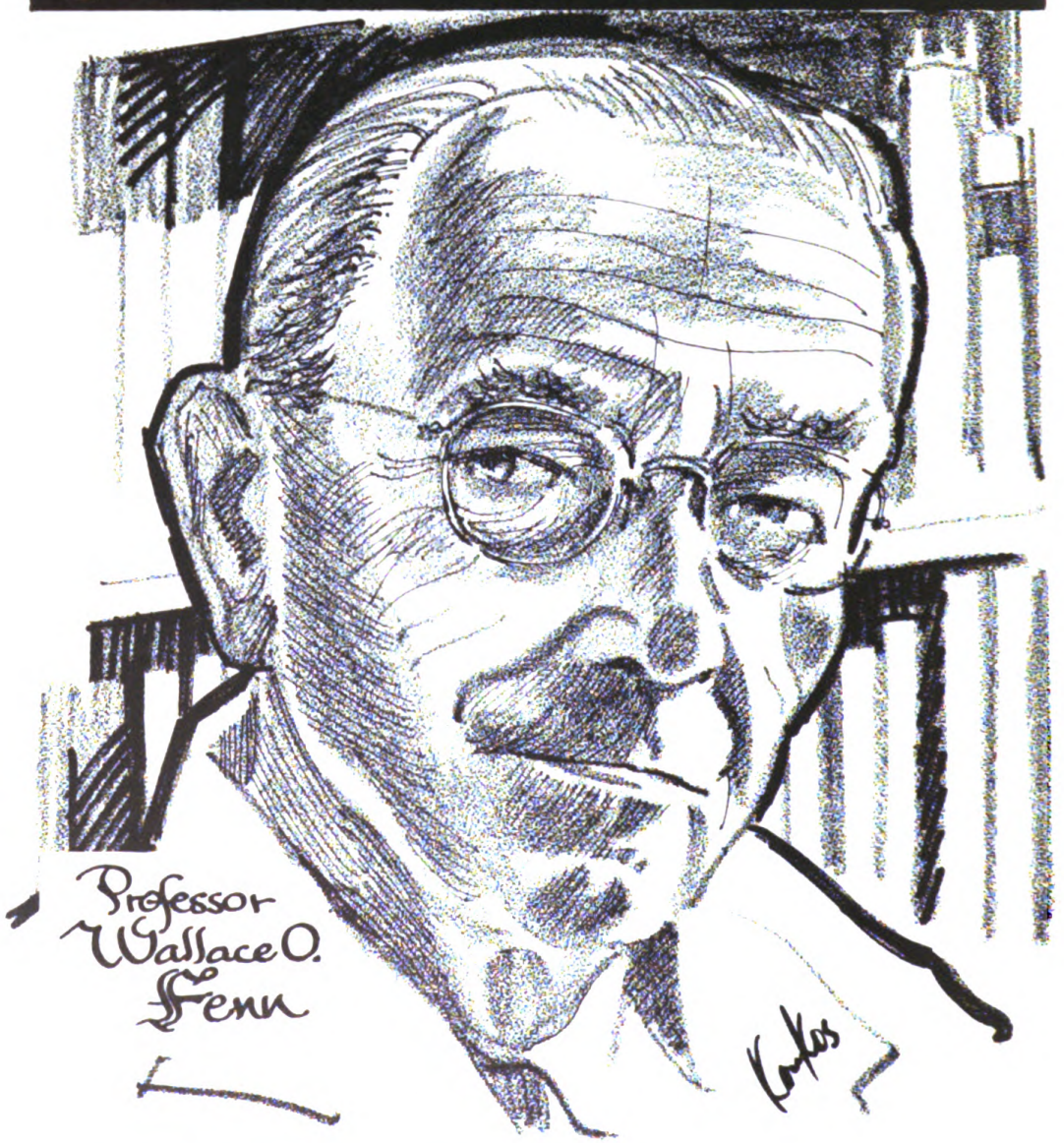
Portraits in Science



WALLACE O. FENN IS DISTINGUISHED UNIVERSITY PROFESSOR EMERITUS OF PHYSIOLOGY AT THE UNIVERSITY OF ROCHESTER, WHERE HE HAS BEEN TEACHING AND DOING RESEARCH SINCE 1924. OVER THE YEARS HE HAS BEEN A PROMINENT ONR CONTRACTOR. IN HIS RESEARCH, DR. FENN HAS MADE MAJOR CONTRIBUTIONS TO UNDERSTANDING THE METABOLISM AND ION EXCHANGE OF MUSCLE CONTRACTION. HE MADE CONTRIBUTIONS OF GREAT IMPORTANCE TO FLEET OPERATIONS IN RESPIRATORY PHYSIOLOGY INCLUDING BOTH AVIATION AND DIVING. HE IS ACTIVE AS A CONSULTANT TO THE DEPARTMENT OF DEFENSE, THE NAVAL LABORATORIES, AND THE NATIONAL ACADEMY OF SCIENCES.

A Research Program in Diver Communication

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While an enormous scientific program currently is being focused on the conquest of outer space, a much smaller—but vigorous—research effort has been initiated to explore another relatively unknown frontier adjacent to our coastline. This rich frontier area is the vast underwater portion of the earth's surface known as the Continental Shelf. An exploding world population combined with dwindling economic resources make essential the exploration and development of this underwater world.

Two approaches to such exploration are being pursued. The first approach is that of the underwater submersible; the second that of the "free" diver in the ocean. This paper will deal with the communication problems related to the free diver, Man-in-the-Sea. The development of reliable diving gear and self-contained underwater breathing apparatus has permitted man to extend briefly his explorations into the uppermost few hundred feet of the earth's lakes and oceans. Prolonged excursions to even greater depths will soon become common. Such forays may be for: scientific, military, economic, or recreational purposes.

Whatever the purpose of an underwater expedition there is the need for voice communication among individuals comprising the diving teams as well as the support groups on the surface (3,8,20,26). The need for communication is particularly urgent in submerged environments where visibility is substantially limited, and where minor equipment malfunctions can prove fatal, and where dangerous predators or enemy divers may be part of the milieu.

While hundreds of research papers and many symposia have been addressed to questions related to marine bioacoustics, little is known about man's ability to communicate underwater. Hence, there is need to obtain comprehensive data concerning the communication problems of the Man-in-the-Sea; however, to do this one must consider the unique difficulties imposed upon communication by a fluid environment. In air, humans communicate both by written and spoken language, including gestures and facial expression. In water, however, gestures and facial expressions dwindle markedly due to curtailed visual contact, and the use of a number of life support devices such as regulators and masks. Writing is extremely limited as a method of underwater communication

as are systems such as the international or Morse codes. Since these communication approaches are both awkward and slow, speech must solve most of the communication problems. Speaking directly into water is presently impossible, and the recognition or interpretation of speech signals transmitted through the water is sharply limited by the sensitivity of the submerged human ear (Figure 1).

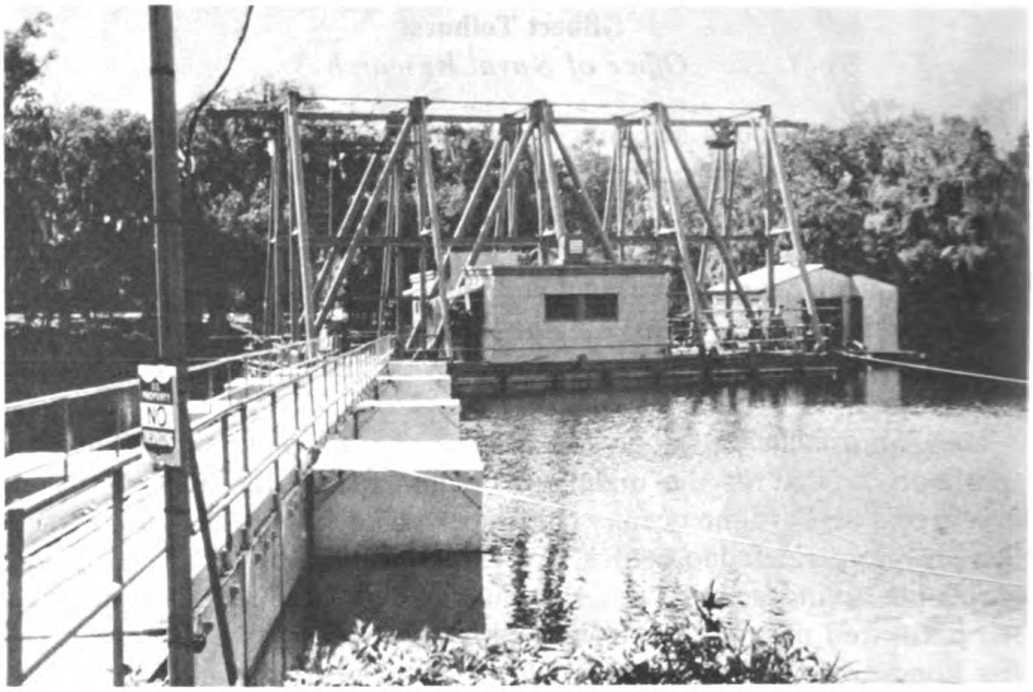

Figure 1 — Field station of NRL's Underwater Sound Reference Division, Orlando, Florida. This facility, located near Leesburg, Florida, provides an underwater environment suitable for experiments on diver speech and hearing.

To date most developments in these areas have been limited and have not dealt with the total problem. For example, a number of devices have been designed either to permit underwater communication or to improve the intelligibility of an individual speaking under the distorting effects of helium-oxygen gas mixtures, either in habitats or in the open sea. These systems, which are often electronically sophisticated (9,21, 29), have been developed under conditions where many of the basic relationships were unknown. Thus, they usually are of somewhat limited effectiveness, or they suffer from lack of rigorous evaluation since baseline data are not available.

In order to answer fundamental questions about diver communication, it is mandatory to acquire basic knowledge about the factors that limit or allow man to converse underwater. Such a program has been initiated at Communication Sciences Laboratory at the University of Florida

with the support of the Office of Naval Research and the Deep Submergence Systems Program. This program is focused on a number of areas of investigation. The first relates to the study of man's ability to produce intelligible speech under the constraints he encounters as a diver. The second is the study of man's auditory reception underwater. A third area of investigation concerns underwater speech propagation and the various effects of bottom-surface and thermocline wave guide channels, distance, filtering, masking and other distorting underwater characteristics on speech intelligibility. The fourth area focuses on the analysis and appraisal of various types of underwater communicators and habitat communication systems. In the habitat, of course, the emphasis is on the evaluation of electronic systems that reduce speech distortion resulting from exotic gas breathing mixtures usually experienced in these diving conditions. Another part of this area is the analysis and appraisal of divers' voice communications systems.

