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EDITOR: HAROLD A. SABBAGH

FALL 1987 (USPS 420-910)

PRESIDENT'S COMMENTS

Anthony I. Eller

The most apparent change over the past two years that can be observed in the Oceanic Engineering Society is its continuing rapid evolution from the former Council of Oceanic Engineering, with representatives from 18 IEEE Societies giving it a broad base of loosely related technical areas, to its present set of eight Technology Committees that provide a closely integrated focus within oceanic engineering. Within the Technology Committees, substantial organizational growth is seen in Oceanic (including Arctic) Instrumentation and Measurement for both *in situ* and remote capabilities, in Acoustic Systems, and in EE support systems for Underwater Vehicles.

The growing focus of our technical strength is supported also by the strong focus provided by the special issues stimulated by Stan Ehrlich in the Journal of Oceanic Engineering.

Further evidence of technical growth can be found within the AdCom whose six new members, beginning their three-year terms this past January, 1987, all have based their careers on technical participation in some aspect of oceanic engineering.

The policy of the Executive Committee continues to be directed toward the goal of developing relatively small and highly focussed technical conferences or workshops. Our expectation is that such workshops will strengthen the Technology Committees and local Chapters. Plans for new workshops are still preliminary and will be announced, when appropriate, in this Newsletter.

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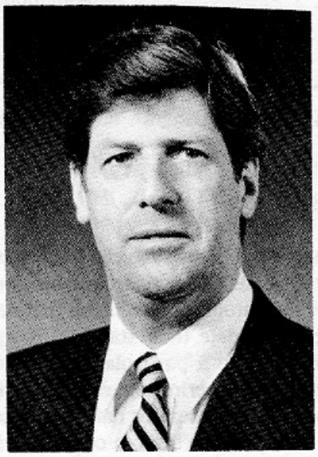
CAMPAIGN '87

This fall members of IEEE Division IX will elect a new Division Director. Dr. Donald M. Bolle, Dean of Engineering at Lehigh University, is a candidate for that position. Don was a founding father of the Oceanic Engineering Society, and has worked assiduously for it since. His statement follows.

CANDIDATE'S STATEMENT

As I approach my thirtieth year as a member of IEEE and its predecessor societies, I have had the chance to observe and participate in the enormous changes that have taken place. The impact that we, as an institute, have had on major technical developments has been crucial through our functioning as the principal source of archival material, and the organizing of conferences that play such an important part in the exchange of information so essential to new technologies. There are many ways in which the institute services our profession, such as the recognition through awards of particularly meritorious accomplishments and when we take part in advisory bodies. Clearly, the health and strength of our institute is important to us, individually as well as collectively. In two decades of participation in institutional affairs, at the local as well as the national level, I have become familiar with the complexities that are inevitable in an undertaking the size of the IEEE. I have been involved in well established activities, as well as new ventures, such as the Journal for Oceanic Engineering, for which I served as founding editor, and the formation of the Oceanic Engineering Society from the Oceanic Coordinating Council. I am enthusiastic about the continuing development of our institute, and would embrace an opportunity to further the interest of our institute and its members as Director of Division IX.



***DONALD M. BOLLE** was born in Amsterdam, The Netherlands, on March 30, 1933. He received the B.Sc. degree with honors in electrical engineering from Kings College, Durham University, England, in 1954, and the Ph.D. degree in electrical engineering from Purdue University, West Lafayette, IN, in 1961.*

From 1954 to 1955, he was a Research Engineer with the Electrical Musical Industries, Middlesex, England. He taught at Purdue University from 1956 to 1962, first as an Instructor, then as an Assistant Professor in Electrical Engineering. He spent the academic year 1962-1963 in the Department of Applied Mathematics and Theoretical Physics, Cambridge University, England as an NSF Postdoctoral Fellow. In 1963, he joined Brown University, Providence, RI, where he was Professor of Engineering. He was the Chandler Weaver Professor and Chairman of the Department of Electrical and Computer Engineering at Lehigh University, Bethlehem, PA from 1980-1981. He now holds the position of Dean of the College of Engineering and Physical Sciences at Lehigh University. He was a Visiting Professor at the Institute for High-Frequency Techniques of the Technical University of Braunschweig, Germany, in 1967, at the University of Colorado, Boulder, in 1972 and Senior Research Fellow at University College, London, England 1979-80.

Dr. Bolle is a member of Eta Kappa Nu, Tau Beta Pi, Sigma Xi, ASEE, AAAS, and a fellow of the IEEE.

MAGNETIC GUIDANCE OF AUTONOMOUS VEHICLES

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(Reprinted from Proceedings OCEANS '86)

ABSTRACT

Increasing interest in underwater autonomous vehicles has resulted in a search for suitable guidance systems. Magnetic techniques could provide supplementary guidance for autonomous vehicles that need occasional precise position fixes to update their standard navigational systems, or that want to return to a particular spot on the ocean bottom with great accuracy. A small permanent magnet resting at a precisely known spot on the ocean's bottom or naturally occurring key features in a magnetic survey of the bottom could provide the necessary magnetic signal. Of the several magnetic guidance approaches considered, an adaptive search technique seems the most promising. In adaptive search, the location of each successive search pass is determined by information gathered on the previous pass. Computer simulation results show that three search passes are usually sufficient to locate the center of the magnetic anomaly to within several feet. The favored sensor configuration is a scalar magnetometer whose outputs are successively subtracted along the path of sensor motion to form an approximation to the spatial gradient of the sensor's output. Data interpretation for this technique appears simple enough to be done automatically by either algorithmic or artificial intelligence techniques.

1. INTRODUCTION

This paper reviews some aspects of using magnetic guidance for underwater autonomous vehicles. Magnetic guidance could provide supplementary guidance for autonomous vehicles that occasionally need precise position fixes to update their standard navigational systems. It also could provide a means for such vehicles to return with great accuracy to a desired location.

We assume that a previously surveyed bottom-resting magnetic anomaly is known to exist within a designated area. The autonomous vehicle is capable of navigating to the vicinity of this area with its standard navigational system. However, once inside the area, a navigational system with greater accuracy is required to position the vehicle precisely over the anomaly in order to update the vehicle's position. The anomaly's position may be accurately known in a permanent global coordinate system or it may simply be a convenient reference point in a local (and temporary) system of coordinates. For the purposes of the current work, we have assumed that the magnetic anomaly is at the center of a square whose sides are 100 feet long. The vehicle's standard navigational system is assumed accurate enough to take the vehicle to a point somewhere in this square, but supplementary magnetic guidance is required to position the vehicle precisely over the anomaly. The square's dimensions are determined both by the vehicle's standard navigational system and the capabilities of its magnetic guidance system. By choosing a 100-foot square, an off-the-shelf proton magnetometer (or, perhaps, two such sensors whose outputs are subtracted to form a gradiometer) could be used to locate small and inexpensive permanent magnets used as magnetic beacons. For much larger squares, either stronger magnetic anomalies or a more sensitive magnetometer, e.g., optically pumped types, might be required. In addition to permanent magnets, naturally occurring key features in a magnetic survey of the area could be used as suitable magnetic anomalies.

The current investigation used a computer simulation to produce numerical results. The magnetic anomaly has been approximated as a point dipole whose field may be influenced by the local earth's field. We have looked at the dipole's signal under no noise conditions, so far, in order to first establish concept feasibility. We assume sensing is done passively with scalar magnetometers, which sense the component of the anomaly's field lying along the earth's field. The magnetometers are used either singly or in pairs with their outputs subtracted so as to form a gradiometer. The interpretation of the sensor data is currently being done by a man-in-the-loop. However, the data interpretation appears simple enough to be performed automatically either by algorithmic or artificial intelligence techniques.

Section 2 will discuss characteristics of the point dipole model used for the magnetic anomaly. Section 3 compares several magnetic guidance techniques and concludes that adaptive magnetic search deserves priority for further study. Adaptive magnetic search is a technique where the location of each successive search pass is determined by information gathered on the previous pass. Section 4 summarizes our numerical results to date using adaptive search. Finally, we present our main conclusions and plans for future work.

2. MAGNETIC ANOMALIES

The magnetic anomaly simulated to date has been that of a point magnetic dipole of total (vector) magnetic moment $\underline{M}$. The dipole approximation is a good one for magnetic objects or bottom features with dimensions that are small with respect to the distance between the anomaly's center and the sensor. The coordinate system assumed for the dipole is shown in Figure 1. The dipole is located at the coordinate origin and its magnetic moment $\underline{M}$ makes an angle Theta with the vertical Z-axis and an angle Phi with the horizontal X-axis. For convenience, the direction of magnetic north is chosen in the plus X direction. The earth's magnetic field (represented by the vector $\underline{F}$) then lies in the XZ plane and makes an angle Dip with the X-axis. Note that in the northern hemisphere the earth's magnetic field points downward, while in the southern hemisphere it points upward.

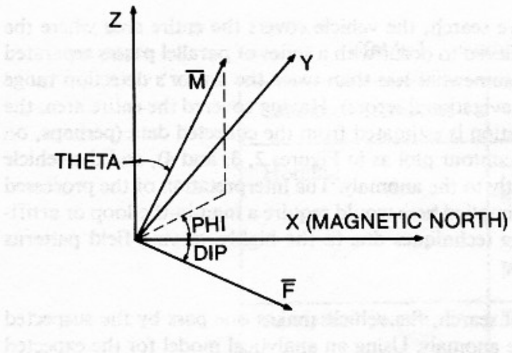

Figure 1. Magnetic Dipole Geometry

We assume that a scalar magnetometer is being used as the sensor. This type of magnetometer, e.g., a proton magnetometer, measures the magnitude, but not the direction, of the total field present. Thus, scalar magnetometers are insensitive to changes in sensor orientation that could be caused by vehicle motions. The total field present is the vector sum of the dipole's field and the earth's field. If the dipole's field is small with respect to the earth's field (as is almost always so in practice), a scalar magnetometer really measures the component of the dipole's field parallel to the earth's field.[1]

A computer model of the dipole's field as seen by a scalar magnetometer has been developed. Computed sensor output varies as a function of dipole orientation, earth's field dip angle, and sensor altitude but is normalized with respect to the magnitudes of the magnetic moment and the earth's field. In the next stage of our work, we plan to model the effects of sensor and ambient noise on computed sensor output.

Figures 2, 3, and 4 show contours of sensor output as computed from our model. In Figure 2 the magnetic moment is pointing along the plus Z-axis, while in Figures 3 and 4 it lies along the plus X-axis and plus Y-axis, respectively. These figures represent a plan view of the bottom with the X-axis horizontal and the Y-axis vertical in each figure. The location of the dipole, in the center of each figure, is indicated by the small cross. Positive contour lines are solid, while negative contour lines are dotted. The numerical values of each contour line (not shown) are proportional to the magnitudes of the magnetic moment and the earth's field. Each figure represents a square area with sides 100 feet long. Tic marks are at 2-foot intervals. Sensor altitude (Z) above the dipole was 10 feet and the earth's field dip angle was 61 degrees (a value typical of Florida).

