NAVAL RESEARCH REVIEWS

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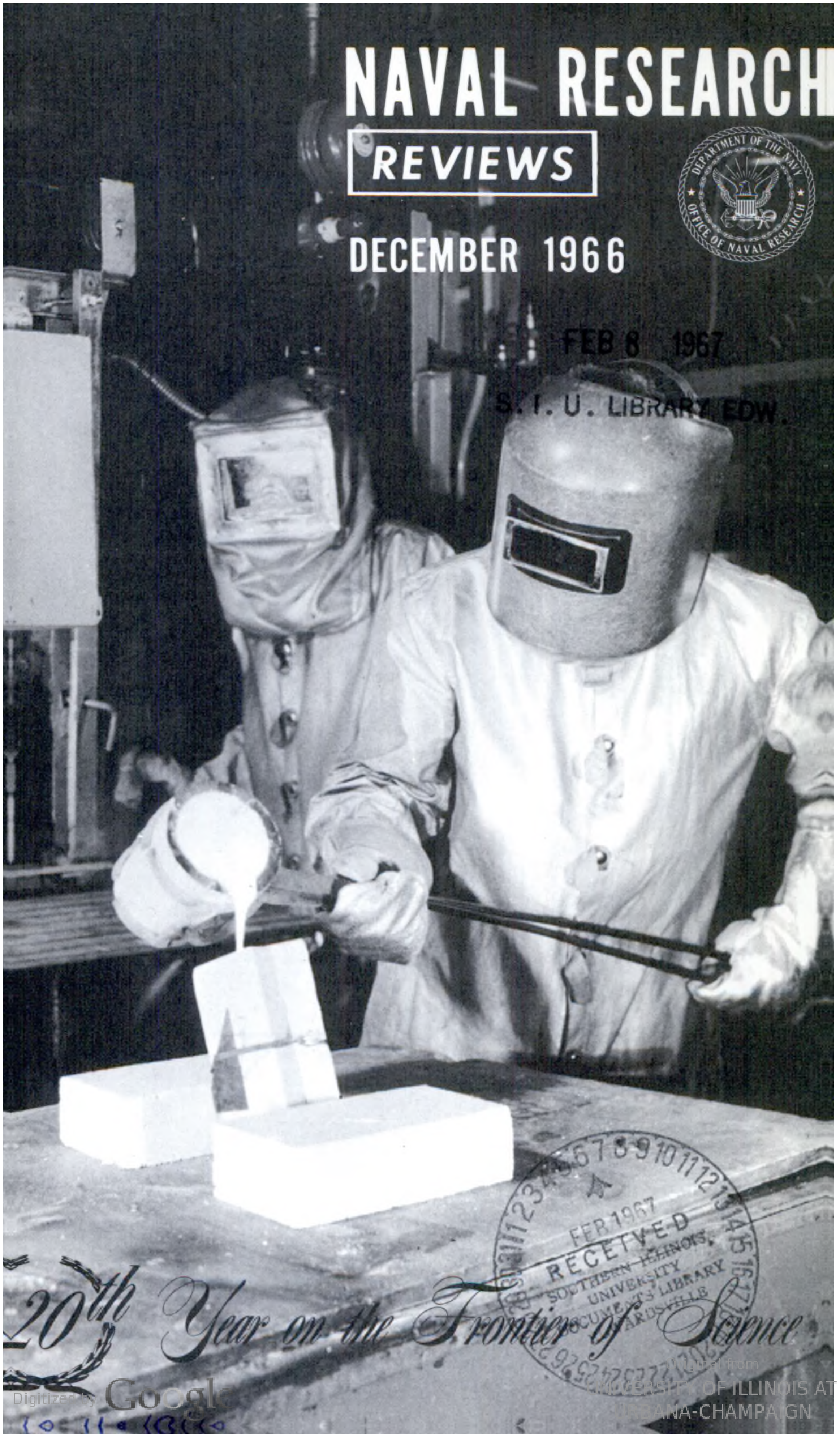

20th Year on the Frontier of Science

Dr. Robert M. Page, NRL's Director of Research, to Retire

Dr. Robert Morris Page, the man who built the first pulse radar system for the detection of aircraft by radio, retires from his position as Director of Research for the Naval Research Laboratory, Washington, on December 31, bringing to a close nearly 40 years service at the Laboratory.

Dr. Page holds more than 50 patents in the field of radar, including substantially all basic radar patents. He invented the basic circuits of pulse radar, the radar duplexer, radar guidance of missiles, monopulse precision tracking radar, very long range over-the-horizon radar, and the Magnetic Drum Receiving Equipment (MADRE) data processing system.

As Director of Research, Dr. Page has been instrumental in maintaining the Naval Research Laboratory as one of the nation's outstanding physical science laboratories. Prior to assuming his present position in 1957, the Naval Research Laboratory scientist served for five years as Associate Director of Research for Electronics. In this position he directed a research program in electronics with long range objectives and broad application.

From 1945 to 1952, he was superintendent of Radio Division III where he directed the continuation of the Laboratory's research and development program in radar gun fire control and airborne radio, and initiated a program in radar guidance of missiles.

On March 8, 1960, President Dwight D. Eisenhower presented to Dr. Page the President's Award for Distinguished Federal Civilian Service—the highest honor bestowed by the government on career civil service employees. He was honored for "remarkable achievements in the fields of electronics research, most particularly in the original development of radar."

Among the other honors accorded the Naval Research Laboratory scientist are the Navy's Captain Robert Dexter Conrad Award, the Institute of Radio Engineers' Harry Diamond Memorial Award, and the Franklin Institute's Stuart Ballantine Award.

The ONR Laser Program

Vicennial Article

Irving Rowe
New York Annex
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Office of Naval Research

The three most important advances in the physical sciences in the first 20 years (the vicennial period) of the Office of Naval Research have been the growth of nuclear science, the development of solid-state physics as exemplified by the transistor and similar devices, and the development of the maser and the laser. ONR has played a key role in supporting basic research in each of these fields, but its activity with respect to lasers has been unique.

Normally, ONR operates by supporting selected research projects directed by outstanding scientists in university and industrial laboratories. The cumulative effect of these individual projects constitutes an active program. In the case of lasers, however, a strongly administered program has been designed to bring the promise of the laser to fruition in practical applications for general use, and more particularly for the benefit of the Department of Defense, as quickly as possible. The program is managed by Mr. Frank B. Isakson, head of ONR's Physics Branch, who assembled a team of scientists to give direction to the work, to follow progress closely, and to redirect projects whenever new information made a change desirable. This team was made up of people who were located in the Washington headquarters and in each of the Branch Offices, so that wide geographical coverage could be given to the supervised program as well as bringing to bear a variety of different kinds of experience. These people, acting as a group, decide on the overall program. In addition, each individual has responsibility for a particular phase of the research. The ONR laser team now consists of the following men:

Mr. Frank B. Isakson, ONR Physics Branch (project director)
Mr. Francis T. Byrne, ONR Physics Branch (scientific director)
Dr. Van O. Nicolai, ONR Physics Branch (crystalline materials)
Dr. Robert E. Behringer, Pasadena Branch Office (basic physics)
Dr. Fred W. Quelle, Boston Branch Office (glass laser materials, diodes, and Raman-type lasers)
Dr. Irving Rowe, New York Annex, Boston Branch Office (chemical, liquid, and organic lasers)
Mr. Lloyd A. White, Chicago Branch Office (laser techniques and optical components)
Dr. Elliot H. Weinberg, San Francisco Annex, Pasadena Branch Office (pump sources)
Dr. Jack Soules, New Mexico State University (general consultant on laser physics)

Although the program described here is managed completely by the Office of Naval Research, it is financed by and operated for the

Advanced Research Projects Agency. That agency also supports other aspects of laser development which are managed by various units of the Department of Defense. The mission assigned to ONR has as its ultimate goal the advancement of high-power, high-energy laser technology, whereas the other Department of Defense components are more concerned with low-energy applications, such as for communications.

The history of the ONR Laser Program had its origin at the end of 1961 in a meeting of a special Institute for Defense Analyses study group consisting of high-level consultants to the Department of Defense. This group analyzed the state of the laser art as it then existed and recommended to the Department that the time was ripe for launching a major effort to build high-power, high-energy laser devices. ONR was chosen as the best instrument for achieving this goal because of its excellent record of research management and because of its close relationship to the invention and development of both the maser and the laser.

Origin and Characteristics of Lasers

In reviewing the early work briefly, let us recall that the laser is a device which generates light with a purity of color (monochromaticity), a degree of directionality, and a concentration of radiant energy many times greater than that of any other type of source, including the sun. Although the total energy emitted by a laser is far smaller than that of the sun, its ability to concentrate that energy within a small wavelength interval and into a small area is so tremendous that its effective temperature may be considered to be much higher than that of the sun. This is accomplished by raising a large fraction of the atoms or molecules in a suitable lasing substance to an energy level higher than normal and then stimulating these atoms or molecules so that virtually all of the excess energy is released simultaneously. The monochromaticity and the directionality properties are increased by placing the laser substances in a resonant optical cavity consisting of a pair of mirrors, one of which is semitransparent, permitting the radiation to escape. The lasing substance may be in the form of a solid rod of either a crystal or a glass, or it may consist of a column of gas or liquid. The process of raising the atoms or molecules to a high energy state is known as "pumping." For a more complete review of this process, the reader is referred to an article by Dr. Francis T. Byrne, which appeared in *Naval Research Reviews,* October 1961.

