems for high performance, optimum adaptability, and maximum reliability.

Fugro Ltd. Completes Major Investigation off Norway

Fugro Ltd. (Hemel Hampstead, Hertfordshire, U.K.) has just completed the geotechnical investigation of 1,360 kilometers of export pipeline route, 80 kilometers of infield flowline, 18 subsea template locations, and a tricky pipeline shore approach off the coast of Norway, according to a spokesman.

The work, performed under its framework contracts with Statoil (Stavanger, Norway), has covered the Asgard floating production/storage and offloading (FPSO) pile or suction anchor locations and sites of proposed subsea templates, which will be of the innovative Statoil hinge over subplate design (HOST), and the 690 kilometer Asgard transport system (ATS) export pipeline to Karstø in western Norway. Other investigations included HOST sites and infield flowline routes for the Gulfaks satellite developments and the 670 kilometer route of the Europipe II trunkline from Karsto to Dornumersiel, Germany.

At the Zeepipe IIB pipeline shore approach off Kolsnes, boreholes were drilled through a prelaid rock berm and samples taken from the underlying strata. Around the perimeter of the berm seabed cores were taken and *in situ* probes performed using Fugro's cone penetration test (CPT) rig, Seacalf. The exercise was performed to confirm the stability of the berm prior to the forthcoming operations.

Most of the work has been performed from the dynamically positioned geotechnical survey vessel M/S *Bucentaur*, however some sections were carried out with two DSVs. Deployed from one of the DSVs was an innovative modification of the Seasprite seabed CPT unit that incorporated the facility to perform *in situ* shear vane tests. This permitted the shear strength of very soft near-surface soils to be determined to a higher degree of accuracy than is normally possible.

New High Tech ICCP System Launched by Subspection Ltd.

An impressed current cathodic protection (ICCP) system with the latest state-of-the-art technology has been introduced for use on board merchant ships by Subspection Ltd. (Alresford, Hampshire, U.K.). The system's power unit features full microprocessor control, providing greater reliability and maximum flexibility in combination with simplified operator controls for greater efficiency.

"Until very recently, development in impressed current cathodic protection systems for merchant ships, has been restricted, with the result that existing systems have been based on technology that is 20-30 years old. Consequently there has been no advantage taken of modern technology which will provide much more efficient systems both in terms of operating costs and, more importantly, self-diagnostic abilities," said Richard Holt, the company's managing director.

The ICCP control unit basically comprises three sections. The upper section is a "systems status" panel and is provided with indicator lights for each anode, the alarm, operating lights, and an LCD display. The center section comprises the "diagnostic and maintenance" unit, while the lower section houses the high power electrical equipment.

Another advantage of the technology is that data can be automatically recorded on a daily basis, thereby eliminating the need for daily, manual recording. The period for storing data can be varied to suit the requirements of the shipowner. Any changes to the system's operating parameters are also logged. The recorded data are used in the evaluation of the system performance. These data can also be used by the ship's engineers, by linking the power unit directly into the onboard computers.

Relief Leads to Record Western Gulf Lease Sale

Oil and gas companies offered a record 929 bids totaling $325.5 million for the rights to drill on 617 tracts in the Western Gulf of Mexico Sale No. 161, according to a Mineral Management Service spokesman.

Recently enacted deep water royalty relief legislation fueled the industry's interest in leases in water depths greater than 200 meters, making the Western Gulf sale the largest on record for this sector of the U.S. Gulf. Federal officials said 433 tracts that received bids are in water depths of 200 meters or more and are eligible for relief under the new rules.

Oil and gas companies snapping up the deep water acreage expressed confidence about available technology to explore and develop new deep water reserves.

The Minerals Management Service (MMS) confirmed that 57 companies participated in the sale and the sum bids submitted was $503.64 million. The sale was the first where water depths of 200 meters or more are eligible for consideration under provisions of the Deepwater Royalty Act signed by President Clinton last year.

MMS officials said the Western Gulf sale, along with the record breaking Central Gulf sale in April, are clear indications that the Gulf of Mexico is embarking on a new era of offshore energy development.

The Western Gulf's previous sale record for high bids was set in 1989 when oil and gas companies offered $263 million in high bids. Last year's Western Gulf sale generated only $144 million in high bids.

Conoco, Reading & Bates Plan to Build New Drillship

Conoco (Bartlesville, Oklahoma) and Reading & Bates (Reading, Pennsylvania) are establishing a venture to meet the challenge of exploring ultra deep waters of the Gulf of Mexico and ensure long-term access to a suitable rig available to meet Conoco's deep water drilling requirements according to a spokesman. The partners set up a 50/50 venture to undertake an aggressive $400 million, five-year drilling program and disclosed plans to build a $200 million, new generation dynamically positioned drillship able to drill in water depths up to 10,000 feet.

The 721-foot long, double-hulled drillship to be constructed at Samsung Heavy Industries of South Korea, will carry the most stringent American Bureau of Shipping requirements for dynamic positioning systems, DPS-3. The drillship will afford Conoco the ability to extend its exploratory efforts beyond the traditional offshore shelf areas so that deeper fields can be developed economically. Conoco's marine department will assist in the rig's design and help oversee construction, while Reading & Bates will provide drilling services to the new venture. Delivery is expected in 1998.

The rig will have the flexibility to perform extended well tests and includes crude oil storage and offloading capacity, provision for simultaneous drilling and testing and eventual conversion to a floating production/storage and offloading (FPSO) vessel. The drillship will feature extremely large deck space and load carrying capability. The rig will be able to load onboard materials for two deep complete wells, eliminating the need for resupply during drilling. */st/*

Ocean Business

Construction Begins on First Hibernia Shuttle Tanker

The joint venture of Mobil Oil Canada Properties (Calgary, Alberta, Canada), Chevron Canada Resources (Calgary), and Murphy Atlantic Offshore Oil Co. Ltd. (MCM) recently announced the keel laying for the motor tanker *Kometik*. This first specially built shuttle tanker will carry crude oil from the Hibernia platform offshore Newfoundland directly to market and later to the onshore transshipment terminal currently under construction at Whiffen Head on Placentia Bay.

The ship is being constructed at the Samsung Heavy Industries' Koje shipyard in South Korea. It will be Canadian flagged and crewed, and managed by Canship Ugland Ltd. of Newfoundland.

The completion is set for this July and arrive in Newfoundland in October. She will then begin a series of trial runs in preparation for the startup of Hibernia crude oil production expected to commence later that same month. The first tanker loading is anticipated early 1998.

"The name *Kometik* is taken from the Inuit world for sled," said Chevron employee and MCM administrative coordinator Ken Roberts, "and draws a parallel to the original use of the long sleds found in Newfoundland and Labrador for hauling resources and supplies like firewood, to the long tankers which will be used to carry crude oil. Both were designed to safely and efficiently transport people and goods in harsh operating conditions such as those found in the Grand Banks area."

