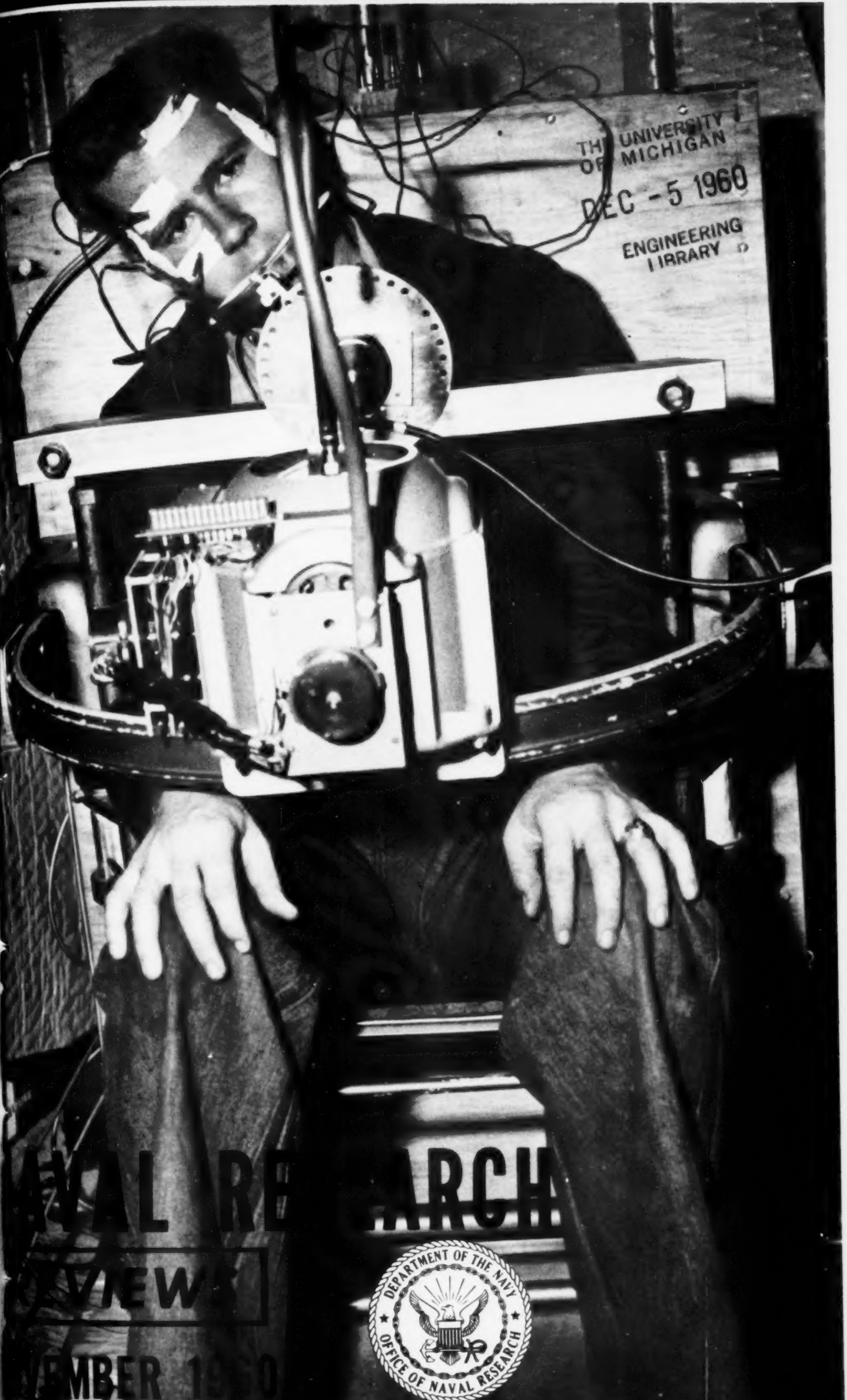

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RADM Martell on Space Power Systems

On 29 September, RADM Charles B. Martell, USN, Assistant Chief of Naval Operations for Development, addressed the American Rocket Society's "Space Power Systems Conference" in Santa Monica, California. Selected portions of his talk are quoted below.

"The Navy has supported basic research programs, primarily through the Office of Naval Research, with a large percentage of its budget since World War II. This is significant because it is through basic research that a strong foundation is laid for system development in the future; our dollars invested in basic research programs are essentially our growth stock--they have the greatest potential pay-off. . . We must be prepared to move in any direction that technological advances may suggest as fruitful. The Navy will continue to examine power research programs searchingly in order to determine potential naval applications and in order to act vigorously and promptly to transform laboratory discoveries and equipment into usable systems.

". . .There is one fact that I should like to emphasize and that is the great similarity of space power requirements with naval power requirements. Each involves extended periods of reliable operation in an isolated, sometimes vigorous, environment under rigid space and weight limitations. The concepts that you have reported here may be important in naval applications; similarly, the experience of the Navy should be of great value in solving specific space problems.

"It is worth reflecting that the unique demands of the submarine for a non-air-breathing power source resulted in practical application of nuclear power. This was the first major breakthrough in the field of power application since the invention of the steam engine, a good bit more than 100 years ago. Although nuclear steam power plants of our nuclear submarines are scarcely adaptable to space vehicles in their present form, the philosophy of these self-contained units of great reliability lends importance to the weight of the state of the art of power applications. As dramatically successful as our present nuclear designs have been, the Navy is still faced with problems that are familiar to you. These are cost, weight, space reliability, safety, and efficiency. . .

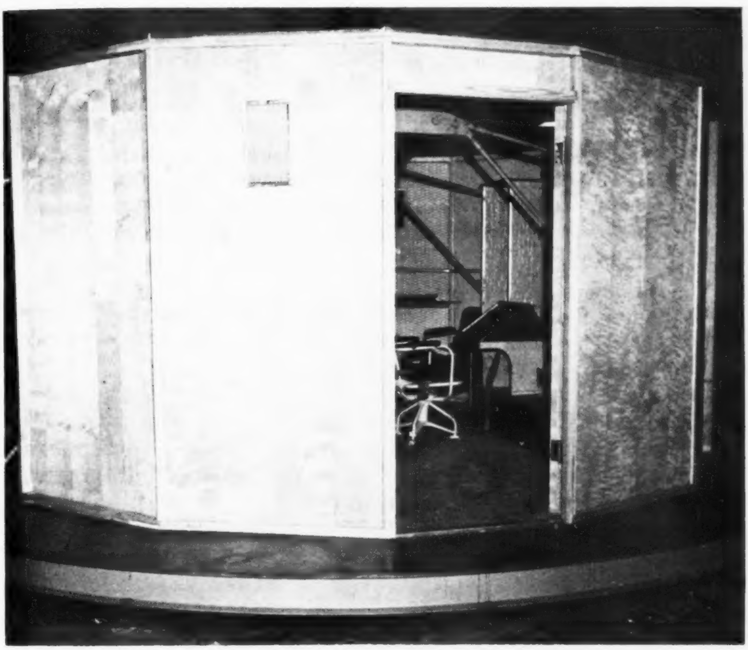
"In addition to the many naval efforts that you heard described in your symposium relating to power, there are companion pieces of research falling into the propulsive power problems. Direct conversion of heat electricity commands attractive bonuses of space, weight, simplicity, sound operation and--hopefully--efficiency, that makes such a power transfer medium extremely attractive for both submarines and high performance surface craft. In the successful conclusion, a really efficient direct-conversion process may well be a development that is important to the progress of our civilization as can be conceived in our lifetime. While we are hardly in a position to produce such plants in the megawatt range at this time, we are using the reverse thermoelectric effect to produce practical and extremely quiet refrigeration for our submarines. Needless to say there is many a householder who would be greatly relieved if the noise from his neighbor's air conditioner could be reduced from today's compressor to the level of a noisy electron. Discussion of all our power research would [also] include fuel cells [and] magneto hydrodynamics.

"With due modesty, we believe the efforts of the Navy in power, both at sea and in space, will go far towards stimulating progress in the power field. After all, the Navy lives on power and the effort represented in this symposium, we feel, is of great importance to us all."

Activities of Naval Laboratories in Space Medicine

CAPT C. P. Phoebus, MC, USN
Director, Aeronautical Division
U. S. Navy Bureau of Medicine and Surgery

There are six Navy laboratories currently active in various subareas of research and development in the field of space medicine. Of these six, the Aviation Medical Acceleration Laboratory at Johnsville, Pennsylvania, the Air Crew Equipment Laboratory at Philadelphia, Pennsylvania, and the School of Aviation Medicine, Pensacola, Florida, are devoting a significant portion of their current activities to space medicine; the Naval Medical Research Laboratory at New London, Connecticut, and the Naval Medical Research Institute, Bethesda, Maryland, have space medical capabilities of an appreciable degree, although their primary missions are in other fields; and the Pacific Missile Range, Point Mugu, California, is having capabilities in space medicine rapidly



Entrance to the world's largest human centrifuge.

built up. These laboratories are under the cognizance of the Bureau of Medicine and Surgery or the Bureau of Naval Weapons, and are funded by both.

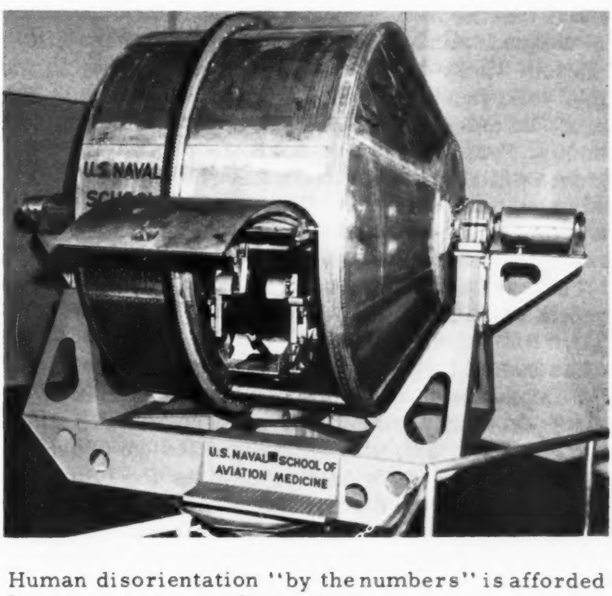
The Aviation Medical Acceleration Laboratory (AMAL) has its activities centered around the operation of the world's largest human

This famous spider monkey, a passenger on the flight of the first primate into outer space, appears to be quite interested in this Miami, Florida, newspaper headline--"If Monkey Can, Man, Can, Too."