Studies of Diver's Speech Production

This major program of research is directed toward the problems related to the ability of free divers to produce intelligible speech underwater especially when encumbered by breathing apparatus. The research studies are:

- investigations of speech intelligibility as related to ambient pressures;
- regulator back pressures;
- constriction of the articulators;
- the addition (and removal) of cavities to the vocal tract; and
- the efficiency of the various types of compensatory speech modes.

These studies must be both basic and yet be relevant to diver application. Consider the effects on speech intelligibility when an external "cavity" to the vocal tract, such as a face mask, is added. In this regard, research is being carried out in order to estimate the ideal size and configuration of such a cavity. Data abstracted from the laws governing the resonance characteristics of such cavities and from phonetic theories of speech production will be used to provide predictions of the size and configurations of the cavities optimal for intelligible speech. Later, actual prototype units will be built. These units will include the constraints imposed upon such cavities by the nature of respiratory physiology and the total configuration needed to provide a good seal over the facial structures. Empirical research then would be utilized to discover which of these muzzles most closely approaches the ideal. Additional investigations of speech production which are presently being carried out are those to assess the efficiency of available regulator bits, muzzles,

Figure 2 — Divers wearing Bioengionics muzzle (left) and U.S. Divers mask (right). These units are two examples of the various types of masks/muzzles/ helmets used by the Communication Sciences Laboratory in underwater speech intelligibility experiments.

mouthcups, and full face-masks (see Figure 2). These investigations will also include the distorting effects upon speech created by high ambient pressures.

Research of this nature is not necessarily confined to intelligibility evaluation. Other techniques are used in an attempt to identify the specific errors that are made under particular speaking conditions. These data are probably more important than simple intelligibility scores because they factor out those phonemes most affected by the specific environmental characteristics encountered by the diver.

Another related area focuses on investigations of the so-called "Donald Duck speech" which is caused by various exotic gas breathing mixtures (primarily HeO_2) used in underwater habitats and in saturation diving (7,10,19,23,27,28,31). The emphasis in these studies is placed on speech intelligibility measurements and on the puzzling, non-linear vowel formant shifts. Other investigations in this area are concerned with diver's speech production and reception adaptation, particularly with respect to their apparent ability to eventually improve speech intelligibility by experimenting with articulation. It is important to

discover just what speech sounds are most affected by the milieu, as well as obtaining an index of a general speech intelligibility level. It has been determined that speech intelligibility is reduced as a result of depth and the HeO_2 mixture. At 600 feet for example, speech intelligibility levels are around 20 percent (14). Subjects for most of these studies are Sealab-3 aquanauts in training.

A final series of investigations in the "speech" category have resulted in the development of special underwater speech testing methods which allow a more sophisticated assessment of speech production under all diving conditions as well as in more efficient evaluation of certain electronic systems designed to improve speech intelligibility among divers. For example, the results of a number of studies on the nature of speech testing materials allowed the construction of a "profile" test based on a combination of phonemically balanced words, rhyming words, vowels, and synthetic sentences. The "profile" approach may allow a more precise definition of the specific speech problems under investigation (15).

Reception of Speech

A second major research area focuses on the accumulation of information concerning the hearing of divers underwater (11,22,24,25,30).

Auditory acuity for both pure tones and speech are included in the study (4,5). The ability of submerged divers to understand speech (diver's speech discrimination) has also been evaluated (5). The parameters explored here have included auditory acuity as a function of: depth (6), the contents (HeO_2 or air) of the middle ear, ambient pressure, and contents (water or air) of the external auditory meatus (17). Generally, the findings have demonstrated that: ambient pressure alone has little or no effect on hearing acuity; immersing the head in water creates a substantial hearing loss; and underwater hearing probably is accomplished by bone conduction. However, it has been found that if the speech signal is intense enough to hear, there appears to be little if any disruption of normal speech discrimination.

A second series of studies in the area of underwater hearing function is designed to investigate sound localization. It would seem that there would be very little sound localization ability underwater for human subjects (1,2). This idea is reasonable due to the increased speed of sound in fluid; the fact that sound can be readily transmitted to the cochlea directly through the skull, and the impedance mismatch between the water and the skull itself is relatively low. However, investigations on underwater sound localization reveal that divers often make surprisingly accurate identifications of an underwater sound source (12). In fact, all subjects used in our studies were able to perform at levels

Figure 3 — A diver/subject seated in DALS (Diver Auditory Localization System) and responding to acoustic stimuli in an underwater sound localization experiment. The diver's response is recorded on surface equipment via an underwater switching apparatus.

substantially higher than chance. Figures 3 and 4, respectively, show a diver responding to auditory stimuli at 40 feet and personnel topside presenting these stimuli and recording responses. This research is being continued in order to define the underwater sound localization abilities possessed by man, and to explain these skills.

Miscellaneous Studies in Underwater Speech Propagation

Included in the research on the transmission of speech through water are studies of the effects of distance, filtering, and noise masking on speech signals. An example of this type of investigation is one in which speech intelligibility was functionally related to distance. The principal interest here was the phase distortion effect of the ocean surface and bottom (acting as a wave guide) on the signals being transmitted through the fluid medium. It was found that the major degradation in speech intelligibility results not from phase distortion but from the masking effect of ambient underwater noises. In another study, filtered speech was evaluated both in conditions of quiet and noise; the results indicated that intelligible speech can be transmitted underwater and that propagation of such signals obey perceptual rules similar to those in air (Figure 5).

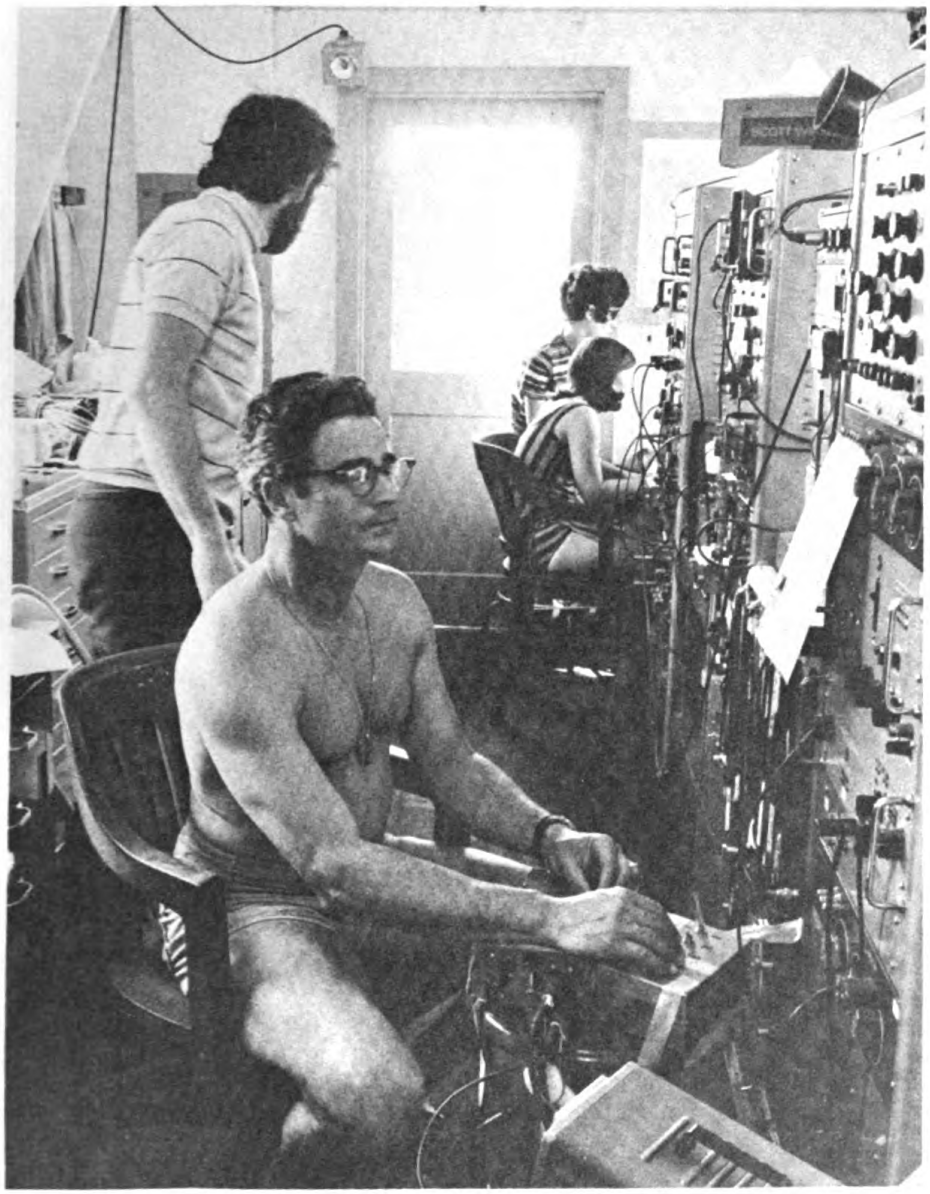

Figure 4 — Tape recordings of stimuli used in underwater sound localization experiments are randomly presented (foreground) by the experimenter. Assistants (background) monitor divers' responses as they are recorded on an IBM key punch.

