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REVIEWS

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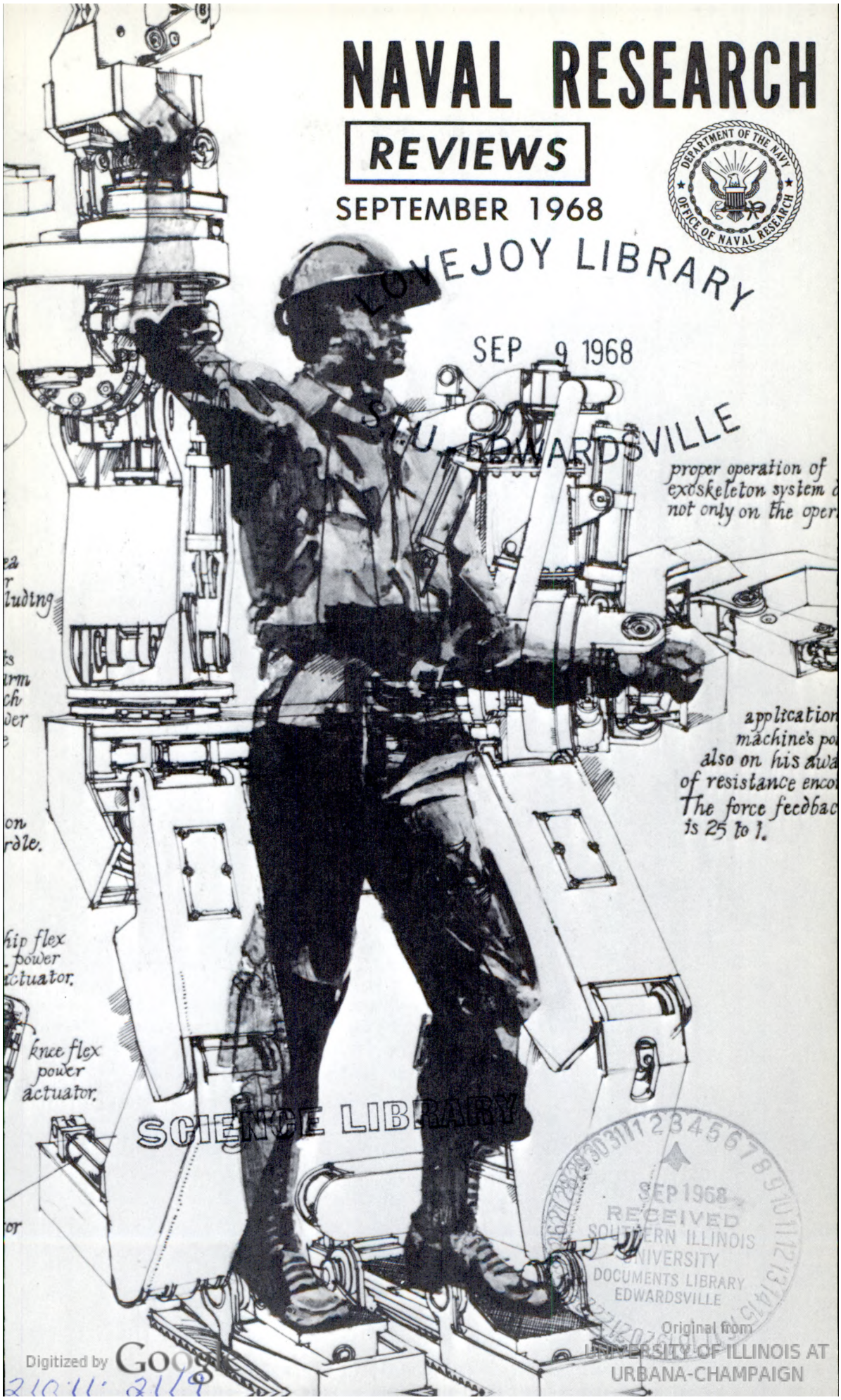

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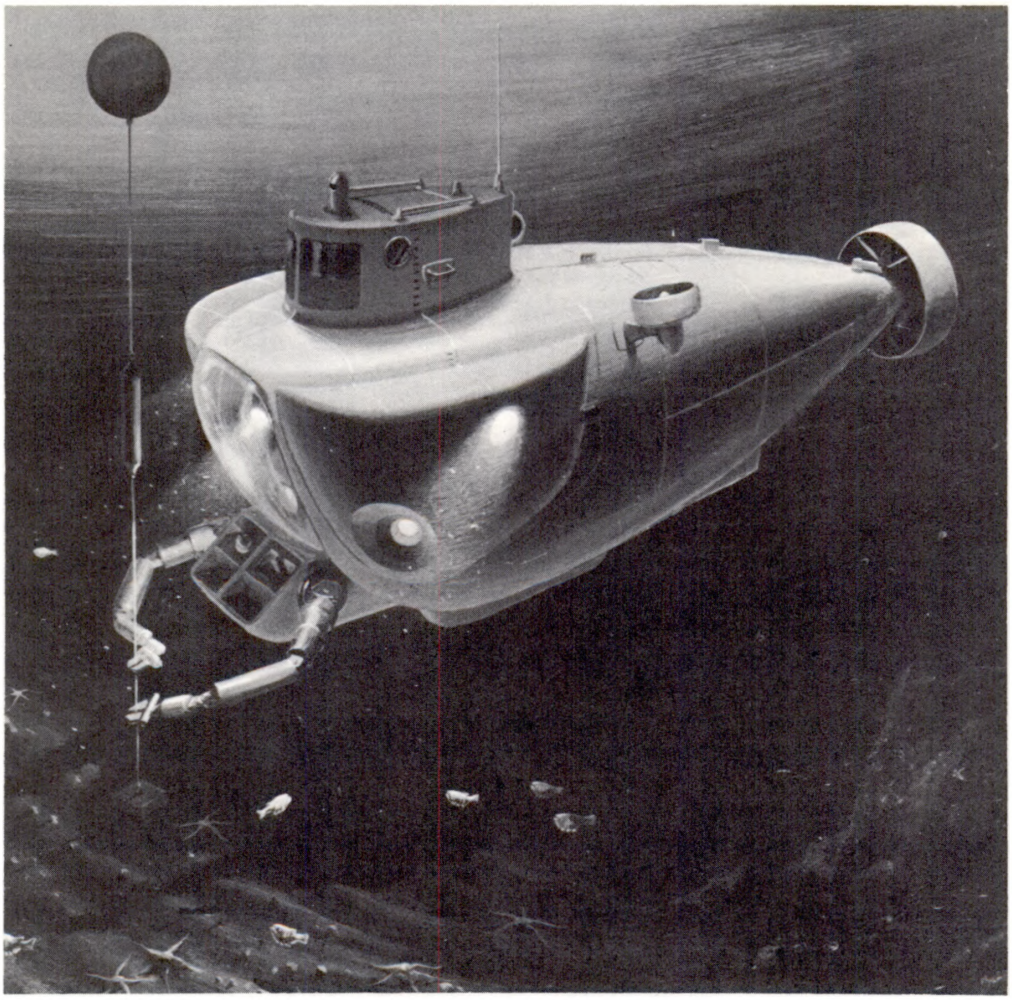

Artist's concept of AUTEC I and II, two identical vehicles for deep sea research. One vehicle is for the Office of Naval Research and the other is for Naval Ship Systems Command AUTEC Range. Here AUTEC is using the manipulators to do underwater work. Between the manipulators is the tool rack from which the manipulators can exchange tools without surfacing. *See page 21.*

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Panic Behavior

Duane P. Schultz
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The year was 1903. The popular Iroquois Theatre in Chicago was jammed with people who had come to laugh at the antics of the great comedian Eddie Foy. Suddenly, someone in the audience screamed that terrifying word—"Fire!"

"The horror in the auditorium was beyond all description. There were thirty exits, but few of them were marked by lights; some had heavy portieres over the doors, and some of the doors were locked or fastened with levers which no one knew how to work.

"It was said that some of the exit doors...were either rusted or frozen. They were finally burst open, but precious moments had been lost—moments which meant death for many behind those doors. The fire-escape ladders could not accommodate the crowd, and many fell or jumped to death on the pavement below. Some were not killed only because they landed on the cushion of bodies of those who had gone before.

"But it was inside the house that the greatest loss of life occurred, especially on the stairways leading down from the second balcony. Here most of the dead were trampled or smothered, though many jumped or fell over the balustrade to the floor of the foyer. In places on the stairways, particularly where a turn caused a jam, bodies were piled seven or eight feet deep....An occasional living person was found in the heaps, but most of these were terribly injured. The heel prints on the dead faces mutely testified to the cruel fact that human animals stricken by terror are as mad and ruthless as stampeding cattle. Many bodies had the clothes torn from them, and some had the flesh trodden from their bones."*

In just eight minutes it was all over—more than 500 people were dead. The theatre itself, however, did *not* burn. Little more than the upholstery on the seats was destroyed and performances could have been given in the building a few days later.

In a nightclub called the Coconut Grove in Boston, in 1942, over 800 people crowded every available table when:

"a girl, her hair ablaze, hurtled across the floor screaming 'Fire!'

"That shriek heralded castastrophe. Some 800 guests, insane with panic, lunged in a wild scramble to get out the only way they knew—the revolving-door exit. Flames flashed with incredible swiftness.... Smoke swirled in choking masses through hallways. The revolving

*Foy, E., and Harlow, A. F., *Clowning Through Life,* New York: Dutton, 1928, pp. 104-113.

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doors jammed as the terror-stricken mob pushed them in both directions at the same time. Blazing draperies fell, setting women's evening gowns and hair on fire. Patrons were hurled under tables and trampled to death. Others tripped and choked the six-foot-wide stairway up from the Melody Lounge. Those behind swarmed over them and piled up in layers—layers of corpses....

"The fire was quickly brought under control, but the fatal damage was done."*

In a matter of minutes some 500 people were killed. Only 100 escaped unhurt, and half of these were employees of the club who were familiar with alternative exits.

In both of these disasters the fire was brought rather quickly under control and was not the major *direct* cause of the high loss of life. Rather, what apparently killed so many was the behavior of the people in response to the threat of the fire—in a word, "panic."

The term, panic, has been given many and varied definitions and is frequently misused in our everyday speech. In sensationalistic news accounts of fires, ship collisions, earthquakes, and the like, panic is frequently used to denote the action of people fleeing a danger which, in many cases, is the only rational way for them to respond. After all, we ordinarily do not prefer to stay in a collapsing or burning building.

We naturally would prefer to escape such threats but the critical difference between simple (and rational) escape behavior and the deadly (and non-rational) panic behavior lies in the manner in which we attempt to implement the escape.

Suppose we find ourselves in a burning building which has just one exit—a revolving door through which only one person can pass at a time. If we file through this exit in an orderly one-at-a-time fashion, the chances of escape are maximized for the group as a whole. Our behavior would be considered rational and adaptive in the light of the situation, and social in that we would be evidencing a concern for (or at least an awareness of) our fellows.

But there is another way in which we might behave in response to this threat. Some of us might not wait our turn and might try to go through the revolving door all at the same time. Is this a rational and adaptive way to behave in this situation? Obviously not! By our own behavior we would be jamming or cutting off the escape exit. In the Coconut Grove fire, the people pushed the revolving door in both directions at the same time. By their own actions, they minimized the escape possibilities of the group as a whole.

The same principle applies to the choking and jamming of stairways where people were knocked down and trampled while others tried to

*Newsweek, December 7, 1942, pp. 43-44.

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swarm over them. Bodies piled up in layers and the stairway became closed. A doorway through which two people can pass at a time is rendered useless when twenty try to go through it at the same time. In these instances, the behavior of the people is self-defeating for it serves to close or jam the escape exits. To further compound the tragedy, others in the situation who observe some people jamming the escape exit may themselves engage in similar behavior as they perceive their own chances of escape as being reduced.

In such a situation, the behavior can be described as non-rational and non-adaptive in that it adds to the danger, and non-social in that there is no consideration for the others involved. In the author's opinion, this is the only kind of situation which may be appropriately labeled as panic. Based on this consideration, we may define panic as a fear-induced flight behavior which is non-rational, non-adaptive, and non-social, and which serves to reduce the escape possibilities of the group as a whole.

The Study of Panic

A large body of literature exists which deals with the nature of panic. However, the bulk of this literature consists of *post hoc* impressionistic speculations with very little substantive material which is amenable to any systematic interpretation. The author's book, *Panic Behavior,** reviews and discusses this material and stresses the great need for more empirical research in this area. The book contains a bibliography of over 260 items dealing with panic, yet it includes only two experimental investigations of the phenomenon. Since that time, only a few additional research programs have been initiated (including the author's own research).

Why this scarcity of studies in an area of behavior which is so vitally important? The answer seems to lie in the difficulty of realistically simulating the conditions of panic in the psychological laboratory. An experimental investigation of panic must provide a threat or danger which is substantial enough to generate flight from the danger. However, at the same time, the experimental situation cannot involve any severe physical or emotional danger to the subjects. The investigator's responsibility to science must, therefore, be tempered by his responsibility to the people who come to his laboratory, voluntarily or involuntarily, to serve as subjects.

Because of such ethical considerations regarding the safety of subjects, any experimental investigation of panic behavior will be, at best, only a conceptual simulation of real world conditions. Research on panic must begin, however, under well-controlled laboratory conditions

*Schultz, D. P., *Panic Behavior,* New York: Random House, 1964.

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which, by definition, will usually be artificial. Once valid baseline data are thus established, however, these findings can then be extended, refined or supplemented with observational data of the relevant behavior under naturalistic conditions.