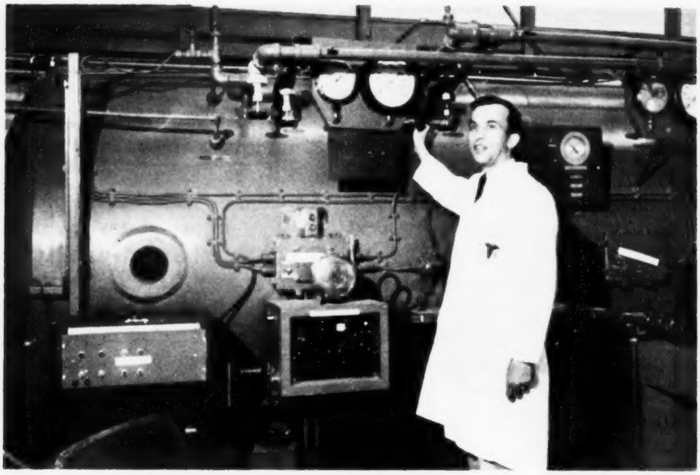
centrifuge. This human centrifuge has capabilities far greater than any similar device known to exist. In addition to the work done to establish the parameters of human susceptibility to acceleration stress, another major asset lies in the combination of the centrifuge with the large computer at the aircraft computer laboratory, also at Johnsville. This results in a capability for Dynamic Flight Simulation, which means that occupants of the gondola can "fly" exact replicas of flight patterns for both aircraft and space vehicles. This capability has resulted in the detection of over 50 potentially fatal situations involving the X-15 aircraft, has given the Project Mercury astronauts the most realistic training for the Mercury flight profile which they have yet received, and provides a tool for the Armed Forces, NASA, and industry for exploring the acceleration, control and display factors involved in flights of aircraft and space vehicles. There are many ancillary studies being conducted at AMAL in the fields of instrumentation, equipment design, biopack development, performance under stress, biochemical stress indicators, etc. This laboratory is a national asset.

The Air Crew Equipment Laboratory (ACEL) has for many years been a leader in the design and development of specialized air crew equipment. Such things as immersion suits, full-pressure suits, protective helmets, restraint apparatus, ejection-seat equipment, oxygen masks and regulators, and crash protection equipment have been designed and developed in this laboratory. The laboratory is currently heavily involved in various supporting activities for the Mercury astronaut program. The full-pressure suit which the astronauts will wear was designed and developed here. Human engineering studies of the displays and controls for the Mercury capsule are currently underway. Heat stress profiles for the Mercury flight have been tested with human subjects. The Mercury astronauts will receive training in a full-scale mockup of a Mercury capsule placed inside of one of the largest low-pressure chambers in the country, located at this laboratory. A number of experiments involving exposure of crews to simulated space flight conditions over periods of many days have been carried out. Current developmental efforts seeking adequate sources of oxygen while at the same time absorbing CO_2 and water vapor have focused attention upon the potential usefulness of superoxides for this purpose. This laboratory's principal role lies in its capability to apply the results of research to the development of useable items of hardware. Nearly all aviation personal protective equipment now used in the Fleet has been developed or evaluated at ACEL. A significant role for this laboratory in the design and development of equipment for man's utilization of future spacecraft is assured.

The School of Aviation Medicine at Pensacola has long been active in many fields of aerospace medical research. It was here, in collaboration with the Army Huntsville group, that the biopack was designed which resulted in the world's first flight of a primate into space and the recovery of the animal alive. This was the famous Monkey Baker ballistic trajectory flight conducted in May of 1959. The small spider monkey is still very much alive and active in her cage at Pensacola. One of the staff members is the world's foremost authority on the biological effects of cosmic radiation. Doctor Schaefer reports: Recent measurements



Human disorientation "by the numbers" is afforded by this aviation medicine device.



An experimenter checks the valves and gages of NMRI's large pressure chamber.

with balloons, satellites and space probes show that, in addition to the Van Allen Belt, other strong proton fluxes occur at certain times and in certain regions in space. The data are sufficient to permit close estimates of the dose distribution in a human target, and work in progress analyzes the hazard involved. It appears that existing official rules and regulations concerning maximum permissible exposure may prove to be entirely inadequate if they are to be applied to the various radiation fields encountered in space. The Director of Research, CAPT Ashton Graybiel, has been selected as the medical officer in charge of planning and executing the medical aspects of the recovery phase of Project Mercury. A unique feature of the laboratory is its capability for studies in disorientation. These disorientation studies are vital to manned space flight in that tolerances to spinning, tumbling, unusual attitudes, and isolation must be determined. The human disorientation device and the rotating room at Pensacola are unique tools for studying these disorientation problems which are unmatched elsewhere. The School of Aviation Medicine also has excellent capabilities and has carried out significant work in the effects of noise on personnel, communication problems, psychological aspects of aerospace medicine, physical standards and qualification criteria, and basic studies in respiration, cardiology and central nervous system functions.

There has been a large contribution to Naval Air Training made by the School's Department of Psychology in its program of selection and assessment of aviation personnel. This program was expanded a year ago with Project Astronaut, which is designed to use proven measures of performance in aviation as selection devices for future astronauts. A project recently initiated is a study of hibernation, suspended animation, and resting cells, in which there is a minimum of metabolic activity. This study is basic to preparation for extended periods of space travel, and is being sponsored by the National Aeronautical and Space Administration (NASA). The staff is small, the spaces in which the facilities are housed are crowded, but the past record of performance of this laboratory indicates that its capability for work in space medicine is significant.

The Naval Medical Research Laboratory at the Submarine Base, New London, Connecticut, has been pre-eminent for many years in studies of men occupying closed environments. Much of our long-submerging nuclear submarines' capability can be traced to work carried out in this laboratory. It seems apparent that the Navy's experiences in the closed environment which the submarine represents have almost an exact parallel in the closed environments which will be encountered in spacecraft. Fundamental studies in respiratory physiology have brought this laboratory to a peak of eminence in this field which has resulted in many other scientists beating a pathway to its door for technical information. Other studies in human engineering, visual problems, hearing and personnel selection have direct bearing upon space medicine. The Mercury astronauts will be trained in underwater escape techniques by personnel of this laboratory. New facilities being constructed here will reinforce the laboratory's capability for further studies of closed environments, particularly in the determination of breathing problems. They have already determined the safe level for long-term exposure to carbon dioxide. Now their attention is being directed to the ideal composition of respiratory gases. No one has yet fully determined the requirement for nitrogen in man's breathable atmosphere. Here we have an example of a laboratory's capabilities for studying problems in a field of current military importance which has resulted in a capability for solving problems in an entirely different medium.

The Naval Medical Research Institute (NMRI) at Bethesda, Maryland, has the primary mission of carrying out basic studies relevant to all facets of naval medicine. Here are located a number of unique tools, and the skills to use them, which can contribute to nearly any field of naval medical research interest. For example over a period of years the laboratory has been very active in pioneering efforts directed to the telemetering of physiological information from aircraft to ground and airborne receivers. The techniques developed here will certainly have considerable future usefulness in connection with manned spacecraft. The human calorimeter located at NMRI is another unique laboratory instrument which is unmatched elsewhere for basic studies of human heat exchange problems. The Mercury astronauts have been studied on this device. Fundamental studies on the effects of human tolerance to vibration have been in progress here for many years. While much has been learned, there are still many unknowns in this scientific area which must be solved if man is to withstand the extreme exposures to vibration which he will encounter in the launching and re-entry phases of space flight. The chemistry department at NMRI has succeeded in developing the techniques for obtaining potable water from human urine. This problem, which is pertinent to spacecraft, was quickly solved through special research techniques which had been already developed in the laboratory. All that remains is the engineering development of a system applicable to a specific space vehicle. A complete list of all of the research activities being carried out at NMRI of potential significance to space medicine would be inappropriate here; however, it should be pointed out that there are now being constructed at NMRI the most extensive facilities for studies of the biological effects of radiation upon man that have yet been installed anyplace. It is expected that these new facilities, which are financed and otherwise supported primarily by the Defense Atomic Support Agency, will have relevance to radiation effects studies which will be important to future manned spacecraft.

The U. S. Naval Missile Center at Point Mugu, California, has recently established a Life Sciences Department. This Department is being carefully staffed in order to carry out space medical studies in the unique environment represented by the Pacific Missile Range. Here is the opportunity to marry the research and development efforts of space medical laboratories to the operating environment represented by the Range. Men and animals launched into space by the Range will provide the Life Sciences Department with unique opportunities for studying space medical problems. The preparation of these subjects for flight, the telemetering of them during flight and the reduction of the data obtained postflight will be a primary function of this new department. At the same time there will be many opportunities available for carrying out significant research. Much of the research effort in the biomedical problems of manned space flight can be carried out here in conjunction with engineering studies of the vehicles themselves. Arrangements have already been made for the Life Sciences Department to utilize much of the unusual equipment already installed for engineering studies such as shake tables, environmental stress facilities, pressure chambers, etc. A closely integrated medical-engineering program is already underway in the human engineering area and much more is expected to result in the future from close working relationships between medical scientists, electronics and communication experts, mathematicians and other scientific disciplines not normally working in close association with life scientists. While few special facilities for space medical work are now in existence at Point Mugu, it is expected that a major build-up of such facilities will take place here in the future.

You may well ask, "What is the military requirement for putting men into space? Why devote all of this time and effort to achieving a manned space flight capability when there are so many other more pressing problems to be solved?" I can only answer that many of us are convinced of the inevitability of achieving manned space flight, and we must, in our research programs, anticipate that achievement. It is unthinkable that a military role for men in space will not be a requirement for the future, and we must anticipate that requirement. The NASA-Industry Conference, held recently, revealed that NASA does not hestitate to plan for and vigorously prosecute a program that looks forward to manned space flights to the moon, to the planets, and to employing men in future space laboratories. In fact, the primary justification for the development of their largest boosters, Centaur, and Saturn, seems to be the manned space-flight requirement.

As far as the man-in-space versus the black-boxes-in-space controversy is concerned, we feel there is much to be gained by putting man into space. Man has a perceptual constancy. He is able to recognize patterns and objects despite changes in size, orientation, hue, and contrast. He is sensitive to a wide variety of inputs such as vision, hearing, touch, vibration, pressure, linear, and angular accelerations. He is able to deal with low probability alternatives and unexpected events. It is factually not feasible to anticipate and program all possible alternative situations into automatic systems. Man takes advantage of time, redundancy, and sequencial dependencies and thus profits from his experiences. He shows originality in discovering and putting to use data and intelligence gathered incidental to the mission. He is flexible, can improvise, reprogram and even change performance tolerances. He has preservation instincts for himself, the vehicle, and for the mission. He can tolerate temporary overloads without disruption, and can select and filter inputs. He is capable of inductive reasoning, of setting up and verifying generalizing hypotheses. He can find and identify signals in a wide variety of noise patterns and spectra. He is harder to jam than automatic equipment.

In order to go where we wish in space we have to maneuver; and through the reasoning power of the crew we have that ability. If we were flying in space with tremendous speed and a trajectory fixed at burn-out, we would be bound to a definite fixed track, with no room for error. But flying time in space is long. We don't have to make flight path corrections suddenly, using full force. There is time, after the necessary calculations have been made, to do it with small forces over a long period of time. Visual outside information, with the exception of stellar navigation data, will be of no help. The task of a crew in a space ship will be to monitor, to supervise, to readjust, to override, and to repair equipment and instruments. Through the judgment and reasoning power of the crew, necessary corrections to the flight path can be instigated.

They will have to act with alertness, speed and accuracy. They will have to obtain and interpret information concerning vehicle operation, cabin environment, personnel functioning, and anticipate difficulties by advance planning and action. They will have to check, test, and observe all scientific instruments. Finally, in coming back, they probably will have to land the ship safely on Earth.

The automation possible through modern technology is not a complete or satisfying answer to space flight. The answer seems to lie in a clever combination of fully automatic equipment and the reasoning power of man. Only if we let the automatic equipment do what it can do better and let man do what he can do best, can we find the correct answer to space flight. Space will be conquered by man, not by unattended automatic machines.