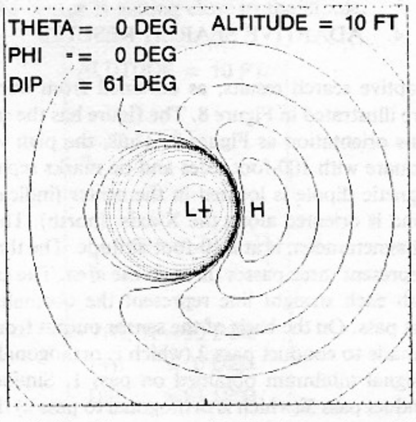

Figure 2. Scalar Magnetometer Contours for a Z-Axis Dipole

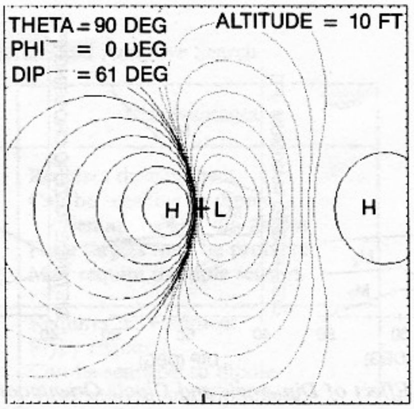

Figure 3. Scalar Magnetometer Contours for a X-Axis Dipole

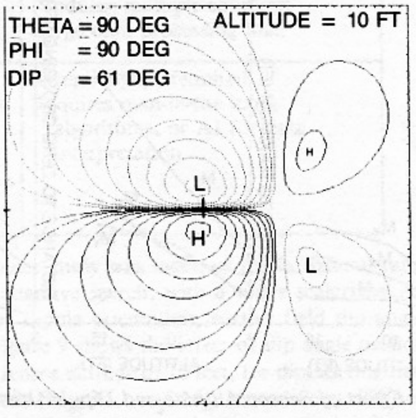

Figure 4. Scalar Magnetometer Contours for a Y-Axis Dipole

It is apparent from Figures 2, 3, and 4 that sensor output is a strong function of dipole orientation. However, for magnetic guidance we are more interested in how the positions of key features of these plots change with respect to the dipole's location for changes in dipole orientation, earth's field dip angle, and sensor altitude. The key features apparent in these figures are relative maxima (H), relative minima (L), and zero-crossings (the regions where the positive and negative contours converge). Figure 5 shows the effect of dip angle and dipole orientation on the horizontal distance between these key features and the dipole's location at an altitude of 10 feet. In the figure, M_Z represents a dipole along the Z-axis, while M_X and M_Y represent dipoles aligned along the X- and Y-axis, respectively. The distance to the zero-crossing shown in the figure represents the distance to that zero-crossing closest to the dipole's location. The range of dip angles shown encompasses places as far north as southern Greenland and as far south as the northern tip of South America. For the equivalent range of dip angles in the southern hemisphere, the minimum and maximum feature curves would interchange (because the sign of the dip angle changed) while the zero-crossing curves would stay the same.

Figure 6 shows the effect of altitude and dipole orientation on these same key features. While increasing dip angle can increase, decrease, or have negligible effect on the key features (depending on the feature and dipole orientation), increasing altitude clearly increases all distances since the pattern of contour lines stretches as altitude increases.

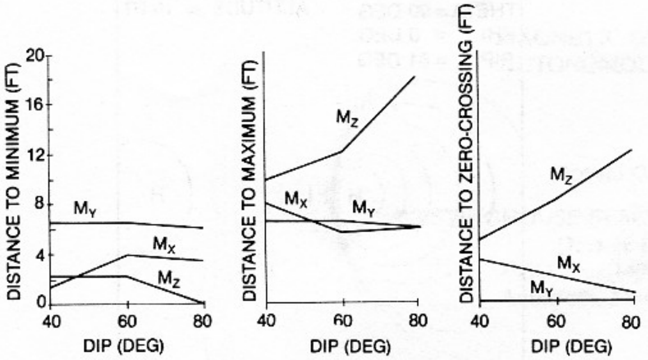

Figure 5. Effect of Dip Angle and Dipole Orientation on Horizontal Distances to Key Features (Altitude = 10 Ft)

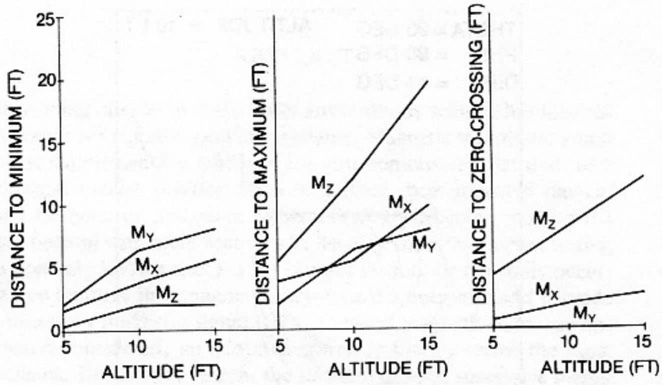

Figure 6. Effect of Sensor Altitude and Dipole Orientation on Horizontal Distances to Key Features (Dip Angle = 61 Deg)

3. GUIDANCE TECHNIQUES

There are two basic approaches to guiding a vehicle to a magnetic anomaly. The vehicle can use its sensor to continuously "home" on some characteristic of the magnetic field, e.g., field strength, or it can search for the anomaly, determine the anomaly's location somehow from the sensor output, and then proceed directly to the now known position. Figure 7 illustrates the homing approach and three different versions of the search approach.

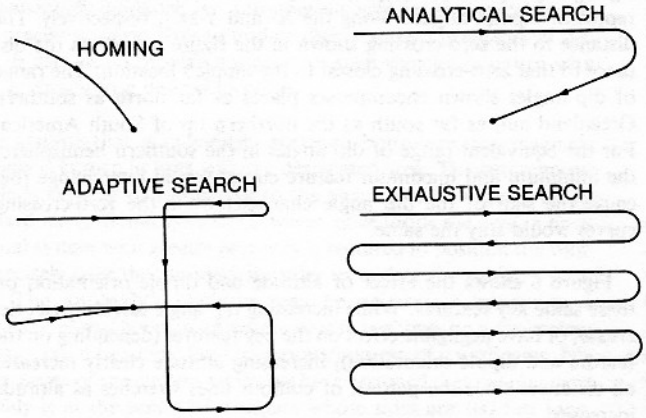

Figure 7. Guidance Techniques

In exhaustive search, the vehicle covers the entire area where the anomaly is believed to occur with a series of parallel passes separated by a distance somewhat less than twice the sensor's detection range (to allow for navigational errors). Having covered the entire area, the anomaly's location is estimated from the collected data (perhaps, on the basis of a contour plot as in Figures 2, 3, and 4), and the vehicle proceeds directly to the anomaly. The interpretation of the processed sensor output implied here would require a man-in-the-loop or artificial intelligence techniques due to the highly varying field patterns that can occur.

In analytical search, the vehicle makes one pass by the suspected location of the anomaly. Using an analytical model for the expected sensor output from a dipole, the anomaly's position and magnetic moment is determined by fitting the model's predictions to the observed data. Once the position has been determined and the anomaly classified as the one of interest (on the basis of its magnetic moment), the vehicle proceeds directly to the anomaly.

In adaptive search, the vehicle first makes a pass through the area known to contain the anomaly. On the basis of information gathered from this first pass, i.e., the location on the vehicle's trajectory of a sensor output maximum, minimum, or zero-crossing, a decision about where to make an orthogonal trajectory is made. On the basis of similar information from the second pass, a decision is made about where to make a third trajectory orthogonal to the second pass. This process continues until the indicated locations of key features on successive passes converge. Geologists use this technique to locate underground magnetic anomalies.[1] Usually three passes are sufficient for the geologist's purposes.

Exhaustive search is time consuming. We have eliminated it from further consideration until the remaining more promising alternatives have been investigated. Table 1 summarizes a general comparison of homing, analytical search, and adaptive search. We have only briefly considered the homing and analytical search techniques in our current work. Homing appears difficult to accomplish because of the strong dependence of sensor output on dipole orientation and susceptibility to false targets. Analytical search requires development of a suitable signal model and, probably, multiple sensors. Existing models are known to require very high signal-to-noise ratios, to be sensitive to orientation effects, and to have multiple solutions arising from the nonlinear nature of the equations involved.

We concentrated our first efforts on adaptive search. This technique, proven in the field by geologists, is simple and appears to be relatively insensitive to dipole orientation and dip angle.

4. ADAPTIVE SEARCH RESULTS

Typical adaptive search results, as obtained from our computer simulation, are illustrated in Figure 8. The figure has the same geometry and dipole orientation as Figure 3. Thus, the plan view of the bottom is a square with 100-foot sides and tic marks separated by 2 feet. The magnetic dipole is located in the center (indicated by the small cross) and is oriented along the X-axis (north). The sensor, a single scalar magnetometer, is at a 10-foot altitude. The three straight lines shown represent three passes through the area. The curved lines associated with each straight line represent the normalized sensor output for that pass. On the basis of the sensor output from pass 1, a decision was made to conduct pass 2 (which is orthogonal to pass 1) through the signal minimum obtained on pass 1. Similarly, it was decided to conduct pass 3 (which is orthogonal to pass 2) through the minimum obtained on pass 2. After pass 3, the dipole's location is

Table 1. Comparison of Homing, Analytical Search, and Adaptive Search

Guidance Technique	Advantages	Disadvantages
Homing	No flyby required Minimum time spent in reaching feature Small data processing load No man-in-the-loop or AI required	Requires development Can be sensitive to dipole orientations and dip angles False targets may be problem May require multiple sensors
Analytical Search	Small time spent in reaching feature Can provide moment estimate as well as moment position No man-in-the-loop or AI required	Requires development Flyby required Can be sensitive to dipole orientation and dip angles Requires high signal-to-noise ratios May require multiple sensors Produces multiple solutions Large data processing load
Adaptive Search	Proven technique in geology Modest time spent reaching feature Simple technique Small data processing load Not as sensitive to dipole orientation or dip angles	Several flybys required Requires man-in-the-loop, algorithms, or AI for data interpretation

estimated to be at the zero-crossing on this last pass. The horizontal distance from this zero-crossing to the dipole's true location is 1.8 feet.

