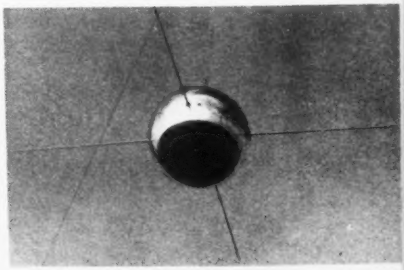
OFFICE OF NAVAL RESEARCH AUGUST 1958

RESEARCH REVIEWS



NRL'S 35TH YEAR

DEPARTMENT OF THE NAVY

WASHINGTON, D. C.

NAVEXOS P-510

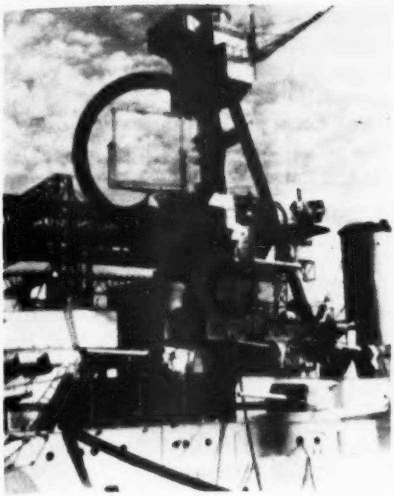
In 1923

NRL's 35th Anniversary

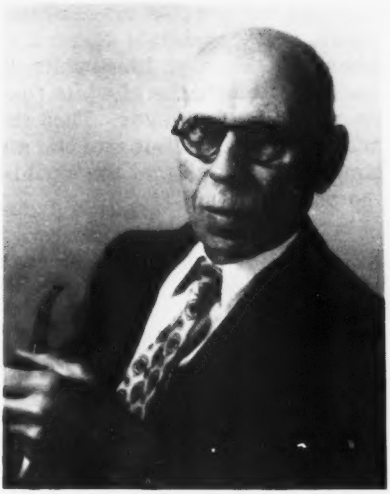
On July 2, 1923, the Naval Experimental and Research Laboratory was established in Washington, D. C., to conduct scientific research and development in the physical sciences and related fields for the Navy. Work of this kind was needed to lay a foundation for the improvement of materials, equipment, techniques, and systems for the Fleet. That the idea was sound has been proved over and over and with increasing frequency through the years.

This year--the Laboratory's 35th--the important work is still going on. The nature of that work--past and present, of the institution in which it is taking place, and of the people doing it are the subject of this NRL anniversary issue of Research Reviews...

Today



A prototype of the Fleet's first operational radar.



Dr. A. H. Taylor, "Father of Radar."

NRL Looks Back*

A. T. Drury
Head, Periodicals Branch
Naval Research Laboratory

The Battle Force was steaming silently through the low rollers of the Caribbean Sea. NEW YORK was leading, with TEXAS behind and the other battlewagons strung out in column astern. Somewhere out in the night, beyond the gray circle of the horizon, a destroyer squadron had probably already started the approach run of a mock torpedo attack.

Above NEW YORK's blacked-out bridge, a strange aluminum-and-wire frame, looking for all the world like a huge upended bedspring, was slowly revolving in the darkness. A few feet aft, in a closely guarded corner of Air Plot, a small group of men were gazing intently into the greenish glow of a small fluorescent screen.

"There's one of them!" said Page suddenly, pointing to a slightly higher hump in the jagged green line wavering across the screen. "About eight miles, I'd say."

As they watched, a second pip, and a third, were identified on the magic screen. "He's getting cagey," remarked the Admiral. "He has apparently divided his cans into three groups."

"Yes Sir," answered the Captain, "And he thought he'd fool us by sending the third bunch in on the same bearing as the second. We'll let them get within searchlight range and then pick 'em off."

*Adaptation of an article appearing in Research Reviews, July 1953.

At the precise moment the nearest group had approached to 5,000 yards, the searchlight stabbed into the darkness to starboard. Far out, where the cone of blue-white light began to fade, the observers could see a tiny mustache of white foam and above it the narrow silhouette of an oncoming destroyer. Then the light switched off, swung over to port, and again stabbed out into the night. And again ten minutes later. Both times the lead ship of the would-be attackers was caught dead-center in the probing beam.

The date: February 21, 1939; the occasion: Fleet Problem XX and the acceptance trials of American radar; the cast: Vice Admiral A. W. Johnson, commanding the Atlantic Fleet; Captain R. M. Griffin of the TEXAS; and R. M. Page,* R. C. Guthrie† and H. E. Reppert of the Naval Research Laboratory.