And what if Project Mercury seems to show that a man cannot tolerate the space environment, and there is no firm military requirement for manned space vehicles which is determined for the immediate future? Is all of this work wasted? Not at all. Most of the space medical research effort is basic in nature and valuable in its own right. The applied aspects are even more useful since they are nearly always pertinent to current aeromedical problems.

In program planning conferences held in the Bureau of Medicine and Surgery on 14-18 December 1959 and 24-26 February 1960, the

Director of the Astronautical Division, BuMed; the Commanding Officers and Scientific Directors of the laboratories concerned; and the cognizant personnel of other Navy bureaus reviewed the basic areas of space medicine research and evaluated our available facilities as to their particular or unique potentials for carrying on work in this field. The efforts of the six Navy laboratories were coordinated to provide a program free from duplication within the naval service or other military organizations and government agencies. It was apprent that naval installations could not cover all scientific areas involved in space medicine, but with carefully planned programs a major contribution could be made to space medicine and to future naval operations. Accordingly, it was decided that a program of research in space medicine would be established with the following objective: To carry out such research, development, test, evaluation and such other basic support as may be required to enable the Navy to place, support, and maintain men in space weapon systems in order to meet Navy operational requirements.

Professional Opportunities for Scientists in the Medical Service Corps

Readers of the U. S. Navy Medical News Letter are often asked about career opportunities that exist for young scientists in the Navy. The Allied Science Section of the Medical Service Corps represents a small but very important research and training group supporting the mission of the Medical Department. While it is readily admitted that a scientific career in the Medical Service Corps does not lead the young scientist down the road to easy wealth, there are nevertheless, many subtle satisfactions to be gained from such a Navy career which are not always found in civilian or academic pursuits. For example, special types of research equipment are often available in Navy laboratories but not on the college campus or in industry. Opportunities exist for continuing to advance one's education at full pay and allowance in one's professional specialty. Promotional opportunities are simple and straightforward, not dependent upon the award of a particular research contract to one's employer. Other than Social Security, no deductions are made from the individual's income to participate in a program of retirement, and there is no need for hospitalization insurance.

At present there are 19 scientific specialties in the Allied Sciences Section (see BuPers Manual C-1322). In general, the minimum qualification for a commission as Ensign is completion of 30 semester hours of postgraduate work toward a Master's Degree from an accredited college or university; pharmacy and optometry are exceptions. The applicant must be at least 21 and under 32 years of age at the time of appointment. Applicants with a D. Sc. or Ph. D. degree are eligible for appointment as Lieutenant Junior Grade with an automatic credit of 18 months precedence in rank.

Informal queries by interested students regarding specific opportunities in their specialty are always welcome. Letters should be addressed directly to: Director, Medical Service Corps Division, Bureau of Medicine and Surgery (35B), Department of the Navy, Washington 25, D. C.

Training of Electronics Maintenance Technicians*

Dr. Glenn L. Bryan
Head, Personnel and Training Branch
Office of Naval Research

In 1951 a small group of professional psychologists, calling themselves the Electronics Personnel Research Group, was organized at the University of Southern California through the joint efforts of the Office of the Chief of Naval Operations, the Office of Naval Research, the Bureau of Naval Personnel, the Bureau of Ships, and other interested activities within the Navy. The primary purpose of the Group was to establish a cadre of well qualified civilian experimentalists interested in the many problems in the operation and maintenance of complicated electronic equipments, but free of line responsibilities for the Navy electronic systems and practices.

Joint support of the several bureaus was essential because it was well known that electronic problems are pervasive and are not the exclusive property of some one bureau. Perhaps this is another way of saying that it seemed unlikely that remedies applied within a single bureau could eliminate the many distressing problems being experienced throughout the Navy.

As a beginning, the decision was made to study shipboard electronics maintenance problems where they existed. Various descriptive techniques, including a number of observational methods, were formulated and employed by members of the research group, traveling in two-man teams and spending approximately one week on each ship during the study. Some 30 ships were studied. Numerous research problems were defined. At this juncture, the decision was made "to put the bird in the cage" and carry it to the laboratory.

The subsequent investigations were directed at one phase of maintenance: trouble shooting. The field observations had revealed that many practicing technicians were critically weak in accomplishing this crucial part of their work. Consequently, the lab was set up to observe technicians as they sought to diagnose and remedy equipment malfunctions. Detailed written records were kept indicating every single action that each technician made. These detailed records (sometimes called "protocols") were then to be subjected to intensive analyses. However, it is extremely cumbersome to generate trouble-shooting protocols in this manner. Much of the difficulty stems from the use of actual electronic equipment. It tends to limit the experimenter to studying one man at a

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*Based on Dr. Bryan's presentation during the July 27-29, 1960, Symposium on Defense Psychology at the NATO Headquarters, Paris, France. (Technical Report No. 30, ONR Contract No. Nonr-228(02), Glenn L. Bryan and Donald H. Schuster, Department of Psychology, University of Southern California.)

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time. It also restricts the scope of the study to those particular equipments that happen to be available for research purposes. Furthermore, working with live equipments can produce serious consequences. The vehicle equipment itself can be damaged. Test equipment can be ruined. Inept trouble shooters may be exposed to high voltages or other hazards. And, it is not at all unusual for the equipment to develop a fault of its own while the experimental subject is attempting to find the fault that was put in by the experimenter. It was obvious that life would be simpler if some way could be worked out to produce trouble-shooting protocols without using actual equipment.

Consequently, a study was designed to determine the feasibility of generating trouble-shooting protocols by artificial means. A "synthetic format" (described hereinafter) was developed. Its usefulness was evaluated by comparing the behavior of technicians attempting to trouble shoot real equipment with their behavior when trying to trouble shoot the synthetic format.

The procedure employed with the live electronic equipment is straightforward and easy to understand. While the technician whose behavior is to be studied is looking elsewhere, an experimenter adjusts the electronic equipment until it operates at peak efficiency. Then, he introduces a specific malfunction into the equipment. For example, he might replace a good resistor with a faulty one. The technician is then furnished with test equipment, schematic diagrams, wiring diagrams, parts lists, and other typical job paraphernalia, and asked to work on the malfunctioning equipment and to effect its eventual repair. While he is working, a trained observer records all of the technician's trouble-shooting behavior.

The synthetic format is quite simple. It consists of a large masonite board containing approximately 600 one-inch holes plugged with labeled corks. Beneath each cork is a legend describing the results of a particular check made on the actual malfunctioning equipment.

The trouble-shooting procedure, using the synthetic materials, is analogous to that employed with the real gear. At the beginning of each problem, the symptoms of the malfunction are described briefly. For example, the technician might be told that a radio receiver has a background hum in the speaker but no signals are available on any frequency. Armed with this information and the printed paraphernalia described above, he starts to trouble shoot. Numbered test points are indicated on the schematic diagrams. The technician can get information about waveforms, voltages, and resistances, or determine the effects of adjustment and parts replacement simply by raising the appropriate cork.

The results obtained from this early experiment indicated that substantial correlations existed between performance scores earned while trouble shooting actual electronic equipment and those earned while trouble shooting with the synthetic materials. Detailed comparisons of the protocols elicited by each format indicated strong tendencies for the same subjects to employ the same techniques regardless of format being used. These findings were accepted as evidence that protocols obtained with the use of synthetic materials were sufficiently similar to those obtained with real electronic equipment to justify the use of the former, and led to the development of an automatically recording form of the device just described. As a result, the self-recording device was employed by a large number of technicians in their attempt to solve trouble-shooting problems. All in all, over 1500 protocols were collected and analyzed.

The analyses exposed many weaknesses in the trouble-shooting techniques of trained technicians leading the author to break down the trouble-shooting sequence into arbitrary steps appropriate to their usefulness in directing the training effort. In addition, such an organization by steps also provides a basis for the development of automatic trouble-shooting routines to be programmed into electronic systems containing appropriate computers.

The first stage in the trouble-shooting task may be referred to as "symptom recognition." It entails a sensitivity to problems on the part of the technician, access to appropriate circuit-status information, and a concept of the normal performance level of the equipment. In many real-life cases, the technician is handicapped from the outset by poor equipment design which denies him access to very important information—including, in some cases, circuit status information which, if known, would signal incipient failures. Often the technician is penalized by the lack of clearly stated equipment-performance standards. From a training standpoint, the trainees require sufficient practice in determining that a piece of equipment is functioning below allowable tolerance levels. Too often the "canned" problems used in training start with the assurance that an equipment is indeed malfunctioning. Too often the initial symptoms of malfunctions are obvious. In actual practice, it is frequently difficult to decide whether or not trouble-shooting procedures should be initiated.

An extremely important but often overlooked phase in the trouble-shooting process is the exploration of the initial stimulus situation to ascertain the complete stimulus (symptom) pattern being generated by the equipment. Not infrequently, thoroughness at this point will result in the discovery of a displaced switch or faulty tuning which will completely eliminate the symptoms of a malfunction. Unfortunately there is a tendency for technicians to attempt to solve the trouble-shooting problem before they have defined it. Perhaps this is an indication that they regard their task as a search rather than a solution to a problem. Undoubtedly, it would be useful to design training courses to give each trainee sufficient practice in "symptom elaboration" before allowing him to engage in the next stage in the trouble-shooting process.

In the ideal case, the next step is to formulate all of the hypotheses which could account for the pattern of symptoms being observed. In actual practice this seldom happens. As a part of a study conducted by Moore, Saltz, and Hoehn in 1955, a group of airmen listed "all possible causes that they could think of that might be responsible for the symptoms" in their preplanning technique. The results comparing the effectiveness of the preplanners versus controls led them to recommend this type of activity as a means for improving trouble-shooting effectiveness.

At this point, one of the hypotheses must be selected for testing. Perhaps this is the point where so-called "probability trouble shooting" is most valid. Here, it would dictate the most likely hypotheses in line with past experience with that particular piece of equipment, or equipments of that sort. The selection of the hypothesis should also take into account such factors as the difficulties associated with tampering with certain portions of the circuitry. Under some circumstances, a trouble shooter might elect to test the second most attractive hypothesis instead of the most attractive—on the grounds that the first one would involve difficulties that should be avoided, if at all possible. This view is somewhat different from the usual view of probability trouble shooting which tends to encourage premature and unsystematic component replacement.

The technician should formulate, now, a more-or-less concrete plan for testing the hypothesis. It is probably best if the plan extends beyond the selection of the first test to be made. In any event, the plan should include definite criteria for abandoning the hypothesis being tested, because technicians without a plan tend to proceed in unsystematic ways and tend to persist in courses of action that are not productive. These conclusions are substantiated in the preplanning study conducted by Moore, Saltz, and Hoehn. The fact that this type of activity is a necessary part of trouble shooting is dramatized in those equipments which include a great many "go/no-go" indicators. Although all of the information necessary to the solution of a problem may be displayed in the form of console lights, the problem may be far from solved.