The decision as to which sensor output feature (maximum, minimum, or zero-crossing) should determine the position of the next pass can require some experience. For example, after pass 3 in Figure 8, the estimated dipole's location was chosen to be at the zero-crossing since the peaks on either side of the zero-crossing were of about the same amplitude. However, after pass 1, the zero-crossing was not chosen to locate pass 2 since the amplitude of the minimum greatly exceeds that of the maximum. A choice between key features in early passes seems to affect final location accuracy very little. In fact, choosing the zero-crossing of pass 1 in Figure 8 to locate pass 2 led to the same final horizontal range error of 1.8 feet after three passes. However, choice of key features in the final passes can affect accuracy. After the third pass in Figure 8, choosing the minimum as the estimated location of the dipole, instead of the zero-crossing, would have increased the horizontal range error to 3.4 feet. Fortunately, the choice between key features is usually clearest in the final passes when the sensor is getting close to the dipole.

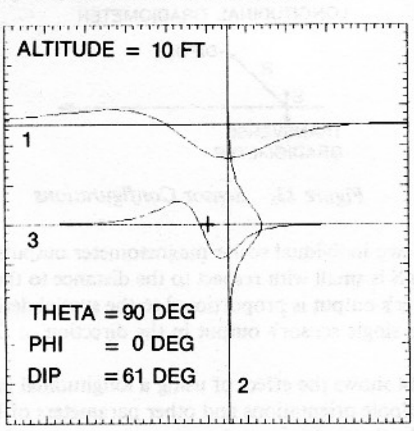

Figure 8. Adaptive Search

A computer study was made of the horizontal range errors produced by adaptive search, with a single scalar magnetometer, as a function of dipole orientation, earth's field dip angle, and sensor altitude. Figure 9 shows the effect of dip angle on horizontal range error, at a sensor altitude of 10 feet, for dipoles oriented along the X, Y, and Z-axis (M_X, M_Y, and M_Z, respectively). Figure 10 shows the effect of altitude on horizontal range error, at a dip angle of 61 degrees, for the same dipole orientations. In each figure, three search passes were made, and the dipole's position was estimated on the basis of sensor output taken during the third pass. The indicated horizontal range errors are quite small over the entire range of parameters and have a clear tendency to decrease with increasing dip angle and increase with increasing altitude.

Upon examining the computer output for the errors shown in Figures 9 and 10, it was noticed that the horizontal errors along the Y-axis were usually zero or close to zero so that the entire horizontal range error was coming from the X-axis error. This was traced to the symmetry (or anti-symmetry) of the sensor's output about the X-axis for the axial dipole orientations M_Z, M_X, M_Y as is evident from Figures 2, 3, and 4, respectively. This symmetry in Y means that $Y = 0$ is always the exact location of a sensor output maximum, minimum, or zero-crossing and leads to very small errors in the estimated Y coordinate. Accordingly, some dipole orientations without this type of symmetry were investigated to see what the impact on horizontal range error would be. For example, Figure 11 plots the contours of sensor output for a dipole in the XY plane, i.e., Theta = 90 degrees, which makes an angle of 60 degrees with the X-axis, i.e., Phi = 60 degrees. The earth's field dip angle is 61 degrees, and sensor altitude is 10 feet. Figure 11 should be compared with Figure 3, where the dipole is along the X-axis, or Figure 4, where the dipole is along the Y-axis. The symmetry in Y has disappeared in Figure 11 because of the dipole's off-axis orientation.

A series of adaptive searches was run for dipole orientations similar to that of Figure 11. The dipole was in the XY plane and the azimuthal angle (Phi) was varied from 0 to 90 degrees. Figure 12 plots the resulting horizontal range errors as a function of Phi. The results for Phi = 0 and 90 degrees correspond to values listed previously (at the same 10-foot altitude) in Figure 10 for M_X and M_Y, respectively. However, the degrading effect of intermediate azimuthal angles (resulting from the asymmetry in both X and Y) is now apparent. Figure 12 also shows the effect of increasing the number of sensor passes beyond three. For the curve labeled "More than 3 Passes," adaptive search passes were continued until no further discernible change in estimated dipole location was obtained. For the step size used in the simulation, this smallest discernible change amounted to ±0.1 feet. This condition was typically reached in four to six passes. It is evident from Figure 12 that simply making more passes helps reduce horizontal range error very little and may even hurt if the key feature "locked on to" is not close to the dipole's true location.

In an effort to lower the high points of Figure 12, a gradiometer sensor simulation was developed and exercised. In addition to possibly "sharpening" the response to key features, a gradiometer could be helpful in an operational system by cancelling ambient noise. The two types of gradiometers considered are shown in Figure 13 along with the single magnetometer case. In a longitudinal gradiometer, the two scalar magnetometers are separated by a distance S that lies along the direction of sensor motion. In a transverse gradiometer, the distance S separating the two scalar magnetometers lies in a horizontal plane and is orthogonal to the direction of sensor motion. In either type of gradiometer, the output consists of the difference between the two individual scalar magnetometer outputs. If the sensor separation S is small with respect to the distance to the dipole R, the gradiometer's output is proportional to the spatial derivative, or gradient, of a single sensor's output in the direction of S.

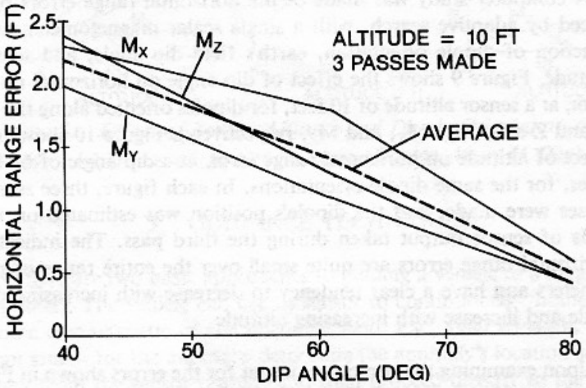

Figure 9. Effect of Dip Angle on Magnetometer Adaptive Search Horizontal Range Error

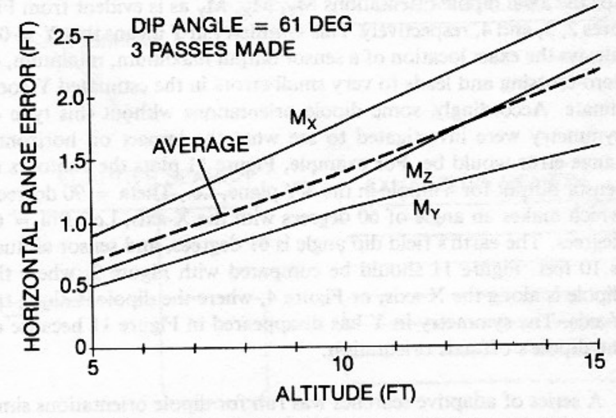

Figure 10. Effect of Altitude on Magnetometer Adaptive Search Horizontal Range Error

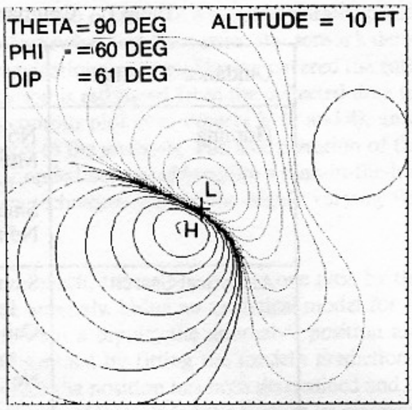

Figure 11. Scalar Magnetometer Contours for an Off-Axis Dipole

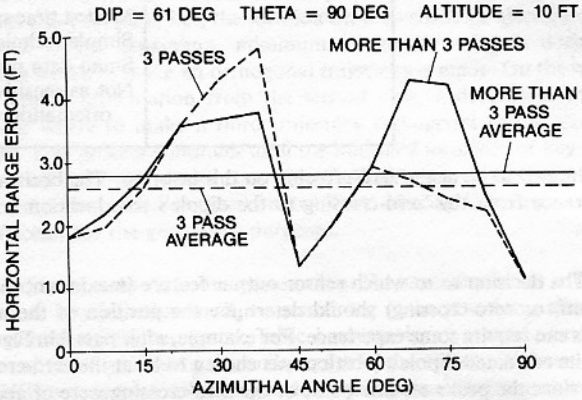

Figure 12. Effect of Magnetic Moment's Azimuthal Angle on Magnetometer Adaptive Search Range Error

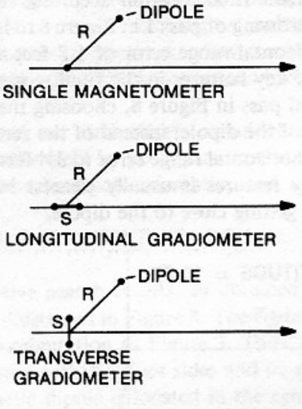

Figure 13. Sensor Configurations

Figure 14 shows the effect of using a longitudinal gradiometer for the same dipole orientations and other parameters of Figure 12. The sizable reduction in horizontal range errors compared to Figure 12 is readily apparent. Again, the effort expended in making more than three passes produces negligible result. The sensor spacing is 6 feet in Figure 12. Decreasing this spacing to 1 foot produced little change in the results.

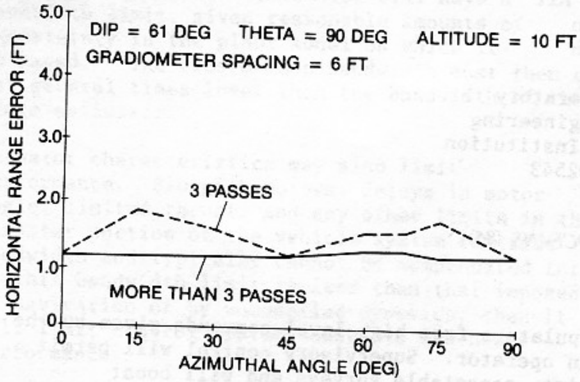

Figure 14. Effect of Magnetic Moment's Azimuthal Angle on Longitudinal Gradiometer Adaptive Search Horizontal Range Error

Figure 15 shows the effect of using a transverse gradiometer under the same conditions as the longitudinal gradiometer in Figure 14 and the single magnetometer in Figure 12. The transverse gradiometer results are significantly poorer than those of the longitudinal gradiometer and are about the same as those of the single magnetometer.

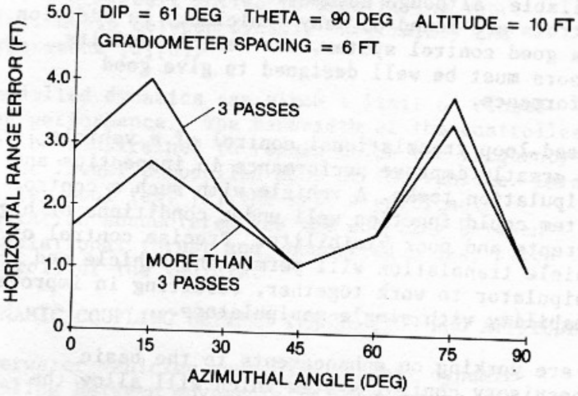

Figure 15. Effect of Magnetic Moment's Azimuthal Angle on Transverse Gradiometer Adaptive Search Horizontal Range Error

The longitudinal gradiometer has also been evaluated over the same range of earth's field dip angles, sensor altitudes, and axial dipole orientations as the single magnetometer was in Figures 9 and 10. Results are equivalent to the excellent single magnetometer results shown in those figures. Hence, the longitudinal gradiometer produces horizontal range errors much smaller than those of a single magnetometer for off-axis dipole orientations and produces errors that are about the same as those of a single sensor for axial dipole orientations, under the conditions so far investigated. In an operational system, it may be possible to form an effective longitudinal gradiometer by using just a single magnetometer and subtracting successive measurements along the sensor's path of motion.