It was a dramatic high-point in an outstanding success story, the story of a then little-known scientific institution that had cost the American taxpayers less than the price of a light cruiser in 16 years of research operations for the Navy. If the Naval Research Laboratory had done nothing else except produce radar, it would have justified itself as one of the best investments Congress ever made. But it also, in those same years, gave to the Navy the finest radio-communications afloat, greatly shortened the life-expectancy of enemy submarines, and contributed diverse other improvements and "black boxes" that proved their worth in the great sea battles of World War II. Furthermore, it gave solid vindication to the once-tenuous proposition that academic research can prosper in a military environment.

The proposition, as has oft been told, was Thomas Edison's. It was taken up enthusiastically in 1915 by Secretary of the Navy Josephus Daniels, and Congress passed the enabling act in 1916. But the sands of peace ran out too swiftly, and we were in World War I before an experimental laboratory could be built. The postwar Congress, though economy minded and in a mood for disarmament, had learned that America could not with impunity afford to stay technically behind the other nations of the world. So on July 2, 1923, the Laboratory came into being, as planned by Edison, Daniels, and the Naval Consulting Board. And their blueprint—a research institution headed and administered by Naval officers, but with the scientific work in the hands of civilians—was followed to the letter.

The key to the whole plan, of course, lay in the choice of the original staff—particularly the civilian scientists. The Navy already had three small radio research groups working in Washington, and one in underwater sound at the Engineering Experiment Station in Annapolis. These four groups—about 20 men in all—were moved bodily to the new laboratory. Later in the initial year the staff was filled out to four officers and 92 civilians.

As it turned out it was a remarkable cadre. It included Dr. A. H. Taylor, the Navy's Chief Physicist, who was probably more than any

*Now Director of Research at NRL.
†Now Head of the Radar Division at NRL.

other American responsible for the development of radar, and Dr. Harvey Hayes, for 25 years the Superintendent of the Sound Division. Dr. E. O. Hulburt joined the complement in 1924, later becoming Director of Research. Practically all of the charter members remained through World War II.

Nowadays you can run down the alphabet from A-bomb to Zodiacal light and find at NRL almost every branch of physical science that has been given a label. But in its first two decades nine-tenths of the program was confined to two fields, radio and underwater sound. The limitation was imposed not only by economics but by "consumer demand" and by the research talent available.

Back in the early twenties, the terror of the German U-Boat was still fresh in people's minds. War beneath the sea had become an awesome reality, and the Navy was willing to spend money on any likely device or weapon that would restore the supremacy of the surface ships. Meanwhile, radio was just coming into its own. President Harding had broadcast the dedication of the Lincoln Memorial in 1922, and commercial programs were making their first impact on American life. Furthermore, wireless communication had made itself indispensable to the Fleet in 1917 and 18. Radio and sound research offered foreseeable results; the naval construction bureaus (whose backing provided two-thirds of NRL's operating funds) were willing to support them.

Greater-range, around-the-clock communication, more channels, and stability within channels—these were the goals of the Navy's radiomen. By seeking ever higher frequencies, by adoption of crystal control and continuous waves, they had achieved in 1930 reliable transmission from such remote places as Australia and the South Pole. Thanks largely to the wide-awake research and salesmanship of NRL, Naval communications became the recognized leader in American radio development.

Naturally the Navy's modest laboratory, with only a handful of radio engineers and little money to spend, couldn't do this alone. Radio improvement depends probably more on the development of better tubes, capacitors, resistors, transformers, and similar components, than on intuitive research. These were a mass accomplishment of the radio industry, both in America and abroad. But what Taylor and his associates did do was some highly effective "scientific bird-dogging"—sniffing over new discoveries and pointing the way to new applications. Lacking the wherewithal to make components themselves, they prodded the radio industry into making them.

Along the way, NRL did some impressive radio research on its own—such as the Taylor-Hulburt wave-propagation theory which revolutionized prior thinking on how radio waves travel. And it designed some very ingenious gadgetry, like the guidance circuits for the first successful radio-controlled aircraft, flown by C. B. Mirick in 1923, and for the first target drones in 1938. As for prototype development, many an NRL "breadboard" model was translated into specifications for standard equipment used throughout the fleet—for instance, radio direction-finders.

It was this combination of "bird-dogging" the work of others, and home-base research where necessary, that led NRL to radar.