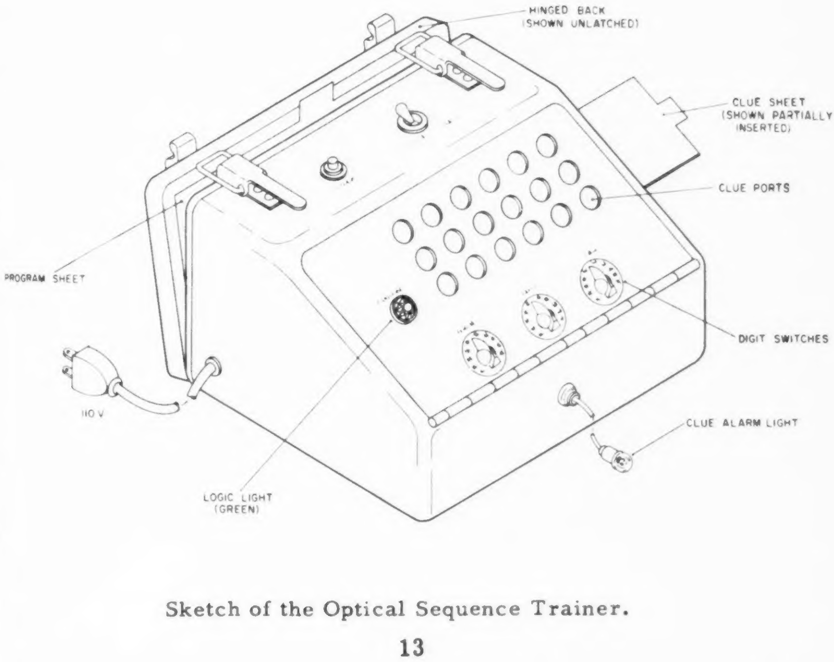
In 1959 Gagne called attention to the relationship between certain aspects of the trouble-shooting sequence and concept formation studies. It may well be that this is where studies of concept formation and studies of trouble shooting could benefit by mutual exchange. For it is at this phase of the trouble-shooting sequence that the individual is confronted with undifferentiated elements of information which can be combined in different ways. Formation and application of concepts—such as continuity, simultaneity, rise time, gating, and so forth—are necessary to take the trouble shooter farther down the road toward realizing his ultimate objective.

In the event the initial hypothesis must be rejected, rejection is likely to be on the basis of a pattern of information developing which is at odds with the hypothesis under test. In going back to select another hypothesis, the trouble shooter shouldn't take the one that seemed to be the second best bet at the start of the problem. He has now obtained additional information about the circuit and should be in a far better position to choose a hypothesis consistent with the total information available. Trouble-shooting protocols show that technicians are indecisive about rejecting hypothesis. It would undoubtedly be a good idea to provide trouble-shooting trainees with specific practice which required them to recognize the fact that their initial hypothisis had been discredited and should be replaced by another. A flexible device, such as that employed by R. Dale, in 1957, would appear to be useful for this purpose.

This idealized sequence is concluded when the technician makes some crucial adjustment or component replacement that eliminates the source of the difficulty. Crowder, in 1954, found that a group of 126 radar mechanics failed to make a sufficient confirmatory check before replacing a subunit, in 397 out of 600 problem trials where such a check was possible and necessary. Actually, it is not unusual for a technician to complete the repair of an item and to restore it to normal operating condition without knowing exactly what had caused the difficulty, or exactly what he had done to correct it. From a theoretical point of view, the confirmation of the correct hypothesis is an important contributor to the learning process. Obviously, "solving" a trouble-shooting problem without knowing what was malfunctioning has little training value for the technician.

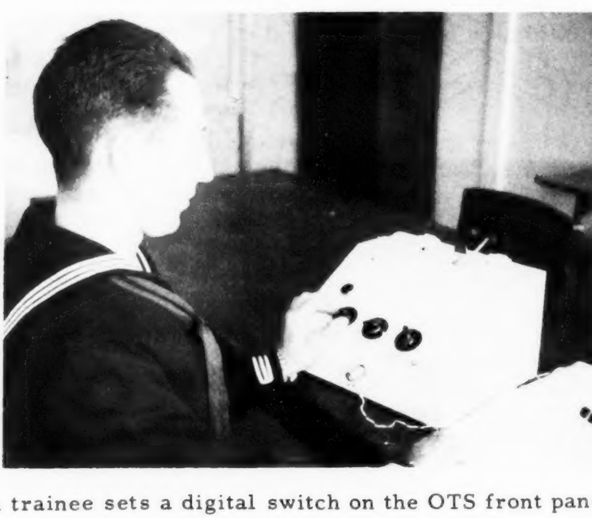
Since trouble shooting involves many sequential dependencies, weakness in one of the areas discussed can be extremely handicapping. None theless, many training programs fail to single out the separate phase. Rather, to a very large extent, trouble shooting is taught by the whole method. While "wholistic" considerations are important to the development of trouble-shooting excellence, premature reliance upon "wholistic" training can obscure individual weaknesses. It appears reasonable to develop the program so that electronic technicians can be trained how to locate faults on the basis of stages of trouble shooting, and then provide the trainee with ample opportunities to do the whole task after he achieves some degree of mastery of its parts.

An experiment conducted by the author and D. H. Shuster last year compared the effectiveness of several ways of teaching trouble shooting



Sketch of the Optical Sequence Trainer.

and demonstrated that the trainees could develop rather keen strategies—if trained in the proper manner. This study was conducted at the Navy Electronics Training School at Treasure Island, California. One hundred and sixty-two students served as subjects and devoted their 19th week of training to the experiment. The first day of each experimental work was spent in intensive study of the DAS-3 Loran—an operational-navigational aid which combines a superheterodyne receiver and fairly complicated pulse-type networks. During the next 3 days, the subjects were divided into groups, each group receiving a different type of trouble-shooting training. On the last day of the experimental week, the subjects were tested to measure their trouble-shooting proficiency. In addition, a number of trainees were individually tested 4 weeks later on an independent sample of trouble-shooting problems administered by school instructors using the SPS-10 radar. One purpose of the experiment was to measure the improvement in trouble-shooting proficiency attributable to sheer practice. The results obtained clearly indicated that such improvement did occur. However, those trainees who received guidance during the 3-day "learning period" improved even more. And presenting the student with written after-the-fact explanations of the guidance principles also proved to be beneficial. The psychologically interesting feature of the experiment and the exciting possibilities for useful application hinge upon the fact that guidance was given without prior rationalization. These groups employed a laboratory device named the Optimal Sequence Trainer (OST). The trainee was required to go through the following sequence during his trouble-shooting practice. He had to examine the symptom material as a preliminary to deciding what checks to make toward initiating the trouble-shooting sequence. There were about 1000 possible alternatives open to him—ranging from simple "knob twisting" to more complicated test equipment readings. When the trainee decided on a check, he would set a three-digit code number representing his intended action into the OST by means of the digit switches on the machine's front panel. If his selection exactly duplicated that of a "ghost expert," the green logic light on the face of the machine would come on. If he failed to duplicate



A trainee sets a digital switch on the OTS front panel.

the expert's choice, no light would come on and the trainee would have to refer back to the problem materials and decide upon another check. If the green light did come on, provision was made for the technician to obtain the results of the approved check. The experimental procedures are set up to deny him information under any other circumstances.

In effect the trainee had to "second guess" the expert at each step of the trouble-shooting sequence without any advance information regarding the expert's principles of trouble shooting. During the early portions of the 3-day practice session, many of the men trained in this manner felt as if they were trying to follow footprints in the snow while blindfolded. Toward the end of the 3-day period, however, they began to show that they had learned to think like the expert.

The fact that the experimental test results indicated that a man can be trained "to think like a trouble-shooting expert," by being required to follow in his footsteps, was deemed particularly desirable. This desirability stems from the fact that it is not uncommon for an expert trouble shooter to behave inconsistently with respect to his own "pious"

An experimenter places a program sheet in the back of the machine.

pronouncements of general trouble-shooting principles. Careful analyses of experts' trouble-shooting protocols strongly suggest that trouble-shooting problems are highly situational and are not ordinarily solved by the routine application of general principles. A particularly gratifying result of the experiment was that the men who had received guidance (learned "to think like the expert") not only excelled in the criterion test given at the end of the experimental week, but also in the SPS-10 equipment performance test independently administered.

To summarize, an attempt has been made in this article to present a concept of trouble shooting and the background against which it developed. Analysis of present training courses and the weaknesses of present school graduates, both have suggested the need for substantial revisions of training procedures. Recent successes of various synthetic devices and the demonstrated advantages of certain "feedback" techniques have been cited as attractive bases for the necessary modifications.

Discovery of the Ultraviolet Spectrum of the Sun*

Dr. Richard Tousey
U. S. Naval Research Laboratory
Washington, D. C.

Although the extreme ultraviolet spectrum of the sun has interested astronomers and physicists for nearly a century, it is a field in which progress has been made only within the last 14 years. The narrowly limited character of the solar spectrum, as compared with spectra obtained in the laboratory, first attracted attention over 100 years ago. Crookes, Piazzi-Smyth, and Cornu studied the matter and attributed the ultraviolet limit of the solar spectrum to absorption by the earth's atmosphere. Hartley, who discovered the strong ultraviolet absorption of ozone bearing his name, guessed that it was ozone that limited the solar spectrum. This was first established, however, by the work of Fabry and Buisson in 1913.

The early work of Cornu was not only important on its own, but it stimulated Victor Schumann to construct the first vacuum spectrograph, and so to discover the portion of the extreme ultraviolet known as the

Figure 1--Victor Schumann, the pioneer who opened the field of the vacuum ultraviolet between 1885 and 1903.

*From a paper presented by the author during the Astrophysical Symposium at Liège, Belgium, and used by permission of the Institut D'Astrophysique.

Figure 2—Theodore Lyman, for many years Professor of Physics at Harvard University and Director of the Jefferson Physical Laboratory, is shown in the early 30's beside his last vacuum spectograph. He discovered the Lyman series spectrum of hydrogen.

Schumann region. This extends from the limit of transparency of air, near 1800A, to 1230A, the extreme wavelength transmitted by fluorite, which was the material used by Schumann for the prisms in his spectrograph. Schumann was a most unusual person from today's point of view. He was trained not as a physicist, but as a designer and machinist, and became the part owner of a machine-shop business. At the age of 40 he turned to optics, and published 37 scientific papers between the years 1885 and 1903.

Theodore Lyman is the next great name in the field of extreme ultraviolet radiation. He received his Ph.D. from Harvard University in 1900, the title of his thesis being, "False Spectra from the Rowland Concave Grating." He was Professor at Harvard and Director of the Jefferson Physical Laboratory for many years.

Schumann's spectrum extended to 1269A, the limit imposed by the fluorite prism used to disperse the beam. It was left for Lyman to discover in 1914 the spectrum series of hydrogen, which bears his name, and whose first line lies at 1216A. This he was able to do by using one of the newly developed concave diffraction gratings, ruled by Rowland at the Johns Hopkins University. With this instrument he commenced, in 1906, a program of wavelength measurements in the extreme ultraviolet. Lyman died in 1954, but he lived to see the Lyman-alpha line discovered in the spectrum of the sun.