Research on Communication Equipment and Procedures

The final research area is concerned with communication equipment and assessment techniques. Attempts have been made recently to develop systems which enable divers to communicate efficiently with each other by the voice mode. Because of relatively limited knowledge concerning underwater communication and perceptual processes, the design of these systems has been focused primarily around electronic

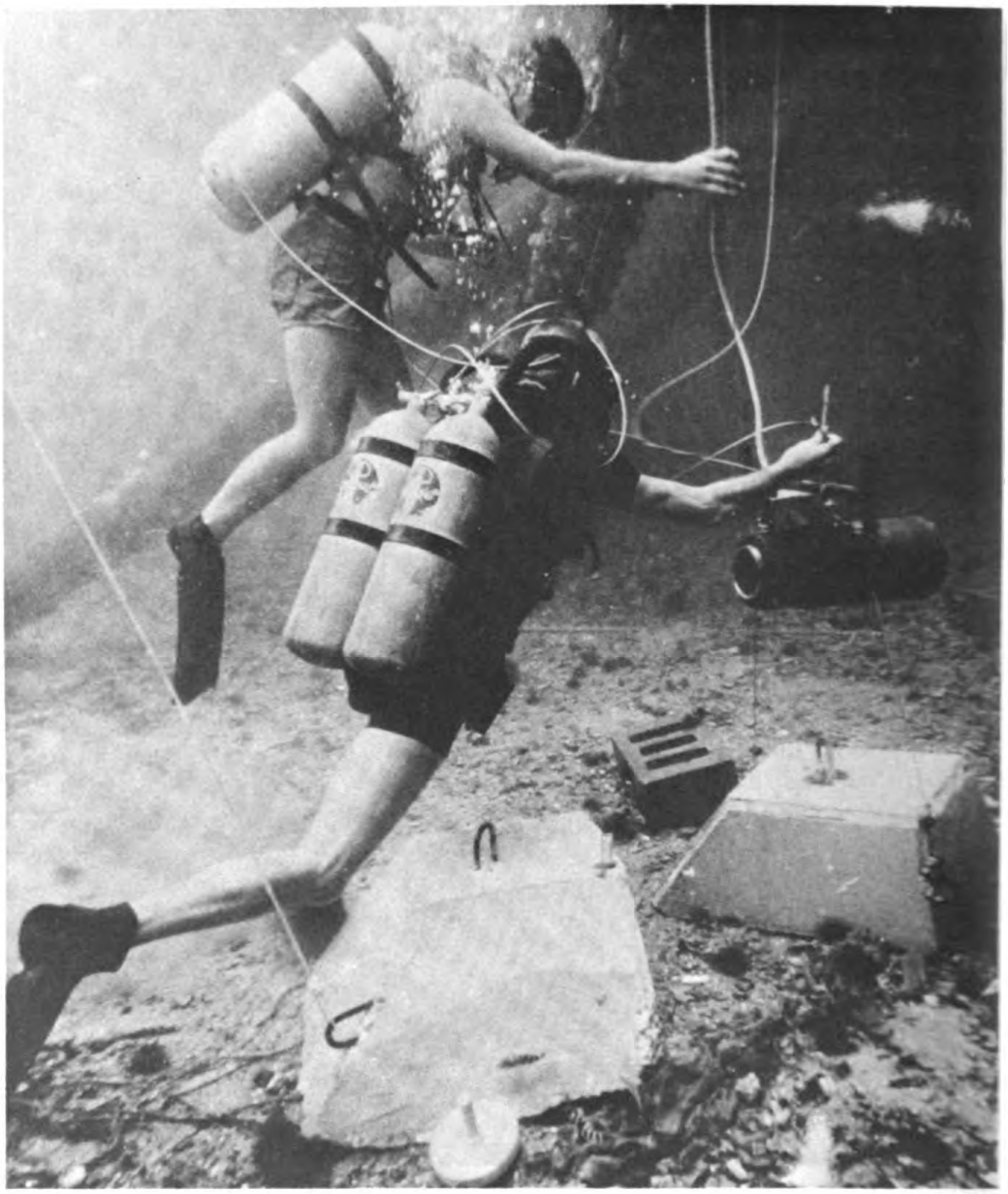

Figure 5 — Naval Ship Research and Development Laboratory (Panama City, Florida) divers positioning a J-11 projector for underwater sound and speech propagation studies conducted at NSRDL's Stage 1 located in the Gulf of Mexico.

considerations. Therefore, there is a pragmatic need for a means of diver-to-diver communication system evaluation including appropriate methodologies based on data derived from the speech production studies described above.

In this portion of the research program methodologies for testing diver communicators have been developed. Such research was confined initially to relatively near-field work. One justification of this approach is based in part on the fact that if a communication system does not

provide efficient transmission under idealized conditions, it makes little sense to evaluate it initially under more severe conditions, such as in the open sea, over long distances. Appropriate methodologies have been developed, and evaluations of most available commercial and military underwater communication systems have been carried out with respect to both diver-to-surface and diver-to-diver links (16,18). These evaluations have been concerned with determining speech intelligibility levels as well as the error matrices which depict listener responses in such a manner that the phonemes and phoneme classes most affected by the distorting factors are identified. These studies essentially have demonstrated that while some promising units are now available, none as yet can provide a totally acceptable communication link.

An important area of research on speech transmission must include devices often referred to as "Helium Speech Unscramblers." These systems attempt to process the grossly unintelligible speech resulting from the effects of helium-oxygen breathing mixtures and ambient pressure and reconstruct such signals in order to provide adequate oral communication. A number of such systems are available and have been tested (15). A preliminary evaluation protocol has been developed based on speech material spoken by divers under a variety of environmental conditions: at a number of ambient pressures, in different HeO_2 mixtures, and in underwater habitats as well as among individuals swimming in the sea. Included in these tests are samples of highly intelligible speech, low intelligible speech, and noisy environments. These off-line evaluations of HeO_2 unscramblers obtain measures of both overall and subtest intelligibility levels, as well as structuring the data analysis in order to identify those speech sounds that are most affected. The unscramblers evaluated to date provide substantial improvement in speech intelligibility, but this is not enough to allow for easy communication, especially with divers at great depths. A study is now in progress by which "unscrambler" units used in conjunction with Sealab-3 are being evaluated on-line (see Figure 6) and eventually at Sealab-3.

Development of Specialized Instrumentation

Many of the investigations in the four areas of diver-to-diver research described above require precision instrumentation similar to that used in speech communication conducted in air. Research design must allow for experimental control of subject position, stimulus presentation, and subject response.

Dr. Hollien has directed the development of two such systems (13), a Diver Communication Research System (DICORS) and a Diver Auditory Localization System (DALS). A group of divers may be seen in the

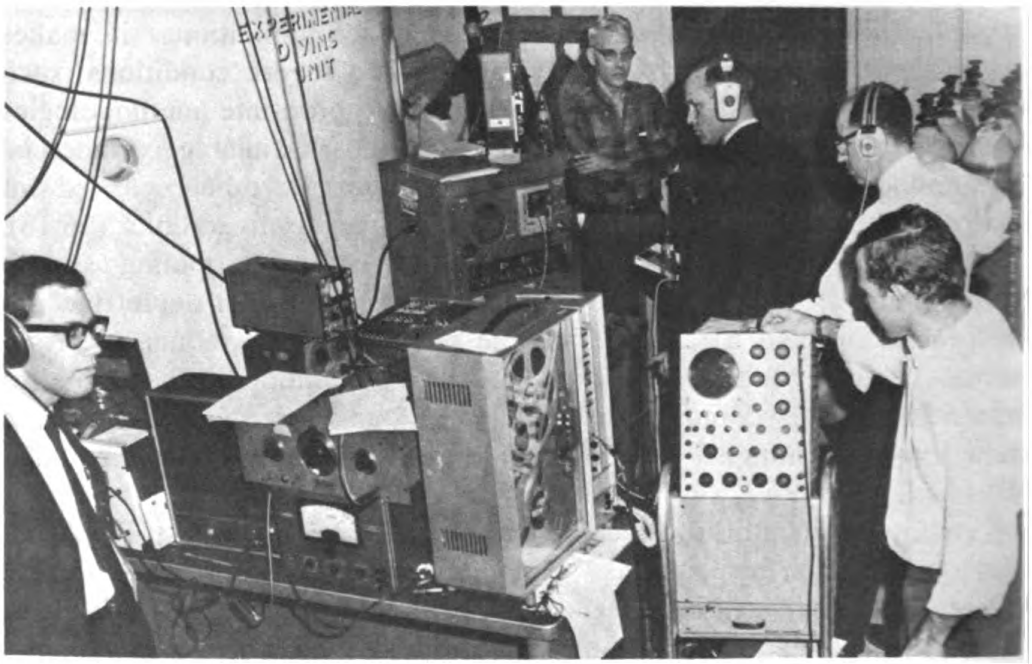

Figure 6 — Evaluation of helium speech unscramblers being conducted at the Experimental Diving Unit in Washington, D.C. Word lists read by the Sealab-3 aquanauts are processed through various electronic devices designed to make the speech more intelligible.

cover picture positioning DICORS for shallow water research; it consists of an open framework of plastic tubing, which is acoustically transparent to audible frequencies, used to support a diver and appropriate equipment. The basic accessories used for most of these investigations include an underwater television monitor and camera, calibrated hydrophones, response switches, and sound projectors (Figure 3). A head positioner and weight belt insure proper diver positioning; the use of a monitoring TV camera, emergency switch, and reserve air supply insure that a diver is protected from excessive hazards. DICORS allows studies in speech production, hearing evaluation, and instrumentation assessment to be carried out under controlled experimental conditions. For example, if pure tone hearing thresholds are being studied, the diver is placed an exact distance from a calibrated projector and given a hand switch which will control the intensity of an audio oscillator. In this manner, an auditory threshold can be determined by means of the Bekesy technique.

Underwater communication systems can be evaluated on a diver-to-diver basis if two DICORS units are used. In the first DICORS a diver/talker who is wearing a communicator reads a series of standarized speech stimuli presented to him *via* the TV monitor. In the second DICORS, two diver/listeners observe a set of multiple choice words

on their TV monitor, one of which is the stimulus word. They select a word in response to the diver/talker's utterance and activate the appropriate switch (from a multiple set) connected to an IBM keypunch on the surface. The second system, DALS, provides similar subject, stimulus, and response control for studies of underwater sound localization.

Research utilizing DICORS and DALS currently is being carried out by personnel of the Communication Sciences Laboratory, at the Naval Research Laboratory's facility at Bugg Springs, Florida. These systems are lowered through a well by means of a winch and hand suspended between two floating laboratories while the experiments are carried out; Figure 7 shows divers preparing for an experiment at this site. Other facilities which have provided support for this research program are the Navy Ship Research and Development Laboratory in Panama City, and the Experimental Diving Unit in the Washington Navy Yard. Cooperation also has been extended by the Navy Post Graduate School, Monterey, California; by Marineland, Florida; and by Rainbow Springs, Florida. Experiments are being carried out on the underwater communication systems, networks, and instrumentation used on Sealab-3. Without access to these physical resources and without assistance of highly skilled naval personnel, research on the many aspects of diver-to-diver communication would have been impossible.

Figure 7 — Subjects preparing to participate in diver communication research at Bugg Springs

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Oceans as a Source of Carbon Monoxide

Evidence that the oceans may be a source of carbon monoxide (CO) for the atmosphere has recently been uncovered during field experiments performed by scientists of the Naval Research Laboratory. Previous theory indicated that the oceans might be a sink, rather than a source, since more man-made carbon monoxide is being produced annually than is being retained by the atmosphere.

Dr. V. J. Linnenbom, Dr. J. W. Swinnerton, and Mr. R. A. Lamontagne of NRL have released results of research indicating that the surface waters of the deep ocean are supersaturated with CO vis-a-vis the partial pressure of this gas in the atmosphere. This evidence suggests that there may be a net transport of CO molecules from the ocean into the atmosphere across the air-sea boundary. Calculations from these measurements also suggest that the oceans are possibly the greatest natural source of this pollutant with a capability for providing up to 10% of the amount annually added to the atmosphere by man.