5. CONCLUSIONS

Of the approaches so far looked at for magnetic guidance of underwater vehicles, adaptive search using scalar magnetometers appears the most promising. Adaptive search is a simple procedure but leads to localization errors of only several feet in reacquiring a position over a previously surveyed magnetic dipole. The dipole anomaly could be either natural or of man-made origin. The localization accuracy holds over wide variations in the dipole's orientation, the earth's field, and sensor altitude. The most accurate sensor configuration investigated so far consists of two sensors separated along the direction of motion whose outputs are subtracted to form a longitudinal gradiometer. In an operational system, this configuration may be achieved by using a single sensor and subtracting successive sensor outputs as the vehicle moves.

Adaptive search data interpretation is currently being done by a man-in-the-loop. However, the interpretation appears simple enough to be performed either algorithmically or by present day artificial intelligence techniques that should be available to autonomous vehicles of the future.

Plans for our future work in the area include the following:

- further dipole orientation studies at intermediate angles to ensure horizontal range errors remain small;
- model sensor and ambient noise;
- investigate cases with more than one dipole present;
- investigate automatic data interpretation using either algorithmic or artificial intelligence techniques

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DESIGN OF UNDERWATER VEHICLES FOR HIGH PERFORMANCE CONTROL

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ABSTRACT

Design considerations for high performance control of remotely operated underwater vehicles are presented, focussing on the performance limits imposed by navigation, actuators, dynamic uncertainty, control strategies, and the dynamics of the vehicle. As coupling between translation and attitude present a major impediment to high bandwidth control, techniques for reducing this coupling are presented. In-water test data is presented for the new JASON Junior vehicle currently being designed and built at the Deep Submergence Laboratory.

INTRODUCTION

Remotely operated underwater vehicles (ROV's) can be made more capable through the use of automatic controls. If all movements of a vehicle are automated, the system can be made more capable and easier to operate. To obtain good closed-loop performance however, careful attention must be paid to all elements of the system, including sensors, control algorithms, and the dynamics of the vehicle. A solid closed-loop control system for all vehicle motions can then serve as the foundation of a supervisory control system that allows the human operator to command movement from a high level interface.

This paper examines the issue of dynamic coupling between translation and attitude. This coupling is pronounced in many vehicles. Earlier analytical and experimental work has shown such coupling to be a signficant problem both for manual and automatic control. In manual control, such coupling is disorienting to the operator and reduces video quality. In automatic control, this coupling can form a significant limit on the performance in translation.

This work is being applied to JASON and its predecesor JASON Jr., ROV's for deep ocean scientific applications under development at Woods Hole. JASON will be deployed from the ARGO optical and acoustic imaging vehicle [1], while JASON Jr. will be deployed from the manned submersible ALVIN. The JASON program emphasizes the refinement of supervisory control techniques that will control and coordinate the movements of the vehicle and manipulators from high level commands given by the human operator. Supervisory control will permit precise, repeatable surveys and will boost productivity in sampling.

In supervisory control a computer interacts directly with a process while a human operator manages the system. The foundations of the supervisory control system for an ROV will be closed-loop trajectory controllers. Closed-loop control of manipulator functions is common in the offshore industry today, and servo-controlled arms are available from several manufacturers. However, closed-loop control of vehicle translation is not available, although automatic depth and attitude controls are found on many vehicles. In addition to a good control system, the vehicle and its sensors must be well designed to give good performance.

Closed-loop translational control of a vehicle can greatly improve performance in inspection and manipulation tasks. A vehicle with such a control system could function well under conditions of high currents and poor visibility. Precise control of vehicle translation will permit the vehicle and manipulator to work together, resulting in improved capability with simple manipulators.

We are working on enhancements to the basic supervisory control system which will allow the operator to command the vehicle in coordinates which are referenced to the environment or task being performed. This reduces the number of degrees of freedom that the operator must manage, improves performance in many tasks, and eases operator workload [2].

LIMITS ON CLOSED-LOOP PERFORMANCE

Controller performance is restricted by the system bandwidth and dynamic uncertainty. Sorting out the most significant limiting factor in any given design is a complex task. Analytical tools to aid the design process are now under development [2][6].

In most demonstrations of closed-loop ROVs, the sensor bandwidth limit has been dominant, as low frequency acoustic navigation was employed [3,4]. Most acoustic navigation systems provide relatively coarse information at low update rates, and at long ranges time delays become substantial. A state estimator must be used to filter this data and to provide estimates of the unmeasured states (e.g., velocity). Any state estimator will have a bandwidth limit, given reasonable amounts of uncertainty in the plant model on which it is based. The closed-loop bandwidth must then be set several times lower than the bandwidth of the state estimator.

Actuator characteristics may also limit performance. Sluggish motors, delays in motor logic, limited thrust, and any other limits in the thruster portion of the vehicle system restrict bandwidth and typically cannot be compensated for. If this bandwidth limit is less than that imposed by navigation or by unmodelled dynamics, then it will limit control system bandwidth and hence performance.

Dynamic uncertainty will introduce severe performance limits. Uncertainties in vehicle models arise from two sources: simplifications in the vehicle model and errors in the model parameters. All vehicle models include simplifications which represent compromises between simplicity and accuracy. Similarly, the accuracy with which individual parameters can be determined can always be improved through more tank testing or more rigorous analysis. A new nonlinear control system design technique call sliding control is particularly well suited to quantifying the relationship between dynamic uncertainty and performance [5][6].

Unmodelled dynamics can place a limit on closed-loop performance. The bandwidth of the controller must be constrained to remain below the frequency of the lowest unmodelled mode of the vehicle. In an earlier pool test [2], the most significant limitation encountered was the coupling between translational thrust and unmodelled modes, pitch and roll of the vehicle.

DYNAMIC COUPLING BETWEEN TRANSLATION AND ATTITUDE

Underwater vehicles generally exhibit dynamic coupling between movements in translation and attitude. As the vehicle translates, imbalances between inertial and drag effects produce torques about the center of mass of the vehicle. These moments combine with the spring-like torques produced by separation of the centers of buoyancy and gravity to produce oscillations in pitch and roll. Typically the oscillations are lightly damped and extremely pronounced.

These oscillations cause problems in both manually controlled and automatic operation. Under manual control, the oscillations cause operator fatigue and disorientation. Video quality is reduced, and the operation of scanning sonars and similar equipment is greatly disrupted. Under automatic control, these oscillations can be accentuated even more, particularly if high bandwidth control is used. If the coupling is not considered in the design of the translational controller, it can make the system unstable.

In an earlier test of closed-loop translation, the frequency of the translation-attitude coupling was found to be the major limit to overall performance. The vehicle responded to a step input in horizontal thrust by pitching upward. The navigation responder, fixed to the bottom of the vehicle, yielded an ambiguous superposition of translation and attitude changes. If the control system bandwidth was set near the natural frequency of the vehicle in pitch or roll, the system became unstable.

This is a classic example of unmodelled vehicle dynamics limiting available system bandwidth. A decrease in the coupling to the mode can reduce the magnitude of the oscillation, but will not change the frequency. The only ways to increase the bandwidth are to instrument the vehicle in the unmodelled mode and include the mode in the controller, or to increase the frequency of the mode.

MINIMIZING DYNAMIC COUPLING

Dynamic coupling can be minimized through several techniques. Increasing the metacentric height (separation between centers of gravity and buoyancy) will decrease coupling in several ways. Proper thruster placement will also decrease coupling, as will proper attention to hydrodynamic drag effects.

Increasing the metacentric height of a vehicle will increase the stiffness of the "torsional spring" that acts to keep the vehicle upright. As a result, the magnitude of oscillations will be less for a given torque disturbance, and the frequency of the oscillations will go up. Raising the frequency can prevent the attitude coupling from constraining translational bandwidth.

If a vehicle is to be actively controlled over a wide range in attitude, then an increase in the metacentric height will limit the maximum angles of pitch and roll. If active control is used only to keep the vehicle level, then an increase in metacentric height will reduce the load on the attitude controllers and actuators.

Tanaka, Mochizuki and Oda [7] present a series of simulations in which a large submersible (7800 kg dry weight) with variable metacentric height is commanded with a step input in forward thrust. The simulations were based on the results of scale model tests. Some of their results are presented in figure 1. The lowest metacentric height, 0.1 meters, results in oscillations through approximately 25 degrees of pitch with a period of approximately 40 seconds. To control such a vehicle in translation, controller bandwidth would have to be set below this frequency to avoid exciting it, and performance would be very poor. Alternatively, this mode could be actively controlled, which would require additional sensors, actuators, and a more complex controller.

By increasing metacentric height to .2 meters, the magnitude of the oscillations drops to about 7 degrees and, more importantly, the period falls to about 15 seconds. With the metacentric height at its design value of .3 meters the period is down to about 10 seconds, a more reasonable figure for a large vehicle of this sort, and oscillations are quite small.

Proper thruster placement can also decrease coupling. If the thrust forces are directed through the center of mass of the vehicle, then the vehicle will not accelerate in pitch or roll when thrust forces are applied for translation. The precise location of the center of mass may be difficult to predict, however, since "added mass" must also be taken into account.

Finally, the hydrodynamics of the vehicle can be designed so that torques are not generated by translation and also so that attitude oscillations are well damped. This can be achieved by placing the center of drag at the same level as the center of mass. Complete elimination of the torques is unlikely however, especially given the collection of lumpy shaped objects typically mounted on an ROV. Rotational damping can often be added fairly easily by fins or wings. Such damping can decrease the magnitude of oscillations and make them settle out sooner.

Ideally, the vehicle would have all thrust and drag forces act through the center of mass so no torques would be generated. While this cannot be achieved exactly. The center of drag changes with speed, for example, and the center of mass cannot be known with absolute certainty due to added inertia effects. However, this criteria can be approximately met.

JASON Jr. CASE STUDY

These principles were tested in the design of the JASON Jr. vehicle. While JASON Jr. does not have strict requirements for closed-loop translation control or integration with a manipulator, pursuing the techniques outlined earlier were valuable for improving its performance in manual control. Also, the exercise provides preliminary data for the JASON program, where such qualities will be required.