The task wasn't easy. Pulses of radiant energy are measured in millionths of a second, and they travel out to the target and back at the speed of light. Fortunately, the men of the Navy's laboratory had the know-how, and they had ten years of radio-detection studies behind them (see table). A project was established for the program in 1932. Two years later two operable systems—one continuous-wave, the other pulse—had been worked out, and by 1938 a reliable pulse system had been designed, built, sea-tested, and was ready for submission to the Fleet.

It is always an interesting pastime to speculate on "who done what first." It is particularly interesting in the case of radar, because without any interchange of specific information the development was almost concurrent and parallel in the United States and in England. The wonderful new device was sea-tested in the same year, 1939, aboard the U. S. Navy's NEW YORK and TEXAS and aboard the Royal Navy's RODNEY and NELSON. Our Navy was apparently a year ahead of the British in the original development, but the RAF closed the gap by greater speed in producing an operational prototype. The significant fact is that both Allies had radar when the shooting began, and were able to use it to great strategic and tactical advantage in overcoming the common enemies. Let credit be where credit is due, however; American radar was conceived and born at the Naval Research Laboratory.

Meanwhile sound research at NRL, while attracting less notice, followed much the same path. As a matter of fact, there is a striking similarity between radar and what is called "active" sonar. Substitute

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TIME TABLE OF RADIO-DETECTION AT NRL

1922 – A ship was detected passing through a high-frequency radio field (by Tanner and Young, later to join NRL).

1925 – NRL built the pulse transmitter and receiver used by the Carnegie Institution to measure the height of the ionosphere.

1930 – Airplane in flight detected by continuous-wave (CW) radio.

1932 – Project established at NRL by BuShips for "location of enemy ships and aircraft." Complete plans for an early-warning system turned over to Army.

1933 – Use of pulses suggested and work started on a pulse system.

1934 – CW radio-detection system demonstrated to members of Congress. Workable pulse transmitter and receiver built.

1936 – 80-MC pulse-height radar detected aircraft at 40-mile range.

1937 – 200-MC radar tested at sea on USS LEARY.

1939 – Greatly improved 200-MC radar tested on USS NEW YORK (range to 98 miles; bearing to ± 1 degree; shell splashes spotted; navigation by radar). Contracts let for commercial production.

1940 – US compared notes with British.

1941 – 19 NRL-model radars installed on Naval vessels.

"supersonic" for high-frequency, "pings" for pulse-echoes, "transducers" for antennas, seawater for air, and you get what amounts to radar under water. The analogy should really be reversed, because the sound engineers got there first. By 1935 they had developed a complete echo-ranging system using the NRL Rochelle-salt transducer. This, together with the "passive" listening devices, became the integrated sonar of World War II.

Just as the Japanese blamed their loss of the turning-point sea battles of the Solomons on the U. S. Navy's possession of radar, so did Admiral Doenitz, the Commander of the German U-Boat fleet, cite American and British antisubmarine devices as the major reason for Germany's failure in the Battle of the Atlantic.

We can grant, then, that NRL helped the Navy score touchdown after touchdown in the middle of the game, but how about the one that finally won the War, the A-bomb? Was the Laboratory in on that too? Indeed it was—at ground level. The Naval Research Laboratory, although the initial program was very small, was the first U. S. Government agency to take an active interest in nuclear energy. In 1939 Ross Gunn, of the Mechanics Division, enthusiastically backed by his Director, Admiral H. G. Bowen, established a project that later led to an isotope-separation process (liquid thermal diffusion) which produced some of the materials for the Hiroshima bomb.

This effort in nuclear physics serves to point out that busy and alert research was going on at NRL in fields other than radio and sound. Studies in Optics began about a year after the Laboratory opened, and by the mid-thirties, three other divisions had been established: Metallurgy, Chemistry, and Mechanics. Always short on manpower and shorter still on funds, their achievements were fewer in number and less glamorous than those of the two larger, more powerfully supported groups. Taken together they accomplished two big things, however. They proved that there was both a place and a need for basic-science research in the Navy, and they gave the Naval Laboratory professional stature among the critical brotherhoods of learned men.

NRL had—in all its divisions—done something else for the Navy; it had continued or resurrected scientific problems of purely military interest. The American Government and American industry had marshalled a vast developmental effort for World War I, but after the armistice military research was dropped like so much excess ballast. When OSRD and NDRC were established on the eve of Pearl Harbor, scientists flocked to the Laboratory by the dozens and scores to be "briefed" up to date on such matters as camouflage, protection against gas, submarine batteries, body armor, infrared signalling devices, and the like. Furthermore NRL in keeping these subjects alive had prepared its own house for the even vaster emergency to come.