The operating principle of the laser was first enunciated by Dr. Charles H. Townes of Columbia University and Dr. Arthur Schawlow of the Bell Telephone Laboratories in a paper published in the *Physical Review* on December 15, 1958. When the first lasers were made, the letter "l" in laser stood for visible light, but now lasers can be made which operate in the ultraviolet or in the infrared portions of the spectrum as well as in the visible. However, the laser was derived from earlier work on the maser, which operates on the same principle but in the microwave region of the electromagnetic spectrum. The first working maser utilized a stream of ammonia gas. A set of specially shaped electrodes permits only those molecules in the higher energy states to enter a resonant microwave cavity. Once in that cavity, the excited ammonia molecules give off their excess energy in sharply defined micowave radiation at 23.87 Gc. This maser was designed and built at Columbia University in 1954 by Professor Townes with the assistance of a student, James P. Gordon, and a post-doctoral associate, H. J. Zeiger. They described this work in a paper published in the *Physical Review* in 1955. Going back still further, the basic physical ideas behind both the laser and the maser were conceived by Professor Townes in 1951 while working in the general field of microwave spectroscopy. His work at the Columbia University Radiation Laboratory was supported by a research contract funded jointly by the Office of Naval Research, the Army, and the Air Force.

Early Applications

The Navy was quick to utilize these important concepts. The first practical application of the maser was as an ultrasensitive low-noise receiver in the Naval Research Laboratory's 50-foot radio telescope. This use permitted the detection of very weak radio signals from the planets and the stars. Other applications of microwave spectroscopy and the masers were the design and construction of the Atomichron and the hydrogen maser as ultraprecise standards of frequency, particularly for use in navigation. Much of the credit for these developments should go to Dr. Arnold Shostak, head of ONR's Electronics Branch, who had the foresight to arrange the contracts under which these devices were brought to a useful state and who encouraged the Naval Research Laboratory to test them for shipboard operation. For a review of microwave spectroscopy and its applications, see the article by Dr. Shostak in the February-March 1966 issue of *Naval Research Reviews* entitled "Research Origins of Modern Time and Frequency Control."

The Maximum Possible Brightness

It was because of this close association with the early history of the laser, the maser, and related scientific work that the Advanced Research Projects Agency asked ONR to undertake a massive program of bringing the laser to a state of practical perfection. By that time, Dr. Theodore Maiman had built the ruby laser, utilizing the principles of Townes and Schawlow, and had demonstrated that the monochromaticity and coherence of light which they predicted could indeed be achieved. Subsequent work done with larger rubies and much more powerful xenon flash lamps, which acted as pumps, brought the amount of radiant energy emitted in a single pulse up to 50 joules (a joule is the amount of energy consumed by a 10-watt night lamp in one-tenth of a second). The duration of the pulse was of the order of several milliseconds. Further, the Q-switch had been invented. This was a technique which permitted an optical pump to work for a relatively long time, so that almost all of the atoms were brought to a high degree of excitation, and which then stimulated the laser rapidly, so that all of this energy was released in an extremely short time, of the order of a few billionths of a second. This extremely rapid rate of emission of light meant that powers of the order of many millions of watts were radiated during this short time interval. However, the total amount of energy radiated was very small, less than a joule. Since, for most practical applications, the more energy the better, ONR's mission was to develop lasers which would emit large quantities of radiant energy at high rates of power and at the same time keep the diameter of the beam from spreading more than the theoretical amount (known as the diffraction limit). In other words, we wanted a source of light with the maximum possible brightness. To accomplish this, it was necessary to determine what bottlenecks were limiting the delivery of large amounts of energy and to overcome them.

At the beginning of 1962, the ruby crystal was the most successful laser material. The use of optical quality glass containing small amounts of neodymium as the active material also seemed promising. Gaseous lasers utilizing mixtures of helium and neon produced light of excellent quality with respect to monochromaticity and coherence, but at very low power levels. Because a gas inherently contains a low number of atoms per unit volume, it did not seem that this type of device could ever give high power, so it was removed from consideration. A few other types of crystals likewise had been shown to lase, but also at low power levels. Consequently, it was decided to concentrate on lasers whose active material was either ruby or glass.

In 1962, Mr. Frank B. Isakson summoned prospective contractors to a bidders' briefing. Intense excitement was generated in the industrial world by news of this meeting, and more than 60 firms sent one or more representatives. Subsequently, proposals were received to perform short-term design concept studies for the type of laser needed to satisfy the ONR objective of extremely high intrinsic brightness. The proposals were evaluated by the ONR laser team, aided by consultants from the Naval Research and Ordnance Laboratories, the National Bureau of Standards, Lincoln Laboratory, and the Institute for Defense Analyses. A number of them were accepted in order to encourage a wide range of ideas.

As a result of the design concept studies, four contracts for construction of high energy, high power lasers were awarded. At the same time, a number of contracts also were awarded for the development of improved materials, including new techniques for growing high-quality ruby crystals and for improving the optical properties of glass. Of the four equipment contracts awarded, the first required the construction of a short-pulse, high-brightness laser to be used as a laboratory tool; the second was to show that laser amplifiers could be operated in parallel and in the same phase so that their energies could be added coherently; the third required the construction of a laser with adjustable pulse lengths and pulse shapes and without random peaking of energy (known as spiking); and the fourth called for the construction of a high-gain glass-type laser to deliver a single high-energy pulse.

The first project was completed quite successfully with the delivery of a 30-joule short-pulse laser. It utilized one ruby rod as an oscillator, which was followed by three ruby-rod amplifiers. Although this energy was less than the amount specified, it was far more than had ever been obtained previously in a short-pulse Q-switched laser. This laser has been updated from time to time by the substitution of improved ruby rods but is essentially the same as when it was first designed. It is still operating and remains one of the most reliable systems in its energy class.

The second project required rigorous control of the phase of two separate laser amplifiers so that they could be combined for maximum effectiveness. An accurately designed servo system was built to control the phase, but such control turned out to be much more difficult to achieve than had been anticipated. At the completion of the contract period, phase control had been demonstrated, but the combined output of the two amplifiers was disappointingly low. The third project involved the control of the shape and duration of the emitted radiation pulse by means of a feedback system which had been invented by Dr. Van O. Nicolai. The contractor refined Nicolai's concept by elaborately computing the details required for the feedback circuits and showed that the pulse could be adjustably controlled, but again the energy output was lower than had been hoped for. The fourth project required the operation of large lengths of high-optical-quality glass containing neodymium ions. These rods were operated in a so-called "avalanche mode" invented by Dr. Francis T. Byrne. It was found that the glass was subject to breakage when large amounts of energy were passed through it.

The Bottleneck

What, then, was the bottleneck that limited the energy in all of these projects? Investigation by means of interferometric analysis and by other types of refined optical measurement soon revealed that it lay in the relatively poor quality of both the ruby and the glass materials used to generate and amplify the laser radiation. The word "relatively" is of great significance here, for actually these materials were of an extremely high quality compared with anything made previously. Ruby is grown as a single crystal up to 12 inches long by the Verneuil process. Here, the ingredients, aluminum oxide and chromium oxide, are powdered and slowly sifted into an extremely hot oxyhydrogen flame, where they melt and then drop down to congeal into a crystal. The process was originally used to produce synthetic jewels for watch bearings, and the crystals are indeed gem-like and beautifully clear to look at. These crystals are fine for low-power, low-energy lasers, but the small quantities of impurities, and the small deviations from perfect crystallinity prevent them from satisfying the critical needs of this program. A similar condition holds for the glass used in lasers. During the past hundred years, very fine types of optical glass have been developed. However, even for the largest telescopes, the thickness of glass through which the light must pass is only a few inches. In the larger lasers the problem is much more difficult because the light is required to go through six feet or more of glass with an absolute minimum of scattering, absorption, and distortion.

The Materials Program

Major programs of materials improvement were, therefore, undertaken. Dr. Van O. Nicolai supervised the effort to grow more perfect forms of crystals. To be suitable as a high-energy laser material, a substance must have a relatively long fluorescence lifetime so that it can store energy, it must have a broad absorption band at a suitable wavelength so that it can be pumped efficiently, the crystal must be strong and able to withstand the high-energy densities and the high temperatures produced, it must be optically clear and free from scattering, absorption, and distortion at the emission wavelength, and it must be available in large sizes. This is a formidable set of specifications. Dr. Nicolai supported research on magnesium and cerium oxides, lanthanum aluminate, yttrium oxide, strontium titanate, barium zirconate, thorium oxide, and other materials. In particular, he sought crystal structures in which the lasing ion is located in a position of inversion symmetry, which promised to give long fluorescent lifetimes. While some of these materials did lase, none had as good a combination of properties as the original material—ruby.