The investigations were conducted at two sites in the tropical Atlantic, one, east of Trinidad and the other, east of Barbados. Atmospheric and seawater samples were taken every two hours at each station for twenty-four hours. The analyses were performed aboard ship in a specially equipped chemical laboratory by means of an improved gas chromatography technique developed by the scientists. The method is based on the conversion of carbon monoxide to methane, a light hydrocarbon which is more readily measured by the system than CO.

Samples were also analyzed for methane, a common atmospheric pollutant derived from the decomposition of organic matter. The results indicated that methane in the surface waters is generally in equilibrium in respect to methane in the atmosphere, in contrast to the situation prevailing with carbon monoxide.

(Continued on Page 30)

Plague

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Plague, a disastrous evil or affliction, caused by the bacterium *Pasteurella pestis* (*P. pestis*), has been a recognized and feared entity the past two millennia. The disruption of social and economic life by war and famine, and changes in the ecology of rodents and man, has led to outbreaks of plague in which millions of people have died with resulting drastic changes in the patterns of civilized life. Plague's malignancies have induced a descriptive literature, as well as somber records in the annals of the graveyard. Some outstanding examples are found in Hecker's account of the effects of plague on life and civilization in the Middle Ages, and in MacArthur's report on plague in England. Defoe's famous "Journal of the Plague Years" was a fabrication designed from records and hearsay about events in London. A flight from an epidemic afforded Boccacio the device of congregating the refugees who whiled away with fanciful tales. During World War II, there were epidemics of plague across North Africa. In our time, therefore, Camus in "Plague" gives a philosophic account of a make-believe outbreak in Oran in 194- and of human reactions in the struggle for survival. Of more immediate concern in our time has been the sizeable plague outbreak in Vietnam.

The disease, primarily one of rodents, is passed to man by flea bites. In common with other infections, the causative organism was unknown until the advent of adequate technology and scientific judgment in the late nineties and the early years of this century. Kitasato and, independntly, Yersin found the causative agent in cadavers during an epidemic in Hong Kong in 1894. The latter investigator also found *Pasteurella pestis* in rats in the same year, thus substantiating the hitherto suspected relation between epidemic mortality in rats and plague in humans. In 1887 Ogata "produced plague in mice by injecting an emulsion of crushed fleas taken from a plague-infested rat." Independently, Simond (1898) confirmed the finding. The interrelationship of the rodent and the flea in the genesis of epidemics was verified by many subsequent investigators who provided knowledge required for control in many instances. Modern control by vaccination, according to Wu Lien Teh. was initiated by the work of Yersin, Calmette and Borrel in 1895 and in 1896 by Haffkine.

The United States has known epidemics of both bubonic and pneumonic forms of plague in its seaport cities of Seattle, San Francisco. New Orleans, Los Angeles and San Diego among others, and these were traceable to sources outside of North America. Enzootic plague

of wild rodents was recognized as early as 1903. Human Plague contracted from this reservoir has occurred in eight Western States. Wild-rodent plague is endemic in at least fifteen Western States. The potential for epidemics is with us. In spite of careful control by Federal, State and local authorities, and the availability of effective antibiotics, sporadic cases do terminate fatally.

The period from the inception of the Naval Biological Laboratory (NBL) to the time of the Pearl Harbor attack was occupied with research relating to respiratory diseases in the Navy—expecially basic studies on influenza. There was some concern that migration, crowding, increased shipping, and allied changes associated with war, would provide conditions for plague epidemics. The Laboratory was considered administratively and technically adaptable to support studies on preventive measures and able to extend studies on respiratory diseases to include those on pneumonic plague.

A prime requirement for the study of airborne pathogens is an efficient and safe apparatus for the quantitative production and sampling of clouds of airborne microorganisms and for the exposure of small animals to respiratory infections. Ingenious equipment was devised in which such studies were possible. The Reynier Cylinders, primarily designed for raising germ-free animals, were modified to permit exposure of small animals to clouds of microorganisms (Figure 1). Internal manipulations were accomplished through ports equipped with rubber gloves,

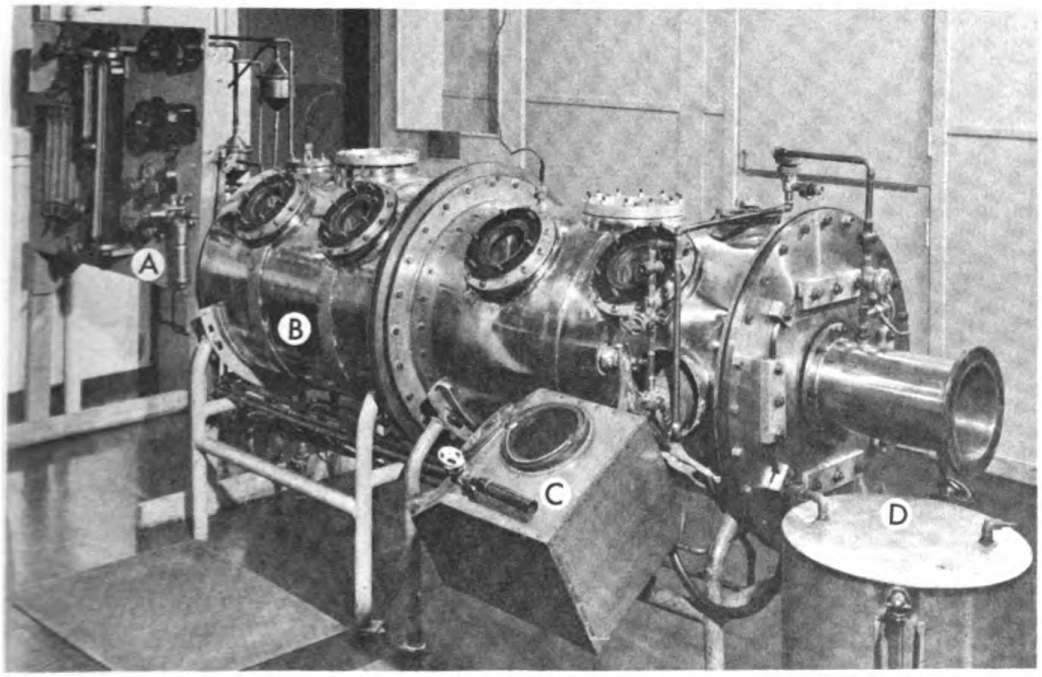


Figure 1 — Reynier Cylinder modified for exposing small animals to aerosols: (a) Air control unit, (b) Animal exposure cylinder with glove ports, (c) Detachable unit with air filtration for holding infected animals, and (d) Disinfectant for sterilization of sample containers.

air of varying humidities was introduced to maintain clouds emanating from nebulized bacterial suspensions. Animals held in the clouds inhaled the microorganisms. During exposure, air samples were impinged into fluids and bacterial numbers were determined subsequently (Figures 2 and 3). Samples were removed through special ports designed to prevent escape of the organisms. Excess contaminated air was incinerated and fluid wastes were decontaminated before disposal.

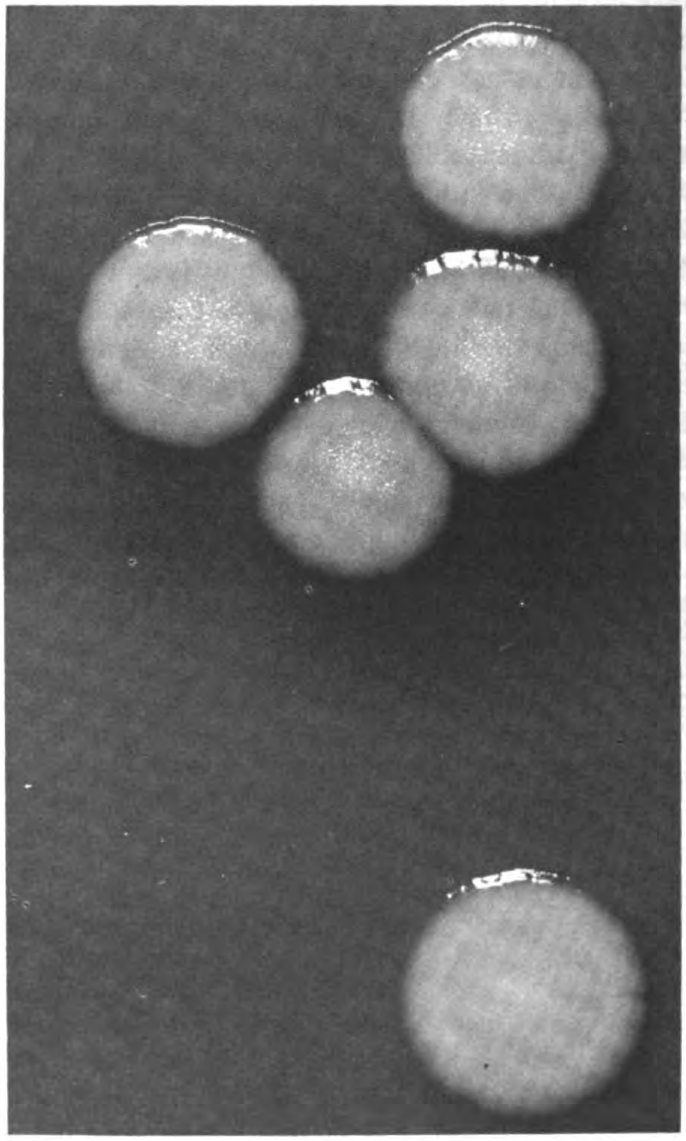


Figure 2 — Smooth colonies of Pasteurella pestis

After exposure, animals were removed through the special ports and were maintained in aerated, self-sufficient units. Of course, animal exposure experiments were preceded by extensive studies on methods for regulating successful production and utilization of aerosols. Such factors as temperature, time, humidity, effect of atomization on particle size and viability of microoganisms in the airborne state, were studied.