All in all, the tanker will have over 22,000 tons of steel in its double-hull, permitting it to navigate safely in sea ice as well as withstand a collision with "bergy bits" of "growlers"—small, not-easily-seen pieces of glacial ice—of up to 10,000 tons. It will have a 850,000 barrel cargo capacity. The tanker will be 271 meters long and 46 meters wide with a draft of about 15 meters.

Rockwell Agrees to Form Venture with Chinese Firms

Rockwell International Corp. (Cedar Rapids, Iowa) has announced an agreement to form a company to design, develop, and build commercial global positioning system (GPS) navigation receiver systems with Chinese partner companies in Shanghai. Initial activities of this joint venture are expected to begin once the business license is approved.

The limited liability joint venture, known as Shanghai Rockwell Collins Navigation and Communications Equipment Co. Ltd., will be formed to provide locally developed and manufactured commercial GPS equipment to the Chinese market.

Applications for the products include handheld, maritime, and commercial vehicle tracking and management. Rockwell's Collins Avionics & Communications Division will operate the joint venture with the Chinese partners Shanghai Avionics Corp. and Shanghai Broadcast Equipment Factory. Company offices and manufacturing facilities will be located in the greater Shanghai area.

"This is truly a gratifying occasion for Rockwell and for the Collins division operating the limited liability company," said Jack Cosgrove, Rockwell's Avionics and Communications president in Cedar Rapids. "We now have additional international opportunities to grow our business and to support an entirely new customer base."

Emerson & Cuming Establishes Buoyancy Reconditioning Stations

Emerson & Cuming Composite Materials Inc. (Canton, Massachusetts) reports it may have found a way to help its customers extend buoyancy life and help preserve the environment at the same time. The company says many buoyancy modules could be economically restored to service rather than scrapped if expert and timely repairs could be made.

Therefore, Emerson & Cuming has announced the establishment of three reconditioning stations for restoration of damaged or worn syntactic buoyancy used by the offshore and ocean industry to support drilling and production risers, mooring lines, flowline tow-outs, ROVs, manned submersibles, and other oceanic instrumentation.

The stations are located in Houston, Rio de Janerio, and Perth, Australia. Another station is being considered in Europe. These stations will be staffed with factory-trained technicians and stocked with company-certified materials to restore buoyancy to full performance as an alternative to replacement, thereby avoiding expense, lost time, and overloading of landfills.

Aker Omega Inc. Changes Name to Aker Engineering Inc.

Effective January 1, 1997, Aker Omega Inc. (Houston) changed its name to Aker Engineering Inc. The name change has been made to symbolize and reconfirm Aker Maritime's focus and commitment to the deep water drilling and production arena, according to a spokesman.

With corporate responsibilities in the Gulf of Mexico and West Africa, the company will continue to provide front-end engineering, detail engineering, and product management services covering floating production technology, subsea production systems, and marine pipelines.

For further information on Aker Engineering Inc., contact R.T. Hill, vice president, at (281) 870-1111.

WHISL Receives Contract From Seoul National University

Woods Hole Instruments Systems Ltd. (Cataumet, Massachusetts) announced the award of a contract from Seoul National University (SNU), Korea, for a buoy system to measure ocean currents and meteorological data. The system will consist of a bottom-mounted acoustic doppler current profiler (ADCP) and a surface buoy with sensors to measure wind speed and direction, barometric pressure, air temperature, and water temperature. The data will be telemetered to a central base station located at SNU for later analysis in support of its ongoing oceanographic programs.

Leica Wins Australian Beacon DGPS Contract

Leica Inc. (Torrance, California) has been awarded a contract from the Australian Maritime Safety Authority for a beacon differential GPS (DGPS) systems network. The network consists of beacon broadcasting stations, monitoring stations, and a control station.

The beacon systems network will provide enhanced navigation accuracy in coastal waters along much of Australia's east coast by using marine radio beacons to broadcast DGPS error correction data. It will become part of what will eventually be a nationwide system covering the entire Australian coastline. The contract calls for DGPS beacon broadcasting sites to be established in Sydney, Cooktown, and Mackay with an additional station to be used for training and spares. One control station will be located at Victoria and three monitor stations will be located at Melbourne, Canberra, and Brisbane. All the broadcast stations, monitor stations, and the control station will be linked by a communication network.

The Australian installation will be based on Leica's recently introduced 12-channel MX 9400 series of DGPS receivers. The MX 9400 has extremely stable pseudorange measurements and unsurpassed accuracy, according to a spokesman. When the MX 9400R reference station is teamed with the MX 9400N navigator, accuracy of better than 30 centimeters can be achieved.

The Australian system will comply with RTCM SC-104 and International Association of Lighthouse Authorities standards.

Business Briefs....William & Associates Inc. (Seattle, Washington) announced successful completion of three simultaneous geophysical surveys. One, for the **Alaska Department of Fish & Game,** was conducted near Sitka, Alaska, using the AMS-150 swath mapping system in water depths up to 225 meters over a 14 x 48 kilometer area. The second survey for both the **NOAA** and **U.S. Geological Survey** took place in 3,400-meter waters off Washington and Oregon. The last survey happened across the Pacific on a fiber-optic cable route survey for a Japanese telecommunications company. That survey covered a 300-kilometer-long route ranging in depths from 20 to 3,000 meters....**ORE International Inc.** (Houston) has announced a new U.S. distributor's agreement with **Marimatech A/S** (Hinnerup, Denmark). Marimatech manufactures a wide range of hydrographic survey instrumentation such as echosounders, multibeam bathymetry systems, tide gauges, CTD-sound velocimeters, and other advanced hydrographic packages....**Focal Technologies Inc.** (Dartmouth, Nova Scotia, Canada) has announced that the company will be expanding its facilities to keep up with the steady growth in the business. Effective January 1, Focal was doubling its floor area and implementing a capital program to provide increased work space for all departments of the company....**Western Marine Electronics' (WESMAR)** (Woodinville, Washington) thirteenth international training seminar held this past November was declared a success. The five-day event covered the entire company's product line and customers were provided the opportunity to test the equipment for themselves....**DWS International Inc.** (Corpus Christi, Texas) has obtained the rights for marketing and sales of the ISIS-100 and ISIS-300 from **Submetrix Ltd.** (Bath, U.K.) in North America. DWS will provide complete sales and service support for the ISIS line of products from its Texas headquarters. */st/*

Navy Currents

Lockheed Martin CEO Speaks to USNA Alumni Association

Norman R. Augustine, chairman and CEO of Lockheed Martin Corp. spoke to U.S. Naval Academy Alumni Association January 15 on the subject of the aerospace industry. Some thoughts expressed included:

• The United States has not been prepared for six of the last seven wars (Persian Gulf War was the exception). When addressing the question of why the United States should spend for defense you have to think of the threat that is more distant than the near future—we have never been able to predict what we would need for war.

• Currently, there are 71 conflicts around the world. Alluding to the Cold War era, Margaret Thatcher (former prime minister of the United Kingdom) remarked that "Ice was most dangerous when it was breaking up."

• Current defense expenditures are at a pre-Pearl Harbor level. At the current Department of Defense (DoD) recapitalization rate, the process will take over 50 years. Readiness has been kept up but acquisition is falling far behind.