An Experimental Approach to Panic

The author has been engaged in the study of panic behavior under laboratory conditions since 1965 under contracts from the Group Psychology Branch of the Office of Naval Research.

A wide variety of variables have been studied using a research approach designed to simulate a panic situation which is conceptually analogous to a theatre fire in which the doorway becomes jammed if too many people try to go through it at the same time.

In groups of five, subjects are placed in a danger situation and faced with a threatened electric shock three times stronger than a sample shock of 50 volts actually given, if escape does not take place within a specified time period.

Escape occurs by operating a lever on the subject panel for two seconds. However, only one subject can operate the escape lever at a time. The instructions indicate that if more than one does so, the escape mechanism will jam and no one can escape.

The situation is so constructed that each subject receives information that other members of the group are jamming the escape route in their own attempts to escape. Thus, the subject perceives that the escape route is blocked, at least for the moment. The subject has no way of knowing when the escape route will become unjammed; all the subject knows is whether the escape route is open or closed at the moment.

An alternative method of escape is available to the subject by pressing an emergency button at any time. This releases the subject immediately but closes the regular escape route permanently, preventing the escape of the others and assuring their exposure to the electric shock. The pressing of this emergency button is considered to represent behavior that is non-adaptive from the standpoint of the other group members in that it prevents their escape. The pressing of the button, then, sacrifices the other members of the group but does enable the subject to escape.

Hence, pushing the emergency button in the laboratory and moving out of turn in the theatre fire are considered to be analogous behaviors. From the standpoint of total group survival these behaviors are nonsocial and non-adaptive. Both involve attempts on the part of the individual to save himself at the expense of all others concerned.

A number of situational variables were initially investigated to determine their possible influence in terms of either facilitating or inhibiting the panic response. The situational variables included the

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effects of: (a) total group size, (b) the perceived rate of escape of other members of the group, (c) knowledge of time remaining in which escape was possible *versus* the withholding of such information, (d) variations in the threatened penalty for failure to escape, (e) degree of subject anonymity (visible *versus* non-visible fellow subjects), (f) intense visual and auditory stimulation, and (g) perceiving that another group member had "panicked." Surprisingly, none of these situational variables produced any significant differences in the incidence of the panic response. *Over all these variables, one-fourth to one-half of the subjects demonstrated a willingness to save themselves at the expense of their fellow group members.*

Several of the variables did, however, produce non-significant trends in the direction of increasing the panic response. Those variables which did produce a marked, though non-significant, increase in the incidence of panic included: (a) increasing the level of threatened penalty for failure to escape, (b) increasing the degree of subject anonymity, and (c) introducing intense visual and auditory stimulation.

The performance of male *versus* female subjects was compared in the simulated panic situation and no difference between the sexes was found in the incidence of the panic response.

One study of particular interest compared the behavior of a group of United States Naval Reservists with that of a group of male college students. It was predicted that the Naval Reserve subjects would demonstrate a significantly lower incidence of panic behavior as a function of their military training and presumed greater sense of responsibility toward their fellows. This did not turn out to be the case for the proportion of those who panicked in each group was surprisingly similar.

To further explore this finding, age and length of service data for the Naval Reservists were examined. The mean age of the Naval Reserve subjects was 26.93 years as compared to a mean age of 20.34 years for college students (not a marked difference). The age range was much greater for the Naval Reservists (17 to 54 years) as compared to a range of 18 to 24 years for college students. There also existed a very wide range in terms of length of military service: five months to 23-1/2 years.

When the incidence of panic behavior between (a) older *versus* younger reservists, and (b) short *versus* long length of service, was examined, more interesting results appeared, as shown in Table 1.

These data suggest that the incidence of panic is reduced among the older reservists with greater length of military service. It is interesting to note that the incidence of panic for the younger reservists with less military experience is slightly higher than that for male college students of approximately the same age.

Although these results were obtained from a part-time military organization, they may suggest that a greater identification with the

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TABLE 1
Incidence of Panic as a Function of Age and Length of Service

	Age		Length of Service	
	Younger (17-24)	Older (25-54)	Shorter (5 mo-3 yr)	Longer (4 yr-23-1/2 yr)
Incidence of Panic	42%	17%	40%	24%

military value structure (here defined in terms of length of service) may result in a greater sense of responsibility or solidarity, or cohesion with one's fellows. It might be suggested tha a full-time military organization in which the members are on active duty, imbues the membership with this sense of responsibility toward other members in the group. Accordingly, it is predicted that panic behavior in an active military unit would be considerably lower than in an unorganized random collection of civilians.

A series of studies still in progress is attempting to determine if there are any differences in personality between those who demonstrate the panic response and those who do not. Is the tendency to panic more a function of enduring personality characteristics than of specific aspects of the danger situation? In short, are there "panic-prone" individuals?

Large numbers of subjects have been given a variety of objective tests of personality prior to their performance in the experimental task. The personality test results of those who panic have been compared with the results of those who do not panic. The results to date are far from conclusive but the data do *tentatively* suggest that those who panic score higher on scales of neuroticism than those who do not panic.

It is emphasized that this finding is only suggestive but it does, nonetheless, provide an interesting lead for further research.

The results of three years of research have revealed a quite consistent incidence of the panic response of approximately 35 percent (with civilian subjects) over a number of variations in the experimental situation and in the nature of the groups studied.

That approximately one-third of the civilian subjects have consistently displayed the panic-facilitating non-adaptive behavior is an interesting result in and of itself. It may suggest that the non-social, non-rational and non-adaptive behavior of panic may occur quite independently of specific characteristics of the situation; assuming the necessary condition of a threat or danger.

Also, in a naturalistic danger situation, if equally large numbers of the participants behave in such a way as to save themselves at the expense of other people, then catastrophes such as the Coconut Grove

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fire and the Iroquois Theatre fire are readily explained and understood. In each of these tragedies, as discussed earlier, approximately 500 people were killed because of the non-adaptive behavior of jamming and rendering useless the available exits.

A second general finding of considerable interest is that some subjects demonstrated non-adaptive behavior extremely early in the experimental situation (during the first three seconds of a 12-second escape period). For example, dealing with the college student subjects, of those who button-pressed, 17 percent pressed during the first three seconds. It appears that these people did not even attempt to escape through the regular escape route in cooperation with their fellow group members, but, rather, panicked almost immediately upon introduction to the danger situation. One would suspect that if the situation allowed other group members to see 17 percent of their fellows "panicking" so quickly, then this non-adaptive behavior would rapidly spread to a majority of the group as they saw their own chances of escape diminishing.

NRL Corpsman Honored for Distinguished Service

A hospital corpsman currently assigned to the Naval Research Laboratory has been honored for distinguished service in Vietnam.

Hospital Corpsman First Class Byford R. Durbin received the Navy Achievement Medal from CAPT James C. Matheson, Director of NRL, during recent ceremonies.

From February 1967 to February 1968, Durbin was Petty Officer in Charge of the Battalion Administrative Section for the Third Medical Battalion, Third Marine Division. In addition to skillfully supervising a myriad of administrative functions, he volunteered to assist in handling and treating casualties arriving at his unit at night.

According to the certificate which accompanied the medal, the veteran of 11 years' Navy service "distinguished himself in performance of his demanding duties. His superior technical skill and sincere concern for the welfare of his comrades were an inspiration to all who observed him and contributed significantly to the accomplishment of his unit's mission."

The certificate was signed by Lieutenant General V. H. Krulak, U.S. Marine Corps, Commanding General of the Fleet Marine Force, Pacific.

NRL Presents RESA Awards

Dr. Martin E. Glicksman and Dr. Henry Shenker received the 1968 Scientific Research Society of America (RESA) awards from the Naval Research Laboratory's branch of the organization.

Two RESA awards—one in Pure Science and the other in Applied Science—are presented annually to the Naval Research Laboratory scientists judged to have made the most significant contributions in these areas. The program was initiated in 1955 to recognize outstanding work done at the Laboratory.

Dr. Glicksman, a research metallurgist in the Metallurgy Division, won the Pure Science Award for his outstanding contributions to solidification science and crystal growth theory. Dr. Shenker, Head of the Infrared Branch in the Solid State Division, received the Applied Science Award for development of improved detectors for the far-infrared spectral region.

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Models for Human Factor Studies

Arthur I. Siegel
J. Jay Wolf
Applied Psychological Services, Inc.
Wayne, Pennsylvania

Applied Psychological Services, Inc., under contract with the Psychological Sciences Division of the Office of Naval Research, has developed digital computer simulation techniques for studying the human factors in system effectiveness predictions. In this context human factors refer to operator proficiency, training, team cohesiveness, individual and crew morale, level of aspiration of crew members, operator personality, crew size and composition, and human engineering of the hardware.

Because these techniques emphasize psychological and crew psychosocial variables as they affect system performance, they differ from other digital modeling techniques. The techniques aim to uncover areas in which human operator and team failure can be anticipated. Identifying these areas early in the system development cycle can prevent machine-crew mismatching and the effects of such mismatching on system reliability. For example, a recent analysis of a new shipboard system for the Naval Ship Systems Command, through these methods, indicated around 30% gain in successful attacks if the system were designed for one set of operator procedures as opposed to another set of procedures. In view of these findings, the system was modified.

Digital psychological simulation in a model starts with the design conception of the hardware system. Hardware operation for each of the mission tasks is simulated on a digital computer which yields computer printed output records on crew performance. The set of rules which govern the actions and behavior of the crew as they operate the system is called a model. The model is essentially a computer program which attempts to capture the essence of what is known about the behavior of individuals in complex situations. The computer programs account for crew members' behavior in terms of current psychological theory.

Figures 1 and 2 show an overview of one simulation model recently developed. The computer operates on the input data regarding mission, equipment, and personnel parameters (figure 1). From these data estimates are made regarding minimum crew size (by rank, rate, and rating) needed to perform the tasks during the mission. The next step performed by the computer is to assign an identify to each crew member along with initial values representing his proficiency in his primary specialty, personality (orientation), and alternate skills proficiency (secondary specialties, if any). These values are computed on

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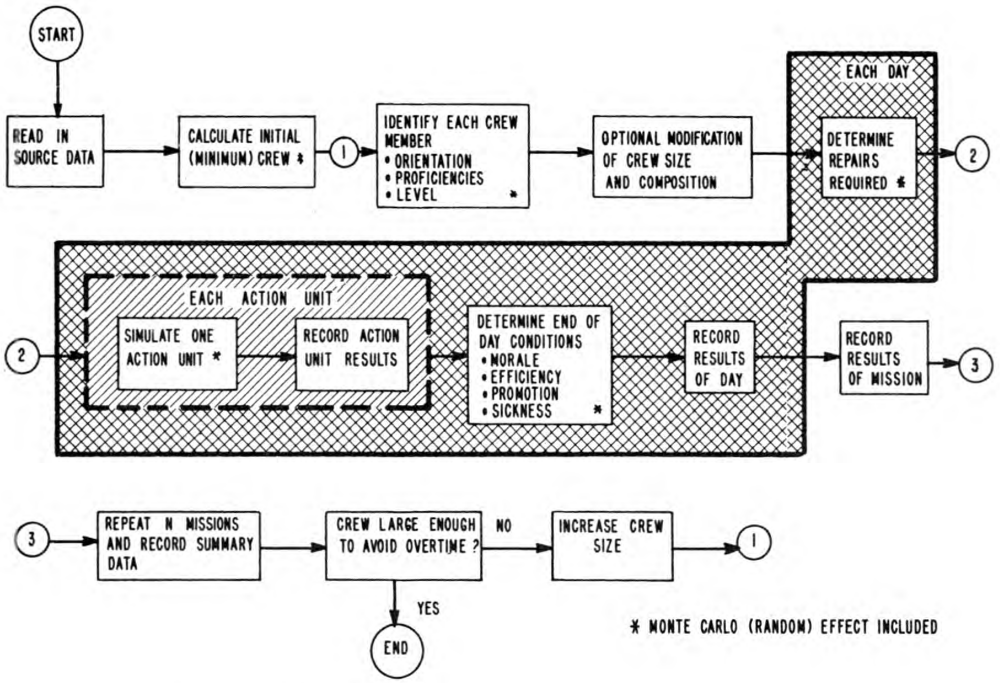

Figure 1 — Overall flow diagram of psychosocial simulation model

the basis of known characteristics of Navy personnel. Since human characteristics vary widely, the calculations are based on random processes. When a crew is formed and identified, the computer is ready to start the simulation of the performance of the first day's work by the crew. However, before the start of the simulation, a determination must be made regarding which, if any, equipment repairs are to be simulated during the day. The equipment repair determination is made stochastically on the basis of hardware reliability data. If the calculation indicates an equipment failure during the day, the time of day at which the failure occurs is also determined.

On the basis of these determinations and the input data, the computer is ready to start the simulation of the performance of each task (called an action unit) performed by an individual crew member or group of crew members on the first day of the mission. An action unit may consist of repairing equipment, standing a watch, manning a piece of gear, or of any other task which individual crew members or groups of persons may perform. Action units are simulated sequentially, one at a time, until the total day's work is completely simulated.