Methodology

The effort began with a review of existing vehicles. While details of the distribution of mass and buoyancy of most vehicles were not available, it was clear that some designers had pursued a similar track, while others ignored these criteria completely.

A list of all components was assembled, including thrusters, main housing, scientific payload, etc. A crude layout of the vehicle was then performed to meet the desired criteria. Detailed analysis was completed using weight and buoyancy data of all components using a spread sheet. The computer program was used to predict the location of the centers of gravity and buoyancy and moments of inertia. This information could then be combined with estimates of drag effects to position components, in particular the thrusters. Iteration between the spread sheet analysis and the drawing board then produced the final layout.

Design Results

The analysis guided the design in both the overall structure and shape of the vehicle as well as the detailed placement of the components.

A preliminary criteria was that the design would be restricted to four thrusters. Active control of pitch and roll were not possible, therefore passive attitude stability was mandatory.

An important conclusion was that vertical and horizontal thrust should be provided by a "vertrans" arrangement, despite the negative features of such a thruster layout. In this type of thruster layout, one thruster is placed on each side of the vehicle, with each able to contribute vertical and horizontal force components. When both thrust in the same direction, vertical force is generated. When operated differentially, side thrust is generated. The vertrans design was required, as vertical and side thrusters could not be placed to act near the center of mass. The principle advantage of such an arrangement is that flow doesn't have to move through the vehicle, allowing the thrusters to be placed on each side of a central pressure housing. Bad points of a vertrans design include inefficiency, a lack of symmetry when thrusting in different directions, and the placement of heavy thrusters up high.

The density of the syntactic foam used for buoyancy had a major influence on the structure of the vehicle. To work at the required depth (4000 meters), the foam is much heavier than in shallower vehicles. The particular foam chosen has a density of 35 lb/ft^3. Because of this high density, the center of mass of the vehicle will be located within the foam block, unless the vehicle was made very tall. A traditional open-frame ROV design has foam on top, thrusters in the middle, and payload on the bottom. Given the density of the foam required for operation at great depth and height limitations, an open frame design could not have the forward thrusters aligned with the center of mass. Instead it was necessary to place the forward thrusters up into cutouts in the foam.

The resulting design is shown in figure 2. All components were placed based on the analysis. The centers of mass and buoyancy, and their relationship with the thrusters, and moments of inertia were produced by the spread sheet. Results were as follows:

1. A metacentric height of over 1.3 inches could be obtained by proper component placement. This implies good static stability. The vehicle will tilt about 1 degree for each 0.4 ft-lb of torque.
2. A roll period of 2.0 seconds and a pitch period of 2.3 seconds was predicted.
3. The thrusters were placed so that their moment arms about the center of mass were less than 1.5 inches.

These results projected good performance for the vehicle. The substantial metacentric height implies that the vehicle will not be sensitive to torque disturbances. The pitch and roll periods will permit moderate translational bandwidth to be achieved without interaction.

POOL TEST

The stability and the dynamic coupling between translation and attitude were investigated experimentally for the JASON Jr. vehicle. The computed metacentric height was verified. Dynamic measurements of vehicle pitch and roll were made while applying translational thrust to the vehicle.

The metacentric height was checked by an inclining experiment. A foam block was attached to the vehicle on the end of a rod to induce a moderate rolling moment. The roll moment of the vehicle is related to the roll angle, vehicle weight, and the metacentric height by the following relationship:

$$M = (W*GB)*\phi$$

where:

M is the applied roll moment
W is the weight of the vehicle
GB is the metacentric height
ϕ is the roll angle

For a vehicle weight of 217 lb., an applied roll moment of 2.5 ft-lb produced a deflection of 5.0 degrees. The corresponding metacentric height was 1.5 inches (+- 20%), compared to the computed value of 1.35.

Dynamic coupling was investigated by imposing step thrust commands separately for forward and side thrust. The vehicle attitude was measured using a Watson 2 axis inclinometer, which integrates a pendulum with angular rate sensors to produce attitude measurements. Unlike a standard pendulum, the attitude measurements are independent of translational acceleration. Measurements were sampled at 10 hz. using 12 bit A/D conversion and recorded on a personal computer.

Figure 3 shows the pitch response and the corresponding thrust commands. Both forward thrusters are set to their maximum value for a period of about 4 seconds. The pitch data was processed using a 1 hz. first order smoother to remove noise. Initially the vehicle noses down slightly and then begins characteristic oscillations of about 2.7 seconds. Drag induced moments then cause the vehicle to pitch up. The magnitude of the largest displacment is less than 3 degrees.

The observed pitch period of 2.7 seconds compares well to the projected period of 2.3 seconds. The predicted value neglected added inertia, so it was expected to underestimate the period.

Figure 4 shows the roll response to side thrust. The roll data is processed in the same manner as the pitch data. For this axis, oscillations are much larger, with a maximum magnitude of about 15 degrees. The characteristic period is 2.4 seconds, again longer than the projected 2.0 seconds. Both acceleration and drag effects roll the vehicle in the same direction, and the response is extremely underdamped.

Several conclusions can be drawn from this data. The coupling is low for forward motion. For roll however, coupling is substantial.

The pitch oscillations will interfere with high bandwidth positional control if they are ignored. If the translational bandwidth is set higher than about 0.14 hz. (1/3 the frequency of the pitch mode), instability will result. However, if attitude is instrumented and this coupling considered in the design of the translational controller, pitch oscillations will not be large. This design succeeds in meeting the goal of low pitch coupling.

Likewise, roll oscillations will also interfere with high bandwidth control. If the roll coupling is treated as an unmodelled mode, translational bandwidth for lateral movement would be limited to about 0.16 hz. If the attitude is instrumented and the coupling included in the design, oscillations will still be large. For automatic control of translation, JASON Jr.'s performance in this axis should be improved.

Several changes to the vehicle would improve the roll characteristics. The vertrans thruster layout could be improved. Apparently they are inducing a larger moment about the center of mass than the forward thrusters, although they are aligned as well as the forward thrusters. More detailed investigation of the flow through the vertrans would be helpful. In addition, lowering the center of drag for lateral motion would be beneficial

CONCLUSIONS

High performance closed-loop translational control of an ROV requires careful attention to many system details. Strong performance limits can be imposed by navigation, actuators, dynamic uncertainty, control strategies, and the dynamics of the vehicle.

In this paper, the issue of dynamic coupling between translation and attitude was examined. Techniques to minimize such coupling were outlined and their application was illustrated in tests of the JASON Jr. vehicle.

ACKNOWLEDGEMENTS

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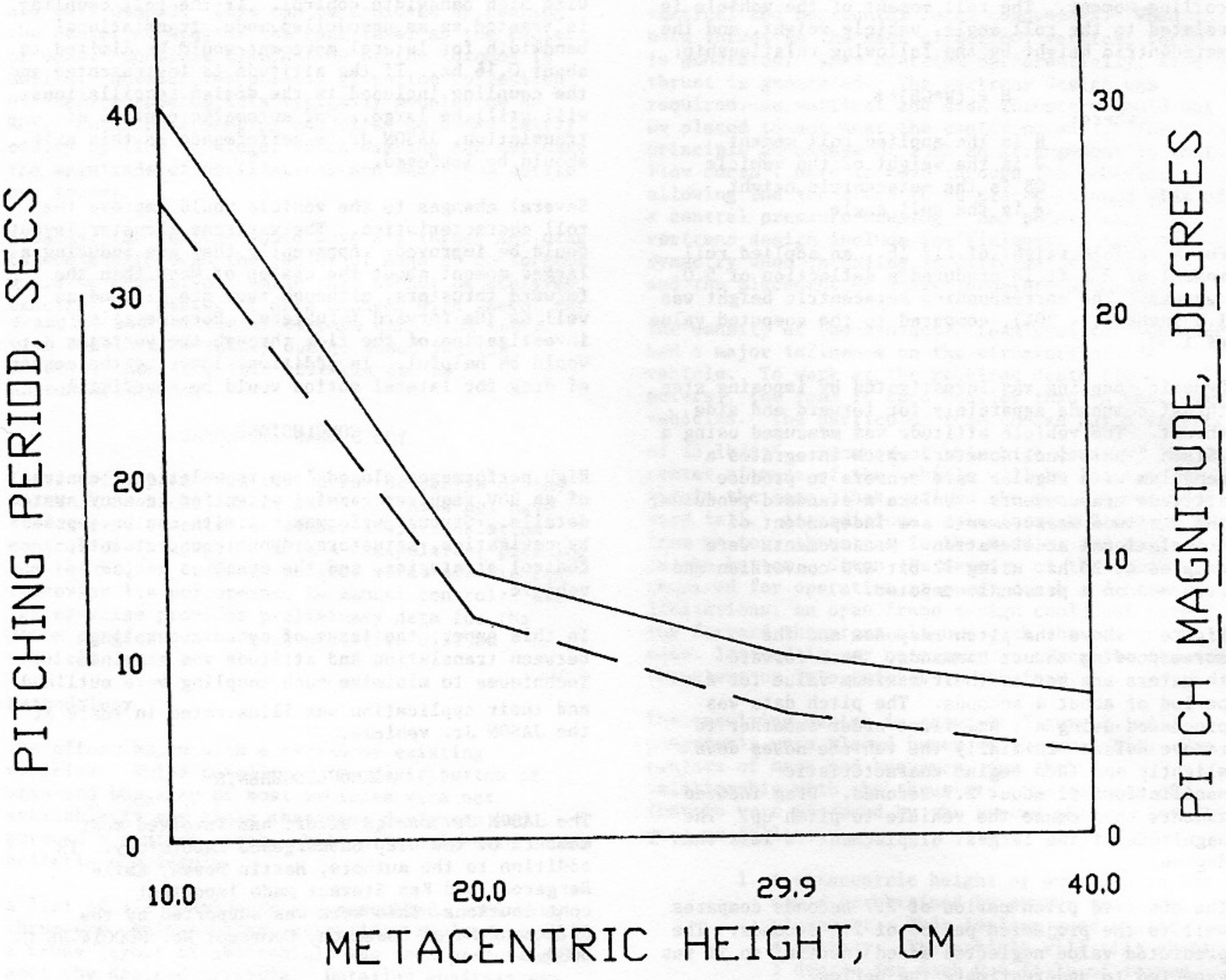

Figure 1. Period and magnitude of pitch oscillations of a large ROV following a step in forward thrust, plotted as a function of metacentric height. The large increase in frequency of this mode with increasing metacentric height will allow higher bandwidth translational control without active control of pitch. Adapted from Tanaka et al [7].