Consequently, more effort was expended on perfecting ruby crystals. First, the Verneuil process was improved by exercising greater control. Then, nearly perfect rubies were produced by melting the ingredients in a flux instead of in a flame and by growing them in solvents under controlled conditions of pressure and temperature. However, these crystals were too small and contained too many inclusions to be useful. A fourth method was to vaporize aluminum trichloride and chromium trichloride at a temperature of 1750°C and to let these gases then condense on a seed crystal. Fairly good rubies of high chemical purity were made in this way. Very recently, the so-called "Czochralski method" of melting the ingredients in a refractory metal crucible at a temperature of about 2100°C and pulling crystals out of the molten mass has succeeded. Several years of support were required to perfect this technique, while various methods of temperature control, application of gaseous atmospheres, and pulling procedures were investigated. Now, rubies are available having a very high degree of crystal perfection. Some crystals as large as 5/8 inch in diameter and 22 inches in length have been made in this way. The density of dislocations—a measure of structural imperfection—has been reduced by a factor of 10,000. Tensile strength has been doubled, and thermal conductivity has been increased because of smaller impurity content. The passive angular spread of a transmitted light beam has been reduced by a factor of 20, increasing the brightness of the laser accordingly. Accompanying all these benefits, greater yields of high-quality material will make the cost of a Czochralski-type crystal less than that of a comparable Verneuil-type crystal. These new melt-grown rubies may prove to be the answer to better high-energy lasers.

In conjunction with the crystal program, Dr. Fred W. Quelle was assigned to obtain better glass materials for lasers. The three major American makers of optical glass participated in this work. Thousands of different compositions of glasses were made and tested. Highly purified ingredients were found and utilized. To ensure uniformity and freedom from striae, the glass was made in large batches, sometimes by a continuous-flow process. To avoid contamination, the glass was melted in large platinum crucibles. However, it was found later that glass made in these crucibles had a tendency to break when subjected to high energy densities. Apparently, the platinum became oxidized to a gas, was transported as a vapor, and reappeared in the glass as metallic inclusions, which then acted as local centers for absorbing radiation. A vigorous effort was made to eliminate this difficulty. Now, the crucibles are protected by a neutral gaseous atmosphere to prevent oxidation. At the same time, ceramic crucibles were found that were free from impurities and that resisted attack by the molten glass. As a result of all of these efforts, large glass rods of amazing clarity and freedom from absorption are now available. Some of these rods are 2 inches in diameter and about seven feet long. With rods of this type, energy outputs greater than ever before have been achieved—but not in the short pulses that ONR would like to see. It might be noted that although the ingredients of ordinary glass are very cheap, the care and effort required to make a large, high-quality rod may cost as much as $10,000!

Energy Pumps

Good materials are not enough. With them, one must have large, efficient pump sources that match the absorption bands of the laser materials. Dr. Elliot H. Weinberg undertook the task of improving these sources. The original pump was a xenon flash lamp which emits a copious amount of white light in a few milliseconds. One attempt to improve the efficiency was the addition of other gases to the xenon to make the spectral output a closer match to the laser. This proved not to work in large lamps, because the xenon and the other gases were so hot that they gave essentially the same type of spectrum. However, the technique is useful for lasers of lower power. Other projects dealt with explosive shock-induced radiation in gases, sensitized fluorescence in gases, and external fluorescence converters to absorb harmful ultraviolet radiation and to change it to useful light. Plasma types of light sources were investigated. Nuclear-pumped light sources, cathodoluminescence, and other possible light pumps were also explored. An advanced type of lamp now available is the coaxial model. In cross-section, it looks like a doughnut, the ring being filled with xenon gas and the hole being filled with the laser rod. The outer surface is made of a white ceramic, which reflects all of the lamp light onto the laser rod. Such a lamp has a relatively high efficiency and is particulary well suited for use with the large glass rods mentioned above. Close cooperation with an active and experimentally oriented lamp manufacturer made it possible to feed back information from the users of lamps so that noticeable improvements in performance and reliability could be quickly incorporated into the equipment. A theoretical program is underway to analyze in a fundamental way the radiation from partially ionized plasmas, such as exist in a flash lamp. In addition, a standardization of lamp measurement procedures has been initiated that may lead to a significant advance in technology.

Bleachable .Filters

At the outset of the laser program it was clear that a research and development effort was needed to improve the Q-switches available at that time—namely, rotating prisms and Kerr cells. A program was established by Mr. L. A. White to study this problem. Two contracts were awarded in this area. One study resulted in a film of Victoria Blue B dye on an optical flat substrate which constituted an inexpensive, self-synchronizing, short-time constant passive Q-switch. The contractor also demonstrated the utility of absorbing organic dye solutions as a nondestructive, passive, reversibly bleachable Q-switch in a ruby cavity. Cryptocyanine in methanol was one of the dyes that served most successfully as a Q-switch. The other contractor observed saturable filter action in uranyl doped glass and demonstrated its utility as a light-pumped Q-switch.

The significance of the bleachable Q-switches is apparent in present laser technology. These elements permit one to have the most coherent, single mode, giant pulse ruby lasers with the shortest pulse length ever available. Likewise, lasers relying on neodymium-doped glass provide the shortest pulse length mode-locked devices ever obtainable. Pulse lengths are less than a billionth of a second.

Exotic Lasers

All of the lasers mentioned thus far have the active material in the form of long, thin rods. A different variety of laser now being investigated is one made of a series of large-diameter but thin discs. The material is pumped through one face, and the light is emitted or reflected from the other face. A basic law of optics says that the spread of a beam of radiation is inversely proportional to the diameter of the source. These discs should, therefore, give a very sharp, intense beam.

Another variation is the "laser-pumped laser." In this case, a number of small, not necessarily precise lasers are used to irradiate a large, high-quality one. The purpose is to get a more effective pumping system.

An entirely different category of laser employs organic materials in liquids and plastics, inorganic liquids, and chemical lasers. The development of lasers of this type, which is under the direction of Dr. Irving Rowe, does not require large, perfect crystals nor highly purified glass rods. The ingredients are inexpensive and readily prepared. A liquid is not subject to breakage, and it can be circulated to provide cooling. By using different chemicals, many wavelengths of laser emission can be obtained, thus providing a degree of tunability not easily achieved in solid lasers. The liquid and plastic lasers are pumped by conventional flash lamps. However, the chemical laser is a new type in which the energy is provided by a chemical reaction occurring inside the laser cavity. This arrangement could eliminate the need for large flash lamps and large sources of electrical power, greatly increasing the efficiency and reducing the cost of the laser systems. These exotic lasers do work, but the energy achieved to date is quite small. There is hope that improved materials will be found in the near future.

Semiconductor and Raman-type lasers have also been studied under the guidance of Dr. Quelle.

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On A Clear Day

"On a clear day, you can see forever!" So go the words of a popular song. But is it really true for lasers? The optical inhomogeneities in glass discussed above have their counterpart in the atmosphere. But the atmosphere is not a static material and the inhomogeneities are constantly moving, fading out, and new ones are developing. This motion in the atmosphere, which is responsible for the shimmering of stars, leads also to the breakup and random "hopping" of a narrow laser beam transmitted over large distances. For instance, a laser beam, which in vacuum would have a six-inch diameter at one mile distance, illuminates an area of roughly one-yard diameter at an equivalent distance in the atmosphere. The unsteady atmosphere makes its presence felt also in amplitude and frequency modulation of a continuous-wave laser signal. In addition, the atmosphere, like all substances will not transmit extremely high intensity beams because of damage to the air itself. This breakdown phenomenon has been explored only at the focus of high-intensity pulses. The plasma produced is similar to that produced in high-voltage sparks.

A problem that beset the equipment designers is the tendency of optical components to be damaged by the high intensity of the laser. Calcite is a common component of polarizing prisms. Cements are used to make special optical lens and prism combinations. Both of these items are readily damaged, even at low intensities; so are the reflecting films of mirrors and glass and quartz lenses. Consequently, projects were set up under the guidance of Mr. Lloyd A. White to create new techniques for optical components which will result in damage-free designs.

The Naval Research Laboratory was brought into the project at an early date. Funds were allocated to the Laboratory to develop new types of laser glasses, to investigate new methods of growing crystals, to study laser optics and propagation, and to increase the efficiency of plasmas as pumps. Subsequently, the Laboratory received funds directly from ARPA to carry on this work. It now has an active program of high-power laser research.

Basic Physics

The questions raised by the need for advanced systems, new materials, and improved pump sources and by atmospheric propagation problems all demand answers which are beyond the present state of knowledge. Puzzling questions have arisen in fundamental optics and physics. To provide new information from which answers to these problems can come, a program of basic physical research was set up. Dr. Robert E. Behringer is in charge of this work; he is aided by Dr. Jack Soules, who acts as a consultant. Approximately 25 projects have been initiated, in both university and industrial laboratories, to investigate such topics as energy transfer between ions, the spectra of fluorescent solids, Raman effects, cross-relaxation in glass, ligand fields, anomalous dispersion, and nonlinear interactions. The data coming from these research efforts will feed directly into the design of new and improved equipment.

New Trends

When the ONR Laser Program began in 1962, the potential of gas lasers for providing high energy seemed very remote. In subsequent years, the picture began to change. The ionized argon laser was invented, which yields several watts of power at a number of useful wavelengths, whereas the helium-neon type gives only milliwatts. Then came the nitrogen gas laser, which emits short, sharp pulses of fairly high peak power. Within the past year, the carbon dioxide laser has been developed. This laser contains a mixture of carbon dioxide, nitrogen, and helium, in which lasing is produced by exciting vibrational states of the CO_2 gas. Originally, it gave only a few watts, but now powers have reached the level of a kilowatt and are emitted continuously. The effect that this concentrated energy has on materials is fantastic. Asbestos, refractory fire brick, steel, and glass all burn or melt under its influence. In view of these capabilities, ONR is now undertaking a program of developing high-power radar amplifiers based on this type of laser. Three experimental contracts have been let for this work, and great hopes exist for developing new high-resolution radars. In addition to its other benefits, the carbon dioxide laser is potentially less expensive to build than solid-state lasers of equal energy output.