• At the peak of World War II, the United States produced a fighter aircraft every 10 minutes, 24 hours a day, seven days a week. The minimum time recorded for the construction of a Liberty ship was four days. Today we think we are doing great to produce three Aegis ships per year.

• The United States has a large service industry today—wars can't be fought by a service industry. Productive capacity, an industrial base is needed.

• He noted that 40 percent of DoD expenditures were for electronics.

• In regard to the increasing cost of fighter aircraft (the escalating cost over the history of aviation), at the current rate by about the year 2050, only one plane will be able to be procured. He was reminded of what President Coolidge said when approached for $25,000 to acquire fighter aircraft "Can't you just buy one and have the pilots rotate flying it?"

• The aerospace industry has been through three phases since its zenith in 1987. First, the companies who were in defense as an avocation left the industry—companies who had other core businesses. Then there was a consolidation phase in the early 1990s—the components of Lockheed Martin, originally 17 companies, were merged or acquired in this period. At a loss of about 1.5 million employees defense-wide, full service defense companies emerged. There are actually two full service companies, Lockheed Martin and the merged McDonnell Douglas/Boeing organization. Augustine thought the competition between the two was a good thing.

This whole consolidation process was of substantial benefit to the Department of Defense—in Lockheed Martin's case, there is a savings of about $2.5 billion in reduced government procurement cost *annually*—but the government did not pay for the restructuring, the shareholders did.

In responding to the question of why Lockheed Martin was not bidding for Hughes Electronic Corp., he said that their acquisitions were made in the early 1990s at a cost of about 49 cents to a sales dollar. Hughes was costing about

$1.40 per sales dollar and did not fit Lockheed Martin's portfolio.

• He strongly supported basic research because products of research from DoD 6.1 R&D funding is where the changes in warfare come from—if the country misses out on one particular breakthrough in warfare, the next war will be lost.

BBN Installs Active Noise Control on U.S. Navy Ships

BBN Systems and Technologies (Cambridge, Massachusetts) was awarded a $572,000 contract by the Naval Surface Warfare Center Carderock Division to provide active noise control systems for all ships of the PC 1 class, the Navy's newest high-speed patrol craft. The BBN active control system reduces low frequency airborne noise levels in individual crew bunks which have experienced high airborne noise levels.

The active noise control unit provides a stand-alone system that incorporates a loud speaker, microphones, and an electronic controller within individual bunks of aft crew berthing. After the microphone senses the ambient noise, the electronic controller analyzes it and creates an anti-noise signal, which is then sent to the loudspeaker, effectively reducing the noise at the head of the bunk. Successful at-sea performance of these units resulted in the Navy's order.

Sperry Claims First Use of Digital Nautical Charts Aboard Navy Ships

A spokeswoman for Sperry Marine (Charlottesville, Virginia) reports that the U.S. Navy has introduced digital nautical charts (DNC) in an electronic chart display & information system (ECDIS) for the first time. The system is deployed on the guided missile cruiser *Yorktown* (CG 48) as part of Sperry's integrated navigation system.

DoD Awards $44.5 Million for University Research Equipment

Director of Defense Research & Engineering Anita Jones announced plans to award $44.5 million under the Defense University Research Instrumentation Program (DURIP). DURIP enables DoD-supported university researchers to purchase scientific equipment that costs more than $50,000. Researchers normally have difficulty purchasing instruments that cost that much under their research contracts and grants. The 273 awards to 105 academic institutions are expected to range from $47,000 to $700,000 and average $163,000.

The announcement is the result of a merit competition for DURIP funding conducted by four research offices: the Army Research Office, Office of Naval Research, Air Force Office of Scientific Research, and Science & Technology Directorate of the Ballistic Missile Defense Organization. The offices solicited proposals from university researchers working in selected areas of importance to the DoD such as • high-performance computing, • propulsion, • electronics and electromagnetics (e.g., millimeter-wave circuits, low-power circuits for mobile power applications, and high-power and radio-frequency circuits for directed-energy plasma science), • advanced materials (e.g., bio-engineered or biomimetic materials, nanoscale assembly, nonequilibrium processing, and polymers for photonic materials and chemically resistant barrier layers), • virtual-reality and three-dimensional display systems, and • oceanographic and atmospheric sensors. /st/

International

Series of International Subsea Technology Events Set to Go

The Society for Underwater Technology of London has announced sponsorship of Underwater Technology International (UTI), a new series of international subsea technology events. The inaugural conference and exhibition will be held April 8-10, 1997, at the Aberdeen Exhibition and Conference Centre. The following UTI conferences will be held between Aberdeen and other worldwide venues.

The focus of this year's UTI will be "Remote Intervention." SUT president Sir Anthony Laughton states, "This theme will be particularly relevant to those interested in deep water exploitation using remotely operated or autonomous vehicles. Of special note will be the opportunity to see the technologies ripe for transfer from the nuclear and space industries."

The technical conference will feature multimedia presentations with some papers incorporating live video demonstrations of hardware from stands in the exhibition hall. Invitations to speak at UTI 97 have been greeted with enthusiasm according to Laughton. The conference will also present a concurrent exhibition of commercial subsea technology, products, and services.

"UTI will serve to stimulate the uptake of new technologies and innovative applications, as well as generate new business opportunities for those participating. Although it is primarily aimed at the offshore oil and gas industry, UTI will stimulate discussion and interchange across all of the industries that employ remotely operated, autonomous, robotic or autonomic systems underwater and, therefore, generate cross-fertilization of technologies and applications," said Brian Redden, organizer on the behalf of SUT.

Southern Oceanics Delivers Air Dive System to Korea

Southern Oceanics (Pty) Ltd. (Cape Town, South Africa) recently delivered a custom-built 6-meter ISO-containerized air dive system to Korea Ocean Engineering and Consultants Company Ltd. (Seoul, Korea).

The system will be used on a contract for the laying and protection of a submarine power cable and includes a recompression chamber, 120m^3 air storage bank with HP air management panel and HP air compressor, a three-diver air panel, and all interconnect pipework.

The container was modified to provide structural underfloor reinforcing to secure the recompression chamber, fitted with a side access door and observation window, recessed alcoves for power and gas connections, a marine grade electrical system, and fire resistant rubber flooring.

Ground Station Awarded Blue Ribbon Certification

The Defence Evaluation and Research Agency (DERA) (Farnborough, Hants, U.K.), RADARSAT International (RSI) (Richmond, British Columbia, Canada), and the Canadian Space Agency (CSA) (Saint-Hubert, Quebec, Canada) have announced that the DERA West Freugh satellite ground station has been awarded blue ribbon certification for the reception and processing of RADARSAT data, becoming the first international ground station to obtain RADARSAT network station certification, according to a spokesman.

In achieving the certification, West Freugh successfully completed a series of rigorous on-site tests and verification by RSI and CSA of the station's ordering, scheduling, reception, and product generation capabilities. The ground station is now receiving commercial data.