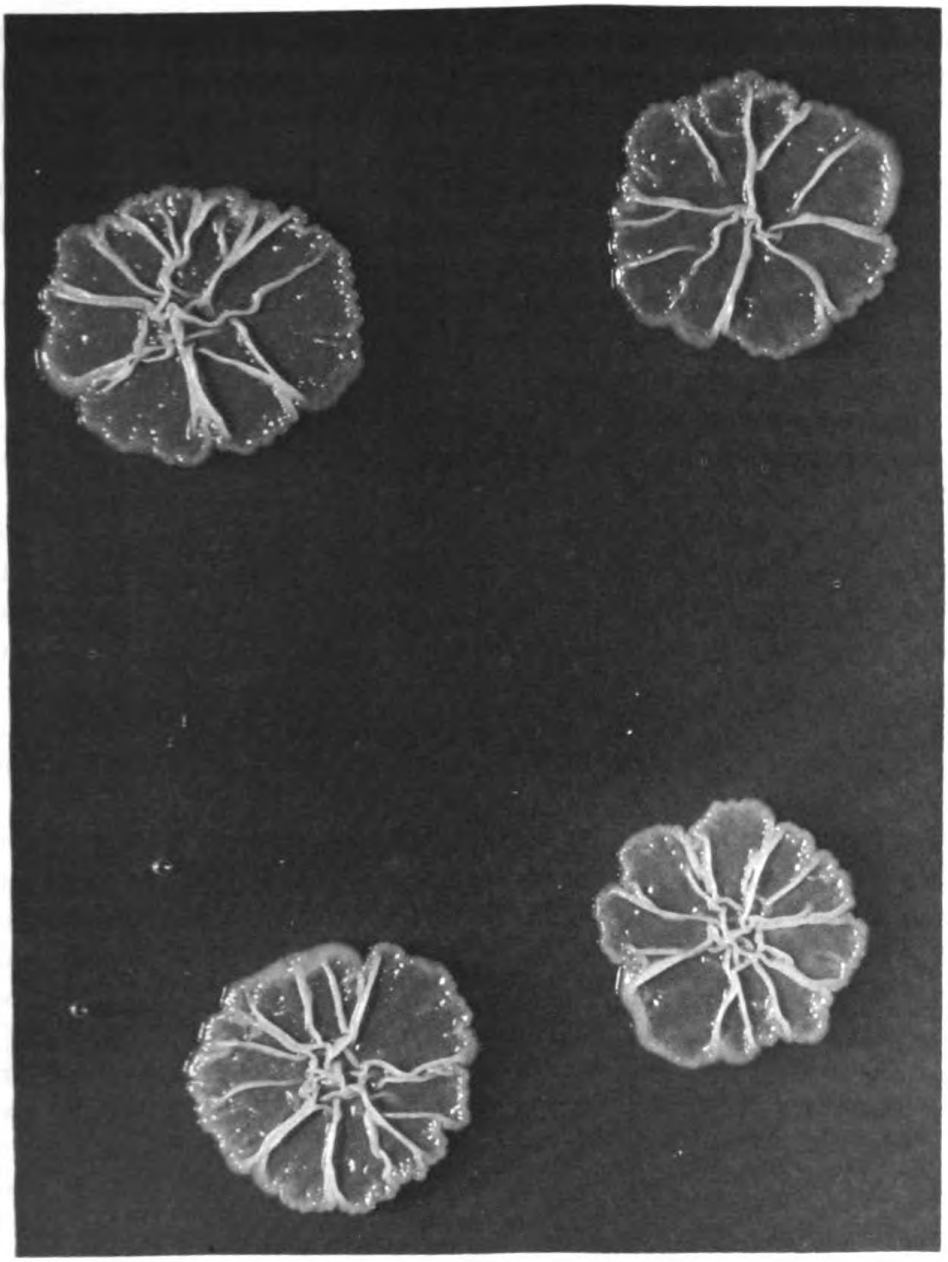


Figure 3 — Nonsmooth colonies of Pasteurella pestis

Optimal conditions were determined and, eventually, modifications of the apparatus were made so that larger animals, such as monkeys, could be exposed.

Mice, guinea pigs and monkeys were exposed to aerosols containing *P. pestis*. It is of some interest that the lethal dose was found to be about 30,000 organisms for each species of animal. This peculiar relationship is still unexplained. It is relatively easy to determine the number of viable *P. pestis* required to infect animals by the subcutaneous, intravenous or intraperitoneal routes. To determine the number required by the inhalatory route is more difficult. In addition to knowing the

composition of the aerosol to which the animal is exposed, one must know the volume of aerosol inhaled by the animals, the duration of exposure and weight of the animal. Not all organisms may be retained in the lungs; some are exhaled and some are swallowed and lost as a result of ciliary action in the large bronchi and trachea. Special measurements were therefore made to determine the retention of radioactivity tagged *P. pestis* in the lungs of exposed animals. The studies showed a 27% retention. This value was considered more accurate than one obtained by cell enumeration from crushed infected tissue.

One of the earliest studies at NBL was a complete description of gross and histopathological changes in infected lungs and other organs of animals (Figure 4). In general, findings were similar to pathognomonic changes in human pneumonic plague.

The relationship between dose of *P. pestis* and subsequent mortality, or dose of *P. pestis* vaccine and protection against challenge was determined as part of studies on the experimental epidemiology of respiratory infections. A special statistical process was developed for this purpose at NBL. The results of investigation at other laboratories could be conveniently compared with those obtained at NBL. Standardized treatment of dose-mortality relationships were possible from experiment to experiment.

Since large numbers of mice have been required for a host of problems, a colony was established at NBL in 1943. The NAMRU mouse was bred from a plague susceptible albino-black cross originally maintained at the George Williams Hooper Foundation for Medical Research in San Francisco. In addition, a Hartley strain guinea pig colony was established in 1967 to provide animals for current projects.

Many strains of *P. pestis* were isolated from world-wide human cases. It was necessary to preserve them, as nearly as possible, with their original virulence, biochemical characteristics, morphology and viability. Investigations at NBL, defined the conditions under which these properties could best be preserved by lyophilization (freeze dried in a vacuum); NBL scientists designed a manifold type of lyophilization apparatus and defined detailed data on the techniques of preservation. About 120 strains of *P. pestis* were lyophilized. Over the past ten years, about a dozen were recovered from the lyophilized form and these retained their virulence for mice and guinea pigs and were readily adaptable for day-to-day laboratory use.

The aerosol studies were accompanied by supportive investigations of the biochemistry and nutrition of *P. pestis*. Investigators formulated several chemically defined media which were used for production of highly concentrated suspensions of *P. pestis*. The chief ingredients included such diverse materials as purified amino acids on the one hand, to fish hydrolysate syrup on the other. All requirements for the production of *P. pestis* for laboratory studies were satisfied.

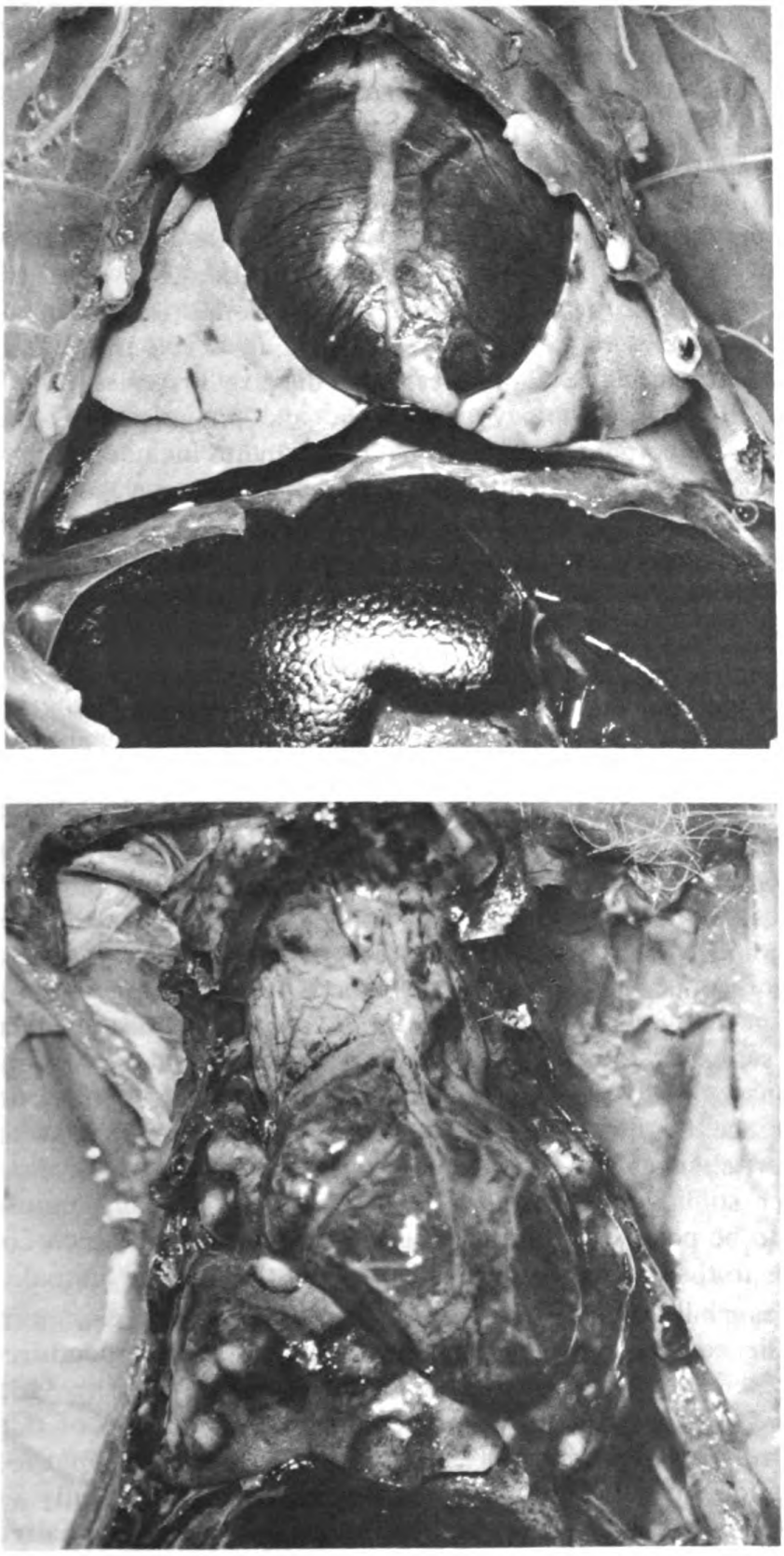


Figure 4 — Lung of normal guinea pig (top). Lung of guinea pig which died five days after exposure to aerosol containing Pasteurella pestis (bottom).

The biochemists were occupied with problems of intrinsic academic as well as applied interests. Thus—the degree of catalase activity of *P. pestis* was tentatively correlated with virulence of the organism; the mammalian hormone insulin was found to accelerate glucose oxidation by *P. pestis*; the validity of the inclusion of amino acids, in synthetic media was established, and the inhibitory effects of organ extracts and component fatty acids on gluconate metabolism were observed.

The period following World War II was marked by varied interests in plague research at NBL as well as in laboratories throughout the world. A number of people were engaged in problems of particular interest to themselves. Emphases were on host response to infection and toxicity, the pathology of bubonic and pneumonic plague; and immunity in laboratory animals. The many studies included within these categories are pertinent to attempts to immunize humans against bubonic and pneumonic forms of plague.