It was fortunate that NRL had 18 years in which to grow and to establish a firm organization and operating procedure. Because when the war came the Laboratory was swamped with rush projects. In the years between 1940 and 1945 the number of buildings increased from 12 to 70, the number of projects from a few score to over 900, annual appropriations from $900,000 to $14,000,000, and the station personnel from about 400 to over 5,000. But mere increases in size and numbers tell only part of the story. Far more significant changes had taken place.

Most apparent was the increase in proportion of naval officers and men. In an extremely tight labor market, the only way to get technicians, stenographers, and even scientists was to requisition them from the Bureau of Naval Personnel. And often the only way to keep draft-eligible engineers was to put them into uniform.

Basic research almost went by the board as long-term investigations gave way to hurry-up applied research or prototype development. Such a wartime evolution had been foreseen, and NRL was prepared for it. The amazing diversity of the "inventions-on-demand" ranged all the way from radio sonobuoys to the sea markers that increased the chances of shipwrecked seamen and down flyers being found by rescue planes.

At the same time, the search for new offensive and defensive weapons extended into every technical field, giving new importance to the so-called "basic-science" divisions. Chemical-warfare research alone more than doubled the size of the Chemistry Division; the building of thousands of welded ships handed a host of new research problems to the Metallurgy Division. And so it went, leaving the Laboratory at the end of the war with a far better balanced program than it had at the beginning.

The demands of wartime research also solved the problem of space for future expansion. To provide long, open-water ranges for experimental radars, the Laboratory purchased in 1941 a magnificent 140-acre site high on a bluff overlooking Chesapeake Bay. So NRL now has, in its "Annex," a well-equipped testing station within easy commuting distance yet remote from the clutter of a big city.

A typical, if somewhat extreme, example of the wartime "crash" research was the countermeasures program against the German radio-controlled air bombs which were threatening the sea convoys supporting the North Africa campaign. Two American destroyers, equipped with signal-analysis gear, sailed into the Mediterranean, recorded the German signals, and returned with the data. Then, in 12 weeks, NRL scientists built a successful countermeasure. In the Sicily campaign—and later, in the Normandy invasion—this equipment not only jammed the German signals but (on a couple of occasions) apparently took over control of the air-dropped missiles and diverted them harmlessly into the sea.

The Laboratory emerged from World War II in an enviable position: It was big, it was affluent, it had a preeminent reputation among government laboratories. Above all, it was riding high on a wave of unprecedented public faith in scientific research. The most technical of all wars, with its Wagnerian climax at Hiroshima-Nagasaki, had been won largely because America was able to keep a technical stride ahead of its enemies. Now Congress was willing to bear the cost of extensive military research.

So the Naval Research Laboratory was not cut back. While ships were being placed in mothballs by the thousands, research was maintained on a near-wartime footing. New equipment was acquired almost for the asking, and manpower was limited only by the competitive market for trained scientists. Furthermore, the merger with the new Office of Naval Research assured NRL an ample and continuous backing for basic research.

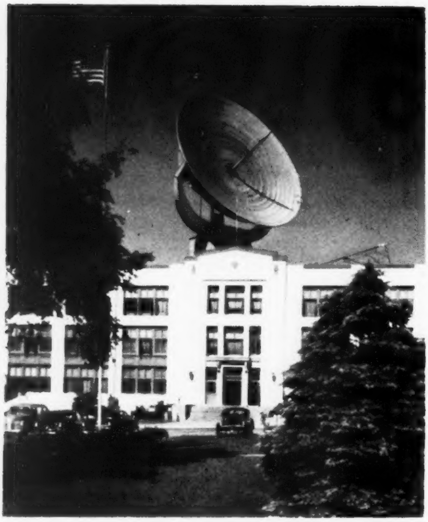
The first postwar task was a weeding-out job. The hectic war years had left the research department with nearly a thousand unfinished or partially finished projects. Many of them were of purely transitory interest, already obsolescent, and others were performance tests or application jobs which could be more profitably pursued elsewhere. The remaining projects—the carry-over ideas and developments that seemed to have a future—were set forth in a well-balanced program which has been aportioned among 13 research divisions and many more "branches," each one following a distinct line of scientific endeavor.