Contracts and Conferences

Over the past four years, the ONR Laser Program, funded by the Advanced Research Projects Agency, has pursued all phases of high-energy, high-power laser development in a strong effort to advance the technology. During this period, approximately 100 contracts covering both experimental and theoretical work have been awarded to many different types of laboratories and organizations. Of these, about 65 contracts are currently active. To keep such a large contractual program in balance requires a high degree of administrative skill and organizational ability. Much of the success of this work is due to the fact that Mr. Isakson, head of the ONR Physics Branch, has these abilities and has been able to coordinate and direct effectively the work of many scientists.

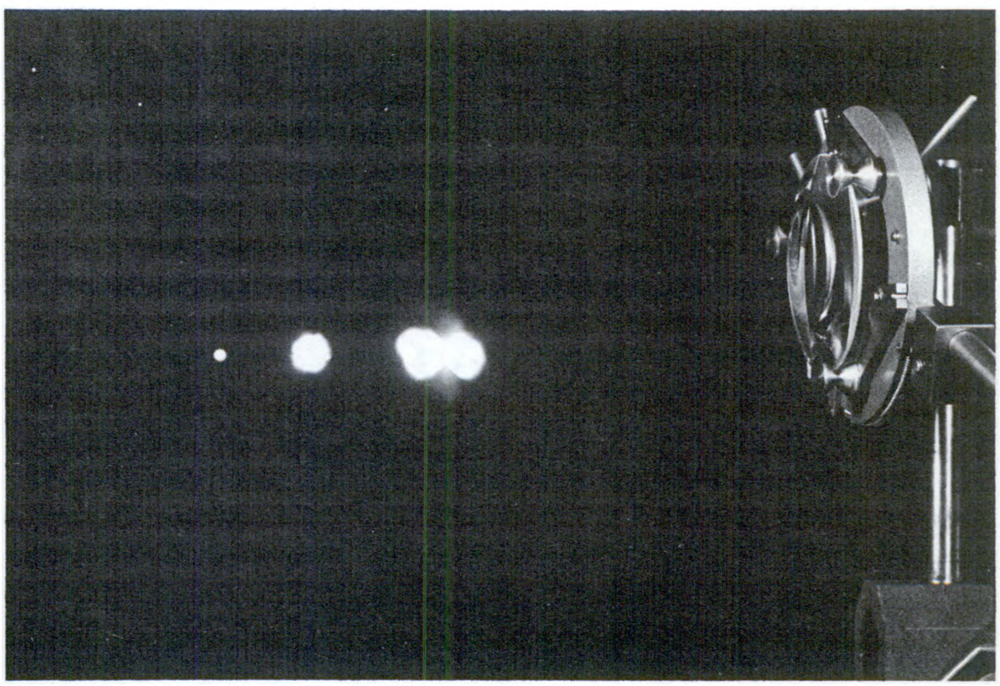
Contracts are not the only way to advance science and technology. An inexpensive but effective way of spreading and increasing knowledge is to bring scientists and engineers together periodically to exchange information and to stimulate each other by their discussions. The effectiveness is increased when the lectures given at the conferences are published, so that other scientists may also benefit. ONR sponsored four international conferences on masers and lasers. They were organized by Dr. Irving Rowe with the joint support of Mr. Isakson of the Physics Branch and Dr. Shostak of the Electronics Branch. The first was held in 1959 in Bloomingburg, New York, with 160 persons attending; the second convened in 1961 in Berkeley, California, with about 300 scientists attending; and the third was held in 1963 in Paris, France, with 1200 persons on hand. The ever increasing number of attendees reflects the growing importance of the subject. A fourth international conference, restricted to the basic physics of quantum electronics, was held in San Juan in June 1965. In his book "Introduction to Laser Physics," Dr. Bela Lengyel writes, "The most notable conference reports are those of the three international conferences on quantum electronics. The papers presented at these conferences were of high quality; the texts were edited after the conference and represent an exceptionally fine collection of review articles and original scientific contributions." Had he written his comments a little later, Dr. Lengyel surely would have included the San Juan conference in his praise.

Most recently, an international conference on quantum electronics was held in Phoenix, Arizona, in April 1966. By this time, the careful nurturing which ONR had given to this series of meetings had taken hold, and the subject had become sufficiently mature that full support was no longer needed. This latest conference was, therefore, organized and operated jointly by two scientific societies, the American Institute of Physics and the Institute of Electrical and Electronics Engineers. However, ONR participated in the planning of that conference, and it will continue to participate in future meetings whenever it can be of assistance.

In addition to these general meetings, the ONR laser team sponsored a series of small specialized symposia. Dr. Rowe organized a meeting on "Organic Lasers"; Dr. Weinberg, on "Flash Lamps"; Drs. Behringer and Soules, on "Laser Physics Research"; and Dr. Quelle, on "Raman Lasers." Dr. Byrne gave support to a meeting on "Chemical Lasers," which was organized by Drs. K. Schuler and K. Brueckner. In each case, the papers and discussions were published and distributed to interested scientists.

By means of contracts and conferences, the influence of this program has gone far beyond what the amount of money expended would indicate. The knowledge that ONR has generated through this concentrated interest in lasers has stimulated a great deal of independent research in industry and in university laboratories that is to the greater benefit of everyone in the Nation.

ONR is frequently asked "Of what use is basic research to the Navy?" The work described here is an effective answer. Starting with the support of really "long-hair" abstract research on microwave spectroscopy, for which no practical use could be foreseen, a whole new technology has arisen. Masers and lasers serve the Fleet now, and they will continue to serve it with evergrowing impact. Frequency control, time standards, navigation aids, inertial guidance, radar, delicate machining processing, surgery, helicopter airspeed measurement, aircraft information displays, mapping systems, and satellite communications are only a few of the applications that have been made or are in the process of development. The number of new applications of masers and lasers increases every day. The Navy does, indeed, profit from its small but significant investment in basic research!



10 Million Degrees K

The white blobs in the accompanying photograph may look like the headlights of automobiles streaming along a highway on a dark night, but they are actually highly ionized gases, more than 10,000,000°K in temperature, that were produced by high-powered lasers at the Naval Research Laboratory, which conducts a broad program of plasma-physics research. Part of the laser equipment can be seen at the right.

The Navy Program in Weather Modification

The following article is based in large part on information contained in "Weather Modification and Control," a report prepared for the Senate Committee on Commerce by the Legislative Reference Service, Library of Congress, dated April 27, 1966. The 181-page document is extremely thorough, covering the history, present status, and legal aspects of modification efforts, the apprehensions that arise in contemplation of artificially induced changes in the weather, as well as including descriptions of federal, state, local, commercial, and foreign programs and the cooperation existing among them.

Man's desire to control the weather and climate is not new to our era or country, but certainly it is being expressed more optimistically today than it has been at any time in the past—in spite of the fact that the efforts aimed at meeting that desire constitute a small area of science and technology in terms of Federal support. That the effort is not larger is surprising in view of the manifest needs and benefits—social, economic, and military—that are associated with the subject. Truly, a very large effort must be made if substantial progress in weather modification is to be realized—one corresponding in magnitude to that of the subject itself, which is large, as the following excerpt from a recent report of the National Academy of Sciences reveals:*

> *"The subject...is concerned with any artificially produced changes in the composition, behavior, or dynamics of the atmosphere. Such changes may or may not be predictable, their production may be deliberate or inadvertent, they may be transient or permanent, and they may be manifested on any scale from the microclimate of plants to the macrodynamics of the world wide atmospheric circulation."*

Weather and climate modification thus includes the intentional increase or reduction of precipitation in specific areas, the modification of hailstorms and lightning, the modification or control of hurricanes and tornadoes, changes in fog or cloud formations, or the redistribution of climates, as well as the effects of civilization on these and other phenomena, including the consequences of air pollution from the burning of fossil fuels or the ultimate proliferation of rocket launches. It is, therefore, as diverse as the characteristics of the atmosphere itself, and its effects can be as widespread as the biological species that can be helped or harmed by it.

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*"Weather and Climate Modification—Problems and Prospects," Vol. 1, Summary and Recommendations, National Academy of Sciences—National Research Council, Publication No. 1350, Washington, D.C., 1966.

In view of the monumental benefits to be derived from the solution of problems associated with weather and climate control, and in view also of the relatively small effort being made to solve these problems, the Committee on Commerce of the United States Senate conducted a study recently of the current status of the Federal commitment to the subject in order to guide future legislation concerning it. In the committee's report, published last April, the programs of the eight Federal organizations which are now engaged in weather-modification attempts are detailed. According to the report, these organizations and the amounts of money they spent during fiscal year 1966 are the Departments of Agriculture ($0.14 million), Commerce ($0.65 million), Army ($0.25 million), Navy ($0.91 million), Air Force ($0.26 million), Interior ($2.98 million), National Aeronautics and Space Administration ($69 thousand), and the National Science Foundation ($2.0 million). In all, a little less than $8 million was devoted to weather-modification programs.

Atmospheric Control Experimentation

In order to meet specific Navy weather-modification objectives while at the same time contributing to the broader national program, the Office of Naval Research has cooperated over the past decade with various Naval laboratories and Government agencies in a program called "ACE," for Atmospheric Control Experimentation.