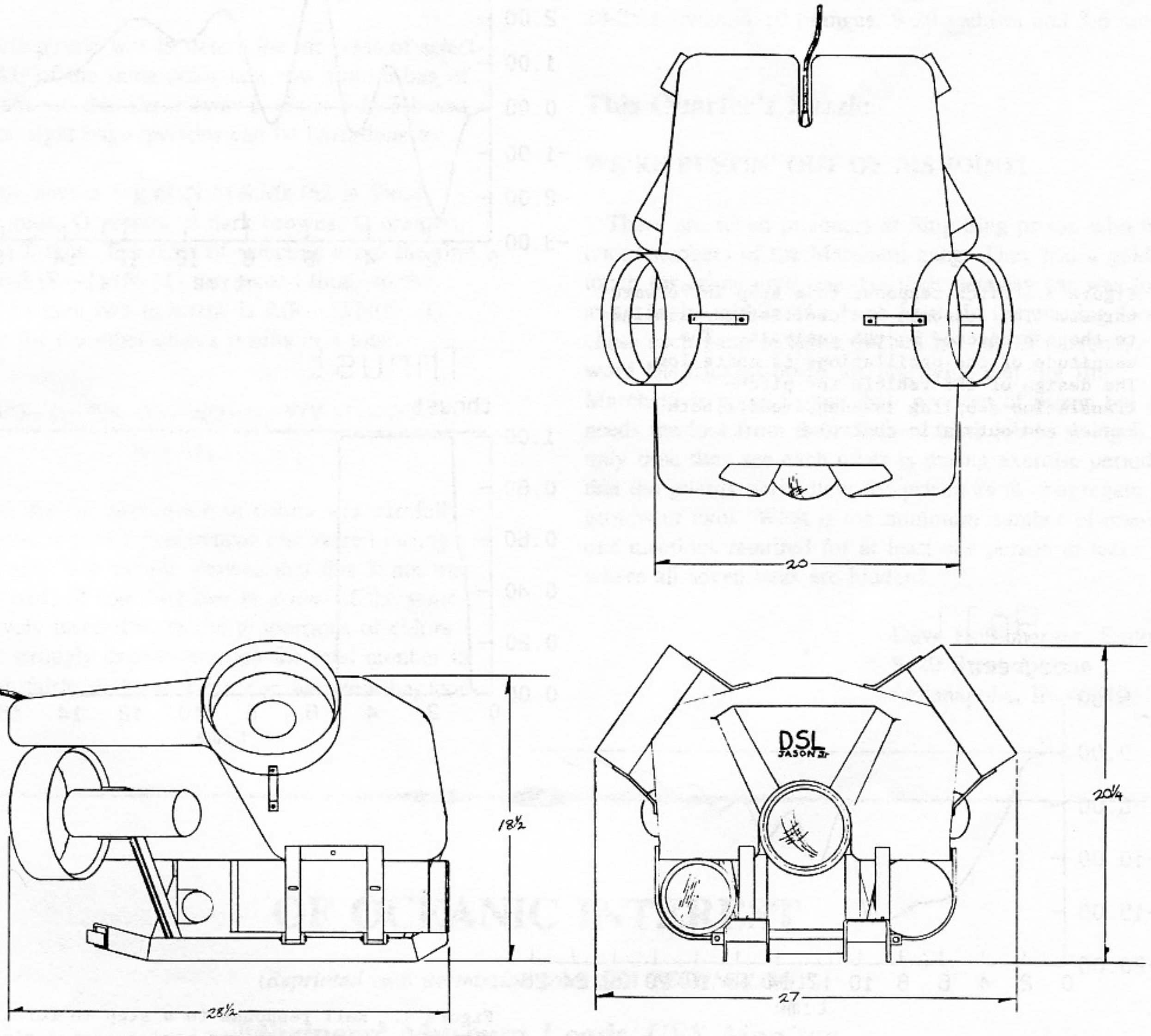

Figure 2. The JASON Jr. vehicle.

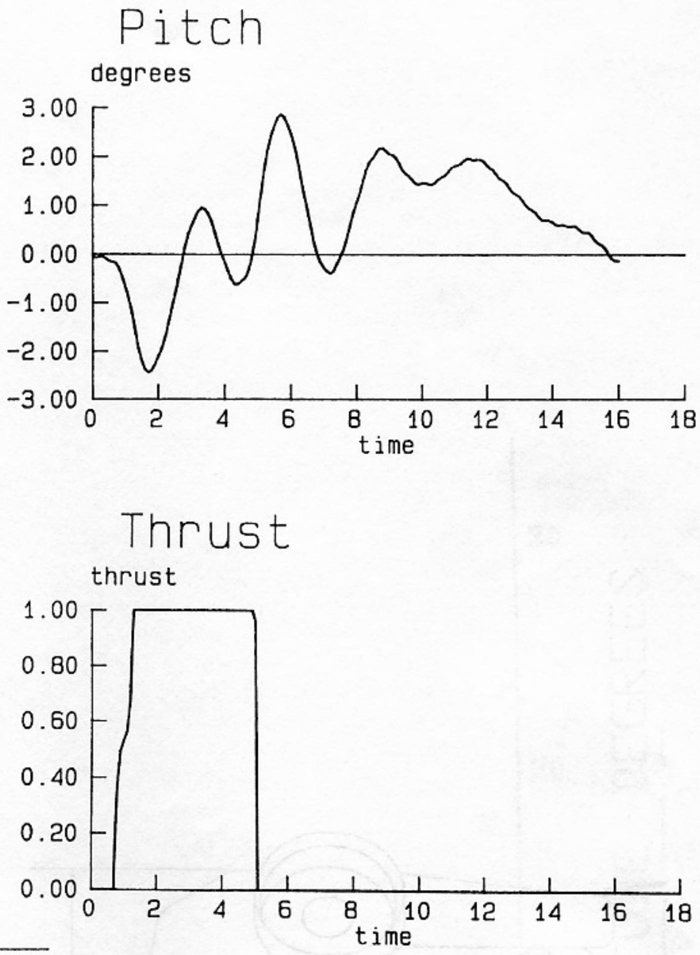

Figure 3. Pitch response to a step in forward thrust. The response has oscillations similar to those projected by the analysis. The magnitude of the oscillations is quite low. The design of the vehicle for pitch-translation coupling is adequate for both manual and automatic control.

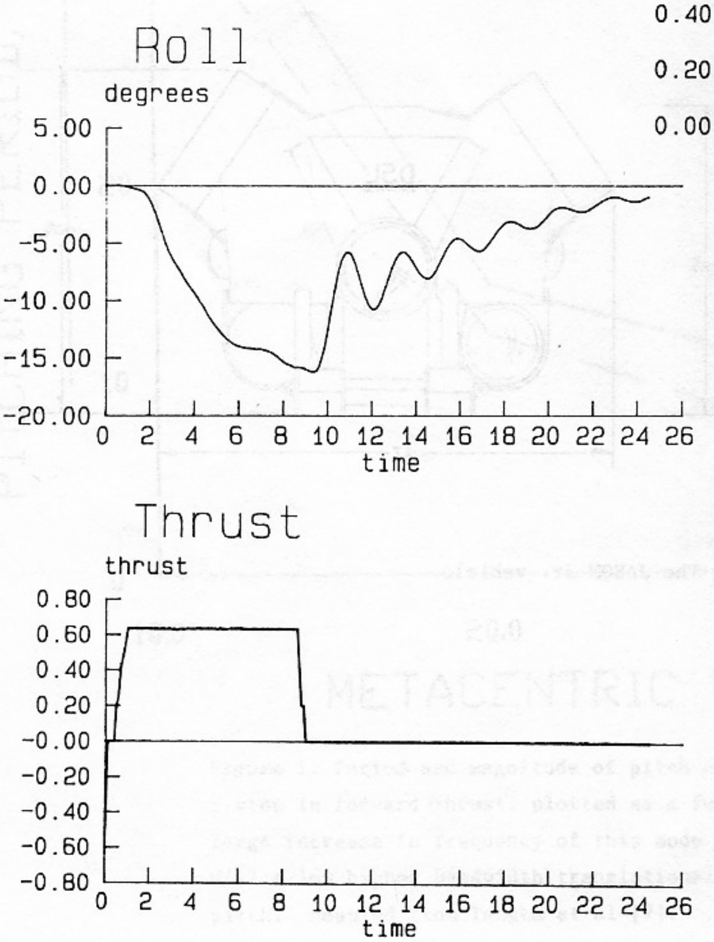

Figure 4. Roll response to a step in forward thrust. The oscillations have a period similar to the projection. The magnitude is quite large, however. The most probable cause of this large roll response is the performance of the "vertrans" thruster arrangement. The center of drag is too high as well.

'TIS A PUZZLEMENT

Last Quarter's Puzzle

MELTS IN YOUR MOUTH

Last quarter's puzzle was to determine the odds of selecting two M&Ms of the same color in a row from a bag of M&Ms. It turns out that the answer is about 1 in 5 based on a sample of eight bags (puzzles can be hazardous to your diet).

Let's say you have a bag of N M&Ms (62 is about average) of R reds, G greens, B dark browns, O oranges, Y yellows and T tans. The odds of selecting a red the first time is R/N and $(R-1)/(N-1)$ the second time, so the probability of picking two in a row is $R(R-1)/N(N-1)$. Repeating this for the other colors results in a total probability of:

$$\frac{R(R-1)+G(G-1)+B(B-1)+O(O-1)+Y(Y-1)+T(T-1)}{N(N-1)}$$

I once heard that the proportion of colors was carefully controlled to match public preferences discovered during marketing surveys. My sample showed that this is not true. However, the odds of selecting two in a row of the same color is relatively insensitive to the proportions of colors and instead is strongly dependent upon the total number in the bag, which fairly uniform. From the sample a bag contained 59 to 63 M&Ms made up of 9-16 reds, 3-9 greens, 14-25 browns, 4-10 oranges, 9-20 yellows and 3-6 tans.

This Quarter's Puzzle

WE'RE BUSTIN' OUT OF DIS JOINT!

There are seven prisoners at Sing Sing prison who were once members of the Marchetti gang. They had a golden touch for crime until one day their getaway car was towed away in the middle of a bank heist. In the ensuing footchase each gang member ditched his bag of currency. The word has trickled down the grapevine that Big Jim Marchetti is going to buy their way out of prison but he needs the loot from their ill-fated bank job to swing it. The only time they see each other is during exercise period and that the guards only allow the prisoners to congregate in groups of twos. What is the minimum number of one-on-one meetings required for at least one person to learn where all seven bags are hidden?

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OF OCEANIC INTEREST

(Reprinted with permission from SEA TECHNOLOGY)

Mariners' Museum Leads *USS Monitor* Preservation Project

By Larry L. Booda
Editor Emeritus

Newport News, Virginia — "The *Monitor* is a national treasure. Its story is part of our rich heritage and is important to preserving a sense of our nationhood. It is not the artifacts of the cold rusty iron resting on the seafloor that moves us, but rather the re-telling of the story that reminds us today of who we are as a people."

With these words U.S. Senator Paul Trible (R-Virginia) commemorated the Battle of the Ironclads 125 years after the event that changed naval warfare.