This diversity means that the Naval Research Laboratory is no longer devoted predominantly to applied research in electronics. Fundamental research in the basic physical sciences now has equal standing, and it is this characteristic above all others that makes the postwar laboratory unique among Government-managed military institutions. It has enabled NRL to poke its roots into the newer fields such as solid-state physics, nucleonics, cryogenics, and engineering psychology—without first having to prove that an end-use item will probably result.

The Laboratory has also dropped much of its former singularity. Since 1945 it has been one arm (together with the Training Device Center) of the bureau-level Office of Naval Research. ONR's other arm, of course, is its vast network of private contractors at universities and industrial laboratories. The two arms have learned to work increasingly together—the one supplementing the other in a highly effective partnership. This teamwork extends into some of the largest programs supported by the government.

And if research has become interdependent and more complex, it has also become vastly more expensive. The research "tools" are no longer a few coil-winding machines and generators and laboratory crockery; they are such things as multimillion-electron-volt betatrons, complex electronic calculators, electron microscopes, huge shock-testing hammers, or giant astral-radiation reflectors. So thousands of postwar manhours have gone into tooling-up for the future, for preparedness, to enable the Navy to have within its own establishment one of the great laboratories of the world.

So NRL is doing all right. Production at the Navy's 35-year-old idea factory is at the highest level in its history. There is every indication, moreover, that this production will continue. NRL still has the academic freedom that attracts the best type of scientists and holds their loyalty; there still exists an environment that permits these men to expand their own capabilities and to pursue their ideas; and it still has the support of the Office of Naval Research, of the material bureaus, and of the Fleet. Furthermore, today's Laboratory has that indefinable yet challenging esprit that is the heritage of a great past.



The Laboratory

Visitors to the Naval Research Laboratory frequently comment that the research atmosphere is like that of a university. Furthermore, the many low buildings arranged around a central mall bear a striking resemblance to a campus.

When the Laboratory was formally opened on July 2, 1923, it comprised four buildings, housing fewer than 100 employees. There were just two scientific divisions: Radio and Sound.

Today the main establishment, at the original location in southwest Washington on the Potomac River, includes 84 buildings on grounds of about 55 acres and represents a capital investment of more than $40 million. The Laboratory staff, including administrative, shop, and other service personnel, now numbers more than 3,000 men and women engaged in research, development, and evaluation work in the physical sciences and related fields.

Forty-two miles from Washington is the Chesapeake Bay Annex (CBA) of the Naval Research Laboratory, which provides services and facilities not available at the main laboratory. These include equipment for the evaluation of automatic fire control and tracking radar for shipboard use and whirling-arm test stands which permit the calibration of aircraft instruments at speeds up to 900 miles per hour. Since CBA is well removed from city smoke and city lights and has unobstructed overwater paths, it permits studies in optics and, particularly, atmospheric transmission of light.

NRL has facilities for studying tropical deterioration at two locations in the Canal Zone. One of these is the Tropical Exposure Site at Coco Solo; the other is a centralized laboratory at Miraflores, established in 1953 as a joint government activity under the technical management control of NRL.

Blossom Point, on the Maryland shore of the Potomac about 40 miles downriver from Washington, is the site of NRL's model satellite radio-tracking station. Here the telemetering receivers have been set up and tested, and here crews have been trained to man the eight other tracking stations in the Western Hemisphere.

Early this year, installation of an 84-foot radio telescope was completed at the Naval Research Laboratory's Maryland Point Observatory. The largest known equatorially mounted installation in the world, it permits detection of fainter signals than has been possible with smaller instruments previously used.

One of the newest research implements at NRL proper is a research reactor facility of moderate power, the first ever established at a defense laboratory. It serves as an important research tool not only in nuclear physics but also for investigations in chemistry, metallurgy, solid-state physics, and other fields of science. Other facilities for nuclear-physics research include a 5,000-curie Cobalt-60 irradiation source and several particle accelerators, ranging from Cockroft-Walton machines through Van de Graaff generators to a 22-mev betatron.

NRL operates a general-purpose digital computer, an electronic differential analyzer, a simultaneous algebraic-equation resolver, and data-reading equipment as aids to research throughout the Laboratory. Nuclear diffusion, nuclear cross sections, normal modes of mechanical structures, power spectra of microseismic disturbances, optimum armoring of aircraft, beam patterns of slotted antennas, and crystallographic constants of complex crystals - these are typical of the many problems that have been treated.