When each action unit is simulated, which is further elaborated in figure 2, a selection is made from the computer assembled crew, of the persons to perform the action unit. The work group is selected first on the basis of the naval rating (lowest level personnel who possess the required skills are selected first), the proficiency of the crew members (most proficient are selected first), and the time the crew members

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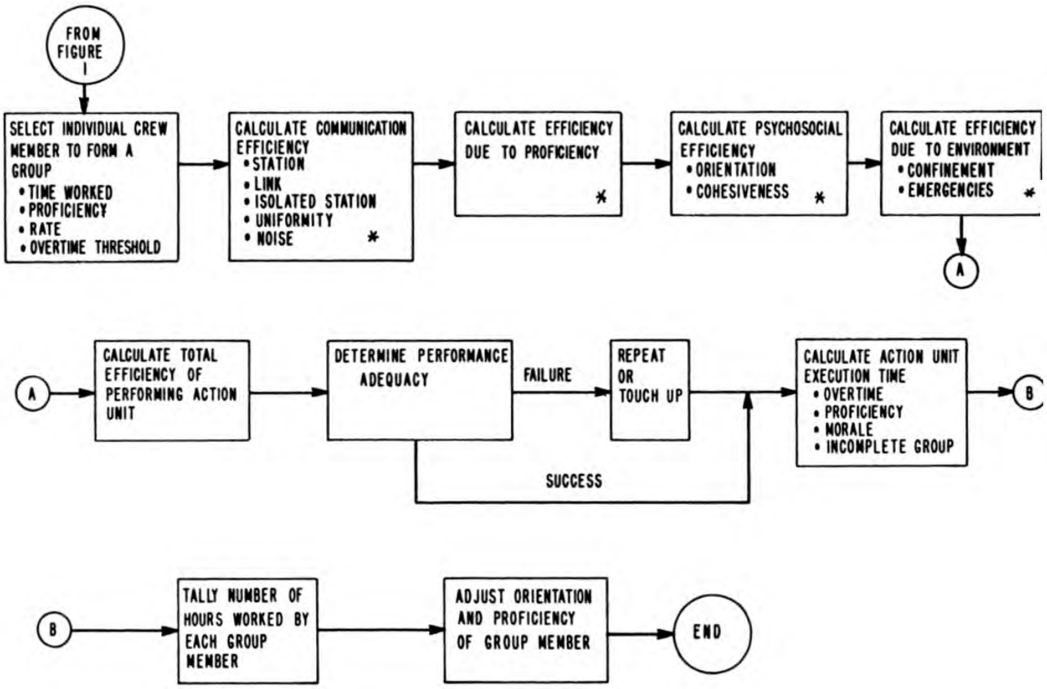

Figure 2 — Flow diagram of simulation of each action unit

have worked during the day (persons who have worked least are selected first).

There are four factors which affect performance efficiency: communications efficiency, proficiency of the personnel, psychosocial efficiency, and environmental efficiency. The first factor, communications efficiency, is based on five terms, which assume that performance will be degraded as:

- The number of stations involved in the network increases;
- The number of two-way links between each station decreases;
- The number of stations which are not able to communicate with any other station increases;
- The communications load becomes nonuniform; and
- Noise in the system increases.

The second factor emphasizes that persons and teams composed of more proficient personnel perform better. The third factor, psychosocial efficiency, considers the personality of the group members, the characteristics of the action unit to be performed, and the unity of the team. The fourth factor, environmental efficiency considers the stresses imposed on the ship's crew as a function of emergencies and in the case of some systems, prolonged confinement.

The simulated time taken to accomplish the action unit is based on several considerations. If the work group performing the action unit has to work overtime on the day being simulated, performance is

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considered to take longer. Similarly, longer performance times occur when less proficient men are assigned to the action unit, when fewer men than required for completing the task are assigned (due to non-availability, sickness, *etc.*), and when the morale of the work group is low. The morale determination is based on the "personality mix" of the men in the work group.

This sequence continues sequentially for each day of the mission until the total mission is simulated. Since many of the processes involved in the simulation are based on pseudorandom processes, the mission is resimulated a number of times in order to obtain stability in the results. At the end of the simulation of a number of missions, a variety of data are provided by the computer in printed form.

Results are printed regarding the selected crew size, its composition, and performance for the mission simulated. For each day of the simulation, summary data are given which include such descriptive statistics as average overtime, average hours spent on repairs, number of action units completed successfully and unsuccessfully, and end of day conditions such as crew morale, efficiency, and cohesiveness. These daily data are also automatically summarized to yield total mission statistics such as average crew efficiency, average morale, average hours worked by personnel rating, average crew cohesiveness, and average hours spent in repairs.

The computer then automatically estimates where efficiency increases could be brought about on the basis of an adjustment of crew size or composition; it makes the adjustment and repeats the mission simulation with the adjusted crew. This process continues until a preset maximum crew size is reached or until no overtime is required.

The psychosocial model described above was tested by way of its ability to predict certain aspects of the operations of a fleet ballistic missile (FBM) submarine. Specifically, the ship control, weapons, and sonar departments within the FBM were selected as a criterion against which the predictive validity of the model might be weighed. On the basis of early FBM design data alone, an analysis was performed on the tasks done by members of these departments. These data provide the basic input for the model. The computer model was then employed and the results compared with current Fleet operationally derived data. On the general level the validity of the technique for predicting both the total manning complement and the manning within individual rates was acceptable. The computer predicted and reported effectiveness results are shown in figure 3.

For the departments simulated, the computer generated prediction of crew efficiency, as crew size varies, is shown in figure 4. Larger crews (those closest to the current manning) were predicted to have higher efficiencies and to demonstrate greater increases in efficiency during a mission.

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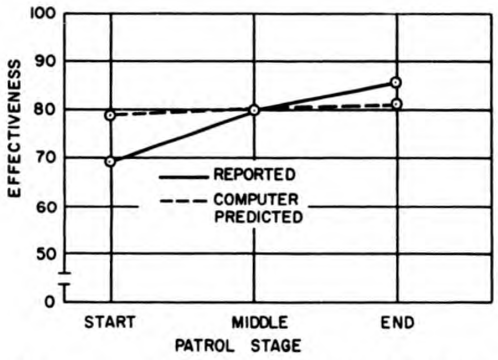

Figure 3 — Computer predicted and reported effectiveness at various patrol stages

The computer predicted that the proportion of action units to be performed unsatisfactorily would be slightly less than one percent. The error in this prediction was found to be not significantly different from actual data. Other predictions, such as the number of hours worked by crew members, the overtime worked by the crew members, and the prediction of the number of nonessential tasks which would be postponed, and crew cohesiveness were also in reasonable accord with criterion data.

While psychological simulation models are not a perfect remedy, they are better than nothing, possibly much better than might ordinarily be anticipated, and certainly superior to engineering judgment.

To date, two psychologically oriented models have been developed by Applied Psychological Services under ONR sponsorship. The content and logic of one of these has been described in the body of this

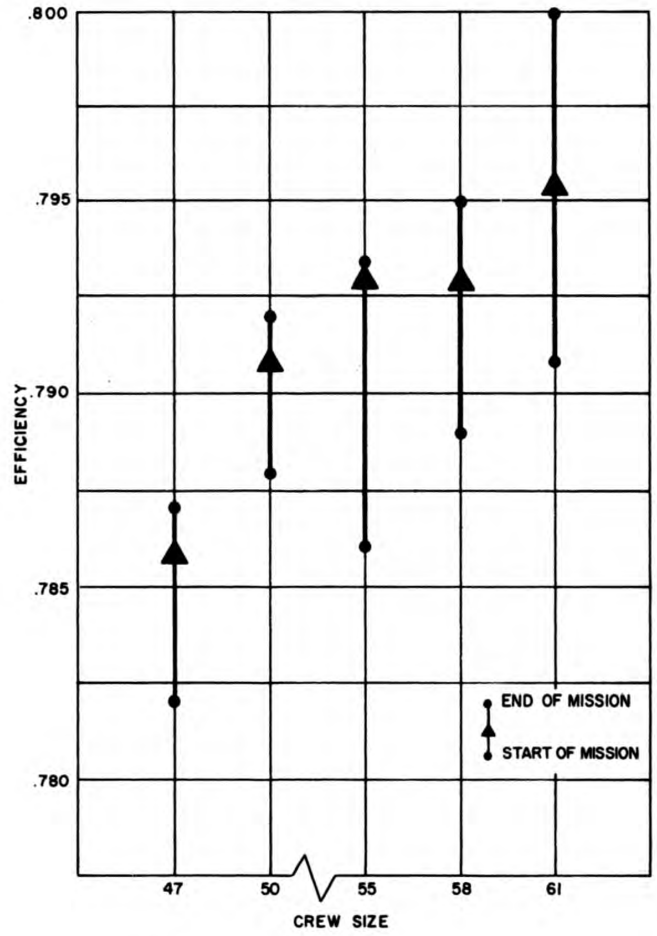

Figure 4 — Computer predictions of effects of varying crew size on efficiency

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article. The second, a model for simulating systems in which one or two operators are involved, is older and has been employed in checking the operability and maintainability of sonar systems, in predicting the operability of a number of space systems, and in developing the design of proposed aircraft. It is currently being modified for tandem employment, along with an operational flight trainer, by the Air Force.

Wave Measuring Systems

The measurement of ocean waves in the open sea is a problem that has challenged oceanographers for many years. Because there are now many practical areas where information on wave characteristics would benefit both military and commercial purposes, interest in this field has increased. During recent experiments the measuring instrument was not directly placed in the sea but was mounted on another vehicle such as on board a ship or an aircraft. In such experiments true wave height must be determined from the data obtained from the particular sensor, together with a correction for the motions of the vehicle on which the sensor is mounted.

One area of application relates to the carrier landing process where under rough sea conditions significant pitch and heave motions of the aircraft carrier may necessitate a wave-off in the last few seconds of the landing approach. Wave-offs resulting from deck motion are currently determined by the eye judgement of either the pilot or the landing signal officer. An experimental wave-off prediction system has been designed and is awaiting evaluation tests at sea. Oceanics, Inc. is conducting theoretical and model scale tests which indicate that six seconds prediction of deck motion can be realized. The proposed technique uses a radar type wave-height sensor mounted on the ship's bow to provide input data, which is run through a computer. When the information from the computer is correlated with the ship's motion a prediction can be made. It was necessary to determine the performance characteristics of different wave height sensors in order to select one sensor for the full scale tests. A series of tests at sea compared an acoustic sensor and a radar sensor.

The acoustic sensor is an ultrasonic altimeter that consists of a sonic scanner and a vertical accelerometer mounted in a single package. The entire package of sonic transducer and vertical accelerometer is roll stabilized, and the accelerometer is pitch stabilized. The radar sensor is the AN/SPN-37 radar height sensor, which was originally used on board an experimental hydrofoil craft.

The performance of the two sensors was almost equal, and the test results revealed the small effect of roll stabilization of a sensor for most motions of ships at sea. The basic sensitivities of both sensors are essentially the same, but the ability of the radar sensor to function at a greater height above the sea surface enhances its utility for application to large ships.

A Symposium on the Structure and Properties of Hydroxyapatites will be held at the National Bureau of Standards, Gaithersburg, Maryland, September 12-14, 1968. Additional information may be obtained from Dr. Walter E. Brown, American Dental Association, National Bureau of Standards, Research Division, Washington, D.C. 20234, phone: Area Code 301, 921-3336. The symposium is sponsored by the Office of Naval Research.

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NRDL - The Navy's Lead Laboratory For Radionuclide Energy Systems

P. E. Zigman
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The Department of the Navy, because of its requirements for compact energy systems, has been one of the prime movers in radionuclide energy system development. Its current and projected applications, as coordinated by the Naval Facilities Engineering Command, were discussed in the article "Radioisotopes—The Navy's Newest Power Source," which appeared in the February issue of *Naval Research Reviews*. This present article attempts to provide further information about the system itself and describe the role being played by the Naval Radiological Defense Laboratory as the lead laboratory in this area.

Description of Radionuclide Energy Systems

Radioisotope thermoelectric generators (RTG's) have been developed by the Atomic Energy Commission under its Systems for Nuclear Auxiliary Power (SNAP) program. The RTG is a relatively simple power generator. Essentially, it consists of a radionuclide fuel surrounded by an envelope of energy conversion and transmission systems (see figure 1). In operation, the encapsulated radionuclide fuel decays, emitting radiation which is absorbed and converted to heat which may be used directly or subsequently transformed into electricity. Since the maximum thermal output of current systems is in the order of one kilowatt, the electrical energy capabilities are limited, ranging from a microwatt to perhaps 60 watts. However, preliminary designs for generators which will deliver kilowatts of electrical energy have been developed.

The choice of an appropriate fuel depends, first, on availability and, second, on its nuclear decay and emission characteristics. Also, the fuel form (or fuel form/encapsulant subsystem) is subject to safety restrictions and must satisfy a number of criteria, *e.g.*, stability, high-power density and thermal conductivity, high-structural strength and melting point, low alloying properties, *etc.* As indicated in figure 1, many radioisotopes have been considered for fuel use. However, to date, only three—plutonium-238, strontium-90 and polonium-210—have been used to any extent. Because of the limited supply (relative to current and future demand) and high cost of these three nuclides, it is apparent that fuels utilizing other nuclides must be developed and incorporated into future systems.