The certification itself encompasses ordering and scheduling of RADARSAT-1 direct downlink data, reception of direct downlinked data, archiving and cataloguing of downlinked data, generation of specific products in RADARSAT CEOS format, and generation of various image products in the same format.

"In awarding this certification, we are pleased that West Freugh is now able to carry out commercial RADARSAT data operations and generate high quality image products which will satisfy a range of customer requirements," said Robert E. Tack, RSI president.

New Test Disk for Low Chlorine Levels Developed

Tintometer Ltd. (Salisbury, U.K.) reports it has developed a new Lovibond® water test disk for determining very low concentrations (0.002 to 0.03 parts per million) of chlorine in water.

DPD reagent is used in the normal way, developing a pale sample color that is indicative of the level of chlorine in the water. The concentration is determined by matching the sample against predetermined color standards in the test disk.

This method, based on visual colorimetric analysis, allows considerably more sensitive chlorine testing than photometric which will typically give accurate measurements down to 0.02 ppm. Field trials have so far highlighted in monitoring seawater to establish the extent of influence of chlorine used to prevent biofouling in outlets and in tropical aquaria, where the new disk was successfully used to detect trace levels of chlorine which can prove to be highly toxic to fish.

Racal Agrees to Sell Marine Business to Litton

Racal Electronics Plc. (Bracknell, Berkshire, U.K.) has announced that it has agreed to the sale of its Racal-Decca marine electronics business to Litton Industries Inc. (Woodland Hills, California) for a cash consideration of £29.5 million. Completion of the transaction is expected by the end of the current financial year, subject to the approval of the appropriate competition authorities.

According to CEO David Elsbury, the transaction includes all of the worldwide businesses of Racal-Decca Marine group, with the exception of the U.K. Decca Navigator chains—which will continue to be operated by Racal on behalf of the General Lighthouse Authorities—and the non-marine activities of Decca South Africa.

Based at New Malden, Surrey, Racal-Decca Marine is principally engaged in developing of maritime radar and navigation systems. Activities covered by the agreement include some 580 staff. In the financial year ending last March 31, the group accrued revenues of approximately £60 million, net assets of £22 million, and an operating profiting of £3.1 million before redundancy and reorganization charges of £0.8 million. /st/

Research/Survey

SHIP	LOCATION	MISSION
Alpine Ocean Seismic Survey Inc., Norwood, N.J.		
Atlantic Twin	East coast	Vibracoring work
American Pacific Marine, Ventura, Calif.		
American Endeavor	Offshore California	Construction support
American Patriot	Drydock California	In port
American Progress	Offshore California	Crewboat operation
American Recovery	Offshore San Diego	Construction support
Bermuda Biological Station, Ferry Reach, Bermuda		
Weatherbird II	Bermuda	BATS-bloom time series
Bisso Marine Co. Inc., New Orleans, La.		
Capt. W.A. Bisso Jr.	Gulf of Mexico	High resolution surveys
Bulls' Eye	Louisiana Coast	Sonar surveys, diving
Eagle Eye	Louisiana Coast	Sonar surveys, diving
Chesterfield Associates Inc., Westport Island, Maine		
Weatherbird	New York Harbor	U.S. Coast Guard project
Coast Enterprises, San Diego, Calif.		
Recovery One	Mexico/U.S. border	Tijuana outfall project
C&W Diving Services Inc., National City, Calif.		
Lizzie Beth	Offshore California	Diving
Deep Sea Development Services, San Diego, Calif.		
Blue Horizon	San Diego	Surveys
Duke University Marine Laboratory, Beaufort, N.C.		
Cape Hatteras	Gulf of Maine	Phosphorous cycling
Environmental Protection Agency, Washington, D.C.		
Clean Waters	Cavens Point, NJ	Maintenance
Hydra	In port	Idle
Lake Explorer	Lake Superior	Acoustic study
Lake Guardian	Great Lakes	Survey
Peter W. Anderson	Offshore Maine	Monitoring
Muddpuppy	In port	Idle
David Evans & Associates Inc., Portland, Ore.		
John B. Preston	Columbia River	Hydrographic surveys
Florida Institute of Oceanography, St. Petersburg, Fla.		
Bellows	Florida Keys	Educational cruises
Suncoaster	Florida Keys	Geological oceanography
Delphinus	East Coast Florida	Educational cruises
General Offshore Corp., Ft. Lauderdale, Fla.		
Offshore Venture	Marshall Islands	DOE survey
Gulf Coast Research Laboratory, Ocean Springs, Miss.		
Tommy Munro	In port	Available
Gulf Ocean Services Inc., Gibson, La.		
David McCall II	Offshore Louisiana	Seismic surveys
Liz McCall II	Offshore Louisiana	Seismic surveys
Harbor Branch Oceanographic Institution, Ft. Pierce, Fla.		
Edwin Link	Bahamas	Midwater ecology
Sea Diver	Ft. Pierce	Open for assignment
Seward Johnson	Brazil	Physical oceanography
Interstate Sanitation Commission, New York, N.Y.		
Natale Colosi	New Jersey Coast	Water quality monitoring
Kinsella, Cook & Associates Inc., Prairieville, La.		
Albuquerque	Gulf of Mexico	High resolution surveys
Jim Bordelon	Gulf of Mexico	High resolution survyes
Will Bordelon	Gulf of Mexico	High resolution surveys
Lamont-Doherty Earth Observatory, Palisades, N.Y.		
Maurice Ewing	Gulf Coast	Mobilizing Navo equipment
Louisiana University Marine Consortium, Chauvin, La.		
Pelican	Gulf of Mexico	Oceanographic research
Marex International Inc., Memphis, Tenn.		
Beacon	N/A	N/A
Deep Quest	N/A	N/A
Southland	N/A	N/A
Monterey Bay Aquarium Research Inst., Pacific Grove, Calif.		
Point Lobos	San Francisco Bay	Oceanographic research
Monterey Canyon Research Vessels Inc., Santa Cruz, Calif.		
Shana Rae	Pioneer Seamount	Instrument deployment
Moss Landing Marine Laboratories, Moss Landing, Calif.		
Point Sur	Southern California	Chemical oceanography
National Science Foundation, Arlington, Va.		
Polar Duke	Antarctica	Station support
Nathaniel Palmer	Ross Sea	Mooring & autumn process
NOAA, National Ocean Service, Washington, D.C.		
Albatross	East Coast	GLOBEC