Mechanisms by which *P. pestis* kills the host and by which the host defends itself have been studied. The organism produces a toxin which kills the untreated host. Studies in rats given purified toxin showed vital changes in heart action, respiration, and blood volume. After the injection of toxin there ensued a series of physiological changes, physiological compensating mechanisms arose, and final respiratory and circulatory failure was induced by the direct action of toxin on peripheral vascular elements.

There have been several studies relative to immunity to plague in laboratory animals. One series was concerned with the response of the normal and immunized host to pneumonic plague. A most important clearing mechanism was ascribed to activity of cilia of the nasal and bronchiolar mucosa; chemical interference with this function resulted in enhanced parenteral dispersion of *P. pestis* and hastened fatality. In this series of studies phagocytosis, so important in survival in other infections, was shown to have relatively little effect on the outcome. Interference by blockade of phagocytic cells of immunized animals with inert chemicals did not result in measurable decrease of immunity. In other studies, the vaccinated and therefore resistant mouse was shown to be possess of an undefined localization factor which confined *P. pestis* to the lung, resulting in recovery of the infected animal.

The capabilities of NBL were extended by the development of a well-designed unit to infect monkeys by aerosol. Safe procedures with highly excitable subjects were guaranteed to the sober investigators. Monkeys (Macaca mulata) were exposed to large numbers of *P. pestis*. The mortality was lower than expected and gross and histopathological examinations revealed chronic pneumonic plague in which fully virulent *P. pestis* was present in fewer numbers than in the lungs of nonsurvivors. The results hinted at a partial natural immunity in this species. The possibility of chronic pneumonic plague and human carriers is perhaps

far-fetched but still of interest as an aftermath of epidemic. Further studies with monkeys showed that both vaccinated and control animals were equally susceptible to challenge even with concomitant streptomycin therapy. Living avirulent organisms, a killed vaccine and a chemical extract, Fraction IB, were equally ineffective in producing significant protection against aerosols containing *P. pestis*. All of which suggests that confidence in plague vaccines may be misplaced.

With the advent of hostilities in Vietnam, there was a renewed interest in plague; in 1965 and 1966 many cases were reported among the civilians. Protection of our military personnel became important, and, in addition to environmental control, a vaccination program was instituted. The manufactures of the Plague Vaccine in the U.S. were charged by the Division of Biologics Standards of the National Institutes of Health to maintain standards of sterility, afebrility and immunogenicity. Acting as an arm of DBS, the Naval Biological Laboratory has been testing many lots of vaccine to insure that the standards have been met. This work has been in progress since September 1965. In addition to the assays in mice, numerous problems attendant on variations in techniques, stability of reference standards, problems in immunizing different types and strains of animals have arisen. Problems of more basic nature have also arisen and are under investigation. Thus the immunogenicity of vaccines prepared by selective inactivation of vital enzymes has been compared with those prepared by conventional methods, and in general, may be proved superior, especially against pneumonic plague in mice.

These, then, are the chief contributions to the study of plague at NBL since about 1945. While the main outstanding achievements have been in the development of techniques for aerosol studies, there have been other contributions in the biochemistry, physiology and immunology of plague. Their nature has been determined largely by the interests of a diverse group of investigators. It is to be expected that work with plague will continue because of the ever present interest attending an organism so profoundly important in human epidemiology.

Dr. Cleeton Presented Navy's Highest Honorary Award

Dr. Claud E. Cleeton, who recently retired after 34 years of service with the Naval Research Laboratory, has been awarded the Navy's Distinguished Civilian Service Award.

Dr. Cleeton was presented the award for his conception and formulation of the basic principles of the Mark XII Secure Identification System. The citation read in part: "through his foresight and personal efforts, the Mark XII program was originated and directed toward its present adoption by the Department of Defense for implementation and use in our military forces."

Prior to his retirement on October 31, 1969 Dr. Cleeton was Associate Director of Research for Electronics at NRL where he was highly regarded in the field of microwave spectroscopy. As Associate Director of Research, he was responsible for five Electronic Divisions of the Laboratory including Applications Research, Electronics, Radar, Communications Sciences, and Electronic Warfare.

Skyhook

CDR W. R. Wilson, USN
Office of Naval Research

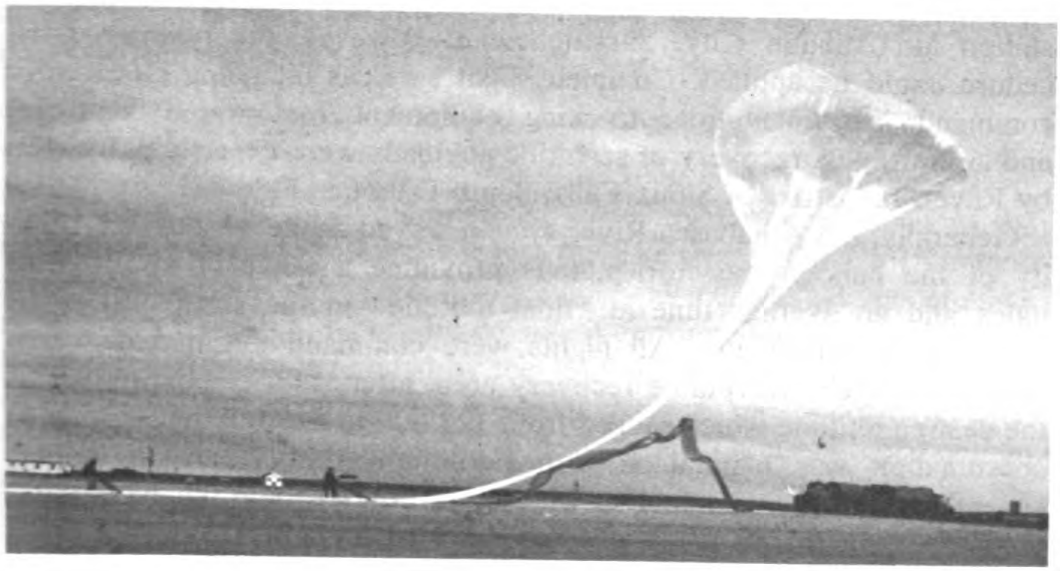
The Navy's Skyhook program has passed another scientific milestone. The completion of the 1969 flight series at Churchill Research Range (CRR) in Northern Manitoba, Canada, marked the tenth successful year of high-altitude balloon-borne research from that location. Since Skyhook is virtually world-wide in scope, each operation is named for the geographic location from which the flights are conducted. Thus, Skyhook Churchill, may be added to the list which includes Skyhook: Panama, India, Australia, Iceland, Minneapolis, and Sioux Falls.

Background

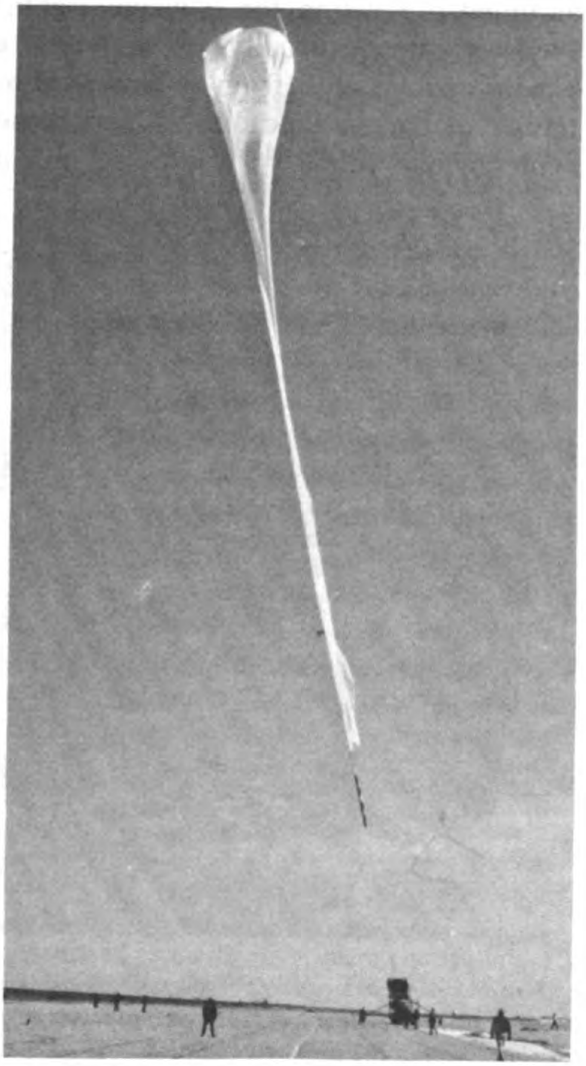
The Skyhook Churchill Program originated in 1959 when five scientific experiments were flown on rather small polyethylene balloons. Subsequent years have seen an increasing number of scientists participating in the program and great technological advances developed in response to demands from the scientific community. Also, there have been considerable changes in the management of the range during this period. The original organization of the Canadian Defense Research Northern Laboratory which was under military control has shifted to the present civilian management of the Churchill Research Range (CRR) which was officially established in 1962. General managment of CRR was assumed by the National Research Council of Canada in 1965 and continues under the joint funding of that agency and NASA. The CRR directorship is occupied by Dr. J. H. Brandy of NRC.