The region of the spectrum discovered by Lyman extends to 500A, and coincides almost exactly with the portion of the solar spectrum that has now been photographed by the Naval Research Laboratory. Millikan pushed the limit as far as 140A with a normal incidence spectrograph, by using a vacuum spark source. Dauvillier, working from the soft X-ray region with a crystal, reached 121A, and Thibaud, making

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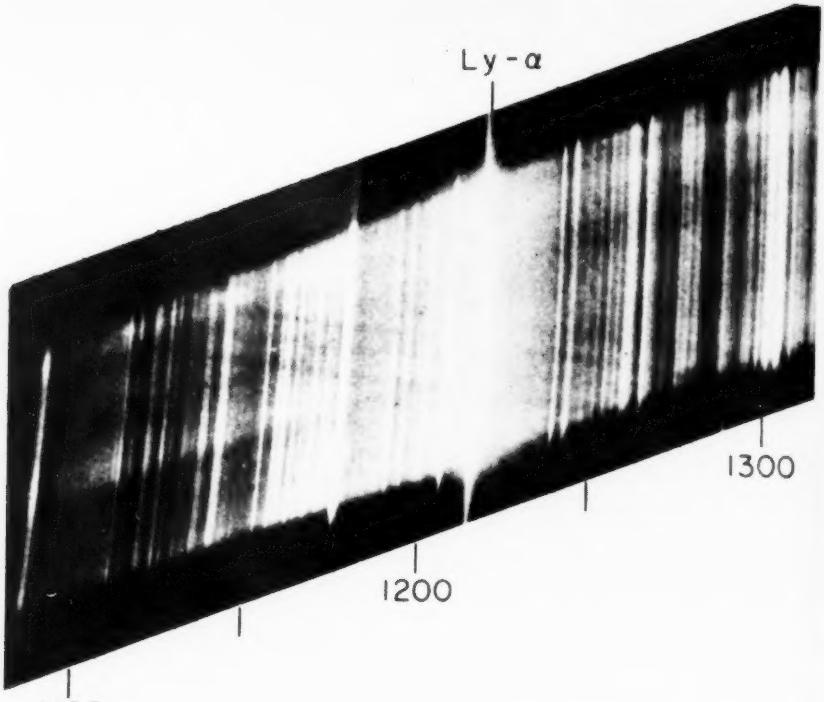


Figure 3--A portion of the solar spectrum, photographed by J. D. Purcell, C. R. Detwiler, and R. Tousey, of NRL, at 200 Km altitude on April 19, 1960. The Lyman alpha line of hydrogen is accompanied by many other emission lines, all superimposed on a continuous emission background.

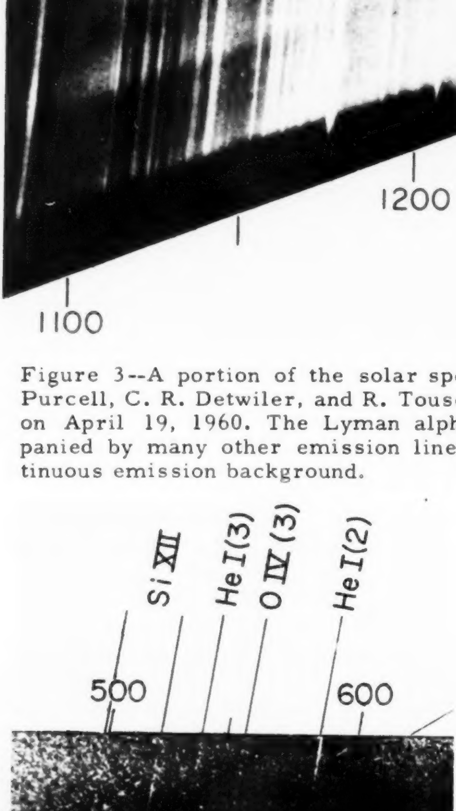


Figure 4.--The short wavelength end of the solar spectrum of Figure 3. The two lines at the left originate in the corona of the sun from silicon atoms that are 11 times ionized. Shown also are two lines emitted by helium and one from three-times-ionized oxygen.

first use of a grating at grazing incidence, reached a long wavelength limit of 68A. Finally, Osgood, in the laboratory of A. H. Compton, employing a concave grating at grazing incidence, bridged the gap between soft X-rays and the extreme ultraviolet in 1927. Thus, techniques for studying the solar spectrum were ready and waiting for the means to carry them above the atmosphere.

Although primarily a laboratory physicist, Professor Lyman was also very much interested in the solar spectrum and in attempting to extend it into the extreme ultraviolet. In fact, he once organized an expedition up Mt. Whitney, carrying with him a grating spectrograph in the hope of detecting possible solar radiations because of the decreased atmosphere above this altitude. At that time this was not as hopeless an idea as it now seems, for the absorption characteristics of air were not known. However, I suspect that Professor Lyman welcomed an official excuse for a climb, for he was a fine mountaineer, with experience in the Caucasus and elsewhere.

Following these attempts there have been many others, but all without avail. I may mention Brian O'Brien's spectrographs, flown to 80,000 feet in 1934 and 1935 with the National Geographic stratosphere balloons. There are also the delicate experiments of Meyer, Schein, and Stoll, and of Kiepenheuer from the Jungfraujoch at 11,400 feet, where some evidence was obtained for a few photons coming through the transmission window near 2150A, between molecular oxygen and ozone absorption, but these results are regarded as inconclusive.

Jumping several decades, we may now review the recent and rapid progress in the discovery and study of the extreme ultraviolet spectrum of the sun. This was made possible, of course, by rockets. The V-2 was the first successful high-altitude rocket. A noted German, Professor Kiepenheuer, has told me that he and Professor Eric Regener designed and constructed a spectrograph for a V-2 rocket. Lithium fluoride optics were used and a very simple guiding device was built. The equipment was ready to fly in 1943, but then there were higher priority demands for V-2 rockets. The end of World War II terminated their program. However, a number of captured V-2 rockets were thereupon made available to scientists in the U. S. A.

A group at NRL constructed and flew the first rocket spectrograph, on June 28, 1946. This instrument was not recovered. The experiment was repeated on October 10, 1946, however, and spectra to about 2200A were obtained. At the Applied Physics Laboratory of the Johns Hopkins University, Dr. J. J. Hopfield and associates also entered the field in 1946 and obtained a similar spectrum on April 1, 1947.

The next great advance was made possible by the biaxial pointing control developed by members of the Physics Department of the University of Colorado under Dr. W. B. Pietenpol, with aid of an Air Force contract. With this device Dr. W. A. Rense and Dr. Pietenpol and their associates secured, on December 12, 1952, the first photographic record of the Lyman alpha line, making use of a grazing incidence grating spectrograph.

Extensive use of the Colorado pointing control is still continuing. Among those taking advantage of its great pointing accuracy are Dr. Rense of Colorado, Dr. H. E. Hinteregger and Mr. A. S. Jursa at the Air Force Cambridge Research Center, and we at NRL. As a result, a great deal is now known about the solar spectrum in the extreme ultraviolet.

Since its first success in 1946, the Naval Research Laboratory has made steady progress in the photographic study of the solar spectrum. The latest flight on April 19, 1960, carried a new type of solar spectograph which produced the first spectrum photograph to be free from contamination by stray light. In Figure 3 a region near Lyman alpha is reproduced, showing many intense emission lines and a smooth continuous background, but no Fraunhofer absorption lines such as characterize the spectrum at longer wave lengths. Figure 4 is the portion showing the shortest wavelengths recorded. Here were detected the resonance lines of silicon XII, that is, silicon atoms with 11 electrons removed; these lines are truly coronal, excited in the 2-million-degree outer atmosphere of the sun.

There is a second category of solar radiation research that has also been very fruitful. This is nonspectrographic in nature and has been carried out largely at NRL. One of the first such experiments was the detection and crude measurement of Lyman alpha by NRL in November 1948. A thermoluminescent phosphor, $CaSO_4$:Mn, was employed. This phosphor was discovered near the turn of the century by Wiedemann and Schmidt, but it was Professor Lyman who showed in 1935 that it could be used to detect and measure extreme ultraviolet radiation. He lived to learn of the first detection of solar Lyman alpha with this phosphor.

Far more efficient and useful detectors, however, are the special photon counters and ion chambers devised by Dr. Herbert Friedman and Dr. Talbot A. Chubb and their associates at NRL and first flown in 1949. The results obtained with these are many and important. The emission of solar X-rays, first suspected by Burnight of NRL in 1948 from the blackening of photographic emulsions placed behind Be and Al filters and flown in V-2 rockets, was confirmed by Friedman with photon counters in 1949.

Following this, photon counters and ion chambers have been flown in a steady succession of rockets, in a program still actively pursued at NRL. These devices are ideal for studying the variability of solar emissions, and transient effects, such as occur during flares. They also make possible the accurate measurement of the attenuation of various wavelengths by the earth's atmosphere, from which data on densities in the upper atmosphere, and the distribution of constituents such as molecular oxygen can be derived.

It is pleasing to note the entrance of other countries into the field of solar research from rockets. The USSR has a program, and excellent spectra from 2990 to 2417A have already been reported in the literature. Other programs are under way in Great Britain, France, and Italy, and also in Japan.

The great remaining unexplored region of the spectrum lies below about 300A and extends to about 1A. Here we know from the photon counter and ion chamber work that radiation is present. Dr. Rense has reported photographing lines to 84A, and Dr. Hinteregger has already made photoelectric spectral measurements in this region. However the nature of the spectrum is not yet well established and much more work is needed.

From the point of view of the range in wavelength, this region is tremendous. From 300A to 1A is roughly a 10-times-greater wavelength range than the entire spectrum above 300A. Only a small portion of the total energy of the sun lies in this spectral tail, perhaps only about one millionth. Nevertheless, because of the ionizing and energetic nature of this tail, it is most important. Detection and study of these emissions should contribute greatly to our understanding of the process by which energy travels out through the atmosphere of the sun eventually to find its way to the earth.

The Earth Behaves Like a Solid

The mantle of the earth is about as rigid as steel, although over millions of years it may behave more like a plastic material. Earthquake waves, which may last a few minutes, have shown that the earth, like a steel ball, can be deformed by strong forces, but springs back to its original shape after the forces are removed. On the other hand, geological processes indicate that over millions of years the earth can be permanently deformed, like a plastic, as when mountains rise where seas once existed.

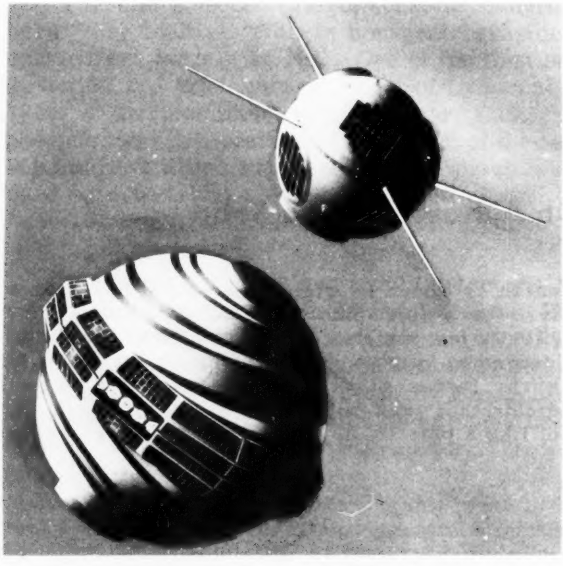
Long-range studies of earth tides by the Institute of Geophysics at the University of California, Los Angeles, under an Office of Naval Research contract, has slightly narrowed the gap between the minutes of seismic wave measurements and the eons of geological time. The earth tides, similar to ocean tides, cause two daily bulgings on the earth's crust. As the earth rotates, the bulges rise and fall under our feet, following the gravitational pull of the moon and the sun. For over a year, a team of UCLA geophysicists under John C. Harrison, assistant research geophysicist, measured the rise and fall of the earth tides at 13 stations all over the globe. The measurements proved that the earth behaves like a solid, not just for a few minutes, but up to 24 hours, and probably much longer.