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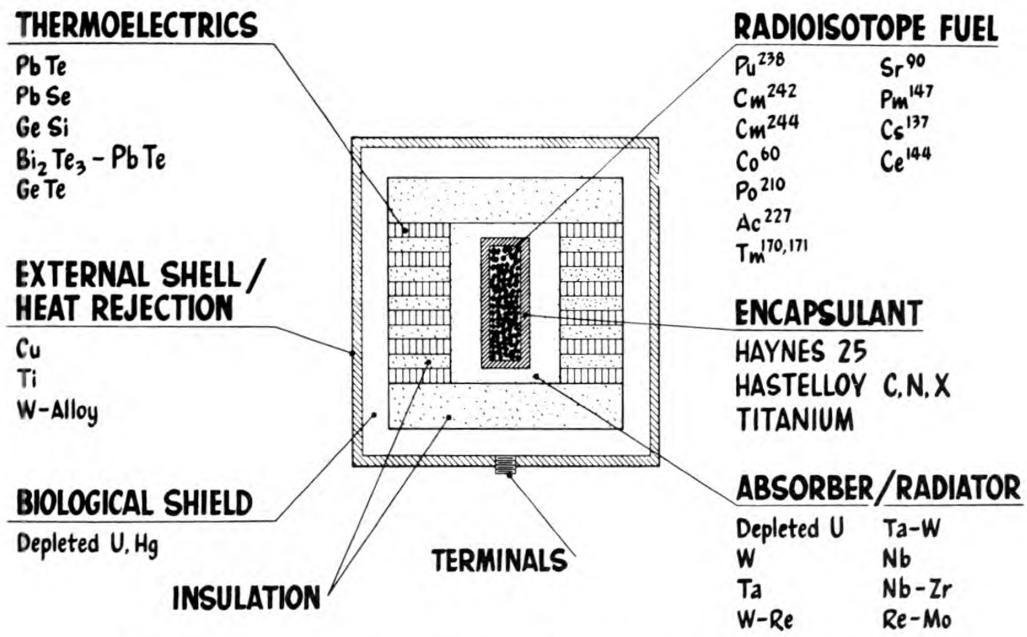

Figure 1 - Schematic of a radioisotope thermoelectric generator. Essentially the generator consists of a radionuclide fuel surrounded by an envelope of energy conversion and transmission systems.

Most fuel encapsulants employed to date have consisted of Haynes 25, the Hastelloys, and tantalum. The primary requirements for the encapsulant are high temperature capability, high heat transfer capacity, resistance to corrosion, and the ability to withstand chemical/physical attack by the fuel form.

RTG thermal output is converted to electricity by thermoelectrics (primarily lead telluride) and wire thermopiles. Achievable efficiency is low—in the order of five percent. Thus, research is currently being directed towards increasing this efficiency by using segmented couples and cascaded multi-couple fixtures and by developing improved materials and geometries. Also, investigations are being conducted on the future use of thermionic energy transfer, either alone or coupled with thermoelectrics, and other dynamic energy conversion systems.

Use Philosophy

A RTG system has long fuel life and, at the same time, is almost entirely independent of its surrounding environment. Each generator can be designed for high inherent reliability, and, therefore, long unattended, maintenance-free operation. Also, since RTG systems are compact—both in terms of weight and volume—radiation insensitive components can be incorporated into them. Thus, they are ideally suited, other considerations aside, for use in remote and/or inaccessible locations, *e.g.,* the isolated terrestrial polar regions, on or in the oceans, and in space.

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Isotopic power systems are particularly applicable to use in space missions because units can be designed to deliver continuous, relatively high, energy per unit system weight; to operate in the absence of sunlight and in opaque atmospheres; to withstand ionizing radiation and extreme temperature variations; and to require little or no ground command/control for start-up and operation.

Three features of RTG units recommend their employment in terrestrial situations; these are: complex, costly long-term operator training or instruction is not required; the intrinsic high reliability possessed by each unit allows for short or long-term (five to ten years) unattended energy production; and within very wide limits, the surrounding environment does not influence the unit or its energy output capabilities.

The preceding suggests that RTGs have a very high use potential. This potential is beginning to be realized, both in present requirements and in suggested future applications. However, recommendations for using an RTG in a specific application or situation must be approached with considerable caution and only after comprehensive comparisons with possible competing energy generation systems have been made. There are several reasons for this. First, the units are expensive—especially in terms of power derived per dollar cost. Second, projected radioisotope fuel availability could impose a considerable restraint. Third, and equally important, each unit contains large amounts of very hazardous radioactive material—a factor that affects not only system safety but which also is reflected in important political implications. Systems used in space vehicles overfly areas other than the United States and systems deployed in or on the open oceans are of concern to every country.

Previous and Current NRDL Involvement

As indicated in the *Naval Research Reviews* issue mentioned previously, the Chief of Naval Material in 1966 designated the Naval Facilities Engineering Command as coordinator of Navy radioisotopic power requirements. To assist NAVFAC in this assignment, the Naval Radiological Defense Laboratory was named as the lead R&D laboratory. Because of the nuclear nature of the power devices and the capabilities and experience of its staff in this area, NRDL is well qualified to perform this assignment, which includes the following functions:

- Assist NAVFAC in providing program definition, including developing appropriate state-of-the-art reports, specifying current and projected Navy requirements, analyzing and developing required RDT&E programs;
- Conduct various experimental and analytic endeavors in fuels and materials behavior, radiation transport, thermal phenomena

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and shallow water environmental research, development and test evaluations;
- Perform radiological safety assessments; and
- Provide technical advisory services, including proposal and concept evaluation and examine other government agency radioisotopic energy programs for their applicability to naval needs.

NRDL has participated in certain aspects of SNAP radioisotopic power development since 1960. The laboratory has not only conducted in-house research in RTG development, and the closely allied field of space nuclear propulsion, but also has acted as technical manager for certain research programs carried out through combined in-house/contractor efforts. For the most part, these studies have been concerned with radiological safety assessments and materials evaluations.

Contributions in radiological safety assessments include:

- A study of the safety in deploying plutonium fueled RTG units in the NIMBUS system which involved the development and application of alpha dose distribution models;
- A safety analysis (together with a number of other laboratories) which dealt with flight safety of the NERVA nuclear propulsion reactor. This project involved the preparation of human/system debris interaction models and the development of radiation dose distribution models. The results of this work have been utilized in the first systematic review of NERVA safety;
- An analysis of the safety of deploying nuclear systems from the Pacific Missile Range;
- A study which provides a method of producing theoretical beta spectra by computers;
- Evaluations of beta energy dissipation in tissue and assessment of subsequent hazard; and
- Estimates of the threat involved in ocean dissolution and dispersal of plutonium fuel.

The laboratory's work in materials evaluation has centered on the behavior of radioisotopic fuels in the marine environment. In this area, reports have been prepared on the reactions of the radioisotopic fuels strontium titanate and plutonium metal when exposed to seawater. Also, laboratory studies are being made on the reactions of plutonium dioxide. This work has included investigations of the physical/chemical forms of released radioactivity. Other laboratory experimentation has dealt with the fuel encapsulants and their behaviors in seawater under a number of impressed conditions such as increased temperature and the presence of ionizing radiation.

To extend past laboratory studies to the real ocean environment, NRDL has emplaced an experimental testing complex at San Clemente Island. This facility is being used initially to expose and proof-test

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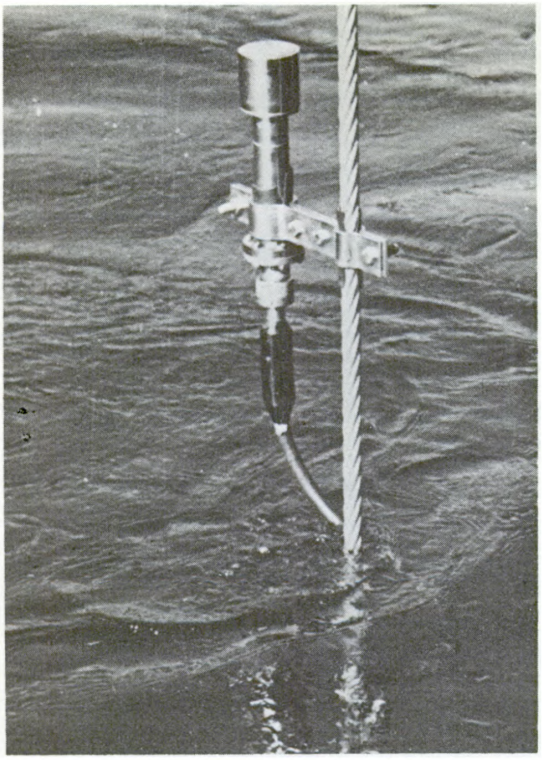

Figure 2 - Implantation of SNAP-21 electrically heated fuel capsule

SNAP-19B and SNAP-21 fuel capsules (see figures 2 and 3). The ocean capsule exposures include partial burial in the sea bottom with consequent impairment of capsule heat transfer capabilities. Also, limited quantities of radioisotopic fuel are being examined at the San Clemente facility. Currently, test plans are being formulated for comprehensive evaluations of complete SNAP-21 generator systems.

Future Applications

Because of anticipated applications in a wide variety of situations, the government (AEC) is planning to develop marine isotopic generators with electrical power outputs spanning the range of watts to kilowatts. A ten-watt system (SNAP-21) for marine use will be available for environmental test in the early 1970's.

Proposed terrestrial/marine uses include: incorporation as power generators in a new generation of meteorological and oceanographic buoys for terrestrial and marine use; applications to provide antarctic heat and power; development of energy for use in diver's undersea habitats (process breathing mixtures, lighting, communication); assist in operation of underwater equipment; applications as disaster markers, underwater navigation beacons, ocean floor seismometers, tsunami indicators, and recoverable sonobuoys; employment to supply power to Navy instrumentation in additional astronautics systems; and, possibly, applications in certain underwater weapons.

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Concurrent with development of the marine systems, attention is being directed to improved, higher power level units for space deployment. These units would operate in navigational satellites, buoy interrogation satellites, interplanetary monitoring probes, weather satellites, lunar probes, and lunar surface experiments. Additionally, an extensive inquiry is in progress as to the direct use of radioisotopic heat energy as such for thrusters for manned capsule heating units, and to provide heat for space water supply evaporators. To fulfill requirements imposed by some missions, plans are well beyond the conceptual state for the production of modular space devices capable of producing 500-watt electrical power. It is, then, not unreasonable to foresee the future existence of space generators capable of producing kilowatts of electrical power.

In addition to the work described above, NRDL possesses other capabilities which are applicable to SNAP system research. Thus far these additional capabilities have been applied only in a limited consultant capacity. For example, the laboratory has significant experience in heat flow calculations and in experimentation relative to the thermal properties of materials. Such knowledge, coupled with available facilities, could be applied to develop better source insulation methods, to improve the emittance/absorption characteristics of the external surfaces of space systems, and to investigate the action of ionizing radiation on SNAP energy conversion devices. Also, NRDL has conducted both experimental and calculational radiation transport work for many

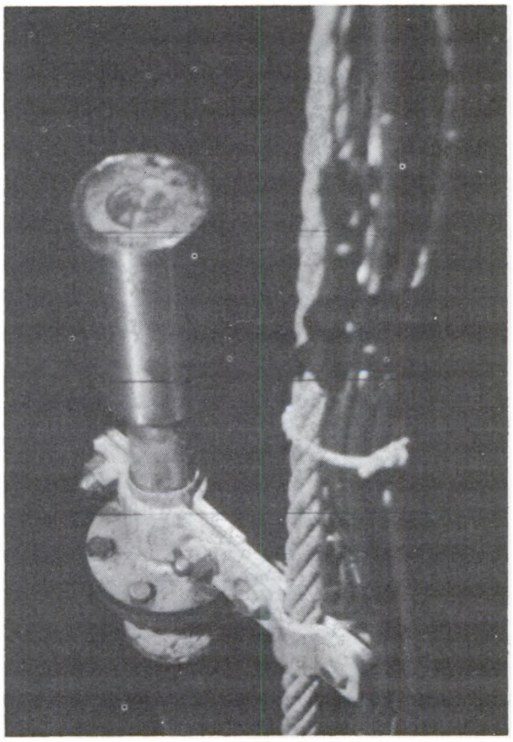

Figure 3 - Emplaced fuel capsule after six months exposure in marine environment

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years, the results of which could be utilized in SNAP shielding studies. Finally, NRDL's nuclear physics and radiochemistry capabilities could be applied to a search for new SNAP radioisotope fuels, to their nuclear characterization, and to the development of separation and purification methods.

It was noted previously that NRDL is responsible for administering certain research programs prosecuted through combined in-house/contractor efforts. These include a Space Electric Power Office radiological assessment and environmental materials evaluation program. Current effort in this program is directed primarily to the in-site ocean materials and systems studies described above. A second, allied project dealing with marine and terrestrial system is in progress for the AEC Division of Reactor Development and Technology. The third program is administered for the joint AEC/NASA Space Nuclear Program Office (SNPO) and directed to the radiological safety of the NERVA nuclear propulsion reactor. All of these programs contribute methods and information which apply to Navy radioisotope power interests. NRDL's administration of these programs coupled with the described in-house research constitute a significant addition to the Navy's work in nuclear power development.

A New Drill for Alvin

ALVIN obtained, by a new procedure, a hard rock core taken at a depth of 1246 feet about 200 miles south of Cape Cod. The planned dives were in one of the canyons that are found along the east coast. The objective was to observe and collect samples of hard rock. This formation extends from the Cape Cod region south to the Carolinas. The material that was sampled was dolomite.

During the dive in the Lydonia Canyon at the depth of 380 meters (1246 feet), the first attempt was a complete success and several samples were collected. The new drill was designed and built by Mr. Clifford Winget of Woods Hole Oceanographic Institution. Mr. Winget is the Project Engineer of the ALVIN group, and his chief interest is in the development of efficient tools to be used with deep diving submarines.

This new drill is capable of obtaining a 3/4 inch diameter core that is 3 inches long, and can be used at any depth down to 6000 feet. The power to operate the drive mechanism is supplied from the 30-volt dc battery system of the submarine. The drive motor is encased in an oil-filled pressurized chamber completely protected from corrosive seawater.

The method of keeping the core sample in the diamond drill is by the use of a water pump that keeps a steady low-suction pressure of water against the sample. When the desired drilling depth has been obtained, the drill is reversed to break the sample from the rock. To remove the sample from the drill, the water flow is reversed and the sample placed in a special container on the forward structure of the submarine.