The commemoration came as the climax of four days of historical reenactments, symposia and exhibitions here in the Virginia Tidewater area at the southeastern corner of the state where there is a concentration of shipbuilding, marine shipping, and Naval installations.

Concomitant with the celebration, the National Oceanic & Atmospheric Administration (NOAA) revealed that the Mariner's Museum here has been selected as the principal museum for long-term curation, preservation, interpretation, and management of artifacts recovered from the wreck of the *USS Monitor*.

It was also revealed that NOAA is considering a proposal by North Carolina to establish a maritime interpretation center at Cape Hatteras near where the ironclad lies in 70 meters of water.

Varied Four-Day Program

There were no traces here of old animosities that grew out of the U.S. Civil War as modern-day Yankees and Rebels met here from March 6 through 9 in celebrating the battle.

The March 9, 1862, battle between the *USS Monitor* and *CSS Merrimac,* the latter converted from the *CSS Virginia,* and now commemorated as a historical event, focused attention to the modern day *USS Monitor* Project.

That project is centered in NOAA efforts to protect, preserve, and interpret the wreck of the *Monitor,* which was designated the first National Marine Sanctuary by the Secretary of Commerce January 30, 1975.

Nationwide participation in the events was highlighted by historical lore buffs from the Virginia Tidewater communities of Norfolk, Virginia Beach, Hampton, Yorktown and Newport News. Here are some of the events:

- Portsmouth Civil War Roundtable.
- Regarrisoning of Old Fortress Monroe by Civil War reenactors. Demonstrations, drills, and firing of weapons on parade field; evening Retreat and flag ceremony.
- Civil War Symposium featuring William Davis, editor of *Civil War Times,* speaking on "Duel Between the Ironclads."
- Civil War reenactor dress and full-dress inspections, weapons firing, and infantry drilling at Fort Monroe.
- Numerous walking tours and lectures.
- National commemorative ceremonies at Mariners' Museum here at Newport News. Speakers were: Edwin Bearss, chief historian, National Park Service; Dr. Philip K. Lundeberg, curator emeritus, Smithsonian Institution (on "Development of a National Cultural Policy for Historical Shipwrecks"); Dr. Nancy Foster, director, Office of Protected Species and Habitat Conservation, NOAA (on "Stewardship of the *USS Monitor*"); F. Ross Holland, Jr., executive director, National Foundation for Maritime Conservation (on "Public and Private Sector Cooperation "); and Edward M. Miller, sanctuary project manager, NOAA (on "The *Monitor* National Marine Sanctuary — The Promise and the Challenge").

Designation of the *USS Monitor* as a National Historic Landmark was formally declared by Senator Trible. He presented a plaque to Dr. Foster. "The story of the *Monitor* belongs to the American people and it must be shared," he declared. "This is the key element in the concept of participating museums."

Other Museums to Participate

Other groups that submitted proposals to establish a principal *Monitor* museum were North Carolina; the Smithsonian Institution and the U.S. Navy (joint proposal); the city of Portsmouth, Virginia; South Street Seaport Museum, New York; and the *USS Monitor* Museum, Inc., New York.

These groups will also have an opportunity to participate in the display and interpretation of artifacts. This could include loans of the interpretation of specific aspects of the *Monitor* story.

As custodian of the existing collection of *Monitor* artifacts, the Mariners' Museum will establish a research library, a project archives, and a conservation facility for NOAA's *USS Monitor* Project. The project will evaluate options for preserving artifacts and recommend what — if anything — should be done with the shipwreck.

Herbert Kaufman, chief of NOAA's Marine and Estuarine Management Division that administers the project, explained that the Mariner's Museum was the only candidate that met all published criteria for a principal museum, including the fact that it already has a facility capable of preserving and interpreting the existing collection of *Monitor* artifacts, records, research material and film.

Sea Technology has learned that funding cuts threaten to cut short planned expeditions to the wreck site this summer. As it stands, the first expedition is scheduled to visit the site in late May. The Navy's Deep Drone unmanned submersible will conduct photomapping runs for an as yet indefinite period. The mother ship for the sub is yet to be determined. She will either be a Navy vessel or one leased for the project.

Editor Emeritus Booda dove to the Monitor *site in 1979. He believes that any tinkering with wreck in attempts to remove the turret that holds up the upside-down vessel would result in disintegration.*—Ed.

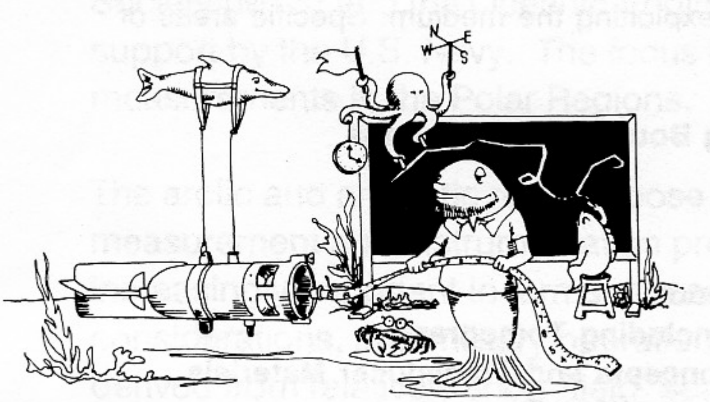
Third Time Is Charm as NOAA Completes *U.S.S. Monitor* Expedition

After support hiccups scuttled attempts for two years running, a joint U.S. Navy/National Oceanic & Atmospheric Administration archaeological expedition went to sea as scheduled in late May. As reported in *Washington Letter of Oceanography* (Vol. 21:11, June 1, 1987), the expedition provided the closest, most detailed look so far at the Civil War ironclad. Using the Navy's Deep Drone ROV — equipped with a high resolution CCD video camera, still cameras, and a 3D imaging sonar — the expedition completed an extensive corrosion study of the wreck, accomplished a photographic structural survey of the *Monitor's* hull and gun turret, completed a survey to locate and identify artifacts near the wreck, and finished a detailed photomosaic of the archeological site. Eastport International Inc. maintains and operates Deep Drone for the Navy. Since her discovery in 1973, the *U.S.S. Monitor* was named a National Marine Sanctuary in 1975 and was designated a National Historical Landmark last month. Of the several visits to the site since 1973, the most ambitious one was the 1983 expedition by Harbor Branch Oceanographic Institution (Ft. Pierce, Florida) that retrieved the *Monitor's* distinctive four-fluked anchor (*Sea Technology,* October 1983, page 46).

Michigan Teenager Wins Navy Ocean Science Scholarship

An 18-year-old from Flint, Michigan, took this year's Navy Ocean Science Award in the form of a certificate and a $1000 scholarship grant. Edward J. Ouellette III was top winner in the 38th International Science & Engineering Fair held recently in San Juan, Puerto Rico. His computer science project was called "Multipro 16: The Dawn of the Personal Supercomputer." The computer Ouellette designed and built is said to have the processing power of 32 IBM PCs and contains as well some features usually found only on the largest supercomputers. RAdm. J. B. "Brad" Mooney Jr. — who retires as Chief of Naval Research September 1 — presented the award on behalf of the organization that created it, the Naval Ocean Research & Development Activity (NORDA).

Fall '87



CURRENT MEASUREMENT TECHNOLOGY COMMITTEE NEWS AND INFORMATION

A primary objective of the Current Measurement Technology Committee (CMTC) of the Oceanic Engineering Society (OES) is to provide a focus for information exchange and promote cooperation and coordination among those in the marine community involved in current measurement. To this end, this column has been established as a regular feature of the *OES Newsletter* and everyone is encouraged to participate by submitting news items and information about active or planned current measurement efforts to Bill Woodward (301) 443-8444 or Jerry Appell (301) 443-8026 for publication in the column. This will be an effective forum only if everybody participates, so let's hear from you.

The National Ocean Service of NOAA deployed an RD 1.2 MHz RADS unit in April near Fort Sumter in Charleston Harbor. The unit is operating in real-time. A Coastal Climate WEATHERPAK is used to transmit both weather data and the RD RADS data to a shore station every 10 minutes. Data is collected in Rockville on a daily basis by dial-up phone link to the shore station.

A second RD RADS unit is being used in Charleston in a self-contained mode. It records data on an internal 60 Mbyte recorder. The unit is deployed at various sites for periods of from 15 to 30 days. The 60 Mbyte recorder was refurbished by RD prior to deployment to correct for some initial system design deficiencies.

The problems encountered have been: 1. compass errors on the self-contained unit, 2. tape recorder head alignment causing data to be lost by recording off-track, 3. hi-low range switch improperly operating causing speed errors.

The Coastal Climate WEATHERPAK has been plagued with reset difficulties caused by momentary power loss. It has required manual power-down-resets to reboot the system.

For further details contact Jerry Appell on (301) 443-8026.

NOAA's National Ocean Service has begun an effort aimed at real-time transmission of shipboard acoustic Doppler current profile data. Initially, four NOAA ships will be equipped with the capability of relaying selected subsets of the absolute current profiles via INMARSAT or GOES for analysis and assimilation into operational ocean models.

For further information contact Bill Woodward on (301) 443-8056.

In March of this year the CMTC contracted with Dr. Gregory Han of Key Consultants, Inc. to construct a database of abstracts of literature on current measurements. When completed in late summer 1987, the database or bibliography will contain over 600 abstracts of relevant papers, will be on standard 5¼ inch floppy discs and will be distributed to the CMTC membership. To be effective, the bibliography must be kept up to date and we will rely on the CMTC membership to provide us with continuous inputs for periodic updates.

For further information contact Jerry Appell or Bill Woodward.

ANNOUNCEMENTS AND CALLS FOR PAPERS

CALL FOR PAPERS

LOW FREQUENCY ACOUSTICS IN THE OCEAN

The October 1988 Special Issue of the Journal will be devoted to low frequency acoustics in the ocean. Progress in acoustical sensing systems constantly occurs and is often occasioned by supportive breakthroughs in allied technologies. Traditionally, the availability of new portions of the spectrum has led to an expansion of application opportunities.

This issue of the Journal seeks to examine applicable technology areas for beneficial acoustical developments at frequencies below 300 Hz to provide a base for assessing where new possibilities exist for exploiting the medium. Specific areas of interest include:

- **Propagation Modelling Including Boundary Interactions**
- **Background Noise Effects**
- **Subfloor Modelling**
- **Reflection Characteristics**
- **System Cost Trade-offs and Trends**
- **Signal Processing Technology Including Tomography**
- **Transduction Including Array Concepts and Transducer Materials**
- **Supportive Ship Design and Construction Concepts**

Applications to be addressed include communications, passive listening, telemetry, nuclear event detection, seismic profiling and echo ranging. Authors should highlight differences from higher frequency implementations to emphasize trends supporting lower frequency designs and to illustrate promising research areas. Papers should be sent to:

Michael Deaett
Raytheon Company
Submarine Signal Division
1847 West Main Road
Portsmouth, R.I. 02871-1087

The deadline for submission is January 15, 1988. The usual peer review will be completed prior to acceptance.