Vessel Activity

SHIP	LOCATION	MISSION
Chapman	Tampa, Florida.	Oculina Atlantic survey
David Starr Jordan	San Diego	LIDAR
Delaware II	East Coast	Marine mammal survey
Ferrel	Priest Ldg, Georgia	Grays Reef NMS
John N. Cobb	Offshore Alaska	Marine mammal study
Ka'Imimoana	Pearl Harbor	TAO/PACS
McArthur	Offshore Calif./Pacific	ETP
Miller Freeman	Dutch Harbor, Alaska	FOCI
Oregon II	Pasccagoula, Miss.	Dockside repair
Rainier	N/A	N/A
Relentless(T-AGOS)	N/A	N/A
Rude	Little Creek, Virginia	Side-scan survey
Townsend Cromwell	Honolulu, Hawaii	Swordfish
Whiting	Wilmington, N.C.	Nautical charting
NYC Dept. of Environmental Protection, Wards Island, N.Y.		
Osprey	Staten Island	Water quality monitoring
Harbor Survey	Staten Island	Water quality monitoring
Ocean Enterprises Ltd., Santa Barbara, Calif.		
William A. McGaw	Santa Barbara Channel	Various projects
Oregon State Univ., College of Oceanography, Corvallis, Ore.		
Wecoma	Oregon coast	Columbia River plume
Rinn Boats/ Fling Charters, Freeport, Texas		
Fling	Gulf of Mexico	Diving cruises
Spree	Gulf of Mexico	GERG buoy maintenance
San Francisco State, Romberg Tiburon Ctrs., Tiburon, Calif.		
Questuary	San Francisco Bay	Instrument installation
Scripps Institution of Oceanography, La Jolla, Calif.		
Melville	Indian Ocean	Mooring recovery
New Horizon	Southern California	Deep tow
Roger Revelle	Columbia River	LMER studies
Robert G. Sproul	Punta Arenas, Chile	Sea Beam & seismic
Seaward Explorer Inc., Miami Beach, Fla.		
Seaward Explorer	In port	Available
Texas A&M Univ., College of Geosciences, College Station, Texas		
Gyre	Gulf of Mexico	Mammal survey
Texas A&M University, Ocean Drilling Pgm., College Station, Texas		
JOIDES Resolution	Costa Rica	Ocean drilling
University of Alaska, Seward Marine Center, Seward, Alaska		
Alpha Helix	Resurrection Bay	Class instruction
University of Delaware, College of Marine Studies, Lewes, Del.		
Cape Henlopen	Delaware Bay	Chemistry
University of Hawaii, Marine Center, Honolulu, Hawaii		
Kila	Offshore Hawaii	Blue water marine
Moana Wave	Offshore Hawaii	Ocean time series
Univ. of Miami, RSMAS, Miami, Fla.		
Calanus	Florida Straits	Physical oceanography
Columbus Iselin	N/A	N/A
Univ. of Michigan, Ctr. for Great Lakes & Aquatic Sciences, Ann Arbor, Mich.		
Laurentian	Grand Haven	In port
Univ. of Rhode Island, School of Oceanography, Saunderstown, R.I.		
Endeavor	New Jersey coast	GLOBEC process
Univ. of Texas at Austin, Inst. of Geophysics, Galveston, Texas		
Longhorn	Gulf of Mexico	Fisheries
Univ. of Wash., College of Ocean and Fishery Sciences, Seattle, Wash.		
Alaska	Seattle	In port
Barnes	Puget Sound	Student instruction
Henderson	Lake Washington	Instrument testing
Miller	Puget Sound	Instrument testing
Thompson	Guam	JASON
West Coast Seaworks, Alameda, Calif.		
White Lightning	San Francisco Bay	Commercial diving
Woods Hole Oceanographic Institution, Woods Hole, Mass.		
Atlantis	Woods Hole, Mass.	In port
Knorr	Woods Hole, Mass.	Globec moorings
Oceanus	Woods Hole, Mass.	Globec, broadscale study

NOTE: *Operators not included may submit vessel information and contact name to the editor. New vessels listed on space-available basis. "N/A" = current vessel data unavailable.*

Ocean Mining

Dr. Michael J. Cruickshank

Revisiting Environmental Factors in Ocean Mining

Now that environmental issues have been well established as a major factor in minerals development—a point reiterated by both U.S. presidential contenders last fall—it may be useful to reappraise the environmental targets formulated in the *Berlin Guidelines* four years ago.

The meeting was organized by the Development Policy Forum of the German Foundation for International Development (DSE) and the United Nations Department of Technical Cooperation for Development (UN/DTCD), and it resulted in a series of recommendations for sustainable mining under appropriate environmental guidelines. The mixture of proposed interactions between industry, government, non government organizations, and the public has a familiar ring as does the subtitle of one of the chapters that "mining is a dirty word."

Very sensibly the participants concluded that while taking into account global environmental concerns, each country should apply these concepts to meet the needs of its environment and economic circumstances. Given the present status of mining throughout the world, it is ever more apparent that the environmental aspects of mining the oceans may offer definite advantages over those aspects of mining on land and that the United States needs to continue to assist in environmental research activities directed to the health of the mining industry ***and*** the health of the oceans.

Recent congressional support for the university-based marine minerals centers may make up partially for the loss of the U.S. Bureau of Mines, but the regulatory agencies would do well to heed the guidelines and look at them in the perspective of the marine environment as a serious supplement to the long-term minerals supply for the United States.

Perhaps the greatest problem that faces the industry still is the public perception of the fragile ocean and the "rapacious nature of the industry" in its exploitation. Neither the regulators in the U.S. Environmental Protection Agency nor the environmental pressure groups do much to dispel these notions. One wonders if the problems do not stem from our legal system, which provides the opportunity for anyone to make a fortune or at least achieve their 15 minutes of fame by the simple application of a lawsuit to bring new developments to an immediate and expensive halt. Even the new amendment to the OCS Lands Act (P.L. 103-426)—which sought to simplify the transfer of sand and gravel resources from the OCS to state or local governments for appropriate public uses such as shore protection and beach maintenance—has run into opposition initiated by competing agencies.

More recently, a request for information by the Minerals Management Service (MMS) on a sand and gravel lease sale off the state of New Jersey has resulted in a spate of comments and objections that have resulted in delays and cast considerable doubts on the usefulness of proceeding with the planned EIS. MMS, which takes its management and stewardship responsibilities very seriously, is one of the more realistic federal organizations when it comes to making fair and common-sense decisions about resources; hopefully, the document will be processed and concerns expressed by the House Subcommittee on Fisheries, Wildlife & Ocean Resources; many New Jersey coastal officials; and residents will be objectively addressed.

Scoping meetings will be held and the draft EIS will be made available for public scrutiny and discussion. The pre-operational tenets of the Berlin Roundtable will in fact be addressed in almost their entirety and the operational and post-operational guidelines will hopefully be met in due course.

Readers interested in the MMS program managed by the Office of International Activities & Marine Minerals should request a copy of the *Current Activities Update* from MMS at (703) 787-1300 or by fax at (703) 787-1284. Marine minerals information is also available on the web at http://www-.gov/omm/intermar/mineral.html. /st/

Meetings

MARCH

March 3-6, 1997—AGU's Microgal Gravimetry: Instruments, Observations, and Applications, St. Augustine, Florida. Information: American Geophysical Union Meetings Department, 2000 Florida Ave. NW, Washington, DC 20009; (202) 462-6900.

March 11-14, 1997—2nd Turkmenistan International Oil & Gas Exhibition, Ashgabat, Turkmenistan. Information: Paddy Young, Project Director, ITE Group, Byron House, 112a Shirland Rd., London W9 2EQ, U.K.; 44+ (171) 2869720.