Scientists can now sample any part of an outcrop using this new drill. They no longer have to rely on finding a small rock or bits and pieces which have been weathered by constant seawater action. In this way, they can study the geological formations of the continental shelf more completely than ever before.

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Research Notes

Navy to Get Two New Research Subs

Two midget deep diving submarines now under construction in Groton, Connecticut, by the Electric Boat Division of General Dynamics are expected to be delivered to the Navy by the end of this year. One of the vehicles will go to the Office of Naval Research and the other to the Naval Ship Systems Command. The twin vessels, presently dubbed as AUTEC I and AUTEC II, are in the same class as the Navy's research submarine ALVIN.

ALVIN, built for the Navy by the Applied Sciences Division of Litton Industries, has proven invaluable to oceanographers in surface-to-bottom research since 1966. It is presently in use by scientists of the Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, under a contract sponsored by the Office of Naval Research.

The new subs will be 25 feet long, three more than ALVIN, and will have a diving capability to 6500 feet. This is 500 feet deeper than the record dives of ALVIN and is expected to afford marine scientists a chance to probe even deeper into ocean depths. An additional mechanical arm will be added to the new subs giving the use of two, compared to one in ALVIN, in handling tools for underwater research mission at the ocean's bottom. The remotely controlled mechanical arms are used to obtain ocean bottom samplings and other oceanic data while submerged. One distinct difference in the appearance of the new submarine as compared to ALVIN is a large transparent plexiglass fairing placed over the nose to give it greater streamlining.

Like ALVIN, AUTEC I and AUTEC II will have a personnel sphere that is some seven feet in diameter with a thickness strong enough to withstand water pressure in deep dives. The personnel sphere accommodates a three-man crew and instrumentation. It is buoyant and can be released by a lever from within the sphere to carry the crew safely to the surface in case of an emergency. Other portions of the crafts can also be jettisoned to increase buoyancy when needed.

The AUTEC's will incorporate externally mounted tool compartments much like those of ALVIN. The tools are selected, through the use of the mechanically controlled arms by the crew, for a variety of deep-ocean work tasks and research without surfacing. The compartments can be detached, if not to be used, or in emergencies may be released underwater while in use.

Movement of the mechanical arms is observed by the operators on closed circuit television monitors and through four plexiglass viewports. The viewports, one on each side, one in front and one underneath are also used for underwater observations and photographic missions.

Operating equipment on AUTEC I and II is about the same as their predecessor. The gear includes lights, cameras, sonar, gyrocompass, a fathometer and an underwater communications system.

Maneuvering of this type sub is accomplished by propellers mounted on the stern and sides. Power for the motors driving the propellers is supplied by lead acid-batteries. The side props are rotatable which provide a thrust so that the sub may be directed up or down, ahead or astern. The stern prop can be turned side-to-side to steer the vehicle in a way similar to that of a small boat. The use of this system allows research submarine crews the maneuverability to move the ship in any direction. It affords them an opportunity to search the ocean's cliffs and crevices which is an impossibility in other types of submersibles.

ONR's new AUTEC sub will be assigned to the Woods Hole Oceanographic Institution as a sister ship to ALVIN to aid scientists in oceanographic missions. The other AUTEC

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will be assigned to the Naval Ship Systems Command. It is expected to operate primarily as a research and inspecting vehicle at the Atlantic Underwater Test and Evaluation Center (AUTEC) Range off the Bahama Islands.

Oceanographers Study Meanders in Gulf Stream

The course of the Gulf Stream wandering aimlessly along its northern edge after flowing from Florida to Cape Cod on a fairly straight, well-defined path still puzzles ocean scientists. Six oceanographers of the U.S. Naval Oceanographic Office during the summer added more data to the file on Gulf Stream meanders, the deviations of the flow pattern of the current, by a combined ship-aircraft operation.

The oceanographers studied the structure and the rate of change in the meanders along the northern boundary of the Gulf Stream. The primary phenomena under investigation are the volume of water transported by the meanders, the distribution of heat in the study area and the horizontal or vertical flow of sea water as it deviates from its flow pattern. Data accumulated by the scientists will support the analysis and prediction program of the Antisubmarine Warfare Environmental Prediction Services (ASWEPS), which is under the direction of the Oceanographic Office.

The scientists selected a 55,000-square-mile area located about 200 miles south of Halifax, Nova Scotia, for the area of operations. This area, which is broad enough to cover several branches of the meandering Gulf Stream, was chosen because it is well to the east of Mt. Kelvin, the largest underwater mountain in the chain off New England. The oceanographers reached their destination July 20 aboard the USNS LYNCH (T-AGOR 7). An ASWEPS aircraft carrying other scientists took six flights over the area, starting July 29. The oceanographers aboard the LYNCH divided their 5-week operation into two phases as their ship travels on an east-west path over the area.

Every 10 miles along the east-west course, they dropped expendable bathythermographs—instruments used to detect and record the temperature distribution pattern of the water in relation to depth. The bathythermographs are expendable in that the scientists do not need to recover the instruments to get the data. The instruments, which are catapulted over the side of the ship, are connected by wire to recorders aboard the vessel. These recorders make a temperature trace as each bathythermograph sinks.

At stations on the borders of the ship's survey area, the scientists used new salinity temperature and depth instruments to obtain data from which the relative current velocities and the volume of water coming through the area can be computed. They also collected temperature and salinity data with 13 Nansen bottles wired for different depths and lowered on one string extending down to the ocean floor. Continuous surface measurements of salinity and temperature are also being obtained.

Phase II of the operation which began August 9 was essentially a repeat of the bathythermograph tests of the first phase. The second readings will be compared with those taken on the first trip and could give the scientists an idea of any changes in the course of the meanders.

While the oceanographers aboard ship conducted their experiments, the airborne scientists flew over the same area on a north-south pattern. They dropped expendable bathythermographs at 45-mile intervals between the ship's lanes. Installed in airborne canisters, the expendable bathythermographs will transmit temperature readings in relation to the instruments' depths by radio back to the scientists aboard the plane. The temperature readings will be put on magnetic tape and fed to Oceanographic Office computers, which can either store the information or make graphic plots of the data.

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The airborne scientists also will make a surface temperature survey and will look for large fields of phytoplankton blooms—visible evidence of tremendous concentrations of microscopic marine plants. Because pilots on previous flights over the Gulf Stream have noticed these large fields, Alfred Lewando, a scientist aboard the LYNCH hopes to find out what nutrients are present in the area to cause the tremendous phytoplankton growth and to collect samples of the yet-to-be-identified organism.

New Oceanographic Research Vessels

The MELVILLE, first of a new generation of Navy sponsored oceanographic research vessels, was launched July 10 at Defoe Shipbuilding Co., Bay City, Michigan, and will arrive in San Diego next spring to join the fleet of UCSD's Scripps Institution of Oceanography. The MELVILLE, named for the late Rear Adm. George Wallace Melville, Arctic explorer, hydrographer, and Navy chief engineer, will be equipped for research in biological, geological, physical, and chemical oceanography. Built at an estimated cost of $7 million, including equipment, the vessel has a maximum capacity of 60 scientists, technicians, and crew members.

The MELVILLE features a propulsion system using vertically mounted, four-bladed, cycloical propellers, one at the bow and one at the stern. Turning of the blades enables the ship to proceed forward, backward, or sideways, or to remain stationary over a fixed point in 35 knot winds and heavy seas.

Special features of the MELVILLE, in addition to the cycloidal propellers, include:

- A bulb-like viewing port that extends from the bow, housing sonar equipment for undersea mapping and having viewing ports for scientists.
- An 8-by-10-foot well that makes it possible to conduct coring and drilling operations through the hull.
- Capability of carrying six portable, prefabricated vans that can be preloaded with scientific equipment and bolted to the ship's deck. Portable vans make for quick turnaround time in port and a rapid interchange of scientific programs.
- Deck equipment that can handle the launching, servicing, and stowing of 15-ton vehicles, deep-sea submersibles, deep moorings up to 20 feet in diameter, and multiton transducers for acoustic experiments.
- Capability of towing large vehicles, such as FLIP, Scripps' Floating Instrument Platform, or unmanned, 40-foot, "monster" buoys.
- Four completely independent laboratories, including a scientific chart room and operations center.
- All machinery has been designed and will be installed for minimum vibration.

The MELVILLE, which is 245 feet long and 2075 tons, will have a sustained sea speed of 12 knots, and a cruising range of 10,000 miles. She has a beam of 46 feet and a full load draft of 14 feet, 10 inches. She is powered by a slow-speed, 2500 horsepower engine, has three diesel generators with a total capacity of 800 kilowatts, and can distill 6000 gallons of fresh water daily.

Navy designation for the MELVILLE is AGOR-14 (Auxiliary General Oceanography Research). A sister ship, the KNORR (AGOR-15), under construction by Defoe, will be launched later this year and be operated by Woods Hole Oceanographic Institution.

Two more research ships, the USNS JOHN D. BARTLETT (T-AGOR-12) and the USNS LOUIS R. DESTEIGUER (T-AGOR-13), will be delivered later this year; they will join the Oceanographic Research fleet of the U.S. Naval Oceanographic Office.

These ships, which are smaller than the MELVILLE, measure 208 feet in length and have 37-foot beams and 15-foot drafts. Displacement is 1320 tons, speed is 12 knots, and endurance is 12,000 nautical miles.

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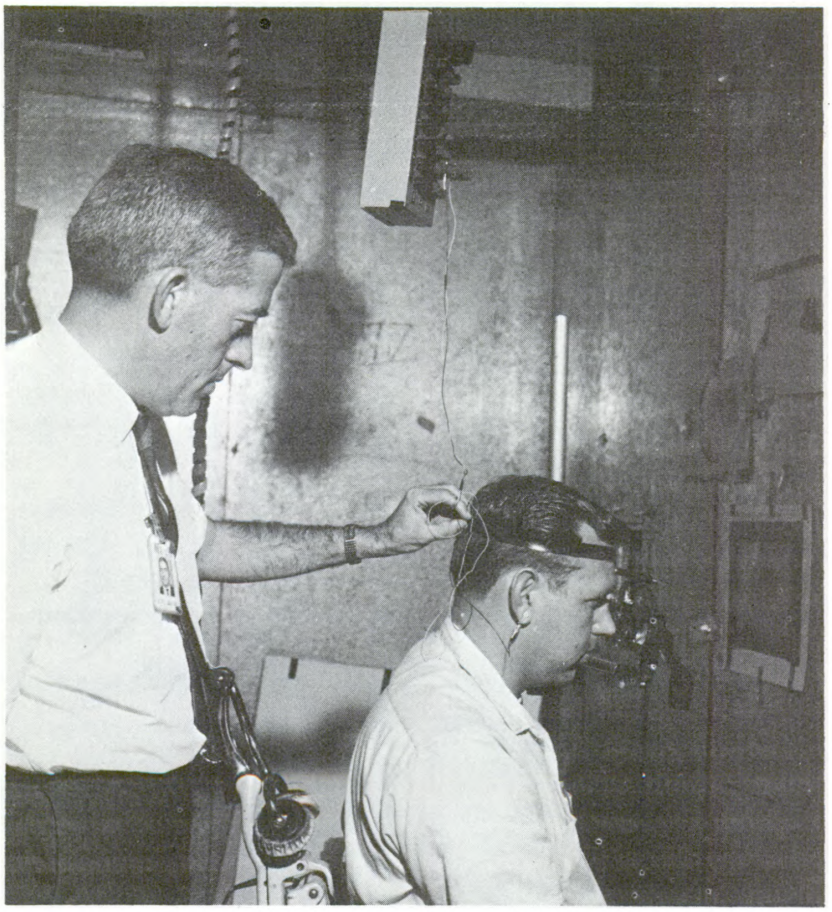
Computerized Eye Examination



The electrode is adjusted to insure proper position before recording the brain wave impulses to determine subject's visual responses to the chart

Dr. Carroll T. White and Dr. M. Russell Harter, experimental psychologists in the Naval Electronics Laboratory Center's (NELC) Human Factors Division, can diagnose the exact amount of nearsightedness, farsightedness, or astigmatism in a subject's vision through the use of a computer which records brainwaves. Specialized computers for biological and medical research can record the response of the human brain to stimulation through any of the senses.

The White-Harter discovery indicates that verbal responses which are necessary in present methods of determining defective vision may be eliminated. The change in electrical energy created by the brain in reacting to a stimulus is called evoked response or evoked potential. This energy is in the range of two to three millionths of a volt and is extremely sensitive to clear, sharp edges, or contours. A marked difference in the electrical energy picked up on the recording device is found when the image is sharply focused or blurred.

Experiments have proven 100 percent correct in a year's testing of more than 30 subjects, indicating that brainwave recordings can serve as a new method in determining lens correction. The brainwave recording technique will be useful in testing babies' vision since the need for verbal responses and use of judgement on the part of the subject has been removed.

The technique of the computer is already used as a standard way of checking hearing. Tests at NELC have expanded the use of the computer to measure perception of all the

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senses. This procedure will be useful to clinics in testing hearing, vision, and all other sensory reactions. Dr. White foresees the development through miniaturization of a black box as small as a sugar cube which could be taped to the head and used by an optometrist or opthalmologist. Such a device could possibly be developed for a few hundred dollars.

During the experiments at NELC the subject sits on a chair in a small dark room in front of the stationary lens holder. A black and white checkerboard image is flashed at short intervals and the evoked response is translated to the computer. The image is cleared or diffused by use of various optical lenses. Without ever asking the subject what he sees when the image is flashed, Dr. White and Dr. Harter can determine when the image is most clear for the subject from the characteristics of the evoked responses measured by the computer. Thus, the degree of near or farsightedness is indicated.