CALL FOR PAPERS
For a Workshop on
INSTRUMENTATION AND MEASUREMENTS IN THE POLAR REGION
27-28 January 1988
Monterey, California

Technical papers are invited for presentation at a workshop on Instrumentation and Measurements in the Polar Regions to be held at the Naval Postgraduate School and the Monterey Bay Aquarium, 27 and 28 January 1988. The Workshop will be sponsored by the Marine Technology Society (MTS) and the Oceanic Engineering Society of the IEEE, with support by the U.S. Navy. The focus is on instrumentation and measurements in the Polar Regions.

The arctic and antarctic regions pose some unique and challenging measurement and instrumentation problems. These regions are becoming increasingly important in terms of resource development, environmental considerations, and military operations. Most of our measurements are derived from relatively short "field" seasons, but measurements are required throughout the year if we are to answer some of the scientific and engineering questions of these regions. Some innovative techniques have been developed, but much more needs to be done. Through this Workshop we hope to foster a dialogue whereby our experiences and ideas can be shared.

The objective of the Workshop is to provide an organized forum for scientists and engineers working in the polar regions to present requirements, problems or solutions for measurements or instrumentation, and on the development, deployment, and operation of in situ and remote sensing instrumentation in these areas.

The agenda will encompass sessions on atmospheric, oceanographic, ice, biological and geophysical instrumentation and measurements. Invited overview papers will be presented by some of the leading scientists and engineers, working in the Polar Regions. A workshop report will be prepared and published.

(Continued on next page)

Authors should complete the enclosed abstract submission form and submit it to the Program Committee by **30 September 1987**. A completed manuscript will be required by **31 December 1987** for papers accepted for publication. Instructions for paper preparation will be mailed on acceptance of abstract. Send your abstract to the Program Chairman:

Dr. Warren W. Denner
Science Applications International Corporation
205 Montecito Avenue
Monterey, California 93940
(408) 649-5242

In addition to Dr. Denner, the Technical Committee will be comprised of Dr. Ira Dyer (MIT), Dr. Ken Davidson (Naval Postgraduate School), Dr. Ben Gerwick (Ben C. Gerwick, Inc.), Dr. Wilford Weeks (U. of Alaska), and Dr. Elliot Weinberg (Naval Postgraduate School)

Paper Title: ______________________________

____

Corresponding Author: ______________________________
(with whom we will correspond on all matters)

Affiliation: ______________________________

Mailing Address: ______________________________

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Authors:

(List names in the order in which they should be printed in the program. Provide addresses for all authors on separate sheet.)

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Date received:

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Session: __________

NOTE TO AUTHORS: **The Program Committee will evaluate papers solely on the basis of information supplied on this abstract form. The abstract should include a description of the instrument or measurement, the application, results and significance. The back side of the form may be used if necessary.**

ANNOUNCEMENT OES

PRELIMINARY CALL FOR PAPERS

OCEANS 88

THE MARINE TECHNOLOGY SOCIETY (MTS) AND THE INSTITUTE FOR ELECTRICAL AND ELECTRONICS ENGINEERS/OCEANIC ENGINEERING SOCIETY (IEEE/OES) INVITE PAPERS FOR THE OCEANS '88 CONFERENCE AND EXPOSITION.

GENERAL CHAIRMAN OF CONFERENCE:	ADM. PAUL A. YOST COMMANDANT, U.S. COAST GUARD
CONFERENCE DATES:	31 OCTOBER - 2 NOVEMBER 1988
CONFERENCE LOCATION:	BALTIMORE CONVENTION CENTER BALTIMORE, MARYLAND
ABSTRACTS DUE:	1 MARCH 1988 (TENTATIVE DATE)
MANUSCRIPTS DUE:	15 JUNE 1988 (TENTATIVE DATE)

WATCH THIS SPACE FOR MORE INFORMATION

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USAB HOT LINES is designed to provide IEEE Sections and Societies up-to-date information
on the United States Activities Board and professional activities. Contents can be used in their entirety or excerpted as you see fit.
We invite your comments on format, content, and lead time.
IEEE Washington Office, 1111 19th Street, N.W., Suite 608, Washington, DC 20036, USA, (202) 785-0017

Vol. 2, No. 11 John J. Kelleher, Editor—Catherine Sadler, Associate Editor June 1987

Careers Conference—"The Engineer's Life and Career in Today's World" is the theme of the fifth biennial IEEE Careers Conference, which will be held in San Diego, California, from October 14 through October 16 at the Hyatt Islandia Hotel. The Conference will be sponsored by IEEE-USAB's Committee on Career Maintenance and Development.

This year's Conference will address the status of engineers' careers in today's world as viewed by practicing engineers, industry managers, human resource managers, and social and behavioral scientists. Eight sessions are scheduled for the two-and-a-half-day event and will focus on such topics as current issues in engineers' careers; utilization of engineers; issues for engineers in Federal service, workplace issues; career-related activities in IEEE; engineers' career problems; and engineering and the family.

The cost of the Conference is $250 for IEEE members and $275 for non-members. However, if you register before August 31, the cost will be $175 (member) and $225 (non-member). All fees include reception, breaks, lunches and a copy of the *Conference Record*, which will be published after the Conference. For more information or to receive a registration packet, contact the IEEE Washington Office.

Defense R&D—Walter Beam, Chairman of the IEEE Defense Research and Development Committee, testified April 30 before the House Subcommittee on Defense to address IEEE's concerns about the FY 1988 defense budget for Research, Development, Test and Evaluation (RDT&E). He focused on the need to ensure a strong technology base program; the need to improve DoD support for electronics materials research; and the need to improve DoD support for measurement standards and metrology, telling the Subcommittee that IEEE would like to see increased Defense support of the technology base programs. Copies of Dr. Beam's testimony are available from the IEEE Washington Office.

Science and Technology—IEEE President-Elect Russell C. Drew testified April 30 before the House Science, Research and Technology Subcommittee, addressing the National Policy and Technology Foundation bill and the Department of Science and Technology Act. "The two bills being considered . . . are a valuable first step toward the definition of new measures to mobilize our scientific and engineering resources and direct these resources more effectively toward the solution of our current problems," Dr. Drew said. "We support them in principle and strongly endorse further discussion and refinement over the coming months.

"The Foundation appears to fill an important gap in our national treatment of technology policy and also consolidates important aspects of its implementation," he said. The additional advantages of a DST beyond the Foundation concept are less apparent, but he added, "we believe the proposal should be given careful consideration in the context of the current crisis we face in industrial competitiveness." Copies of Dr. Drew's testimony are available from the IEEE Washington Office.

Employment Guides—Both the *Employment Guide for Engineers and Scientists*, Second Edition, and the *Employment Guide for Engineers and Scientists*, Student Edition, have been reprinted by USAB's Employment Assistance Committee, in order to meet the continued high demand for these practical guidance publications. Employed engineers may purchase the Second Edition from the IEEE Service Center for $7.50 (member) or $15.00 (non-member). Please specify IEEE Catalog Number UH0157-8. Unemployed members may request a complimentary copy of the Second Edition by writing to the Washington Office and including their IEEE membership number. Students may purchase the Student Edition through the IEEE Service Center for $8.95 (member) and $11.95 (non-member). Please specify IEEE Catalog Number UH0174-3. All sales are subject to tax, billing and/or shipment charges. Sales orders may be placed directly with the Service Center by calling (201) 981-1393.

1987 NATIONAL PACE WORKSHOP, September 4–7, Kansas City, Missouri—Sections and Societies are encouraged to send representatives to the 1987 National PACE Workshop. The theme of this year's session is "Professional Awareness for Career Enhancement" (PACE). Professional issues will be reviewed from an individual member's perspective, looking at the impact of IEEE actions on members and how IEEE helps members meet their professional needs. All interested members are encouraged to attend. Section and Society representatives, except PACE Chairmen, are asked to pay $100 for meals and printed materials, in addition to covering their own travel and lodging costs. PACE Chairmen should contact their Regional PACE Coordinators for assistance in covering their expenses. Registration forms for the Workshop may be obtained from the IEEE Washington Office.

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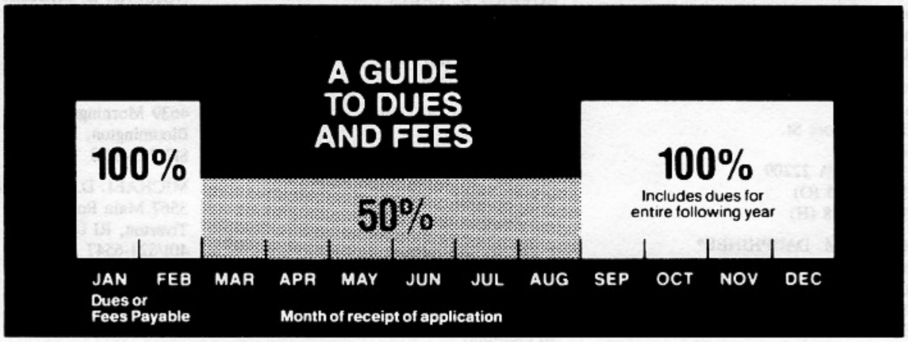
It's always time to upgrade your career. Membership gives you ready access to state-of-the-art meetings and conferences in your areas of interest, and to their published proceedings. You get to meet experts from other organizations and to participate in technical activities with the prime movers in engineering, science and business. Our membership is worldwide.

At least one periodical is included in your Society fee, keeping you abreast of the latest developments in your field. And, as an IEEE member, you may choose from a wide range of books, Standards, conference records, employment surveys, short courses and other career-building aids—all at discounted member prices.

Please take this opportunity, now, to broaden your outlook, open your mind to new concepts, new techniques, new fields of interest. There will be no better time. Return the Membership Application form below. *(Students should contact their IEEE counselor or write for a Student Membership brochure.)*



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☐ 100% ☐ 50%

Society fee: $6.00 (Includes *Journal of Oceanic Engineering*) ☐ $ ______

IEEE entrance fee (for non-IEEE members only): Remit $15.00 regardless of month of application. ☐ $ ______

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☐ I am an IEEE member. Please enroll me in the above Society.
IEEE member No. ☐☐☐☐☐☐☐☐

☐ IEEE membership plus Society membership.
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Full signature ______ Date ______

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Date of birth ______ Month ______ Day ______ Year ______ ☐ Male ☐ Female

Were you ever a member of IEEE? ☐ Yes ☐ No If Yes, please furnish (if known): Grade ______ Membership No. ______

EDUCATION (Highest level completed):

Name of educational institution ______

Course ______ Degree received ______ Date ______

ENDORSEMENT (Signature of one IEEE member, who knows you professionally.) ______

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