March 11-15, 1997—Sea Trade Cruise Shipping, Miami Beach, Florida. Information: Sea Trade Cruise, 125 Village Blvd., Suite 220, Princeton, NJ 08540; (609) 452-9414.

March 13-14, 1997—2nd Annual Developing & Producing Offshore Marginal Fields, Houston. Information: E. (Rick) Fontova, Chairman, c/o Strategic Research Institute, 500 Fifth Ave., New York, NY 10110; (212) 302-1800 or (800) 599-4950.

March 17-28, 1997—Design For Fixed Offshore Platforms, Austin, Texas. Information: The University of Texas at Austin, College of Engineering, Continuing Education Studies, P.O. Box H, Austin, TX 78713; (512) 471-3506.

March 17-19, 1997—4th International Conference Remote Sensing for Marine & Coastal Environments, Orlando, Florida. Information: ERIM/Marine Conference, P.O. Box 134001, Ann Arbor, MI 48113-4001; (313) 994-5123, ext. 3234.

March 19-20, 1997—ASNE Day 1997, Washington, D.C. Information: American Society of Naval Engineers, 1452 Duke St., Alexandria, VA 22314; (703) 836-6727.

March 20-21, 1997—PSTI/MTD Technical Forum: Emerging Technology for E&P, Aberdeen, Scotland. Information: Jane Kennedy, The Petroleum Science and Technology Institute, Offshore Technology Park, Exploration Drive, Aberdeen AB23 8GX, Scotland; 44+ (1224) 706600.

March 20-22, 1997—Aquaculture 97: Combining Technology & Nature, Fresno, California. Information: George Ray, California Aquaculture Association, P.O. Box 1004, Niland, CA 92257; (619) 359-3474.

March 24-27, 1997—California & the World Ocean 97, San Diego, California. Information: Coastal Zone Foundation, P.O. Box 279, Middletown, CA 95461; (707) 987-0114.

March 25-27, 1997—Sea/Air/Space Exposition, Washington, D.C. Information: Navy League of the United States, 2300 Wilson Blvd., Arlington, VA 22201; (703) 528-1775.

March 31-April 1, 1997—24th Annual MTS Cable & Connector Workshop, Orlando, Florida. Information: Marine Technology Society, Undersea Cable and Connector Committee, 409 Woburn St., Wilmington, MA 01887; (508) 658-3319.

APRIL

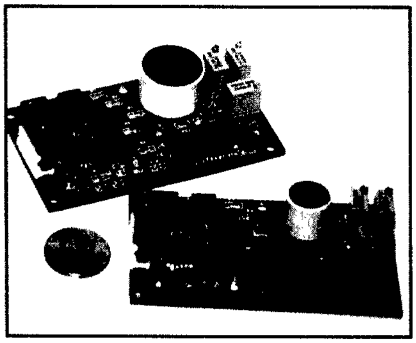
April 7-10, 1997—International Oil Spill Conference, Fort Lauderdale, Florida. Information: 1997 International Oil Spill Conference, 655 15th St., NW, Suite 300, Washington, DC 20005; (202) 639-4202.

April 8-10, 1997—Underwater Technology International 97, Aberdeen, Scotland. Information: Nautilus Offshore Ltd., Aberdeen, Scotland; fax at 44+ (13398) 83219 or e-mail at bgr-nautilus@sol.co.uk.

April 13-18, 1997—16th International Conference on Offshore Mechanics and Arctic Engineering (OMAE), Yokohama, Japan. Information: University of Hawaii at Manoa, School of Ocean and Earth Science & Technology, Department of Ocean Engineering, Holmes Hall 402, 2540 Dole St., Honolulu, HI 96822; (808) 956-7572.

April 16-18, 1997—Maritime Vietnam 97, Ho Chi Minh City, Vietnam. Information: Amsterdam RAI, International Exhibition and Congress Organizers, Europaplein, P.O. Box 77777, NL-1070 MS Amsterdam, The Netherlands; 31+ (20) 549 12 12. /st/

Angle Conversion Module



EZ-Tilt 3000 operates 5-18 VDC; unipolar or bipolar power supply; ratiometric; 73.6 mm by 41.3 mm; max. height 17 mm; continuous, simultaneous inclination information for both tilt axes; max. range -75 to +75 arcdeg; response time 40mS @ 10-90% output; shatterproof polymer tilt sensor. Advanced Orientation Systems Inc. CIRCLE **NO. 201**

Flowmeter Software

New addition to open channel flowmeters allows operator to use own DOS based computer as display and data logger for 2031H Electronic Flowmeter; real-time display in selectable units of measure; package includes software, 9 pin serial connector, 9 volt battery, and 30 feet of underwater cable. G.O. Environmental Inc.

CIRCLE **NO. 202**

Strain Relief Fitting

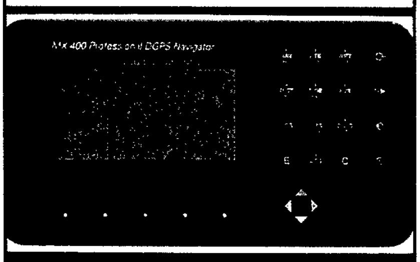
Mini component nickel-plated brass cord accommodates wires from 2.0 mm to 5.0 mm; brass finish protects against environmental elements; liquid tight; allows for submersible applications with 150 PSIG pressure rating; O-ring creates reliable seal; available with BUNA-N seals. Sealcon.

CIRCLE **NO. 203**

Exhaust System

Neptune Marine "2000" Exhaust System is designed to improve engine performance and eliminate environmental problems existing in present vessels; self-contained; easy retrofit; filtration system reduces emissions; compact design; can process exhaust up to 30,000 horsepower engines. Neptune Marine Systems Inc. CIRCLE **NO. 204**

DGPS Navigator



New 12-channel version of MX 400 marine DGPS navigator, the MX 412; can track all GPS satellites simultaneously; built-in beacon differential receiver; carrier-smoothing technology; accuracy levels less than 1 meter (3.3 feet); includes all features of the 6-channel MX 400. Leica Inc.

CIRCLE **NO. 205**

Underwater Positioning System

Suited for local 3D locating within the range of up to 330 feet from a reference point; full stand-alone system; free of bottom to surface cables; can be operated by single diver; accuracy of radial distance ±2 centimeters; lightweight. PLSM. CIRCLE **NO. 206**

Linear Accelerometer

The QLC-400™ is a low-cost liner accelerometer; well-suited for applications such as inclination, vibration, tilt/sway, motion control, leveling, and stabilization; one-year bias stability of less than 0.05% of full scale; scale factor stability of less than 0.05% full scale. AlliedSignal Inc. CIRCLE **NO. 207**

Satellite Phone Service

KVH Tracphone® is a fully stabilized, three-axis system for open sea use; high-gain 10.5-inch antenna; cost less per minute; less power from satellites; high quality voice and data; receives and send phone calls, faxes, e-mail in rough seas. KVH Industries Inc.