A portion of the Navy funds is used in Project Stormfury, an experiment conducted jointly with the Environmental Science Services Administration (ESSA) for seeding hurricanes and giant trade-wind cumulus clouds, which form parts of the eye wall of hurricanes. These storms are of concern to the Navy because they disrupt its operations at sea, threaten its installations and personnel on shore, and bring damage and death to civilian property and populations.

A second part of the program is devoted to the problems associated with the dispersal of warm fog and stratus clouds, which are distributed widely over ocean maritime regions. Warm fog hampers every conceivable Naval operation, including the detection and surveillance of surface and subsurface operations.

The remaining portion of the program is directed to achieving understanding of the convective processes that lead to the formation of trade-wind cumulus clouds at sea. Emphasis has been placed on this subject because these clouds are involved in one way or another in virtually every adverse weather situation that confronts the Navy in tropical and subtropical waters. Trade-wind cumulus clouds present a special problem in that the convective processes that lead to their formation occur without the influence of strong surface heating, which contributes to those processes over land.

These problems are of such direct concern to Naval operations at sea that, while it is recognized that civilian agencies might eventually solve them, the Navy feels obliged to press for solutions forthwith.

In carrying out the ACE program, the Navy relies upon both contract and in-house research. Its investigations, which are designed to solve weather problems either directly or by stimulating and supplementing the research of civilian workers, are described in the following paragraphs.

Warm Fog

• *Dissipation of Warm Fog.* Essential to any efforts that are made in the future to dissipate warm fog is a better knowledge of fog physics. Two ONR contracts are devoted to obtaining information in this area. One contract, with E. Bollay Associates, Goleta, California, is aimed at measuring the growth rates of fog particles before they become a restriction on visibility. The range within which fog particles reach a critical size for continued existence is 0.1 to 1.5 microns. The second contract, with Litton Systems, Minneapolis, Minnesota, seeks to establish a relationship between the small ion density and the light extinction in the visible region of the spectrum. The relationship, which can be derived theoretically, depends on the fact that both the light scattering and the ion density depend on the number density of light scatterers.

• *Chemistry of Fog Particles.* Under contract with the Naval Weather Research Facility, Norfolk, Virginia, Dr. A. Goetz of the Atmospheric Research Group, Altadena, California, is studying the coatings which occur on water droplets in some fogs along the West Coast. Interest in the coatings arises from the fact that the fogs in which they occur persist even after the relative humidity has dropped to a low enough value for a sufficient length of time to allow ordinary fog to evaporate. The coatings are believed to be responsible for this phenomenon. The study will be carried out by collecting fog droplets and identifying or characterizing the coatings.

Cloud Formation and Rainfall

• *Origin of Trade-Wind Cumulus Clouds.* Dr. Alfred Woodcock of the University of Hawaii, under contract with ONR, is attempting to grow a trade-wind cumulus cloud from clear air under appropriate conditions of humidity and temperature. This experiment is being carried out by dispensing, from aircraft, sodium chloride or concentrated sea-water drops in trade-wind areas. The study is being pursued because it is not as yet clear how a trade-wind cumulus cloud is born. If one examines the temperature lapse-rates below the cloud base, they are found to be too stable to permit initiation and growth of the cloud. What is needed then is some mechanism by which a parcel of air can gain enough additional heat to acquire sufficient buoyancy to rise above the altitudes at which the stable lapse-rates exist. Dr. Woodcock and Claes Rooth, of the Woods Hole Oceanographic Institution, have demonstrated in quantitative terms that for the concentration of sea-salt nuclei frequently existing above the sea surface (10-25 mg/kg of air), the temperature of an air parcel in relative humidities of 75 percent or so can be raised by from 0.1° to 0.4°C. In many cases, this increase in heat should be enough to permit air convection and cloud growth to start.

• *Mechanism of Nucleation.* It may seem strange that, at this late date in the history of weather research, the nucleation process, which is essential to cloud formation and, hence, to weather modification, is not better understood. Because of this fact, Dr. Thomas Hoffer of the Desert Research Institute, University of Nevada, under contract with ONR, is studying the extent to which freezing water droplets serve as an agent in heterogeneous nucleation during cloud formation. The experiments are being conducted in a small vertical wind tunnel containing electrodes, by means of which the potential gradient can be varied.

• *Statistical Analysis of Hail Suppression Experiments.* ONR is supporting Professors Jerzey Neyman and Elizabeth Scott, of the University of California, Berkeley, in a statistical analysis of hail-suppression experiments that were conducted for a seven-year period, 1957-1963, in Switzerland. The hypothesis on which the experiments, called "Grossversuch III," were based is that silver iodide can act as freezing nuclei for cloud seeding below a temperature of about −5°C. To test the hypothesis, silver-iodide seedings were made in carefully randomized experiments under a variety of weather conditions. The Swiss data also contain information on rainfall, even though the objective of the experiments was hail suppression. It is the purpose of Profs. Neyman and Scott to determine under what conditions the seedings may have produced an increase or decrease in rainfall.

• *Dynamics of a Convective Cloud.* A study of convective clouds is being conducted under contract with the Naval Research Laboratory by F. W. Murray, of the Rand Corporation, Santa Monica, California. It concerns the creation of a mathematical model of the dynamics of such clouds so that a comparison can be made between the theoretically predicted values of cloud variables and measurements of these variables made in natural clouds by NRL.

Cloud Physics

• *Basic Research in Cloud Physics.* At the Naval Research Laboratory, basic research in cloud physics has been in progress for many years. This work includes theoretical, laboratory, and field experiments and extensive aircraft-centered investigations. Scientists involved in the program are Dr. J. E. Dinger, Mr. R. E. Ruskin, and Dr. S. Twomey.

One objective is to achieve an understanding of natural cloud and atmospheric processes and from this understanding to search out those processes which may be artificially modified. This approach involves measuring the composition, size, and other characteristics of the nuclei, which serve as condensation centers in fogs and clouds; and determining the variability of the nuclei with different air masses, the relationship of this variability to the concentration of water droplets in fogs and clouds, and, in turn, the effects of this concentration on cloud behavior. Through this work it may be possible to find out if characteristics of the nuclei can be appreciably altered by artificial means and, thereby, how cloud and fog behavior can be modified. Other studies concern the mechanics of cloud-droplet coalescence, precipitation development, and the nature of the mixing of the air surrounding a cloud into that part of the cloud in which convection is occurring. One of the ways the mixing process is being studied is by the application of tracer techniques in and around the cloud.

A second objective is to develop new and improved instruments and measurement techniques that are needed to understand natural processes and to be prepared to determine to what degree artificial modification is achieved in future weather-modification experiments. Instruments have been developed for use aboard aircraft to measure cloud-droplet and ice-particle size and number and to measure the liquid-water content of clouds. Instruments are being designed also to be carried aboard aircraft or on the ground to measure the numbers of cloud or fog nuclei.

A third objective is to use the improved instrumentation to conduct experiments in clouds and their environment from aircraft. These experiments are designed to answer specific questions dealing with the interrelation of many cloud variables, such as cloud nuclei concentration in the environment, droplet size and concentration in the cloud, liquid-water and ice budget in various parts of the cloud, mixing of the cloud and its environment, evolution of coalescence, and the development of precipitation.

Project Stormfury

• *Modification of Hurricanes and Giant Trade-Wind Cumulus Clouds.* Of considerable popular as well as scientific interest is Project Stormfury, the objective of which is to determine if the force of hurricane winds can be reduced. The project grew out of the discovery, made at the Naval Ordnance Test Station, China Lake, California, of a practical method for making silver iodide from silver iodate. Dr. Pierre St. Amand and other NOTS scientists recognized immediately the possible application of this product to the modification of hurricanes and giant trade-wind cumulus clouds. In 1961, therefore, the Navy seeded Hurricane Esther; and in 1963, Hurricane Beulah. Seeding was accomplished by flying a Navy aircraft into the hurricane and dispensing silver iodide into the eye wall of the storm by means of special dispenser units, first designated "Cyclops" and later, "Alecto" (see *Naval Research Reviews,* December 1963).

The assumption behind this procedure is that the silver iodide will release the latent heat of fusion in the supercooled moisture in the eye wall, which is also the location of the maximum pressure gradient; as a consequence, the pressure gradient, and hence the wind force, of the storm will be weakened. The results of both experiments were the same: On the day after each seeding, an opening and widening of the eye wall and a reduction of wind velocity were observed.

In 1963, in addition to seeding Beulah, NOTS seeded several giant trade-wind cumulus clouds in the eastern Caribbean. These clouds, which become the components of the eye wall of hurricanes, occur in much smaller numbers and under conditions of greater atmospheric stability than do the average trade-wind cumulii. They also reach exceptional heights (the top of one was measured at 62,000 feet). The results of each of these experiments were the same: After seeding, rainfall occurred.

Relatively few seeding experiments have been conducted because of the extreme care that must be taken to avoid storms that may come ashore and affect inhabited areas. Another difficulty—the evaluation of the results of the experiments—arises because of the improbability that two similar storms will occur during a single season; thus little likelihood exists that the effects of seeding can be compared with the effects of not seeding. Furthermore, conditions fluctuate so widely in a given storm that one cannot be certain that the effects observed would not have occurred naturally. Nevertheless, the results of the experiments are considered to be promising; therefore, further seedings have been planned for 1967.