The same procedure can pinpoint astigmatism. Instead of the checkerboard, a series of black and white lines is projected and the degree at which they are clearest to the subject will be indicated on the computer. The technique should be useful in early diagnosis of vision defects, such as amblyopia in children. Amblyopia is a condition in which one eye is much stronger than the other.

Scientists Probe Ocean Floor

During the summer oceanographers aboard the USNS KANE began working on Project GOFAR (Global Geological and Geophysical Ocean Floor Analysis and Research). Project GOFAR was proposed in November 1967 by Dr. Bruce Heezen, a consultant for the Naval Oceanographic Office. The overall mission of the project is to conduct field and laboratory investigations to provide global understanding of ocean floor geological processes and their relationship. Such understanding is expected to enhance the Navy's operational capability and increase knowledge of the ocean floor and its natural resources.

In July, the scientists gathered data on a major underwater fracture zone in the Mid-Atlantic Ridge. The fracture zone was created when the crest of the ridge was laterally displaced. Over the fracture zone the team of oceanographers made studies of its magnetic signature, echo soundings, seismic reflection, and seismic refraction. The scientists also are conducting dredging operations at daily station tops over the underwater cliff formed by the breaking movement of the earth. This dredging operation, may enable them to collect rock uncovered by the fracture. Other station work includes piston coring, sea floor photography, temperature and salinity probes, heat flow investigations and studies of the amount of sediment being carried in the water near the bottom.

All magnetic and topographic data is being fed into computers aboard the KANE. From this information, the computer is compiling profiles of the ocean floor. The scientists also are computerizing data from temperature and salinity depth probes and are receiving from this information cross-sections of the water mass. Navigational data from satellites and the VLF Omega precise positioning system are also being computerized and compared with the undersea information, giving the scientists instant knowledge of the ship's position in relation to the geological facts.

When the scientists completed their mission along the fracture zone, they took a one-month cruise off the northwest coast of Africa before returning home along the path of a different, southern fracture zone. On this cruise, they planned to probe the nature of the African continental rise, which is wider than the rise off the east coast of the United States.

Scientists already know that an underwater current, acting as a submarine river, has deposited sediment along the continental rise off the east North American coast. The oceanographers wanted to see if a similar condition exists on the African side.

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Dr. Harvey C. Hays Dies

Dr. Harvey C. Hayes, who was one of the nation's pioneers in the field of underwater acoustics, served the Navy for 30 years, 24 of which were with the Naval Research Laboratory. His efforts in the development of both active and passive sonar equipment were instrumental in turning the tide of the Battle of the Atlantic during World War II.

Dr. Hays was born in North Fenton, New York, on November 2, 1878. He received AB, MA, and PhD degrees from Harvard where he was an instructor from 1911 to 1913. From 1913 to 1918 he taught physics at Swarthmore College. During World War I the serious threat of enemy submarines to U.S. shipping prompted Dr. Hayes to work on the detection problem. He concluded that the best chance of detecting enemy submarines was by the use of underwater sound. His work sufficiently convinced him of the potentialities of underwater sound, and he volunteered his services to the Navy. The offer was accepted, and he began work at the Experimental Station at Fort Trumbull, New London, Connecticut.

In 1923 he joined the staff of the New Naval Research Laboratory as superintendent of the Sound Division and initiated research on active sonar. After success in the field of active sonar, Dr. Hayes attacked the problem of passive detection. By 1932 a combination of listening and echo-ranging equipment was available to the Navy, largely as a result of his efforts.

During World War II Dr. Hays led the Sound Division of the Naval Research Laboratory into the development of improved sonar domes and dome material, improved transducer designs, and techniques of localizing the target beyond the resolution of the sonar beam. Harbor defense sonar and mine location sonar were among his important developments. It was he who first recognized the potentiality of the helicopter and blimp in anti-submarine warfare, and his efforts led to the first sonar equipment for these vehicles.

After World War II Dr. Hays administered from the Naval Research Laboratory the Underwater Sound Laboratory in New London, Connecticut. Dr. Hayes reorganized the Sound Division of the Naval Research Laboratory and reoriented its program with more emphasis on basic research. He began work in physiological acoustics and other new areas.

Dr. Hayes was the first recipient of the Pioneer in Underwater Acoustics award given to him in 1959 by the Acoustical Society of America. In 1945 the Secretary of the Navy bestowed on Dr. Hayes the highest civilian award, the Distinguished Civilian Service Award, for his outstanding service to the United States Navy.

Random Noise

Dr. B. Floyd Brown, head of the Physical Metallurgy Branch of the Naval Research Laboratory, has received the Laboratory's highest science citation, the E. O. Hulburt Science Award, for his work in combating corrosion. Although Dr. Brown has made numerous contributions in the field of corrosion, particularly marine corrosion, the award specifically recognizes his development of a precracked cantilever beam test for measuring the stress corrosion of high strength metals and alloys.

Mr. Henry A. O'Neal received the Department of Defense Distinguished Civilian Service Award in recognition of 23 years of superior performance in the Federal Government as a creative scientist and an imaginative administrator. The scientific leadership and management ability of Mr. O'Neal was demonstrated in administering a massive study of underwater acoustics, in initiating and directing a program exploring the capabilities of man to live for long periods in the ocean, and in other ocean technology projects.

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On the Naval Research Reserve

NRRC 9-3 Learns of Army Research and Development

NRRC 9-3, Ann Arbor, Michigan, combined their drill night with the monthly meeting of the Institute of Electrical and Electronic Engineers. The main feature of the meeting was a talk by Dr. Russell D. O'Neal, Assistant Secretary of the Army for Research and Development, whose topic was "Trend in Army Research and Development." A number of exhibits illustrated current research and development work being done at the University and by Ann Arbor industries.

NRRC 8-1 Holds Weekend Seminar

NRRC 8-1, New Orleans, Louisiana, was the host for a seminar on Regional Resources Research held on April 5, 6, and 7 in New Orleans, Louisiana. The unit is commanded by LCDR C. W. Unangst, USNR. The objectives of the program were to illustrate how Naval Research Reserve Companies can serve regional as well as national interests. The program emphasized research in resources as a basis of national strength. The speakers, who represented local universities, industry, and research organizations, covered a variety of subjects pertinent to the development of Gulf Coast resources. Emphasis was placed on resources such as fishing, shrimping, off-shore oil development, oysters, marine biology, and sulphur.

Dr. James Stone, Gulf South Research Institute, spoke to the group on "Prospects of Research in Gulf Marine Biology." Paul D. Bybee, Freeport Sulphur Company, talked about off-shore sulphur mining, pointing out the increased tonnage of sulphur exported to Japan could increase industry and economic development around the gulf states.

Of the 85 attendees, 22 were civilians. Research companies from Colorado, Texas, Mississippi and Louisiana were represented as well as representatives from local reserve companies. The meeting demonstrated the important role Naval Reserve Research Companies can play in bringing together research knowledge from diverse sources.

NRRC 8-4 Leadership Program

NRRC 8-4, Houston, Texas, participated in the Organization Improvement Laboratory (OIL) program sponsored by Humble Oil and

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Refining Company. OIL is a special course designed to increase the effectiveness of individuals through team solutions to problems.

Last year Humble presented a program for NRRC 8-4 based on the Managerial Grid concepts of Dr. Blake and Dr. Mouton of the University of Texas. The Managerial Grid illustrates the behavioral science concept that more problems will be solved correctly and better decisions will be made by an organization where free and objective use of information is encouraged. For this reason the findings of a carefully organized team is almost always better than any individual solution. This training course has been given many times to Humble divisions, to overseas affiliates, to church groups and to government officials.

Early this year, several members of NRRC 8-4 who had taken the course presented an abbreviated version to the rest of the unit. The problem assigned for the evening was "What measures should be taken to improve unit recruiting efforts and overall effectiveness." The unit was divided into three groups, and each group's recommendations were tabulated after one hour. The recommendations mentioned most often were:

- Make up for retirement losses by making every member responsible for recruiting in his civilian business, social groups, and professional organizations.
- Develop better esprit de corps by having more group training duty and informal social events.
- Permit wives and friends to attend nonclassified programs that are of general interest.
- Improve the quality of the training schedule through more interesting subjects and more active participation in the programs.

Change of Command for NRRC 1-1

NRRC 1-1, Boston, held its change of command ceremonies in uniform on July 1, 1968; CDR Paul W. St. George was relieved by CDR Charles F. Davis, Jr., the company's former executive officer. While commending the Company on past accomplishments, CDR St. George recalled two ONR Seminars, four weekend Active Duty Training seminars, field trips to industrial and military establishments, and the many speakers from the Boston area.

At the annual Naval Research Reserve Dinner Rear Admiral Thomas B. Owen, USN, revealed the challenging role of the Office of Naval Research.

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Selected Contract Research Reports

The contract research reports listed below have been extracted from U.S. Government Research & Development Report 68, No. 10 of May 25, 1968 and No. 11 of June 10, 1968. Government agencies and their contractors who are registered with the Defense Documentation Center of the Defense Supply Agency may obtain copies from the Center at Cameron Station, Alexandria, Virginia 22314. Abstracts of the reports are found in USGRDR 68, Nos. 10 and 11.

For non-DDC users, most reports may be purchased from the Clearinghouse for Federal Scientific and Technical Information, Department of Commerce, Springfield, Virginia 21151.

AERONAUTICS

Assignment of Aircraft to the Naval Advanced Jet Pilot Training Mission; Center for Naval Analyses; Boness and Schwartz; AD-667 574

ASTRONOMY AND ASTROPHYSICS

Solar Radiation and Atmospheric Absorption in the mm Wave Region; Calif. U.; Silver and Welch; AD-667 599

Nucleosynthesis During Silicon Burning; Rice U.; Bodansky *et al;* AD-667 667

A Spatio-Temporal Analysis of Velocity Fields in the Solar Photosphere; Calif. U.; Frazier; AD-666 621

The Energy Distribution in Nova Herculis 1963; Washburn Observatory; Bless and Houck; AD-666 835

A Model of the Sunspot Umbra; CalTech; Chitre and Shaviv; AD-667 073

Nucleosynthesis in Big and Little Bangs; CalTech; Fowler; AD-667 080

Non-Radial Pulsation of General-Relativistic Stellar Models. Analytic Analysis for 1 Greater or =2; CalTech; Thorne and Campolattaro; AD-667 081

Solar Neutrinos; CalTech; Bahcall; AD-667 082

Critique of the 'Clark Effect'; CalTech; Wagoner; AD-667 083

Friedmann Cosmological Model With Both Radiation and Matter; CalTech; Jacobs; AD-667 084

ATMOSPHERIC SCIENCES

The Radio Emissions From Close Lightning; Stanford; Oetzel and Pierce; AD-666 711

Charge-Exchange Lifetimes for Low-Energy Protons in the Outer Radiation Zone and Implications Concerning the Density of Atomic Hydrogen in the Terrestrial Exosphere; Iowa U.; Swisher and Frank; AD-666 964

The Climate of the Rupununi Savannas; Mcgill U. (Canada); Frost; AD-666 616

Inertial Characteristics of the Winds and Their Predictive Implications for the Water Movements off Southwest Africa; Ocean-Atmosphere Research Inst.; Schell; AD-666 631

The Singly and Doubly Charged Particles in the Primary Cosmic Radiation; Minn. U.; Freier and Waddington; AD-667 490

Summertime Radiation Balance and Energy Budget of the Canadian Tundra; Wisconsin U.; Ahrnsbrak; AD-667 488

An Investigation of the Structure of Turbulence Over Water Surface Waves; Michigan U.; Portman and Davidson; AD-667 739

BEHAVIORAL AND SOCIAL SCIENCES

Economic Problems of Information and Organization; Calif. U.; Radner; AD-667 842

The International Research Groups on Management Information System; Pittsburgh U.; Barrett; AD-667 242

Automatic Informative Abstracting and Extracting; Lockheed Missiles and Space Co.; Earl and Robison; AD-667 473

On Some Relations Between Human Engineering, Operations Research and Systems Engineering; Johns Hopkins U.; Chapanis; AD-667 474

A Reexamination of Eye Movement Data; Systems Technology, Inc.; Clement *et al;* AD-667 768

CAI – Socratic Dialogue and Laboratory Simulation in Pathology; Harvard Computing Center; Hellerstein *et al;* AD-667 590

Strategy in Intra-Triad and Inter-Triad Interaction; State U. of N.Y.; Vinacke *et al;* AD-667 266

Depth and Movement; Columbia U.; Graham; AD-667 622

Learning With One and Two Cues; Sussex U. (England); Sutherland and Andelman; AD-667 624

Reaction Time to Different Wavelengths at Various Luminances; Army Lexington Signal Depot; Pollack; AD-667 627

Extinction in Discrimination Learning: Presentation and Contingency Variables and Associated Side Effects; Pittsburgh U.; Cohen *et al;* AD-667 656

The Effects of Task Characteristics on Response Latency and Latency Trends During Learning and Overlearning; Pittsburgh U.; Judd; AD-667 657

Talcam: A Computer Program to Perform a Tucker Analysis of Learning Curves and More; Princeton U.; Wainer; AD-667 741

Practicable Models in Personality Research; Ill. U.; Cattell; AD-667 841

Duality in Discrete Programming. Nonlinear Objective Function and Constraints; Carnegie-Mellon U.; Balas; AD-666 627

Organization of Topics and Literature References in the Earth Sciences for Machine Storage and Retrieval; Northwestern U.; McMonica; AD-666 817