There is still a tremendous time span between a day and the million-year flow of continents, but in the future UCLA geophysicists hope to narrow the gap further by measuring fortnightly, monthly, and ultimately annual earth tides.--ONR, Pasadena.

The Navy Reports on Its Solar-Radiation-Measuring Satellite

The U. S. Naval Research Laboratory's Solar Radiation I satellite—launched on June 22, 1960, as the "piggy-back rider" of the Transit II-A navigational satellite—is transmitting the first continuous measurements of solar activity in X-ray and ultraviolet radiations. These solar weather reports can be correlated with a host of ground level observations to help unravel the mysteries of ionospheric behavior as well as the mechanisms of solar storminess.

Far ultraviolet rays and X-rays cannot penetrate the upper atmosphere. At heights of 50 miles and more above ground, these rays ionize the atmospheric gas and produce the electrified regions of the ionosphere. For past decades astronomers and ionospheric researchers have sought to deduce the nature of the invisible short wavelength emissions from statistics of ionospheric behavior and optical indices of solar



Drawing of the Naval Research Laboratory's Solar-Radiation-Measuring Satellite shorty after its separation from TRANSIT II-A—the second experimental doppler-type navigational satellite to be launched by the Navy—and after being placed simultaneously in orbit with the navigational satellite. (From the cover of the August 1960 Naval Research Reviews.)

activity. Such phenomena as sunspots, the patterns of bright visible mottlings known as "plages," green-tinged coronal clouds, brilliant solar flares, and the accompanying radio noise storms are all related to fundamental mechanisms of energy transfer in the solar atmosphere. These mechanisms include shock waves, magneto-hydrodynamic waves, and the acceleration of corpuscles by cyclotron and synchrotron processes. The Navy's X-ray and ultraviolet monitoring satellite adds a new dimension to the study of solar storminess.

Rocket-borne experiments have already given clear evidence that soft X-rays from the sun create the important E-region of the ionosphere between 60 and 100 miles above ground. The ultraviolet emission of the hydrogen atom, known as Lyman-alpha, creates an absorbing region at lower levels which weakens radio signals transmitted through it. At times of solar flares, this absorbing region becomes so dense that radio fadeout occurs over the sunlit hemisphere. Rocket experiments have shown that very energetic X-rays accompany the visible flares and are responsible for the fadeout phenomenon, but all the rocket experiments performed thus far add up to only a few minutes of observation. The sequence of early events in a solar flare storm are so fast that it has not been possible to launch rockets sufficiently early to reveal the important history of the first few minutes of a flare. Neither do we know the post peak history of the flare processes in any detail. The new satellite monitor now gives us the opportunity to see the entire history of the X-ray and ultraviolet emissions from start to finish.

Many data have been recorded since 1960 Eta was launched, and the progress of data analysis has now begun to reveal some of the results. On August 6, for example, there occurred a solar flare lasting 18 minutes. The flare began just as the satellite came within range of the NASA Minitrack Station at Blossom Point, Maryland. Six minutes of clear signal reception show the history of development of ultraviolet and X-ray emission in relation to the ionospheric behavior and solar radio noiseness. One minute after the start of the visible flare, shortwave radio signals began to fade. Two minutes later, cosmic radio noise which normally penetrates the ionosphere began to fade away. At this point, the satellite showed clearly an increase in solar X-rays. One minute later, the sun began to hiss strongly at 2800 mc/s. This radio noise burst persisted for two minutes during which time the X-ray flux rose to a very high level and remained very intense even after the radio noise burst had disappeared. When the satellite passed out of reception range at Blossom Point, the X-ray flux was still strong, but on its next transit 2 hours later, the sun was completely calm again with no indication of abnormal X-ray emission. Throughout this sequence of events, the sun's ultraviolet radiation remained completely unaffected.

As time goes on, the satellite should contribute many records of solar storms. It seems clear already that this X-ray emission is a major aspect of the flare phenomenon. At least as much energy is radiated in the X-ray spectrum as appears in visible light and far more than in the radio noise. It is belived that both the X-rays and the radio noise are generated high in the solar atmosphere, perhaps 50,000 miles above the photospheric surface, in regions where the density of coronal gas is abnormally high and the temperature is of the order of one million degrees C. A fundamental question arises as to whether the X-ray emission appears first and back-radiates the solar surface to produce the visible flare. Another problem is what causes regions 10 to 20 times the normal density of the corona to form and hang together. Perhaps the coronal gas is confined in a "magnetic bag" reaching up from the sunspots and stretching like a sausage in a radial direction away from the surface. Observations of the corona at distances of several solar radii indicate that virtually all of the gas is confined to streamers occupying about 1/6th of the total volume of space surrounding the sun.

The performance of the solar radiation satellite is a welcome success after previous launching failures early in the Vanguard program, followed by difficulties due to interference by Van Allen Belt particles in Vanguard III and Explorer VII. In 1960 Eta, the effects due to Van Allen Belt electrons have been eliminated by the use of a magnetic broom. Only at the peak altitude of 650 miles is any interference encountered and that appears to be due to high energy Van Allen Belt protons.

Studies of the satellite operation indicate that SOLAR RADIATION I will have an operating lifetime of at least one year. Since solar power exceeds the system requirements, it is unlikely that solar cell deterioration will be discernible in the first year. The transmitter power output varies only with battery voltage and temperature, so no deterioration with time is apparent. The satellite operated in a dark orbit at a temperature of +16 degrees Fahrenheit until September, and then began an eleven day period of continuous sunlight where the temperature rose to +52 degrees. This establishes the temperature limits to be expected in the one year operation of the satellite.

Oceanic Subway Seen in Fish Travels

The swift Cromwell Current that runs eastward across the Pacific Ocean beneath the equator may serve as an oceanic subway transporting shallow-water fish from the East Indies to South America, according to Carl L. Hubbs, professor of biology at the University of California's Scripps Institution of Oceanography. Ten thousand miles of open water separate the tropical shores of the two hemispheres. For the most part, the fish populations of the two are quite distinct, Hubbs points out. However, a few species plentiful in the East Indies have made the eastward trip across the ocean and carved a place for themselves in the New World. How such small and relatively feeble creatures could cross the great reaches of the Pacific has long been a matter of speculation. Hubbs believes the studies of oceanic currents conducted by the Scripps Institution since World War II may have helped clear this up. Although the prevailing surface flow is to the west, there are two large eastward-flowing currents in the equatorial Pacific, he point out. One is the Equatorial Countercurrent at the surface. Another is the more rapid subsurface Cromwell Current. When first measured by Scripps in 1958, the Cromwell Current was traced about 6,000 miles. Now, on the basis of research conducted by the Japanese near New Guinea during the International Geophysical Year, it is believed to extend all the way across the Pacific Ocean. Hubbs believes fishes and other marine creatures trapped in these currents can make the trip across the Pacific in sufficient numbers to establish themselves in the Western Hemisphere. They may use small islands and banks as stepping stones. Only a few species of organisms are commonly found on both shores. There is little evidence for west-to-east immigration, but the east-to-west movement has been thoroughly documented. – ONR, Pasadena.

The XCH6 experimental vehicle--built for research purposes, especially to demonstrate the validity of supercavitation principles.

The Navy's New Hydrofoil Craft

The Navy's most advanced hydrofoil vehicle now in operation was demonstrated to the public for the first time September 21 at the Hague in The Netherlands as part of an international symposium on hydrodynamics, sponsored jointly by the Office of Naval Research and The Netherlands Ship Model Basin. The new 23-foot research craft features one of the first uses of supercavitating hydrofoils and the first installation of a gas-turbine engine in a hydrofoil craft. A supercavitating propeller is also used. Known as XCH6, the craft was designed and built for the Navy by Dynamic Developments, Inc., of Babylon, Long Island, New York, a subsidiary of the Grumman Engineering Aircraft Corp., under contract to the Office of Naval Research. The design of the vehicle was started in October 1958 and the completed vechicle launched in July 1959.

The experimental vehicle has been built for research purposes primarily to demonstrate the validity of supercavitation principles. It is designed to travel at speeds up to 80 mph and has already reached 50 mph. A few earlier hydrofoil boats have reached these speeds but at the expense of a great amount of power associated with the problem of cavitation. This phenomena occurs when vehicles move through the water at high speeds. As the velocity increases, the water pressure decreases. Eventually the pressure is reduced to that corresponding to the vapor pressure of the water. When this condition is reached, the water actually boils even though the water temperature is unchanged. More precisely, the water in the low pressure area flashes into steam, creating vapor-filled cavities from which the name cavitation is derived. In the case of the conventional wetted hydrofoil, cavitation destroys the lifting capacity of the foil, reducing its efficiency and requiring much greater power to drive it through the water. Since the conventional marine propeller is designed with foil sections, its efficiency at speeds of more than 30 knots is also reduced by cavitation.

The principle of supercavitation is the first effort to break through the barrier of cavitation in order to achieve high speeds in a manner never before thought practical. Supercavitation was discovered a few years ago through research by the Navy principally by Marshall P. Tulin. Theoretical work involving the study of the characteristics of cavitation has led to a new foil form which allows for cavitation and maximizes the lift of a hydrofoil. When applied to a propeller, it increases the speed at which a ship can be efficiently driven.

The XCH6 is the first full exploratory application of the principle of supercavitation. In addition, the General Electric T-58 gas-turbine engine, rated at 1050 horsepower offers a special advantage when combined with the supercavitating propeller, which can make several thousand revolutions per minute as compared to a few hundred for the conventional wetted propeller. The direct drive of the gas turbine plant without the requirement of reduction gears can exploit the greatly increased propeller rpm. Power is transmitted from the engine to the propeller through a unique right-angle drive consisting of two sets of spiral bevel gears. The top set transmits the power from the horizontal propeller shaft to the vertical shaft which runs inside the tail strut. The second set transmits the power from the vertical shaft to the horizontal propeller shaft. Each of these gears is suitably lubricated by a circulating oil system driven by a 2-1/2-horsepower, gasoline-powered engine.

There are two basic types of foils that are generally used on hydrofoil craft. The surface-piercing foil, which is simple and rugged, is in the form of a V with a high dihedral. It operates partly submerged and is inherently stable so that the tendency to submerge more deeply is counteracted by the generation of greater lift, thereby maintaining the boat on a constant level. Another type is the totally submerged foil, which gives a smoother ride in a seaway. However, it must have its angle of attack or the position of its flaps adjusted by automatic controls because of the many rapid, small corrections needed. The XCH6, which has an aluminum hull, operates with two surface-piercing main foils forward of the center of gravity and one fully submerged foil well aft of the center of gravity. The two main foils support 75 percent of the weight of the vehicle with 25 percent of the weight on the tail foil, which is steered by the pilot in flight.

The Navy, however, is actively interested in developing automatic controls for submerged foils. In fact, a 20-foot test craft, developed under ONR and Bureau of Ships sponsorship by Gibbs and Cox, Inc., has demonstrated that an electronic sensing system can operate totally submerged foils very well. With further development, they offer the potentiality of a quite comfortable ride with a minimum of pitching and heaving motion even in rough seas.