Hurricane Economics

• *Climate Modification and Economics.* Although it is clear that mankind does not yet have significant capability to modify weather or climate, continued research throughout the world may lead to such a capability. Its full exercise is certain to be contested, however, particularly with respect to the ways in which it affects populated land areas. Any number of conflicts could arise whenever one group stands to benefit from weather modification and another to lose. Because the Navy operates primarily over uninhabited ocean areas, about which potential human conflicts are not as likely to arise, it may prove to be the only potential user of some of the more successful weather-modification techniques during peacetime.

In anticipation of conflicts that might arise concerning the Navy's hurricane seedings, ONR recently provided for a university research study in hurricane economics. The study, conducted at Colorado State University, is applying historical weather data to establish a relationship between crop yields and rainfall for subareas of the hurricane belt. These data, many of which have already been compiled, may provide a basis for predicting the economic consequences of storms as well as for making decisions regarding storm control. In addition, the study will include analyses of the value of storm rainfall runoff to municipalities, in carrying off pollution, to the generation of electricity, and to navigation. The purpose of the program is to determine if differential net benefits exist among alternative modification programs, so that those yielding the highest net benefit might be identified, or whether climate modification in ocean areas would be damaging *per se* to agricultural and other commercial interests.

Will artificially induced changes in the weather cause crop damage? Will they lead to increases or decreases in the Nation's water supplies and, coincidentally, in agricultural production? Will they please resort owners and their guests by bringing more snow to the ski slopes and more sunshine to the beaches? These questions and many similar ones are the concerns primarily of the civilian agencies involved in weather-modification programs. The Navy, on the other hand, is concerned primarily with the weather at sea, in areas remote from human habitation, particularly warm fog and the various manifestations of trade-wide cumulus clouds. To successfully fulfill its obligations at sea, therefore, the Navy will continue to seek solutions to weather-modification problems, as it does to all other problems affecting Fleet operations.

A Conference on Symmetry Principles at High Energy will be held at the University of Miami, Coral Gables, Florida during the period January 25-27. The conference is being co-sponsored by the ONR Nuclear Physics Branch. Additional information may be obtained from Dr. Behram Kursonoglu, Chairman, University of Miami.

An International Symposium on Atomic, Molecular and Solid State Theory will be held at the Nuclear Sciences Building, University of Florida, Gainesville, Florida (Sanibel Island) during the period January 16-21. The symposium is being co-sponsored by the ONR Physics Branch. Additional information may be obtained from Dr. Darwin W. Smith, Chairman, Nuclear Sciences Building, University of Florida.

A Symposium on Circuit Design by Computer will be held at the New York University, University Heights, Bronx, New York during the period January 30-February 1. The symposium is being co-sponsored by the Office of Naval Research. Additional information may be obtained from Captain D. D. Kilpatrick, USN, ONR Air Programs Branch; Dr. W. W. Happ, NASA, Cambridge; or Dr. Elias Schutzman, New York University.

U.S. Naval Medical Research Abroad

That the U.S. Navy should have an interest in studying diseases common to parts of the world far from our own shores is not at all surprising when one considers that it has a long record of service in foreign lands and that the record probably will be extended indefinitely into the future. Because of this fact, the Bureau of Medicine and Surgery has sponsored research in the Near and Far East for more than two decades through contingents called "Naval Medical Research Units," abbreviated "NAMRUs." Two of these units are now in operation, one at Taiwan, Formosa, and one at Cairo, Egypt. Two other NAMRUs are located in the United States, one at Berkeley, California (concerned with airborne biological agents), and the other at Great Lakes, Illinois (concerned with the health of Naval recruits, particularly as affected by contagious diseases.)

The overseas units are engaged in medical research designed primarily to detect and provide remedies for major diseases confronting our military men. In many instances, this research leads to the solution of local health problems and to the control of country-wide epidemics. The two units are an outgrowth of World War II investigations which indicated that malaria, parasitic, and other tropical and sub-tropical diseases of the China-Burma-India and Southwest Pacific theaters of operation depleted the ranks of the allied forces almost as severely as did enemy firepower.

In the Far East

NAMRU-2, the first of the overseas research units to be established, came into existence originally in 1942 at the Rockefeller Institute in New York. After the recapture of Guam in 1944, the unit was moved to that island to study diseases of the Central Pacific. A year later, it was inactivated, and it remained inactive for ten years, after which, in 1955, it was reestablished at Taipei, Formosa. The primary interest of this unit, which now consists of more than 300 medical, scientific, and support personnel, is the study of diseases native to regions of the Far East, including those that reach epidemic proportions. From the Taipei laboratory, teams of scientists have traveled to Nepal, East Pakistan, Okinawa, Korea, the Phillipine Islands, Thailand, Viet Nam, North Borneo, and other places to study many bacterial, viral, and parasitic diseases, including cholera, trachoma, and Japanese encephalitis.

As a result of NAMRU-2's investigations, the mortality rate of cholera, which as late as 1947 was 60 percent in untreated patients, has been reduced to less than one percent in uncomplicated cases and between

Chinese laboratory technician innoculating eggs to culture the trachoma virus—Trachoma Vaccine Study. Virology Department, NAMRU-2, Taipei.

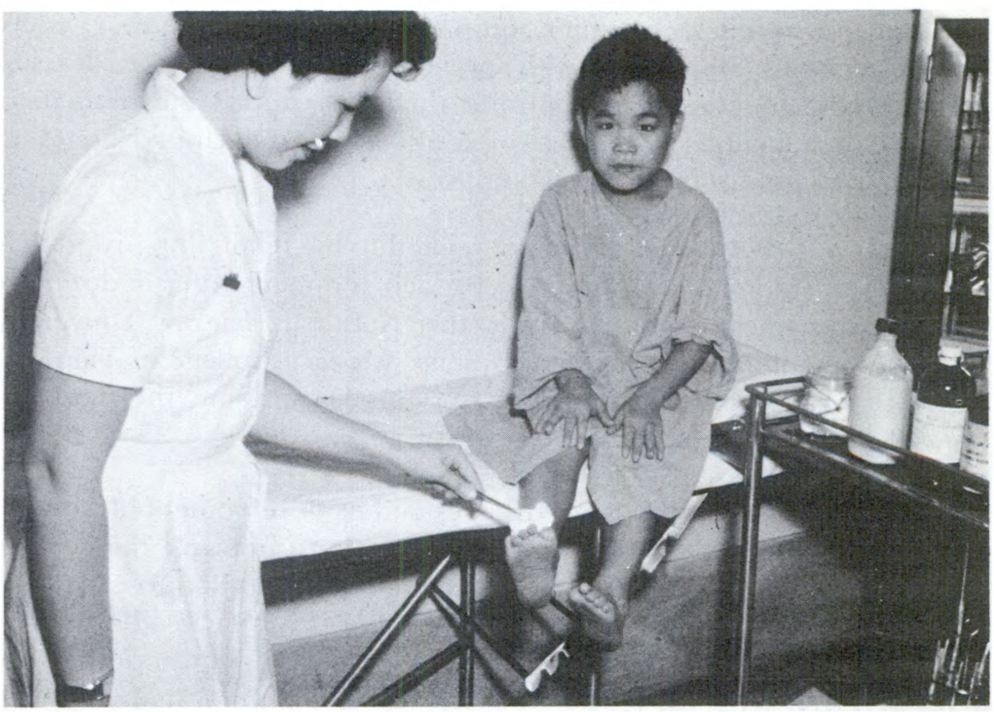
two and three percent in cases complicated by heart disease, tuberculosis, and other afflictions. The development of a field treatment for cholera that requires only the simplest of equipment is one of the most significant achievements of the unit. Work on the therapy of cholera was begun in 1957 at Dacca, Pakistan. During the 1958 outbreak in Thailand, the unit's staff, which was augmented by scientists from Walter Reed Army Institute of Research and the National Institutes of Health, made a thorough study of the disease that resulted in the casting aside of old concepts concerning the effects of the offending organism on the intestinal wall. Analyses of the blood of patients showed that acute dehydration and loss of electrolytes had occurred, and therefore, that the death rate could be reduced to a minimum by the rapid replacements of fluids and electrolytes. By application of the copper-sulphate technique for determining the specific gravity of blood plasma, it was possible to prescribe the amount of fluid needed to maintain the correct balance. Although the team could not treat all of the patients involved, it demonstrated its new techniques to local physicians, convincing them of the soundness of the treatment and of the wisdom of its immediate adoption. The method of treatment and the promptness with which it was given probably were the principal reasons for the remarkable reduction which occurred in deaths caused by cholera.

Trachoma, a progressive infection of the eye tissues and a major cause of blindness, is brought on by an unusually complex virus that was not isolated until 1957. Because of the high incidence of trachoma in Southeast Asia, NAMRU-2 was afforded an excellent opportunity to study the disease. In 1958, it commenced a long-term investigation of problems associated with effecting immunity to trachoma. The unit enlisted the services of blind patients who had anatomically normal corneas to receive inoculum of the virus in their eyes, enabling scientists to isolate the organism that caused the disease, study its characteristics, and produce antibodies, which were used later to protect human volunteers in field trials. A significant degree of protection has been demonstrated, and even more promising results are expected. In addition, the work is serving as a stimulus to trachoma researchers throughout the world.