CIRCLE **NO. 208**

Wave for Windows®
Complete system for wave measurement, analysis, and presentation of data for wave and tides with current speed, direction, and CTD data; performs analysis with the S4DW directional instruments; supports 2D and 3D graphic functions. InterOcean Systems Inc. CIRCLE **NO. 209**

Work Class ROVs
Demon and Diablo ROVs; 3 ton through frame lifts with four point skid attachment; Curvetech powered; bolted outer frames; 6 point variable lifts to balance deployment; Intel 486 based control systems with 96 data channels; integral diagnostics for rapid fault finding. Hydrovision Ltd. CIRCLE **NO. 210**

Structures Positioning Software
Target:Structures™ is designed for precise positioning and monitoring of large mobile structures of platforms; provides visual displays for crane operators to guide structures to any target location to centimeter accuracy improving overall safety and efficiency of the operation. Trimble Navigation New Zealand Ltd. CIRCLE **NO. 211**

Sailboat Autopilot
P3BN Autopilot for use in medium size offshore sailboats; digital compass display; complete navigation interfacing with NEMA 0183 Serial Interfacing; interface with all GPS, Loran, and chart machine outputs; variable speed drive systems; 3 year limited warrantee. W-H Autopilots Inc. CIRCLE **NO. 212**

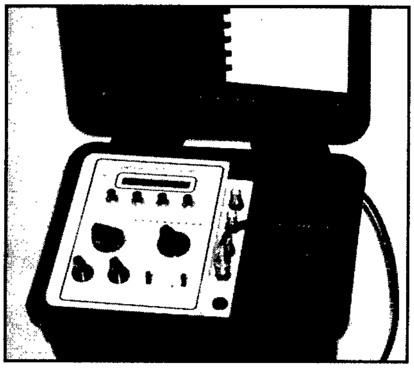
Software Product
The "*-LINK" range of software (Land-Link, Sky-Link, and Ocean-Link) used in conjunction with the Argos satellite system enables travelers to transmit geographical location positions and coded messages via satellite; provides reliable fleet tracking and monitoring services. Oceanscan Ltd. CIRCLE **NO. 213**

Panel-Mount VGA Repeater
The COL-104 Model is a 10.4" color, daylight viewable, panel-mounted VGA repeater to bring PC screen display back on deck; uses active matrix LCD screen; 8 times brighter than common available laptops; 13 x 11 inches overall; 4 inches deep; optional touch screen; ideal for electronic charting applications. Sport Products Inc. CIRCLE **NO. 214**

Navigation Receiver
MNS 2000 receiver provides continuous latitude and longitude positioning using Decca, Loran-C, Transit, Omega, or GPS signals; provides required positioning accuracies; equipped with a NMEA 0183 data port. Racal-Decca Marine Ltd. CIRCLE **NO. 215**

PC Cards
The DT7102 series of PC Card-EZ™ portable data acquisition boards; standard single channel and scan capability; dual analog-to-digital converter for simultaneous sampling of two input channels; highly-accurate, time-based phase analysis; programmable FIFOs; gap free data acquisition. Data Translation. CIRCLE **NO. 218**

Turbidity Sensor
WQ700 turbidity sensor is a low-cost, highly accurate submersible sensor for *in situ* environmental or processing monitoring; precision optical system with sapphire windows; EPA recommended incandescent light; 90° light scattering; accurate linear measurements. Global Water. CIRCLE **NO. 216**

Acoustic Test Probe


SW51 operates in CW or pulse mode; amplitude, sensitivity, frequency, and pulse-width control; displays transmit level, sensitivity, and performance criteria; saves lost time at sea; for ROV and manned sub; portable; sea water resistance. Sunwest Technologies Inc. CIRCLE **NO. 219**

Load Viewing System
ELVIS (External Load Viewing System) has a mini CCD color camera with 24:1 zoom capability; subminature pan & tilt integrated to a remotely operated control/monitoring unit; built-in, flat panel, solid-state color monitoring display. Remote Ocean Systems. CIRCLE **NO. 217**

 CIRCLE NO. 105 ON INQUIRY CARD

ST Looks Back

February Issue

25 Years Ago

1972. Bethlehem Steel Corp. disclosed plans to build standard-design 265,000-deadweight-ton tankers, the largest built in this country, in Sparrows Point, Maryland....Harbor Branch Foundation opened a new marine biological laboratory near Ft. Pierce, Florida to be operated in cooperation with the Smithsonian Institution and Dr. Edwin A. Link's Sea Diver Corp....Sippican Corp. (Marion, Massachusetts) completed production of its millionth expendable bathythermographic (XBT) probe....National Oceanic & Atmospheric Administation (NOAA) and the American Tunaboat Association developed a change to fishing nets that reduced the mortality rate of porpoise by 75 percent.

15 Years Ago

1982. NOAA reported that the lack of a stable investment climate impeded deep ocean mining....Sohio submerged two steel tripods eight miles offshore Alaska in water six meters deep to study the formation of natural ice barriers. The arctic ice study was privately funded....Scientists from Harbor Branch Oceanographic Institution, diving off the Bahamian Island of San Salvador discovered algae at 810 feet, a depth where algae were not known to exist before....Westinghouse Electric Corp. (Annapolis, Maryland) delivered a new surface-towed search system (STSS) to the Navy that could search, locate, classify, and identify objects on the seafloor at depths to 6,100 meters.

10 Years Ago

1987. The U.S. Air Force decided to bypass the grounded space shuttle and procure 20 medium launch vehicles to put GPS into orbit....In the midst of a depression in the offshore oil industry, companies began producing low cost ROVs. In 1984, low-cost was defined as $26,850 for a Deep Sea Systems International Inc. (Falmonth, Massachusetts) *Mini-Rover*; the next lowest cost ROV was $100,000; the remaining ROVs were priced at $300,000 to $400,000. New prices for some were in the $5,000 to $7,000 range. /st/

People

Coutts

Durham

Jeffrey Coutts was recently named the new managing director at Alluvial Mining (Sudbury, Suffolk, U.K.). He will be responsible for the technical and commercial development of the company in its operations worldwide. He comes to the company with over 20 years experience in civil and offshore geotechnical engineering.

The technical/deputy director of the Naval Meteorology and Oceanography Command, **Dr. Donald L. Durham,** has been awarded one of the highest non-military honors bestowed by the Secretary of Defense— the Secretary of Defense Medal for Meritorious Civilian Service. The award was presented at a ceremony held at the Stennis Space Center in Mississippi.

EdgeTech (Milford, Massachusetts) has appointed **Roger Caron** to manage its newly established Houston, Texas, office. He will be involved with all product sales and equipment leasing while initially being responsible for the Gulf of Mexico area.

DigiCOURSE Inc. (New Orleans) has announced that **Kim Fairweather** has joined the company and will focus on North and South America marketing with responsibility for deep water positioning products. **Jay Bole** has also joined the company and will be responsible for the same market with shallow water positioning products.