Although the hydrofoil concept is more than 50 years old, there were only sporadic attempts by individuals with limited success to develop such craft prior to World War II. During the war, the Germans exerted considerable effort to develop fast PT types and tank carriers, but their work ended when an 80-ton version designed for well over 50 knots foundered in a following sea. The Canadians also have pioneered in hydrofoils. Since the war, the Soviet Union has shown great interest in hydrofoil craft. In 1948 the Chief of Naval Operations directed the Office of Naval Research to "explore thoroughly" the hydrofoil principle with the support of the Bureau of Ships and the Bureau of Aeronautics (now combined with the Bureau of Ordnance into the Bureau of Naval Weapons).

The Navy's first major success was in 1952 with the 26-foot, 125-horse-power version built for the Navy by the Baker Manufacturing Company. This is High Pockets, which has a hull of fiberglass reinforced plastic with wood frames. The six-passenger craft has made 40 mph with a gross load of 6000 pounds, while flying in a 4 to 6-foot seaway. High Pockets also has retractable hydrofoils which allows it to operate in the displacement condition in a little more than 2 feet of water. This boat, which utilizes four surface piercing foils, was also demonstrated publicly on September 21.

The initial success of the practical application of the supercavitation principle as demonstrated by the Navy's XCH6 brings considerably closer the possibility of hydrofoil ships and craft traveling at speeds of more than 100 mph while maintaining stability and without the requirement of excessively high powered engines. The U. S. Navy will continue its long-range program of research on hydrofoil craft, investigating further the useful characteristics of supercavitating hydrofoils and propellers and developing improved electronic control systems for submerged foils. The goal is to achieve high-speed hydrofoil ships and craft useful for a variety of military purposes, which will at the same time lead to widespread commercial use.

Gooney Birds Take Flight on Midway

Navy fliers "have won their war" against gooney birds (correctly known as albatrosses) on Midway Island in the Pacific—so reports the Washington (D.C.) Daily News, October 10. Pilots have been dodging the big 7-foot-wingspread albatrosses for years, and they've tried every known trick to frighten them off, including rifle shots just above their nests. Finally, Navy civilian biologists found that an updraft in the runway region, caused by ocean breezes striking buildings and land elevations, acted as a labor saver for the birds when taking off. Now, everything in the area has been leveled, and the gooneys have moved to other parts of the island. (For more details about gooney birds on Midway, see NavResRev, Oct/60, pp. 7-11.)

Dr. Richard Tousey was the unanimous choice of the Board of Directors of the Optical Society of America as the Frederic Ives Medalist for 1960. Dr. Tousey is head of the Rocket Spectroscopy Branch of NRL's Atmosphere and Astrophysics Division. A formal presentation of the medal was made by the Society at a banquet on October 13 in Boston, at which time Dr. Tousey was recognized for his outstanding contributions in the area of atmospheric and solar spectroscopy. He gave the Ives Medalist address on October 14, the closing day of the 3-day convention. (See pp. 16-21 for Dr. Tousey's article, "Discovery of the Ultraviolet Spectrum of the Sun.")

Research Notes

The Wisher System

Underwater Communication Via Sign Language

LCDR Peter R. Wisher, USNR, a professor at Gallaudet College, Washington, D. C., is the author of a manual, Use of the Sign Language in Underwater Communication, that has been incorporated into the curriculum for trainees of both the Underwater Demolition Team at Little Creek, Va., and the Underwater Swimmers' School at Key West, Fla. Dr. Wisher prepared the manual as a partial solution to the problem of a more rapid and simple means of communication between underwater swimmers.

In further pursuit of solving the Navy's acute communication problem of underwater swimmers, Dr. Wisher spent his 2 weeks of active training duty this past summer at the U. S. Naval Submarine Base, New London, Conn. He was previously on active training duty at Little Creek and Key West, where he taught the Wisher System to demolition teams and frogmen. While at New London, Dr. Wisher expounded his system to trainees and contrasted it with the slate-writing method which is extensively used by the Navy.

The Wisher System consists of (1) the manual alphabet, (2) numerals, (3) signs (movements with the hands, or gestures, representing actions, ideas, and objects), and (4) a 169-word vocabulary. The manual alphabet used in the Wisher System is based on traditional signs which have been used for the past 100 years and are still taught at Gallaudet College, a nationally renowned college for the deaf.

It does not take long to learn this means of communication, Dr. Wisher explains. Mastery of the sign language usually becomes a reality after about six 2-hour lecture periods during the trainee's basic indoctrination. The manual alphabet is learned first because it serves as the basis for the description of signs and words not included in the Wisher System vocabulary. Simplicity is essential; related meanings are associated with one sign. For instance, the sign for think ("With the right hand in the "D" position, palm facing left, touch the temple several times with the index finger.") also can convey the words thought, idea, and remember. The manual language of "speaking without words" is not subject to rules of grammar; facility in communication is the determining factor. For the sake of universal understanding, signs should not be distorted. However, upon mutual consent between two communicators, new signs to meet a special need can be improvised.

Not only does the sign language produce faster communication between underwater swimmers, but the system has other uses. It can be used, Dr. Wisher says, in areas where loud noises preclude normal speech or it can be used effectively out of the water when silence is required. Although no system for communication in poor-visibility areas is included in the Wisher System, the sign language can very easily be understood through the sense of touch.

YOU

SWIM

BACK

TO

SHIP

LCDR Peter R. Wisher demonstrates "speaking without words." This group of photos is similar to the ones contained in Dr. Wisher's manual, <u>Use of the Sign Language in Underwater Communication</u>. Here Dr. Wisher forms the sentence, "YOU SWIM BACK TO SHIP." Although "slate writing" is now used extensively by Navy underwater swimmers, the Wisher System also can be used very effectively for rapid communication.

Ship Behavior at Sea

Highlights of the Third Seminar on Ship Behavior at Sea included (1) a panel discussion on the objectives of research on ship behavior at sea and (2) a session on radically different types of ships capable of higher speeds than conventional ships in both smooth and rough water. The Seminar was held at Stevens Institute of Technology, Hoboken, N. J., under the joint sponsorship of the Office of Naval Research and Davidson Laboratory of Stevens Institute of Technology. Sixty scientists and engineers from the United States and several foreign countries attended the Seminar, June 13-17.

The panel chairman, Professor Edward V. Lewis of Davidson Laboratory, offered for discussion the statement that the basic problems of ship behavior at sea have been solved. He suggested that recent advances in experimental model techniques and ship motion theory provide essential tools for evaluating new designs and indicating the direction for improving ship behavior at sea. The panel disagreed with this suggestion.

Dr. William E. Cummins, Head, Seaworthiness Branch, David Taylor Model Basin, expressed his opinion that although ship motion theory has made rapid progress in recent years, it is still inadequate for answering specific questions of designers. He called for more basic theoretical work on pitching and heaving motions—particularly to obtain more accurate coefficients in the equation of motion—more rigorous treatment of three-dimensional effects, and more thorough investigation of behavior in oblique seas.

Professor Korvin-Kroukovsky, Stevens Research Professor (Retired) and Consultant in Hydromechanics, emphasized the need for basic advances in the theory of lateral motions of ships to obtain better automatic steering and better control of rolling in rough seas. Improvement in either area involves the theoretical treatment of the coupling effects among the motions of roll, pitch, and yaw.

Other speakers stressed the need for solutions to some of the practical problems of designers. Mr. James J. Henry, Naval Architect, New York, N. Y., felt that modern cargo ships lose too much time in rough water at sea. Designers need more guidance regarding practicable means of reducing motions, he stressed. Mr. James L. Mills, Jr., Supervising Naval Architect, Bureau of Ships, said that the problem of the naval designer is sometimes more specific than simply reducing motions. For example, in designing aircraft carriers, it is more important to minimize the motion of the after end of the flight deck where airplanes land. He believes that researchers should strive to solve this problem. Mr. Mills is also interested in unusual types of ship hulls which would be capable of much higher rough water speeds.

During the session on radically different types of ships, it was pointed out that ordinary ships require large expenditures of power as speed is increased—beyond 30 knots for a superliner, or 40 knots for a destroyer. This price of power, the session revealed, is exacted by the creation of trains of waves trailing astern, representing a waste of energy that increases rapidly as speed is increased. Furthermore, in rough storm seas destroyers and even superliners experience such severe motions that speed must often be drastically reduced. Mr. E. Frankel of the Massachusetts Institute of Technology described a type of unusual craft for overcoming some of these handicaps. It is actually more like a submarine than a surface ship, with the main hull normally operating a short distance below the surface of the water,* and a fin or strut projecting through the water. This strut provides air for the power plant and for ventilation, and a small navigating bridge located at its top well above the sea. Mr. Frankel reported a reduction in wavemaking resistance in calm water and noticeably reduced motions when running at high speed through waves in the M.I.T. model tank. A similar type of craft is being investigated at the Davidson Laboratory.

Professor Lewis described another unusual craft that resembles a surfaced submarine. This new-type craft cuts through the waves with very little pitching motion when running at high speed. Mr. Paul Van Mater of the Davidson Laboratory described results of model tests of a slender hull form with a large torpedo-like appendage below the keel at the bow and another at the stern. The resistance of these bulbs was appreciably less, at speeds over 30 knots, than for a destroyer of the same displacement. Films of the models in action in the wave basin showed remarkably little pitching motions at high speed, but a moderate amount of heaving.

High-Pressure Reaction Rate in Ceramic Research

The increasing needs for materials to operate at high temperature have spurred research in ceramics. A particular area that has proved to be extremely important has been the investigation of high-pressure reactions. Under an ONR contract, techniques have been developed by which reaction rates are increased by several orders of magnitude. This permits reactions to take place and be studied at temperatures much lower than permissible at usual rates. As a result, it has been found that the conversion of a phase into its high-pressure polymorph can be accompanied in a much shorter time at much lower temperature than is possible in a uniaxial press. This discovery has considerable implication for improved technology in diamond synthesis.

The apparatus which has led to these greatly enhanced reaction rates consists of a uniaxial press having a motor and a gear train so designed as to permit one of the pistons to oscillate through a small angle. The effect of this slight oscillation can be described as being between a pure grinding action, producing brittle fracture (and hence bend rupture) within individual grains, and a periodic application and release of a shearing stress in three dimensions. In brief, an oscillatory motion is superimposed upon a ramming motion. The ramming component can reach 50,000 atmospheres in runs up to 500°C for 20 hours duration.

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*See NavResRev, Feb/60, pp. 1-10.

On the Naval Research Reserve

Three Seminars

Three Research Reserve Seminars were held in July and August—one at Columbus, Ohio, another at Pasadena, California, and the third at Princeton, New Jersey. They dealt with (1) research methods, (2) guided missiles, oceanography, and undersea warfare, and (3) research planning and management. Accounts of the Seminars follow.

NEW PLANNING AND MANAGEMENT AT PRINCETON

Seventy-one reserve officers—50 Navy, 11 Army, and 10 Air Force—attended the New Planning and Management Seminar at Princeton University's Graduate College. A comprehensive review of the major problems of research planning and management which affect the military services and other governmental agencies, universities, nonprofit research laboratories, and industrial research organizations was conducted under the sponsorship of the Office of Naval Research in conjunction with Naval Research Reserve Company 4-1, CDR Charles W. Logan, USNR, commanding.