Other fields of study and associated activities of NAMRU-2 are outlined in the following paragraphs:

- *Parasitology.* Paragonimieasis (caused by a worm that invades the lungs), schistosomiasis (caused by a worm that matures in the blood vessels and organs of the abdomen), and filariasis (a parasitic worm infection of the blood and intestines) are three of the more dangerous diseases being investigated.

- *Biochemistry.* "Blackfoot" is an unusual local disease which appears as a dry gangrene of the extremities. The cause has not yet been



Young Chinese receiving treatment for Blackfoot Disease in the NAMRU-2 treatment room. This young patient is under study and is a full time patient on the clinical ward.

determined, but pathological studies have been made, and promising techniques for treating the disturbance have been developed.

• *Virology and Entomology.* The epidemiology of Japanese encephalitis has been the object of research by both the Navy and Army. Through studies of mosquitoes that were provided by Army entomologists, NAMRU-2's scientists isolated the virus and showed that both birds and animals serve as hosts for the disease-transmitting agents. This work has corroborated and extended the findings of the 406th Army General Hospital, Japan.

• *Research in Viet Nam.* Recently, a detachment of NAMRU-2 was established at the Naval Hospital, Naval Support Activity, Da Nang, Viet Nam, to perform research and development relating to biomedical problems, such as those associated with shock, diarrhea, heat prostration, and immersion foot. Through this detachment, consulting scientists from the United States and other countries will work with the detachment staff to reduce health hazards to which military men are exposed in Viet Nam.

• *Fellowship program.* Probably one of the most consequential of NAMRU-2's activities is its association with scientists throughout the Far East. A close relationship is maintained with biomedical scientists in Taiwan, but research fellows come from all of the Free countries of the Far East to utilize the unit's equipment and participate in a variety of investigations. Many come with special projects of their own, develop their own techniques, and continue the work upon return to their homelands. Qualified scientists come also from the United States to conduct research in the unit's laboratories.

• *Medical students program.* Closely related to the fellowship program is the medical students program, which, each summer, brings a dozen or so senior medical students from the National Taiwan University Medical School and the National Defense Medical College in Taipei to NAMRU's laboratories, where the students learn about the most advanced procedures of medical research.

Through its studies of native diseases and its development of preventive techniques, NAMRU-2 has helped greatly to improve the general health and welfare standards of the region. The excellent cooperation it has received from other U.S. military services has enabled it to send personnel and equipment to stricken areas which might not otherwise have received aid. All of the unit's travel is accomplished *only* with approval of the local governments involved. The fact that NAMRU-2 has experienced little difficulty in obtaining permission to travel in many Far East countries is a tribute to its excellent reputation.

In the Near East and North Africa

NAMRU-3, with its present staff of nearly 200 Americans and United Arab Republic nationals, is situated in Cairo, Egypt. It was set up in 1945 as an outgrowth of the American Typhus Commission, which was established in 1942 primarily to find a means of warding off a typhus epidemic that was expected to occur at the end of World War II. Although the outbreak did not materialize, due in considerable measure to the work of the Commission, the scientists involved in the typhus study felt that their productive collaborative efforts should not be discontinued because of the threats posed by a number of other diseases of the Near East and North Africa. Thus the unit came into being, receiving its title, "NAMRU-3," in 1946 and official Egyptian recognition in 1948.

As at Taipei, the major interests of NAMRU-3 have been infectious and parasitic diseases, although considerable attention is now being given also to the nutritional factors involved. The unit is situated next to the Abbassia Fever Hospital and near other hospitals that treat many cases representing a wide variety of diseases common to the region. Such a cross section of patients similarly afflicted could not be found in the United States, except, perhaps, over a period of time spanning several generations of researchers.

During its more than 20 years of existence, NAMRU-3, through extensive and controlled diagnostic, therapeutic, and follow-up procedures, has effected important scientific inroads to many diseases, including Q-fever, tularemia, sandfly fever, West Nile fever, typhus, Kala Azar, leptospirosis, schistosomiasis, infectious hepatitis, shigellosis, and various forms of salmonellosis, such as typhoid fever. In doing so, it has sent field teams throughout much of the Near East, Africa, and the southern part of Europe to study the role of viruses and arthropods (ticks, lice, fleas, mosquitoes, *etc.*) and their hosts in transmitting infections.

One example of this work is the study begun in 1959, at the request of the Ministry of Health of the Sudan, on Kala Azar (leishmaniasis), a disease that causes massive enlargement of the liver, wasting of the body, and death. At times, this dread affliction has increased to epidemic proportions and taken hundreds of lives. Also, because of its implications, the government has been reluctant to develop the area in which it occurs. As very little was known about the epidemiology of Kala Azar in the Sudan, a large effort was required to determine how, when, where, and why the infections occurred and to recommend control measures. By early 1961, therefore, a sizeable array of delicate scientific equipment, hundreds of experimental animals, generators, vehicles, safari gear, and highly experienced specialized personnel had been moved to a field laboratory, set up by NAMRU-3, in the Sudan, far from scientific supply sources.

The results of this study have been impressive, not only because of their volume and scope, but because of the rapidity with which they were achieved. After a species of man-biting sandfly was identified as the transmitter, studies were made of the fly's breeding habits, flight range, feeding behavior, host preferences, and ecological peculiarities. An expert on sandflies and specialists in tropical medicine, parasitology, and disease transmission came from Australia, California, and Panama to contribute their knowledge to the investigation. Along with medical scientists from the Department of Agriculture and NAMRU-3, this team collaborated to publish more than 25 scientific papers dealing with various aspects of the work. Now, only a few years after the study was initiated, a report is being prepared outlining effective measures that can be taken to prevent and control Kala Azar.

Another example of NAMRU-3's operations is its effort to conquer schistosomiasis, a parasitic infestation of the bladder and lower intestinal tract that ranks second to malaria among the death-dealing diseases of the world. It has existed in the Nile Valley since the time of the Pharaohs and now occurs in tropical regions around the world, affecting not only the local inhabitants, but transients, such as foreign troops; in these areas, for example, many British soldiers have contracted schistosomiasis bladder infections that did not reach serious stages until several years after their return home. The offending parasite spends part of its life cycle in certain snails that live in canals and other waterways. The developing schistosome leaves the snail and swims in the canal water, awaiting the wading human, through whose skin it gains entrance to the body.

Researchers at NAMRU-3, elsewhere in Egypt, and in other parts of the world where schistosomiasis is of major medical concern have devoted and still are devoting a great amount of time and effort to break the chain of transmission of this disease. NAMRU-3 has contributed heavily through its field studies of environmental conditions affecting schistosome control in Egyptian canals, of schistosome transmission, through its discovery of natural schistosome infections in Egyptian mammals, through a survey of the prevalence in Egypt of other members of the same family as the offending schistosomes which might be made to compete with those organisms, and through its development of new laboratory techniques designed to facilitate research on the disease.

In testimony to these accomplishments, the Imperial Government of Ethiopia invited NAMRU-3 to establish a field research facility at Addis Ababa and a substation in southwestern Ethiopia at Gambela. The Addis Ababa facility now occupies laboratory space in the Imperial Central Laboratory and Research Institute, where its principal areas of research are the arbo-viruses, malaria, relapsing fever, schistosomiasis, onchocerciasis, typhus, filarial diseases, and supportive epidemiological and entomological studies. Such diverse programming adds greater depth to the field-research potential of NAMRU-3.

Like NAMRU-2, the Cairo unit also encourages close association with foreign students and members of the medical profession. The unit constantly plays host to outstanding medical scientists of Egypt and other nations and seeks collaboration with them in medical research projects.

It is said that "he who drinks of the Nile shall surely return to drink again." NAMRU-2 and NAMRU-3 are dedicated to the fulfillment of promises of this kind, which are now too often forestalled by diseases common to the Near and Far East.

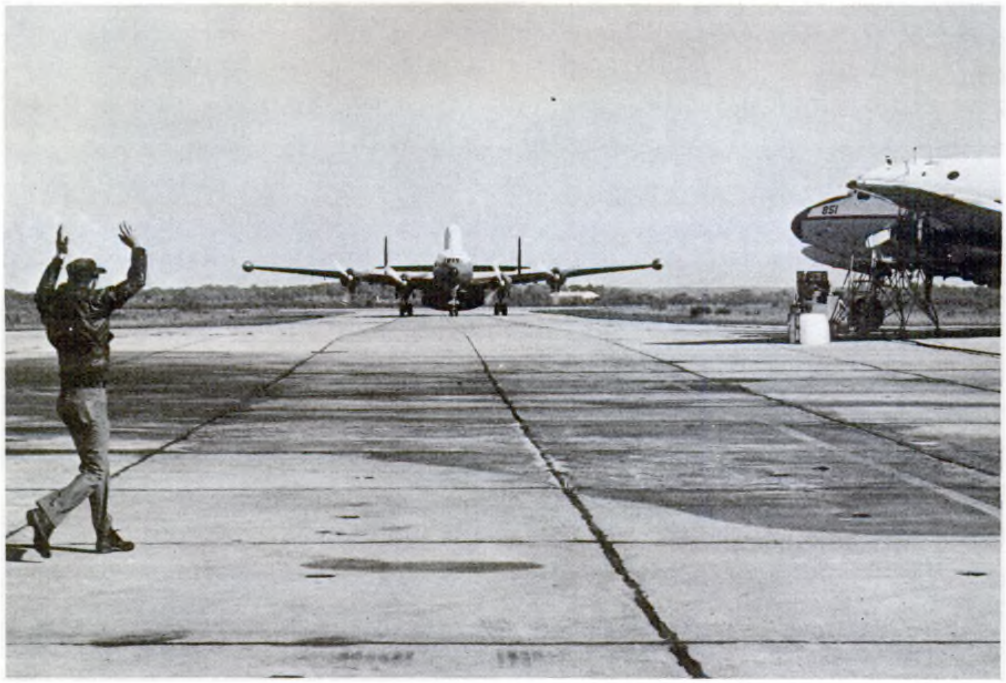
Marvin Lasky Wins DCS Award

The Navy Distinguished Civilian Service Award, the highest tribute the Navy can pay a civilian, has been awarded to Mr. Marvin Lasky, currently Director of Acoustics Programs for the Office of Naval Research. Mr. Lasky, who has worked in the field of acoustics research since 1946, has been with ONR since 1957 and prior to that was employed by the Navy's David Taylor Model Basin.