Eastman Kodak Co.'s (Rochester, New York) Commercial & Government Systems division announced that **Carl A. Marchetto** has joined the ranks as director, image acquisition systems, and v.p., commercial & government systems. The company also announced that **L. Charles Meeks Jr.** has been appointed the position of marketing and program development director and v.p., commercial & government systems. */st/*

Where is SeaWiFS? *By Dr. James A. Yoder*

Dr. James A. Yoder is professor and associate dean of oceanography at the Graduate School of Oceanography, University of Rhode Island. He is currently on a one-year temporary assignment to the Mission to Planet Earth Science Division (Code YS) at NASA headquarters, where he manages the Biological Oceanography Program. Yoder was a Jet Propulsion Laboratory visiting senior scientist assigned to NASA from 1986-1988, during the period when SeaWiFS was first conceived.

What happened to the National Aeronatutics & Space Administration's and Orbital Sciences Corp.'s (OSC) sea-wide field sensor (SeaWiFS)? If and when will it be launched? Why is it taking it so long? Is "SeaWiFS will be launched soon" now the fourth great lie? I have been either asking or trying to answer these questions for almost 10 years. I recently moved (temporarily) from University of Rhode Island to NASA headquarters, so it is my turn again to answer, rather than ask, these questions.

I will attempt to do so with this article but, first, some background.

I first came to NASA Headquarters in summer 1986 to serve a two-year term as a program manager in the Ocean Branch. In the political and budget climate of the times, a business-industry partnership was the only U.S. option for an ocean color mission for the early 1990s. EOSAT Corp. (at that time, a joint venture between Hughes and RCA) was particularly receptive to the partnership idea. EOSAT managed the Landsat program under contract with NOAA.

In late 1986, EOSAT proposed a partnership to put a small and simple four-channel ocean color scanner (SeaWiFS), to be built by Hughes, on the Landsat-6 satellite. Under the partnership concept, NASA investigators could use SeaWiFS data for research and EOSAT would retain the rights to sell data—particularly real-time data—to commercial users and for government operations. In 1986, Landsat-6 was scheduled for launch in 1990.

Thus, a ride on Landsat-6 seemed the earliest option for an ocean color scanner to replace the coastal zone color scanner (which stopped operating in 1986) to support commercial, operational, and scientific applications. Both NASA and EOSAT management approved the plan and the partnership was born.

During 1987, SeaWiFS design and technical specifications went through many iterations based on advice from university and federal scientists as constrained by technical, size, and cost considerations. If I recall correctly, the final SeaWiFS configuration planned for Landsat-6 was for five visible and near-infrared bands for ocean pigment and atmospheric correction and for three infrared bands for sea-surface temperature (SST).

In the summer of 1988, SeaWiFS was kicked off the Landsat-6 satellite owing to a contract dispute between NOAA, NASA, and EOSAT. (Losing the ride on Landsat-6 turned out to be a blessing in disguise since the satellite went in the drink off California following an unsuccessful launch attempt in the mid-1990s.) Hughes and NASA still had an agreement to build the sensor, but there was no ride for it.

A year or so later, NASA formed a new partnership with Orbital Sciences to put the SeaWiFS sensor on OSC's new concept for a small satellite (SeaStar) to be launched on their new concept for a launch vehicle (Pegasus).

Thus, we now had a new instrument to be installed on a new satellite to be launched with a new launch vehicle backed by a new concept of NASA-industry partnership. The key word is "new" and the answer to "Why is it taking so long?" should now be obvious to anyone who has developed complex instruments and mechanical systems to work in space, the ocean, or other harsh environments. "New" takes time.

So where are we?

In anticipation of a SeaWiFS launch in 1993 or 1994, NASA created a SeaWiFS Project Office at Goddard Space Flight Center (GSFC) in the early 1990s and selected a large science team, including representation from many countries. What have we been doing all this time?

The science team has continued to work with CZCS and other satellite data, collected in-water bio-optical measurements for algorithm development and validation, developed new approaches to correct satellite data for the effects of the atmosphere, and used aircraft observations where possible to support Joint Global Ocean Flux Study (JGOFS) process studies and other oceanographic programs.

The SeaWiFS Project at GSFC has also been busy and is the leading U.S. group for technical issues related to satellite ocean color measurement . The project interacts almost daily with OSC on technical "challenges" related to calibrating, testing, and refining SeaWiFS and SeaStar. Others in the project are now involved in evaluating, calibrating, and developing software for the ocean color temperature sensor (OCTS) launched last fall on the Japanese Space Agency's Advanced Earth Observing Satellite (ADEOS).

NOAA and NASA are working together to process and distribute OCTS imagery for U.S. coastal waters, including those off Alaska, Hawaii, and Guam. The SeaWiFS Project is also working on technical issues related to acquisition of data for U.S. coastal waters from the modular opto-electronic Scanner (MOS), a narrow swath ocean color scanner built by Germany and launched by India on its P-3 satellite last spring.

But all this still begs the main question: where is SeaWiFS?

SeaWiFS is on the SeaStar satellite located in one of OSC's test facilities near Germantown, Maryland. It is in the final stages of testing (pre-launch testing tries to simulate the launch and the space environment and, in effect, tries to "break" the satellite and sensors). OSC's launch vehicle, Pegasus XL, had two early failures, followed by three successful launches, followed by another failure at the end of last year. OSC engineers believe they have corrected the problem leading to the last failure and expect the XL to be soon re-certified for launch.

Assuming that SeaWiFS and SeaStar pass their final tests and that the XL is re-certified for launch in the near future, SeaWiFS **COULD** be launched as early as late spring or early summer 1997.

What lessons have I learned from my SeaWiFS experience over the past 10 years? First and foremost, I appreciate just how difficult it is to design, build, test, and launch even relatively simple new space systems. The beauty of one of NASA's early remote sensing programs, Nimbus, was that the same basic satellite design and the same launch vehicle were used time after time to launch new instruments. The success rate was very high and the time between missions relatively short. This is also the concept behind NOAA's polar-orbiting weather satellites, which include the advanced very high resolution radiometer (AVHRR)—an instrument used by oceanographers for more than a decade to determine sea-surface temperatures. Secondly, true partnerships (which are different from traditional contractual agreements in that both parties share risk) between government and industry for space missions are possible—but not yet easy. In the big picture, a successful NASA-OSC partnership leading to successful SeaWiFS launch and operations may be a more important legacy for space science than even imagery from the new sensor. */st/*

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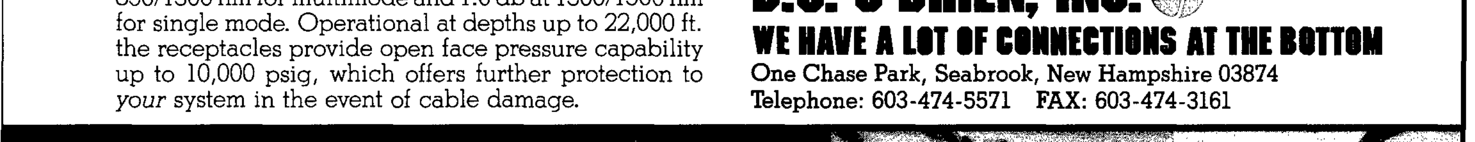

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