Flight Operations

The Skyhook Churchill 1969 field program began 13 June which is slightly earlier than the traditional commencement date. The starting time was established by scientific considerations since the first payload was required to be in the stratosphere coincident with the OGO-F satellite polar passage. These particular flights had all data recorded on-board; thus recovery was absolutely essential. The same scientific group conducted additional flights with instrumentation which measured the spectra of cosmic ray positrons and electrons. These flights were more complex than normal since data were collected at the highest attainable altitude; then the balloon system was "valved down" to a lower specified altitude for the duration of the flight. Generally, "valving" commands were given from the command center at CRR and electronically monitored at both the command center and the down-range



Launch of 18 million cubic foot balloon from Churchill Research Range, July 1969

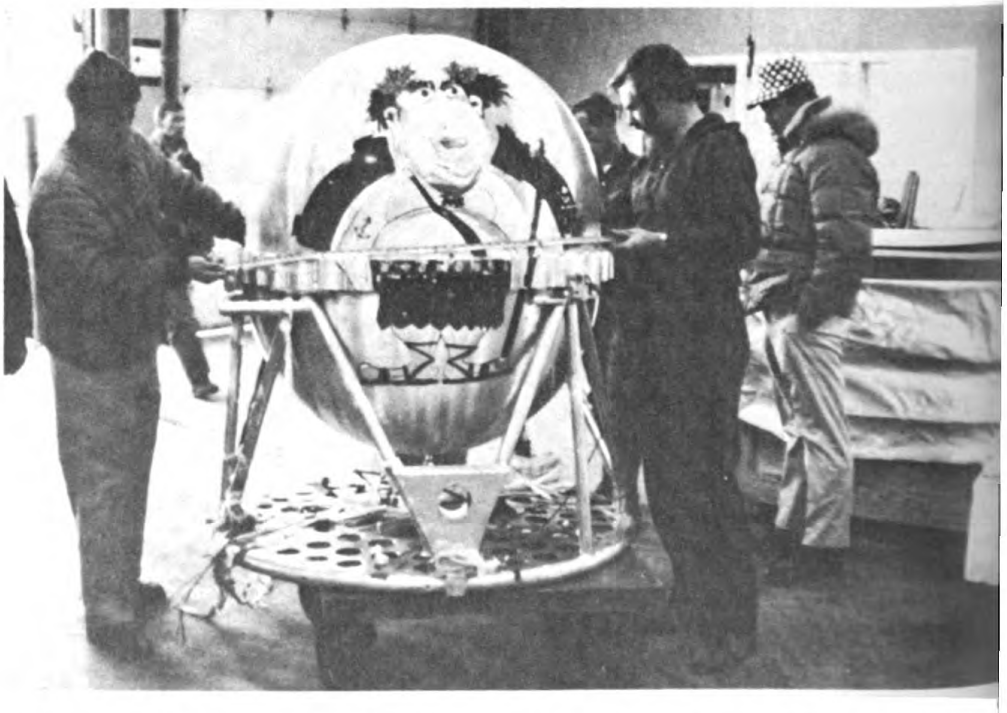


A 10.6 million cubic foot single cell polyethylene balloon rises slowly (800 feet per minute) in the early dawn air (Churchill 1969)

station at Uranium City, Saskatchewan; however, the reverse procedure could be applied. Complete flight services including electronic command instrumentation, tracking equipment for ground stations and aircraft, plus recovery of scientific payloads were expertly provided by Raven Industries of Sioux Falls, South Dakota.

Generally, the Athabasca River system served as the western extremity of the balloon trajectories, thus providing a range of about 800 miles and an average time at "float altitude" in the stratosphere of approximately 15 hours. All flights were command terminated when over a relatively acceptable recovery area, after sufficient exposure at the desired altitude which ranged from 123,000 to 147,000 feet. Careful coordination was maintained with Edmonton Center (an air traffic control station) to avoid conflict with aircraft on jet route polar transits.

Recovery of the payloads was accomplished by a highly skilled team of bush pilots using equipment which ranged from a veteran C-47 aircraft to a modern jet helicopter. The recovery team tracked the balloon-borne payload electronically as it came down range and then assumed a position for a visual sighting prior to actual "cut-down." Payload impact usually presented a challenging recovery situation which might range from a water recovery (Lake Athabasca) to tall timber or barren sand dunes. For the second successive year 100 percent payload recovery was achieved; however, the 1969 season must



Payload used in cosmic ray investigations is returned to launch readiness buildin after successful flight. The scientific group of the University of Chicago did the art work to bring the project good luck.

stand alone in the spotlight of efficiency because two additional payloads—from previous years operations—were also recovered.

Highlights

Skyhook Churchill 1969 provided some unique occurrences in the field of high altitude research. It was the first time at CRR a 15 million cubic foot balloon was flown. The balloon was a single-cell model made by Winzen Research, Incorporated, and it performed flawlessly. Another unique requirement generated by the 1969 flight series was the complex logistics support required for a newly devised super-cooled magnet. For the first time it was essential to provide 1500 liters of liquid helium for the payload. Special air-freight arrangements were made by the ONR Field Office, Minneapolis, which assured the desired support in a timely manner.

The Skyhook Churchill 1969 program is complete; twenty successful flights flown; one balloon failure; twenty-two payloads recovered and a wealth of high-altitude research data gathered.

New Ship for NRL Scientists

A new Oceanographic Research Vessel, (T-AGOR-16) which is expected to be a great improvement over those presently employed, is being constructed for use by Naval Research Laboratory scientists.

The ship, under construction by Todd Shipyards Corporation, Seattle, Washington, will be a catamaran (twin-hull) design which provides for increased capabilities. The vessel is being constructed in modules which are expected to be assembled on the ways beginning in December 1969.

The area developed in the new vessel for laboratories and scientific space, is more than double that of other existing oceanographic research vessels. The catamaran design permits a large increase in open-deck work areas and the wide beam gives the ship more stability than other AGORS. The catamaran design includes a large center well between the two hulls for scientific gear streaming, both forward and aft. This also would allow the handling of deep-research vehicles such as "mini-subs," at the center point of minimum ship motion. The extensive separation of the hulls results in large separation of the controllable-reversible-pitch propellers insuring excellent maneuverability at slow speeds which is necessary to scientific investigations.

When the ship is delivered and fully equipped it is expected to be used by some 30 Naval Research Laboratory scientists and operated by the Military Sea Transportation Service. Although the T-AGOR-16 will be home ported in New York, N.Y. it will often return to the Washington Navy Yard harbor for loading and unloading scientific data and equipment.

The Naval Research Laboratory uses three other oceanographic research vessels, which are operated by the Military Sea Transportation Service in exploring the ocean's environment. The new ship will be used in investigations of the ocean on a world-wide basis in both the Atlantic and Pacific waters.

Construction of the T-AGOR-16 was authorized as the third catamaran design in the Navy's ship-building program. The first two catamarans which are slightly larger than the T-AGOR-16, are the auxiliary submarine rescue ships, ASR's, one of which has been launched.

Research Notes

Navy Studies Possible New Form of Water

The discovery of what may be a new form of water chemically identical to ordinary water but with dramatically different properties has stimulated research on this compound by the Navy.

Studies of the nature and structure of this apparent anomalous form of water have been recently initiated by the Office of Naval Research.

"Polywater," as the substance has been named by one group of scientists, is formed by carefully controlled condensation of water vapor in tiny quartz capillary tubes a few microns in diameter. A Russian scientist was the first to discover that water so formed has little resemblance to ordinary water, and independent experiments conducted in England and the United States confirmed this observation.

Although all the polywater produced up to now would not cover the head of a pin, ingenious measurements indicate that it appears to be about 40 percent denser and about 20 times as viscous as ordinary water. At a temperature of −50 degrees centigrade it does not freeze but turns into a glass-like material. Further, it fails to decompose even when subjected to temperatures high enough to melt lead.

So far scientists have been unable to explain polywater in terms of known chemical-physical processes. Its structure hints that it is a water polymer—many water molecules bound together in a long chain or sheets. This accounts for the name "polywater."

In the United States, investigations in this field were spurred by a symposium sponsored by the Office of Naval Research in February 1969 devoted to a discussion of general anomalies of water. One purpose of the gathering was to determine what was known about polywater and what were the chances that it is actually a new form of water.

Although ONR feels that this fact remains to be established, it is pursuing research on this phenomenon because of potential broad Navy applications in oceanography, meteorology and biology as well as in chemistry and physics. As part of an ONR-supported program dealing with liquid structure in general, contracts were recently awarded to the University of Miami and the University of Missouri at Rolla.

The immediate objectives of the research there are to produce a couple of milliliters (a thimbleful) of the substance to analyze its structures and properties. It is also hoped to determine the role of solid surfaces in the production of this kind of substance. For example, if the surface of the quartz capillaries is instrumental in the formation of polywater, the phenomenon will help to understand the catalytic role of surfaces in condensation and other surface-influenced processes such as boiling and corrosion.

If polywater turns out to be a stable compound, it may be found naturally in such diverse places as ocean sediments, in clays, and dispersed in fuels and lubricants as well as in clouds, fog and ice in the atmosphere.

Polywater could lead to a better understanding of ocean sediments and beach processes, and it could be a critical factor in programs of weather prediction and modification. The properties of polywater may also make it an excellent medium for moderating nuclear reactors.

Launching an Aerobee Rocket

Recently an Aerobee rocket, instrumented by the Naval Research Laboratory with the assistance of the Ball Brothers Research Corporation of Boulder, Colorado, was launched from the White Sands Missile Range. The launching was timed to coincide with a solar flare which was detected a few moments before, nearing its peak intensity. These flares cause disturbances (solar storms) in the earth's ionosphere that prevent carrying on world-wide conversations by radio.

The mission of the rocket was to record the short wavelength ultraviolet and near x-ray emissions from the flare and to send back to earth a moving picture of the flare's appearance in these rays by means of a new type of television system. These findings will help reveal what a solar flare is. Because flares are so short-lived and unpredictable, a rocket launching requires split-second timing and perfect coordination. Solar storms, like tornadoes, appear without warning. Their effect on the earth is to bombard with x-rays the upper atmosphere, which screens life on earth from the lethal rays. When the atmosphere absorbs the x-rays, it changes character. Its mirror-like ionospheric layers move down and stop serving earth as a relay station for radio transmissions.

The detection of the flare was the work of many solar observatories, all reporting by direct telephone to the Space Disturbance Center of ESSA at Boulder, Colorado. Some seconds after the first report, the ESSA watchers sent warning that a flare had started to the rocket launch at White Sands. At once the word was passed to the NASA engineers and the Navy officer in charge to commence the final three-minute countdown, and to alert the entire U.S. Army missile range to go into action. Tracking radars were swung into position to follow the rocket at the moment of launch, and large dish antennas were aimed at the rocket's tiny TV transmitter.

Three minutes after first detection of the flare the rocket was launched; two minutes later it had climbed above the earth's atmosphere, and observations of the flare began. The instruments were turned to point precisely and steadily at the sun by means of a three axis control system developed by the NASA Ames Research Center and Lockheed. The photographic instrument commenced its picture taking, and the TV transmission began. When the rocket reached its peak altitude of 124 miles and began falling back toward the earth, a parachute opened and brought the highly valued instruments down to the desert sands.