On Deterministic and Stochastic Structures; Princeton U.; Dagum; AD-666 972

Strategic Projections and Policy Options in the Soviet-Cuban Relationship; Center for Naval Analyses; Wilson; AD-666 819

Attitudes of Psychologists Toward Their Jobs; Texas Christian U.; Sells and Will, Jr.; AD-666 854

Reversal Learning as a Function of the Size of the Reward During Acquisition and Reversal; Calif. U.; Kendler and Kimm; AD-666 628

Selective Attention Versus Mediation: Some Comments on Mackintosh's Analysis of Two-Stage Models of Discrimination Learning; Calif. U.; Kendler and Kendler; AD-666 630

Reversal and Partial Reversal Shifts With Verbal Material; Calif. U.; Kendler *et al;* AD-666 632

Effect of Aroused Testing Conditions on the Measurement of Fear of Failure; Bucknell U.; Teevan and Dapra; AD-666 963

On the Sigmoidal Law Relating Association Value (a) and Scaled Meaning-Fulness (m'); Georgia U.; Noble *et al;* AD-667 104

BIOLOGICAL AND MEDICAL SCIENCES

Fragmentation of Guinea Pig Complement Components C'2 and C'3c; Johns Hopkins U.; Mayer *et al;* AD-666 734

Gm Factors in Non-Human Primates; Calif. U.; Loghem *et al;* AD-667 054

Whole Organ Freezing and Thawing Heat Transfer and Thermal Properties; Geoscience Ltd.; Poppendiek *et al;* AD-666 824

An Experimental Study of Replacement Solutions in Hypovolemic Shock; Yale U.; Morin and Goldenberg; AD-666 897

Comparative Biosynthesis of Ornithine and Lysine by Mycoplasma and L Forms; S. Dakota U.; Smith; AD-666 637

Properties of Bacteria Isolated From Deep-Sea Sediments; Georgetown U.; Quigley and Colwell; AD-667 064

Studies on the Respiratory Chainlinked Reduced Nicotinamide Adenine Dinucleotide Dehydrogenase. Binding Sites of Rotenone, Piericidin A, and Amytal in the Respiratory Chain; Calif. U.; Horgan and Singer; AD-667 301

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Radiolocation and Tracking of Animals—An Inexpensive Triangulation Recorder; American Institute of Biological Sciences; Cochran; AD-667 582

Cytoplasmic Streaming and Microtubules in the Coenocytic Marine Alga, Caulerpa Prolifera; Princeton U.; Sabnis and Jacobs; AD-667 435

The Initiation and Elongation of Rhizoid Clusters in Caulerpa Prolifera; Princeton U.; Chen and Jacobs; AD-667 436

Uptake and Assimilation of Amino Acids by Platymonas; Calif. U.; North and Stephens; AD-667 632

On Pattern Classification Algorithms—Introduction and Survey; Harvard U.; Ho and Agrawala; AD-667 728

Factors Leading to Overt Monilial Disease; Long Island Jewish Hospital; Isenberg and Berkman; AD-667 614

Stress Reviews. Radiation; Texas Christian U.; Sells *et al;* AD-667 452

Laser Eye Effects; Armed Forces-Nrc Committee on Vision; Sperling; AD-667 494

Stress Reviews. Atmosphere; Texas Christian U.; Sells *et al;* AD-667 451

The Fixation of Tetanus Toxin by Synaptic Membranes; Oxford U. (England); Mellanby and Whittaker; AD-667 618

CHEMISTRY

Long-Range Interactions of Alkali Metals; Queen's U. (N. Ireland); Dalgarno and Davison; AD-667 267

A Study of Random Network Models; Melpar, Inc.; Ordway; AD-667 241

Empirical Calculations for Electron-Impact Ionization of the Alkali Metal Atoms; Queen's U.; Prasad; AD-667 265

Nuclear Magnetic Resonance; Ill. U.; Jonas and Gutowsky; AD-667 268

Theory of Nuclear Hyperfine Interactions in Spherical-Top Molecules; Harvard U.; Yi *et al;* AD-667 345

Solvent and Temperature Dependence of NMR Spectral Parameters in 2-Fluoropyridine Solutions; Ill. U.; Alger and Gutowsky; AD-667 440

A Variable-Temperature Nuclear Magnetic Resonance Study of Complexes of Borane and Boron Trihalides With Acetone, Diethyl Ether, Dimethyl Ether, N,N-Dimethylformamide, Methanol, and Tetrahydrofuran; Calif. St. Coll.; Fratiello *et al;* AD-667 454

Combination of Lattice Modes With Internal Modes in Molecular Crystals; Michigan St. U.; Cahill *et al;* AD-667 470

Electrochemical Processes on Nickel Oxide; Western Reserve U.; Yohe *et al;* AD-667 607

Diffusion and Heterogeneous Reaction. Theoretical Analysis of Non-Steady-State Kinetics; Purdue U.; Rajapakse and Wise; AD-667 611

Ultrasonic Absorption in Bromoform; Scripps; Rasmussen; AD-667 677

Microwave Echo Resonance; Lockheed Missiles and Space Co.; Kaplan; AD-667 687

Some Remarks on Integral Expressions for Scattering Amplitudes; Queen's U.; Rudge; AD-667 693

Three-Body Recombination of Positive and Negative Ions. General Third Body; Queen's U.; Bates and Flannery; AD-667 725

Viscosity as a Function of Shear Rate; Princeton U.; Tobolsky and Chapoy; AD-667 843

Calibration of the Fe57 Isomer Shift; Calif. U.; Simanek and Wong; AD-667 885

Finite Expansion of a Hole in a Rigid-Workhardening Disk of Initially Non-Uniform Thickness; Calif. U.; Nemat-Nasser; AD-666 831

Chemiluminescent Materials; American Cyanamid Co.; AD-460 413

Time-Dependence of Crystal Orientation in Crystalline Polymers; Mass. U.; Stein; AD-666 622

The Polarization of Fluorescent Light From a Uniaxially Oriented Rubber; Mass. U.; Stein; AD-666 623

The Effect of Birefringence on Low Angle Light Scattering Patterns From Oriented Polymer Films; Mass. U.; Stein *et al;* AD-666 624

The Dichroism and Birefringence of Polymers Containing Polyene Segments; Mass. U.; Shindo and Stein; AD-666 625

The Anisotropy of the Polarizability of Polyene Segments; Mass. U.; Shindo and Stein; AD-666 684

Nanosecond Laser Photolysis and Spectroscopy: Excited Singlet Absorption in 1,2-Benzanthracene; TRW Systems; Novak and Windsor; AD-666 715

Raman Linewidths for Stimulated Threshold and Gain Calculations; Toronto U. (Canada); Stoicheff *et al;* AD-666 820

Stress Effects on the Paramagnetic Resonance of Yb (3+) in Th02 and Ho (2+) in CaF2; Calif. U.; Sroubek *et al;* AD-666 887

A New Theoretical Method for the Accurate Calculation of Expectation Values on Functions of Internuclear Separation in Singlet Sigma-State Diatomic Molecules; Pa. St. U.; Herman and Short; AD-666 981

Low-Temperature Heat Capacity of Lithium Tetrammine; Texas U.; Morgan and Thompson; AD-667 042

EARTH SCIENCES AND OCEANOGRAPHY

Ecology of Molluscs and the Culture of Mya Arenaria; General Dynamics Corp; Zuraw *et al;* AD-666 987

A Method of Objective Contour Construction; Rand Corp.; Murray; AD-666 830

Hydrographic Studies in the Northeast Gulf of Mexico; Gulf South Research Inst.; Drennan; AD-666 629

Equilibria and Nonequilibria in Organic Geochemistry; Woods Hole; Blumer; AD-666 949

A Socio-Demographic Analysis of St. Ignatious-Kumu, Rupununi District; Mcgill U. (Canada); Lee; AD-666 617

Depth Distribution and Bathymetric Classification of Some Sea-Floor Profiles. Submarine Geology North of New Guinea. East and West Azores Fracture-Zones in the North Atlantic; R. I. U.; Krause; AD-666 704

The Shores of Megalopolis: Coastal Occupance and Human Adjustment to Flood Hazard; Thornthwaite (C. W.) Associates; Burton *et al;* AD-467 011

Diffusion and Settling of Sediments at River Mouths: A Computer Simulation Model; Stanford; Bonham-Carter and Sutherland; AD-666 968

Current Measurements From Moored Buoys; Woods Hole; Fofonoff; AD-666 633

Surficial Sediments on Undulating Cary Ground Moraine in Central Iowa; Iowa St. U.; Daniels and Handy; AD-666 977

The Controversial Production of Sound by the California Gray Whale, Eschrichtius Gibbosus; R. I. U.; Asa-Dorian and Perkins; AD-667 270

On Some Planktonic Protozoa Taken From the Track of Drift Station Arlis I, 1960-1961; U. of S. Calif.; Tibbs; AD-667 691

A Study of Organic Materials Found in the Upper 60 Microns of the Sea Surface and Their Relationships to Surface Films; Scripps; Harvey; AD-667 844

Directional Spectrum of Wind-Generated Ocean Waves; Michigan U.; Uberoi; AD-667 438

A Doppler Shift Flowmeter; Scripps; Squier; AD-667 710

The High-Temperature Creep of Dunite; Princeton; Eaton; AD-667 478

Submarine Volcanic Eruptions Recently Located in the Pacific by Sofar Hydrophones; Hawaii Inst. of Geophysics; Norris and Johnson; AD-667 588

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Explosion Seismology at Sea; Scripps; Shor, Jr.; AD-667 675

Geological Interpretation of Seismic Profiles in Prince William Sound, Alaska; Scripps; Von Huene *et al;* AD-667 679

Long-Range Ocean Acoustics and Synoptic Oceanography Straits of Florida Results; Miami U.; Clark and Yarnall; AD-667 240

Oceanographic and Underwater Acoustics Research Conducted During the Period 1 May-31 October 1967; Woods Hole; AD-667 450

Track Charts, Bathymetry and Location of Observations: R/V Chain Cruise No. 67. Summary Cruise Report Prepared by Chief Scientists Track Charts, Bathymetry, and Location of Observations North Atlantic Ocean Southwest of Bermuda 10 May-9 June 1967; Woods Hole; Hays; AD-667 453

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Oceanographic Research at M.I.T. in the Department of Geology and Geophysics and the Department of Meteorology; M.I.T.; Biehler *et al;* AD-667 605

Calculation of the Magnetization of Uplifts From Combining Topographic and Magnetic Surveys; Scripps; Richards *et al;* AD-667 676

Seismic Refraction Profile in Coral Sea Basin; Scripps; Shor, Jr.; AD-667 678

A Photographic Compass Inclinometer for the Orientation of Deep Sea Sediment Samples; Scripps; Harrison *et al;* AD-667 683

Position Determination Near the Sea Floor; Scripps; Lowenstein; AD-667 708

Fine-Scale Topography and Magnetic Anomalies of the Deep Sea Floor off Southern California; Scripps; Loughridge; AD-667 712

Natural Desalination and Equilibrium Salinity Profile of Perennial Sea Ice; Washington U.; Untersteiner; AD-667 347

ELECTRONICS AND ELECTRICAL ENGINEERING

Systematic Definitions for Relations; Computer Command and Control Co.; Mann and Schild; AD-667 495

A System for Computer-Aided Selection and Assignment of Electronic Modules; Calif. U.; Gostelow; AD-667 260

Time Sharing. The Fundamentals of Time Sharing. An Evaluation of Commercial Time Sharing Computers. Operational Management of Time Sharing Systems; Carnegie Tech.; Bell *et al;* AD-666 730

A Method for the Design of Stable Nonlinear Feedback Systems; Northwestern U.; Murphy; AD-667 102

Decoding of Graph Theoretic Codes; Northwestern U.; Bredeson and Hakimi; AD-667 103

MATERIALS

On the Development of Two-Phase Structure in Glasses With Special Reference to the System BaO-Si02; Harvard; Seward, III *et al;* AD-666 983

Calculation of Regular Solution Phase Diagrams for Titanium Base Binary Systems; Manlabs, Inc.; Kaufman and Bernstein; AD-666 966

The Effect of Extractives on Water-Vapor Sorption by Wood; Yale U.; Wangaard and Granados; AD-666 951

Species Response to Prestress in Curved Laminated Wood Beams; Yale U.; Wangaard *et al;* AD-667 166

Structural Design Concepts for the Efficient Utilization of Fibrous Composit Materials; G. E. Co.; Rosen and Dow; AD-667 477

The Relation Between Viscosity and Moduli of Filled Systems; Monsanto Research Corp.; Nielsen; AD-667 625

The Mechanical Properties of the Corrosion Product Formed During Oxidation of Copper; Va. Inst. for Scientific Research; Sloope; AD-667 491

Principal Representatives of Carboranesiloxane Polymers and Their Properties; Olin Mathieson Chemical Corp.; Schroeder; AD-667 831

MATHEMATICAL SCIENCES

Combinatorial Configurations; CalTech; Ryser; AD-667 468

An Introduction to Linear Modeling of Stationary and Non-Stationary Time Series; Wisconsin U.; Watts; AD-667 472

From Immersions to Imbeddings of Smooth Manifolds; Columbia U.; Connolly; AD-667 653

Complete Models of Differential Fields; Columbia U.; Blum; AD-667 654

Some Experimental Non-Constant-Sum Games Revisited. Perception of Opponent's Payoffs; Yale U.; Shubik and Stern; AD-667 239