This is the latest in a series of awards received by Mr. Lasky for his direction of research and development projects in the field of acoustics. In September 1952, he received a Superior Accomplishment Award for his work in the area of reducing hydrodynamic noise in submarine sonar and for development of underwater television equipment. In 1962, he received the Navy Meritorious Civilian Service Award for his conception and development of the Atlantic Underseas Test and Evaluation Center (AUTEC). He was also cited for his contribution to a breakthrough in the problem of ship self-noise as it affects listening by means of hull-mounted hydrophones and for his development of a sound and structure program to study the problems of sound radiation from underwater objects.

Mr. Lasky has also received special awards for his inventions. The most significant of these was an award for $1500 received in 1965 for his invention of the Sonar Dome Unit.

At the DCS award ceremony a high Navy official representing Secretary of the Navy Paul H. Nitze, who signed the award, stated: "Mr. Lasky has played a major role in directing significant underwater acoustics programs that have led and will continue to lead to radically new and greatly advanced major operations systems. Through his perceptive vision of the technical advances needed by the Navy, his consistently high application of newly discovered scientific principles has produced advances that have enabled the United States to build and operate the most modern submarine fleet in the the World."



NRL's Super Constellation returns to Patuxent River Naval Air Station, Maryland, after completing a 22,000-mile round-trip to Australia to gather data on atmospheric physics.

U.S. and Australian Scientists Cooperate in Cloud-Physics Study

Atmospheric physicists of the Naval Research Laboratory recently conducted a cooperative study of cloud formation and associated phenomena with the world renowned cloud-physics group at the Commonwealth Scientific and Industrial Research Organization (CSIRO), Sydney, Australia. As the two groups have developed different methods to make similar determinations and as each group has also developed specialized instruments not available to the other, the joint undertaking enabled the scientists to compare their data-gathering techniques as well as to supplement each other's findings.

In addition to working with the Australians, the NRL group, which is part of the Ocean Sciences and Engineering Division of the Laboratory, obtained data on the geographical distribution of cloud condensation nuclei, which are responsible for cloud formation, and on the electrical field and conductivity of the atmosphere over a wide area. In general, there are tens of thousands of particles per cubic centimeter of atmosphere, but only a small fraction of them have the necessary properties to serve as condensation nuclei. When measurements of these nuclei are combined with information on the source, composition, and role of the nuclei in cloud formation, a better basis exists for predicting and modifying the weather. The atmospheric electricity measurements should provide a better understanding of the diurnal cycle of the atmospheric electric field, especially how its variations with longitude are related to weather.

As a platform for making these studies, NRL utilized a modified Lockheed Super Constellation specially equipped with scientific instruments.

NRL's interests in atmospheric physics are outlined in "The Navy Program in Weather Modification," which appears elsewhere in this issue.

On The Naval Research Reserve

NRRC 3-14 Wins National Competition

This year's winner of the Research Reserve Award for General Excellence—Naval Reserve Research Company 3-14, Poughkeepsie, New York—was announced by RADM J. K. Leydon, USN, Chief of Naval Research, on October 27, 1966.

Nominations for the award, which is given to the most outstanding Research Reserve company, were submitted by Commandants of the Naval Districts. CDR William W. Lang, USNR, was in command of NRRC 3-14 during fiscal year 1966, and he is still in command of that company. Presentation of the award is planned for early 1967.

Among the accomplishments of the 15-member Research Reserve company for fiscal year 1966 were the following:

Inspection grade	*3.83 percent*
Ready Reserve status	*100 percent*
Drill attendance	*84.8 percent*
ACDUTRA participation	*73.3 percent*
Correspondence course completion or current in promotion points	*86.7 percent*
Satisfactory federal years earned	*86.7 percent*
Training grade	*3.88 percent*

A panel established to review the records, inspection marks, and other criteria on which the award is based and to recommend the winning company was composed of the following officers: CAPT L. B. Melson, USN, Assistant Chief for Research, Office of Naval Research; CAPT R. J. Stankowski, USNR, Assistant for Training and Mobilization, Office of the Assistant Chief of Naval Operations (Naval Reserve); and CAPT J. E. Kennedy, USNR, Head, Specialist Programs Branch, Bureau of Naval Personnel.

Members of the panel which convened to designate the winner of the Award for General Excellence commented very favorably on the records of the other companies entered in the competition. These companies and their commanding officers for fiscal year 1966 are as follows:

NRRC 1-2	Providence, Rhode Island	LCDR Earle N. Trickey, USNR
NRRC 4-4	State College, Pennsylvania	LCDR James C. Dean, USNR
NRRC 5-9	NRL, Washington, D.C.	LCDR George Abraham, USNR
NRRC 6-3	Oak Ridge, Tennessee	CDR Peter P. Holz, USNR
NRRC 8-5	Austin, Texas	LT George F. Sears, USNR

NRRC 9-19	Iowa City, Iowa	LT James H. Cavanaugh, USNR
NRRC 11-8	Point Mugu, California	CAPT M. Hudson Fields, USNR
NRRC 12-5	Berkeley, California	CAPT Richard W. Smith, USNR
NRRC 13-5	Corvallis, Oregon	LCDR Lafayette C. Harter, Jr., USNR

Admiral Leydon Addresses Washington Research Companies

On September 15, 1966, RADM John K. Leydon, USN, Chief of Naval Research, met with more than 300 Reserve officers to discuss Naval research goals. The occasion was a joint meeting of the three Washington Naval Reserve Research Companies (5-8, 5-9, and 5-10). His talk, which covered research and development philosophy, including management problems, overseas programs, and Navy laboratories, generated a lively and informative discussion period. Also present were members of NRRC 5-11 and 5-12 from Annapolis, Maryland, and Dahlgren, Virginia, as well as members from Politico-Military Affairs Company 5-1, Washington, D.C.

Shown at the joint meeting of Washington Reserve Research Companies are, from left to right, CDR Fred Durant, Commanding Officer, Politico-Military Affairs Company 5-1; CDR Julian Nall, Executive Officer, NRRC 5-8; CAPT D. J. Marker, Special Assistant to Admiral Leydon for Research Reserve; CAPT James R. Patton, Jr., Senior Staff Advisor, NRRC 5-8; RADM Leydon; CAPT M. E. Carroll, Group Commander's Staff; CDR Maynard Eicher, Commanding Officer, NRRC 5-10; and CAPT David L. Spaulding, Area Commanding Officer, U.S. Naval and Marine Corps Reserve Training Center.

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*Articles are arranged under the ONR division or Navy laboratory having cognizance of the research described.

†Written by the editorial staff of *Naval Research Reviews* or adapted from anonymous sources.

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Deep-Sea Search for a Lost H-Bomb, June†

Ocean Science and Technology

AGOR-14 and -15: First of a New Generation of Research Ships, November†

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The Department of Oceanography of Texas A&M University, by Willis E. Pequegnat, June

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The Woods Hole Oceanographic Institution, by Daniel C. Goodman, Jr., May

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AUTHOR INDEX, 1966

An Acoustic Navigation System for Submersibles

Through a chance observation, two Naval Research Laboratory scientists have devised a method that will permit a deep-submergence vehicle to determine its location in relation to a known deeply submerged acoustic source. The method, which was conceived by J. J. Gennari and F. W. Heemstra of NRL, may permit the development of a system that will enable submersibles to navigate in the deep ocean. A number of acoustic sources distributed on the ocean bottom could form the system.

The key to the method is the time difference between the direct reception of a signal emitted by the source and the reception of the same signal reflected from the ocean surface. When both the depth of the transmitter and receiver are known for two separate measurements at the same location, sufficient information is obtained for formulating a mathematical equation, the solution of which gives the range from the transmitter to the receiver.

Mr. Gennari and Mr. Heemstra happened on the key to the method last year while performing acoustic output measurements near Bermuda. Although the two scientists anticipated the reception of one signal pulse per minute from a deeply submerged projector, they found that they were getting two per minute. They determined that the second pulse occurred as a result of the reflection of the signal from the ocean surface rather than from the ocean bottom, which led them to the discovery of the usefulness of the phenomenon.

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Editor: RICHARD D. OLSON

NAVSO P-510

The technicians shown on the cover are pouring a sample of glass, one of the materials being developed for laser research. Over three hundred laser glass compositions have thus far been studied in this program. ONR's role in the development of the laser is discussed in the article beginning on page 1.