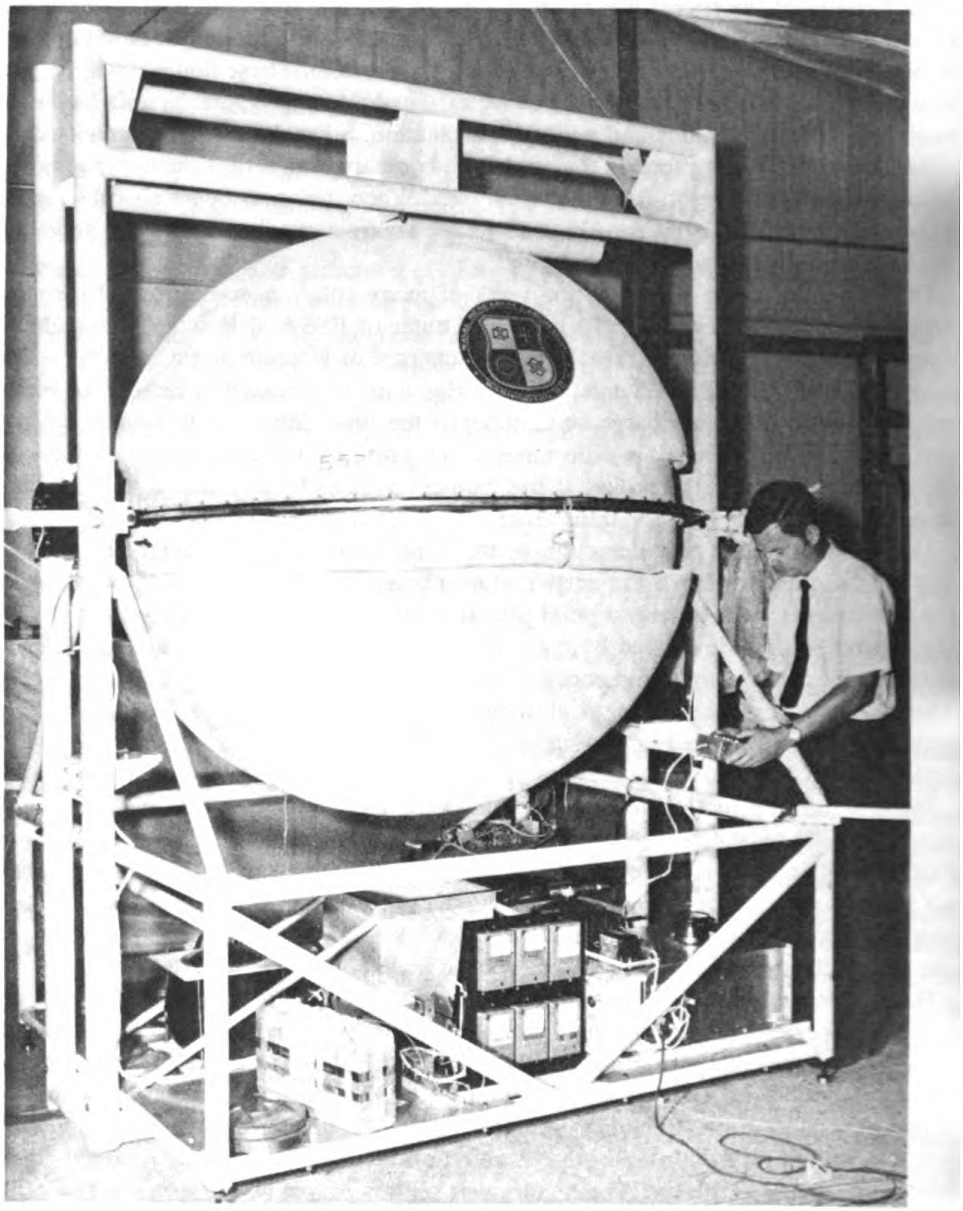
The instruments in the rocket were half-scale models of two of the large telescopes being prepared by the Naval Research Laboratory and Ball Brothers Research Corp. for the Marshall Space Flight Center of NASA, to fly in the first manned space station. They will form a part of the collection of instruments to be carried in the Apollo Telescope Mount, which will be joined to the orbital workshop in which the astronauts will live. The whole cluster will be placed in earth orbit in 1972.

The extreme ultraviolet TV system is first of a kind. Not only is it the first TV system ever to be operated in a small sounding rocket, but it is also the first TV system that is able to view the sun in the mysterious region between the ultraviolet and x-rays, which cannot be seen except from 100 miles or more up. The TV pick-up tube was an ultrasensitive secondary emission conduction vidicon, made by Westinghouse, with its window coated with quaterphenyl, a substance that converts ultraviolet and x-rays into ordinary blue light which the tube can see. The picture was sent to ground by the rocket's 10-watt UHF band transmitter, and received by large dish antennas on the desert floor, some 100 miles underneath.

This is a prototype of the closed loop TV system that will be a part of the Apollo Telescope Mount, and will show the astronaut just what is happening on the sun in ultraviolet and x-rays. With this image in front of him, he will be able to point powerful telescopes and spectrographs at exactly the spots on the sun where he sees the strange regions which are producing x-rays.

New Cosmic-Ray Detector

Naval Research Laboratory scientists have developed a new balloon-payload apparatus that promises to yield important clues to the sources of cosmic rays. The new telescope, designed to detect cosmic gamma rays was developed in NRL's Laboratory for Cosmic Ray Physics, headed by Dr. Maurice M. Shapiro.



The novel detector system has been sent aloft by physicists in a balloon flight from Palestine, Texas, mainly to search for gamma rays in the direction of the Crab Nebula, a remnant of a gigantic stellar explosion. If these gamma rays are detected, then the Crab, long suspected of being a source of cosmic rays, would be established as a site of origin for these energetic particles.

Dr. Shapiro said the observation of discrete cosmic gamma-ray sources would, in effect, open a new window for astronomical studies. Gamma rays, he explained, are particularly revealing because they travel in straight lines, thus "pointing back" to their sources. By contrast, the charged cosmic rays are deflected by magnetic fields in space, thereby "losing their sense of direction."

In addition to searching for gamma-radiation from suspected sources such as the Crab, the NRL scientists also seek to detect and measure the diffuse, general background gamma rays from outer space.

(Continued on Inside Back Cover)

On the Naval Research Reserve

Reserve Assistants Meet in Washington

RADM T. B. Owen, USN, Chief of Naval Research (seated, center) opened the Research Reserve Assistants Conference at Washington, D.C. Attending the opening session were: (seated, left to right) CDR J. P. Johnson, USNR, ONR Pasadena; CAPT C. O. Holmquist, USN, Deputy and Assistant Chief of Naval Research; RADM Owen; CDR F. E. Whipple, USNR, ONR Chicago; LCDR R. G. Gantt, USN, ONR Boston. (Standing) Miss E. F. Kehoe, Training Officer and Fifth and Sixth Naval District Research Reserve Liaison Officer; CAPT C. H. Butt, USN, Director of Administration, ONR; and CDR H. E. Bates, USNR, Special Assistant to the Chief of Naval Research for Research Reserve.

RADM T. B. Owen, USN, Chief of Naval Research opened the annual conference of Reserve Assistants for the Research Reserve Program at the Office of Naval Research, Washington, D.C. CAPT Carl O. Holmquist, USN, Deputy and Assistant Chief of Naval Research, attended the opening session and participated in other sessions in the two-day conference.

This conference, which brought together all Reserve Assistants from ONR Branch Offices with ONR staff personnel, was devoted primarily to recent studies of the Research Reserve and the overall Naval Reserve. The report of the latter study, Naval Reserve Force Study under the direction of RADM J. T. Burke, USN, Assistant Deputy Chief of Naval Operations for Naval Reserve will be released at a later date.

Other matters which affect the Research Reserve were discussed and Reserve Assistants will brief their units on their fall trips. Long-range plans for the Research Reserve will be affected by any changes brought about by the Naval Reserve Force Study.

NRRC 5-2

The theme for the fall schedule of NRRC 5-2, Blacksburg, Virginia is environmental pollution. Lt. W. J. Kennedy, USNR, Commanding Officer, started the series of lectures with a report of the Navy's program to convert from black oil to residual fuel; a conversion partly aimed at reducing air pollution. Other lecture topics were: the legal steps that can be taken against water pollutors, the question of measuring water pollution, land pollution and what can be done about it, political aspects of pollution, and the disruption to ecological systems caused by pollution. Material for the winter program will be centered around applications of probability theory. Lecture titles will be: Modeling of Educational Systems, Modeling of Police Budget Processes, and GERT (Graphical Evaluation and Review Technique).

NRRC 9-10

RADM T. B. Owen, USN, Chief of Naval Research announced that this year's winner of the Research Reserve Award for General Excellence was NRRC 9-10, Evanston, Illinois, commanded by CDR Benedict J. Jaskoski, USNR. The award is given to the most outstanding Research Reserve Company out of a total of 87. The Commandants of the 10 Naval Districts each choose one company from his district; from these 10 choices the panel picks a winner.

Members of the panel commented favorably on the records of the other companies entered in the competition. These companies and their Commanding Officers for Fiscal Year 1969 are:

1-1	Boston, Massachusetts	CDR Charles F. Davis, USNR
3-14	Poughkeepsie, New York	CDR Richard J. Messina, USNR
4-4	State College, Pa.	LT John D. Sink, USNR
5-4	Baltimore, Maryland	LCDR John M. Backer, USNR
6-17	Huntsville, Alabama	LCDR Alfred R. Morse, USNR
8-3	College Station, Texas	LCDR Robert M. Olson, USNR
11-5	San Diego, Calif.	LCDR Craig R. Allen, USNR
12-3	Stanford, Calif.	LCDR Hugh M. Satterlee, USNR
13-1	Seattle, Wash.	CDR Albert S. Hanson, USNR

(Continued from Page 13)

The nighttime and daytime concentrations of these two gases in the surface waters and the atmosphere were studied. While no diurnal effect was observed in the measurements of natural methane, the CO concentration in the surface water increased tenfold between 4 AM and 4 PM, although the atmospheric concentrations remained relatively constant. The cause of this diurnal cycling of CO in seawater is probably related to biological activity and/or photochemical reactions in the upper layers of the ocean.

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The new detecting instrument, which was only recently completed, consists of a unique array of detectors. These include plastic scintillators, nuclear emulsions, a novel type of wide-gap spark chamber and a Cerenkov detector. It has been designed to provide good angular and energy resolution for gamma rays of 20 to 120 million electron volts. In this energy region, the NRL team hoped to detect a higher flux, and to obtain spectral information that would show how the cosmic gamma rays are produced.

The final results of the balloon package investigation will not be known for some time, according to the NRL physicists, because it will take months to explore the results from the telescope's memory system.

The Laboratory for Cosmic Ray Physics at NRL has been widely recognized for its contributions to our knowledge of the composition of cosmic rays, and for its earlier discoveries in elementary-particle physics.

NAVAL RESEARCH REVIEWS publishes highlights of research conducted by Navy laboratories and contractors and describes important naval experimental facilities. Manuscripts submitted for publication, correspondence concerning prospective articles, and changes of address, should be directed to Code 109, Office of Naval Research, Washington, D.C., 20360. Requests for subscriptions should be directed to the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. Subscription price: $1.75 per year in the U.S. and Canada; $2.25 per year, foreign; $0.20 per individual copy. The issuance of this periodical approved in accordance with Dept. of the Navy publications and printing regulations.

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DICORS, fully equipped for speech intelligibility test recordings, being lowered into position at Rainbow Springs, Florida. *See Page 1.*

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