Decomposition Programming and Economic Planning; Calif. U.; Bradley; AD-667 245

Comparative Accuracy of Two Passive Range Finding Systems; Center for Naval Analyses; Spitz and Kenney; AD-667 573

A Note on Sequential Search; Columbia U.; Klein; AD-667 595

Sub- and Superharmonic Synchronization in Weakly Nonlinear Systems: Integral Constraints and Duality; Harvard U.; Musa and Kronauer; AD-667 017

Maximization of System Reliability With Limited Resources; Calif. U.; Bodin; AD-666 619

Machine Sequencing Via Disjunctive Graphs: An Implicit Enumeration Algorithm; Carnegie-Mellon U.; Balas; AD-666 810

On Optimal Solutions of 2-Person O-Sum Games; Northwind Wagb-282; Ben-Israel; AD-666 814

On Weakly Balanced Games and Duality Theory; Northwestern U.; Charnes *et al;* AD-666 815

A Chance-Constrained Approach to Capital Budgeting With Portifolio Type Payback and Liquidity Constraints and Horizon Posture Controls; Northwestern U.; Charnes *et al;* AD-666 840

Some New Approaches to Risk; Carnegie Tech.; Byrne *et al;* AD-666 841

MECHANICAL, INDUSTRIAL, CIVIL, AND MARINE ENGINEERING

Talc in Atmospheric Dusts; Scripps; Windom *et al;* AD-667 167

A Study on Methods for the Development of Reliability, Maintainability and Availability of Shipboard Machinery; United Control Corp.; MacFarlane and Mickel; AD-667 251

A Parametric Study of High Speed Support Amphibians; Hydronautics, Inc.; Miller *et al;* AD-667 251

Motion of a Large Spar Buoy in Sea Waves; Scripps; Rudnick; AD-667 671

The Analysis of Mooring Systems and Rigid Body Dynamics for Suspended Structures; Bell Telephone Labs, Inc.; Gormally and Pringle; AD-666 615

University Sealab, Capital and Operating Cost Analysis for a Saturation Diving Facility for the National Oceanographic Community; N. Hampshire U.; Savage; AD-666 834

METHODS AND EQUIPMENT

Improved Internal Friction Apparatus; Northwestern U.; Brittain *et al;* AD-666 733

Portable Field Recording System; AC Electronics-Defense Research Labs; AD-666 828

A New Family of Life Distributions; Wash. U.; Birnbaum and Saunders; AD-667 247

A Multispectral Survey of a Coastal-Intracoastal Environment; Fla. Atlantic U.; Witmer; AD-667 610

NAVIGATION, DETECTION, COMMUNICATIONS, AND COUNTERMEASURES

Improvements in Side-Looking Sonar for Deep Vehicles; Scripps; Anderson and Lowenstein; AD-667 711

Pictorial Sonar Demonstration Model Program; Sperry Rand Corp.; AD-667 832

A Linear Programming Formulation of Communication Networks With Memory; Northwestern U.; Hakimi; AD-667 095

Spatial Frequency Filtering; Michigan U.; Alward; AD-480 352

Optimum Search for Objects Having Unknown Arrival Times; Sylvania Electronic Systems-West; AD-208 306

NUCLEAR SCIENCES AND TECHNOLOGY

The New Radiosotope 99Ag and Some Measurements on 100 Ag; Calif. U.; Doty *et al;* AD-666 886

The Radionucleide 101 Ag; Calif. U.; Doty *et al;* AD-667 108

PHYSICS

MLD's and the Phase Angle Alpha; Texas U.; Jeffress and McFadden; AD-667 277

Resonance Scattering of Sound by a Small Gaseous Object of Arbitrary Form; Woods Hole; Steinberg; AD-667 394

The Harmonic Interval Fact or Artifact in Spectral Analysis of Pulse Trains; Woods Hole; Watkins; AD-667 449

Production and Measurement of Ultrasonic Surface Waves on Solids; Georgetown U.; Auth and Mayer; AD-667 591

Relation Between Thermal Ultrasonic Attenuation and Third-Order Elastic Moduli for Waves Along the ⟨110⟩ Axis of a Crystal; Columbia U.; Mason; AD-667 619

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Spatial and Spectral Dependence of Acoustic Reverberation; Scripps; Anderson; AD-667 672

Frequency Dependence of Reverberation in the Ocean; Scripps; Anderson; AD-667 680

Ion Pairing of Magnesium Sulfate in Seawater: Determined by Ultrasonic Absorption; Scripps; Fisher; AD-667 684

Ultrasonics and Hypersonics. A Review; Columbia; Mason; AD-667 735

On the Interaction Between Point Defects and Inclusions in Crystals; Harvard U.; Ashby; AD-667 238

The Use of a Bubble Model to Study Stress-Induced Migration and Sliding of Grain Boundaries; Harvard U.; Ashby and Raj; AD-667 589

Dislocation Drag Mechanisms and their Effects on Dislocation Velocities; Columbia U.; Mason; AD-667 736

Nuclear Spin-Lattice Relaxation in Magnetic Insulators; Calif. U.; Beeman and Pincus; AD-667 487

Effect of Density Gradients on an Air Jet; Joint Inst. for Lab Astrophysics; Uberoi and Garby; AD-667 442

A Physical Model of Liquid Helium; CalTech; Hsieh; AD-667 601

Ultrasonic Cavitation in Liquid Helium; CalTech; Hsieh; AD-667 602

An Experimental Investigation of the Structure of a Turbulent Wind Over Water Waves; Stanford U.; Karaki and Hsu; AD-667 836

Solitary Waves on a 45-Deg. Slope; Urs Corp.; Wallace and Wonderly; AD-667 839

Acoustic Self-Trapping of Laser Beams; Perkin-Elmer Corp.; Kerr; AD-667 475

Study of Various Aspects of Raman Scattering Using Gas Lasers; M.I.T.; Javan; AD-667 742

Second Harmonic Light Generation in Crystals With Natural Optical Activity; Harvard U.; Simon and Bloembergen; AD-667 252

Precision Optical Technology; Arizona U.; AD-667 606

Linked-Cluster Expansions for the Nuclear Many-Body Problem; Cornell U.; Brandow; AD-667 256

Relations Among the Superconvergence Conditions for Forward Elastic Scattering. Scattering of a Spinless Particle by a Particle With Arbitrary Spin; Cornell U.; Lin; AD-667 257

Current Algebras, Regge Poles, and the Insovector Anomalous Magnetic Moment of the Nucleon; Cornell; Goldberg and Gross; AD-667 259

Pion Electromagnetic Foam Factor From Coulomb Interference; Cornell; West; AD-667 261

Simple Shell Model Expressions for Coulomb Energies; Mich. U.; Hecht; AD-667 737

Plasma Interactions; Calif. U.; Banos, Jr. *et al;* AD-667 248

Low Beta Plasma Penetration Across a Magnetic Field; Calif. U.; Fried and Ossakow; AD-667 740

Applications of the Dirace-Schwinger Covariance Condition in Quantum Electrodynamics; Cornell U.; Brown and Bludman; AD-667 262

On the Diffusion of Load From a Transverse Tension-Bar Into a Semi-Infinite Elastic Sheet; CalTech; Muki and Sternberg; AD-667 600

Optical Lattice Modes of Mixed Polar Crystals; Pa. U.; Burnstein *et al;* AD-667 609

Study of Non-Radiative Recombination Processes in Semiconductors; Hewlett-Packard Co.; Loebner; AD-667 743

Speculations About Grey Tin; Calif. U.; Sherrington and Kohn; AD-667 837

Effect of Modulation on the Onset of Thermal Convection; CalTech; Venezian; AD-667 476

A Decade of Research in Electromagnetic Phenomena Under Joint Services Contract NONR-1866 (32); Harvard U.; King; AD-667 253

Reflection and Transmission of Plane Waves by Layered Periodic Media; Stanford; de Jager and Levine; AD-667 598

A Method for Photographing Microwave With a Polaroid Film; Harvard; Iizuka; AD-667 729

Gain Measurements of Standard Electromagnetic Horns in the K and Ka Bands; Calif. U.; Wrixon; AD-667 840

Sensitivity of Various Detectors to Knowledge of Signal and Noise Parameters; Bell Telephone Labs, Inc.; Hall, Jr.; AD-666 833

Finite Difference Solutions of the Acoustic Radiation Equation in the Near Field; Houston U.; Lu and Childs; AD-666 960

Two-Phase Gas-Liquid Flow Dynamics: Flow Oscillations in Transparent Parallel, Vertical, Heated Channels. Acoustic Velocity in Two-Phase Flow; M.I.T.; Gouse, Jr. *et al;* AD-666 618

The Effect of a Gap on a Fully Cavitating Flat Plate With a Flap; CalTech; Wang; AD-666 857

Specific Volumes of Water at High Pressures, Obtained From Ultrasonic Propagation Measurements; Harvard U.; Vedam and Holton; AD-667 111

Theoretical Prediction of the Stimulated Thermal Rayleigh Scattering in Liquids; Pa. St. U.; Herman and Gray; AD-666 952

Saturation Effects in Stimulated Rayleigh-Wing Scattering; Pa. St. U.; Herman; AD-666 954

Delayed Alpha Emission From Na20; Calif. U.; Polichar *et al;* AD-666 851

Production of Protons, Deutrons, and Tritons From Li6 on Li7 at 3.5 MeV; Minn. U.; Gale and Blair; AD-666 855

The Form Factor of the Neutral Pion; Columbia U.; Nemethy; AD-666 979

An Effective Nucleon-Nucleon Potential for Use in Nuclear Hartree-Fock Calculations; Carnegie-Mellon U.; Nestor, Jr. *et al;* AD-666 994

Masses and Decay of A124, P28, C132, Sc40, and Their Tz=0 Analog States; Calif. U.; Armini *et al;* AD-667 052

The Determination of the Static Quadrupole Moments of the First 2 (+) States in 126Te and 128Te by Coulomb Excitation; CalTech; Stokstad and Hall; AD-667 071

Lowest Two T=3/2 States of 17F Observed in the 160 (p,p) 160 Reaction; CalTech; Patterson *et al;* AD-667 072

New Method for Measuring the Ratio of the Proton Magnetic Moment to the Nuclear Magneton; CalTech; Marion and Winkler; AD-667 074

A Nuclear Structure Study of 23Na by Means of the 22Ne (3He,d) 23Na Reaction; CalTech; Dubois; AD-667 079

Bootstraplike Conditions From Superconvergence; Harvard; Ademollo *et al;* AD-667 168

Nonlinear Boundary Value Problems for the Circular Membrane; N.Y. U.; Callegari and Reiss; AD-666 961

PROPULSION AND FUELS

A New Application of Perfectly Stirred Reactor (P.S.R.) Theory to Design of Combustion Chambers; Pa. St. U.; Essenhigh; AD-812 114

Flow Fields of Flame Propagating in Channels Based on the Source Sheet Approximation; Joint Inst. for Lab Astrophysics; Uberoi; AD-667 439

The 26th Navy Symposium on Underwater Acoustics will be held at the U.S. Navy Underwater Sound Laboratory, New London, Connecticut, November 12-14, 1968. Additional information may be obtained from Mr. John B. Hough, Office of Naval Research, (Code 466), Washington, D.C. 20360. Phone: Area Code 202, 696-2693.

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Bubbles Offer New Horizons in Flow Visualization

A new technique is being developed for visualizing air flows. It uses soap bubbles which are filled with helium to make them neutrally buoyant. As a result, these bubbles are able to follow even complex air motions with remarkable accuracy.

This approach appears to add a new dimension to flow visualization, a tool which has proven to be immensely powerful in experimental research. Since these bubbles are from 1/16 to 1/4-in. in diameter, the motion of individual bubbles can be traced either by eye or photographically. Even turbulent air flows, for example, can be mapped out accurately for the first time. Smoke, which has been most commonly used for visualization purposes, diffuses too rapidly under these conditions and the particles are too small to be viewed individually. On the other hand, larger particles such as sawdust are generally too heavy to faithfully follow the air motion.

Under the sponsorship of the ONR, Air Programs Branch, a study is underway to determine the feasibility of this technique in air flows in the range of 300-400 fps, typical of vertical/short take off and landing (V/STOL) research. The study is being carried out by Sage Action, Inc., of Ithaca, N.Y. If preliminary tests show that durable bubbles can be generated in flows at these speeds, this technique can be applied to mapping out the complex flow patterns characteristic of V/STOL configurations, either in wind tunnels or field tests.

Sage Action, Inc. has already developed a bubble generator suitable for low-speed flow applications where the requirement for neutral buoyancy is even more stringent. The unit consists of a console, which stores and meters the constituents (air, helium and soap solution), and a head at which the bubbles are formed and injected into the flow. The two elements are connected by lengths of flexible plastic tubing.

This unit has already been tested in a low-speed wind tunnel for studying the flow about aircraft configurations, as well as in the field for observing the pattern of wind motion through crops and forests in support of agricultural studies. A bubble generator of this type is presently being applied to analyze the motion of cooling air through electronic enclosures. Surprisingly, the bubbles pass through fans and blowers without bursting.

Over a wide range in air velocities, it appears that the helium-filled soap bubble promises to be an important tool in future aerodynamic research.

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IN THIS ISSUE

VOL. XXI, NO. 9

Model of HARDIMAN, the man-machine system designed to magnify muscle power and give ordinary man the strength to lift and maneuver loads up to 1500 lbs. This unique concept provides the wearer with a set of mechanical muscles operated by hydraulic pressure. Technically known as an exoskeleton, the machine duplicates and multiplies human movement so naturally that man-machine compatibility is maximized. HARDIMAN is being developed by General Electric Company for the Office of Naval Research and the Army Materiel Command.

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