The 2-week Seminar, designed to provide an insight into the unique methods employed by individual organizations, was the first seminar dealing with research management and planning to be held under the Navy's Research Reserve Program. CDR Charles R. Goldberg, USNR, served as Seminar Chairman.

The opening day session, 22 August, was marked by distinguished speakers. Welcoming addresses were made by RADM C. H. Lyman, USN, Commandant, Fourth Naval District; Dr. J. S. Finch, Dean of the Graduate College, Princeton; and RADM R. Bennett, USN, Chief of Naval Research. Research and Development programs of the three services were presented by the Honorable James H. Wakelin, Assistant Secretary of the Navy for Research and Development, a former member of NRRC 4-1; the Honorable Courtland D. Perkins, Assistant Secretary of the Air Force for Research and Development, now on leave from the Princeton faculty, and Brig. Gen. William J. Ely, USA, Director of Army Research.

Succeeding seminar sessions were devoted to lectures by officials from industry, government, and universities. These presentations were followed by seminar problem solving sessions; conferees were assigned to one of four groups for these sessions. Among the activities which sent representatives to speak at this seminar were International Nickel Co.; International Business Machines Corp. Dunlap and Associates; Applied Physics Laboratory of Johns Hopkins University; Naval Research Laboratory; International Latex Corp.; Armour Research Foundation; Mellon Institute; Batelle Memorial Institute; RCA Laboratories; MIT; Philco Corp.; AEC; National Science Foundation; Forrestal Research Center; Merch Sharp and Dohme Research Laboratories; NASA; and the Alloyd Corp.

CAPT J. W. Jockusch, Jr., USNR, Special Assistant to the Chief of Naval Research (Research Reserve), addressed the conferees on the last day of the seminar on developments within the Naval Reserve program. The annual banquet of NRRC 4-1, held the same evening, was opened to all officers attending the seminar.

Two interesting field trips were made in the course of the seminar. The first trip was a visit to the U. S. Army Signal Research and Development Laboratory at Fort Monmouth, N. J., and the second a tour of Princeton's James Forrestal Research Center.

PASADENA SEMINAR FEATURES MISSILES

The Eighth Annual West Coast Research Reserve Seminar, sponsored by the Office of Naval Research and conducted by the ONR Branch Office, Pasadena, convened for 2 weeks on 1 August 1960. Seventy-three reserve officers from the western half of the United States—60 Navy, 6 Air Force, 6 Army and 1 Coast Guard—were indoctrinated in the latest developments in guided missiles and associated electronics and in some areas of oceanography and undersea warfare. CDR Charles V. Armstrong, USNR, was chairman of the Seminar. Naval Reserve Research Company 11-2 was the host Company.

The Seminar had an especially intensive schedule consisting of 10 full-day sessions, one half-day session and three evening sessions. All but 3-1/2 days of the Seminar were spent at 13 industrial and governmental facilities in the Los Angeles and San Diego areas in order that the Seminar attendees might have a maximum familiarization with actual hardware and developmental models. The list of places visited reads like a "who's who" in Pacific coast research, enabling the conferees to study R&D from steel making at the Kaiser plant in Fontana to advanced electronics at Hughes Research in Malibu.

CAPT J. C. Myers, USN, Deputy and Assistant Chief of Naval Research, spoke on "Research and the Navy of the Future," outlining the technical aspects of the current ONR Program. RADM C. F. Horne, USN (Ret), Vice President and Manager of Convair, Pomona, California, discussed "The Continuing Need for More Effective Scientific Education." CAPT J. W. Jockusch, Jr., USNR, Special Assistant to the Chief of Naval Research for Research Reserve, spoke on recent legislation and other matters affecting the Research Reserve. (During CAPT Jockusch's visit, a special meeting was held with Command Officers of Research Reserve Companies of the Los Angeles area.) CDR J. E. Tuttle, Commanding Officer, Naval Reserve Training Center, Pasadena, California, discussed "Sea Power."

In addition, the following presentations were made to the seminar; "Survey of Space Problems" by Naval Fleet Air Defense Training Center; "Atlas, Titan and Minuteman Program" by Air Force Ballistic Missile Division; "Polaris Weapon System" by Bureau of Naval Weapons Representative, Sunnyvale; "Missile Test Problems" by Naval Pacific Missile Range; "Depot and Shipboard Checkout of Guided Missiles" by Hycon Manufacturing Company; and "Sidewinder Missile" by Naval Ordnance Test Station.

SIXTH ANNUAL SEMINAR IN RESEARCH METHODS

RADM R. Bennett, USNR, Chief of Naval Research, delivered the keynote address of the Sixth Annual Seminar in Research Methods July 11 at Ohio State University, Columbus. The Chief discussed the increased role of science in the Navy and some of the current activities of the Office of Naval Research. The Seminar was presented by Naval Research Reserve Company 4-7, with LCDR Daniel Howland, USNR, serving as Seminar Chairman. Thirty-six reserve officers—20 Navy and 16 Army—attended the 10-23 July meeting.

As in previous years, the Seminar placed great emphasis on the application of research methods to the solution of Naval problems. Papers were presented by members of the faculty of the Ohio State University and the staffs of Battelle Memorial Institute and the Columbus Division of North American Aviation.

CAPT R. W. Mayhew, USN, chaired a session on the general subject, "The Threat and the Defense System." Speakers were Dr. John B. Phelps, of the Mershon National Security Program at Ohio State University, CAPT W. F. Schlech, Jr., USN, of the Office of the Chief of Naval Operations, and CAPT W. E. Kuntz, USN, Surface Warfare Officer, Office of Naval Research. This program provided a broad picture of the problems the Navy is being called upon to solve.

The "system concept" in the physical, behavioral, and social sciences was also presented. Dr. Meno Lovenstein discussed the development of the concepts of social and economic systems, Dr. Earl Warren discussed the development of the system concept in the physical sciences, and Dr. J. Kidd presented views of the behavioral science. The utility of the concept for dealing with complex multidimension problems was discussed and illustrated with examples. Chairman for this program was LCDR Howland.

The remainder of the program was devoted to discussions of research methods and findings in areas which constitute the major dimensions of Naval systems, as discussed in the day devoted to the system concept. These included the physical, biological, medical, and social sciences. Additional topics included "What is Research," chaired by LT Robert Lackey, USNR, and "Communication," presented by LT R. W. Sergeant, USNR.

Tours of Battelle Memorial Institute and North American Aviation provided interesting practical Applications of research methods. The last day of the program was opened by a talk, "The Research Reserve Program" by CAPT J. W. Jockusch, Jr., USNR, Special Assistant for Research Reserve, Office of Naval Research. Later, a broad summary of the 2-week program was presented, with emphasis on present and future problems of research in general and of the Navy in particular.

To obtain the active participation of those attending, the seminar group was divided into four subgroups, and group leaders were appointed for each group. Leaders and groups were changed each week. After the Seminar heard the speakers, the material covered was discussed by the subgroups. The group discussions were followed by a general session in which each subgroup's views were summarized, and selected questions were directed at the speakers of the morning, serving as a panel. This procedure was found to be extremely stimulating, both for seminar attendees and the panels. The wide variety of scientific backgrounds resulted in a wide range of questions and points of view.

Figure 1--Participants in the Sixth Annual Seminar in Research Methods.

Reserve Assistants' Conference

The Research Reserve Assistants from the ONR Branch Offices and from ONR Washington met at the Naval Reserve Training Command in Omaha for a 2-day conference on 13-14 September 1960. This annual conference was sponsored by the Chief of Naval Research in cooperation with the Commander, Naval Reserve Training Command. CAPT J. W. Jockusch, Jr., USNR, Special Assistant to the Chief of Naval Research (Research Reserve) was the Seminar Chairman and CDR T. R. Drake, USNR, Assistant for the Research Reserve program at NRTC, served as Seminar Coordinator.

RADM D. T. Eller, USN, Commander, Naval Reserve Training Command, opened the conference with a most informative discussion of the Naval Reserve program and then requested a feedback of information from Reserve Assistants. Presentations on NRTC followed, led by CAPT J. W. Florence, USN, Chief of Staff, with briefings by heads of departments. LCDR G. N. Scaboo, USNR, Officer-in-Charge of the Reserve Officer Recording Activity explained the functions of RORA, and then led a tour of that activity. RADM J. W. McElroy, USNR, Deputy Commander, NRTC, opened the second day's session with an interesting narrative which pointed up advances of the modern Navy. The remainder of the meeting was devoted to discussions of matters which affect the Research Reserve Program and Research Reservists. Among these were mobilization concepts and plans, training program, new Research Reserve awards program (Naval Research Reviews, September 1960), recent and pending reserve legislation, the promotion outlook and considerations, revision of the curriculum, recruiting, and administrative items.

In attendance at the seminar in addition to CAPT Jockusch and CDR Drake were: CDR R. N. Jennings. USNR, Training Officer and Fifth and Sixth Naval District Research Reserve Liaison Officer and Miss Eleanor Kehoe, Educational Specialist from ONR Washington; CDR L. P. Hoskins, USNR, ONR Chicago; LCDR H. A. Wellemeyer, USN, ONR San Francisco; LCDR N. L. Fish, USN, ONR Pasadena; and LCDR A. Brandt, USNR, ONR New York.

Plug for SPASUR System Gap

The Navy will soon complete negotiations for the equipment and installation of an approximately $2 million, 50-kw, CW transmitter to plug the gap in its silent, or nonradiating, satellite detection net across the southern United States. The plans call for the installation to be completed next spring. It will be located at Lake Kickapoo, about 35 miles southwest of Wichita Falls, Texas. The Space Surveillance System has been in operation since early 1959 to detect, identify and determine the orbits of all nonradiating space objects crossing the United States. Principal components of the system are the data acquisition network, extending an electronic fence from Georgia to California, and the SPASUR operations center, located at the Naval Weapons Laboratory, Dahlgren, Virginia.

At present the data acquisition network is composed of six stations within two complexes, Eastern and Western. Each complex has two 108-mc receivers about 500 miles apart and a 50-kw transmitter equidistant between the receivers. The new transmitter will utilize the inner two receivers of each of the two complexes.

The transmitter radiates in a thin east-west, fan-shaped beam. The reflections from objects passing through the beam are picked up at the receiver sites on antennas having a similar beam shape. The angle of arrival of the received signals is accurately measured at the receiver by interferometer techniques.

The range of the radar, the height of the fence, is still secret, but it is known to be capable of detecting satellites at least to the altitude of current earth satellites, about 2500 miles, and reportedly has not exhausted its capability.

The Dahlgren installation has an "unmatched" computer capability with its Naval Ordnance Research Calculator (NORC), which, though in operation since 1955, still ranks as a leading scientific computer with its 13-decimal digit capacity and speed of 15,000 operations per second.—Electronic News.

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Figure 2--Participants at the Pasadena Seminar.

Figure 3--At work in the "office" for the Princeton Seminar are CDR R. E. Borup, USNR, LCDR T. T. Reboul, USNR, LCDR E. C. Reichard, USNR, and YNC J. F. Sharkey, USNR.

IN THIS ISSUE

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Wired and taped, a sailor steadies himself for a disorientation experiment in the Slow Rotation Room of the Navy School of Aviation Medicine. See pp. 1-8.