Environmental chambers check the behavior of naval electrical and electronic equipment under extremes of weather and other climatic conditions. Among those at NRL is one which can simulate flight conditions from sea level to 35,000 feet within seven minutes and can then "dive" back to sea level within 40 seconds. Unique facilities available for research in solid-state physics include equipment for conducting studies down to temperatures within 0.001 degree of absolute zero, powerful magnets capable of producing magnetic fields of 100,000 gauss, and spectroscopic equipment for measuring emission and absorption spectra into the far infrared.

A variety of ballistics facilities have been established at the Laboratory for use in exploratory studies of new armor materials and related problems. A distinguishing feature of these installations is that most of them utilize missile trajectories only a few feet in length and so can be located in laboratory rooms of normal size.

When specialized units are unobtainable commercially, they are designed and built within the Laboratory itself. Complete shop facilities make possible every step, from blueprint to finished product, in the construction of almost any kind of equipment required by members of the scientific department.

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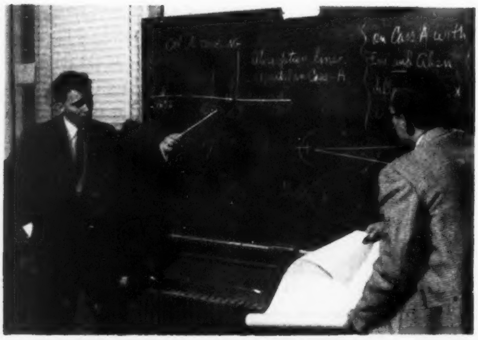
The People

The internal organization of NRL has always followed the pattern conceived by the Naval Consulting Board in 1915 – a laboratory under Navy management, staffed by civilian scientists.

Naval officers serve tours of duty of two to four years. Thus, outgoing officers carry back to the Fleet a definite experience with the scientific method, and replacement officers coming directly from the Fleet bring to the Laboratory the immediate problems and operating experiences of the Navy in the air, afloat, and under the sea.

On the other hand, the scientific organization is permanent and afforded full authority and responsibility for its work. The research department is headed by a civilian director of research who has three associates, one each for the fields of electronics, materials, and nucleonics. There is a further separation into 13 research divisions with their own civilian scientists as superintendents. The branches within these divisions form small, tightly knit, yet interrelated, working units, each concerned with research, development, or evaluation in a specific area of the physical sciences.



Discussing an experiment in radio astronomy.

In NRL's experimental foundry.

The Scientific Program

"Research for our Navy and our country" might well be the most appropriate way to summarize the accomplishments of the Naval Research Laboratory during its 35 years of existence.

As indicated in the article beginning on page 1, the Laboratory is perhaps best known as the "birthplace" of radar. But its scientific work is far from restricted to the single field of electronics, which encompasses radar. More than a thousand scientists employed in the Research Department are at work on research and development problems involving the major fields of the physical sciences. The names of the main divisions of the research program suggest its scope: Applications Research; Astronomy and Astrophysics; Chemistry; Electricity; Mechanics; Metallurgy and Ceramics; Nuclear and Atomic Physics; Optics; Radio; Solid-State Physics; and Sound.

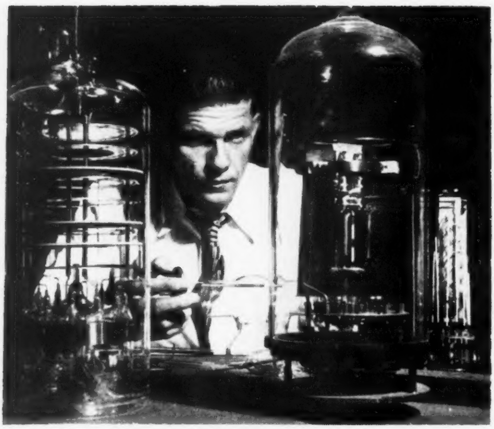
One of the most intriguing programs now underway at NRL is Project VANGUARD. This IGY assignment reflects, in part, the accomplishments of NRL over a ten-year period in the exploration of the upper atmosphere by means of sounding rockets. The German V-2, the Deacon, the Aerobee, and the Viking rockets have been utilized as research vehicles in this program, which has as its primary objective the extension of our present knowledge of the earth's atmosphere to as great an altitude as possible.

A related program for gathering scientific data from outer space is the relatively new field of radio astronomy, which is concerned with the study of the strength, direction, and variations of radio-frequency emissions from the sun, moon, and stars. NRL has been working in this area since 1946. In addition to the recently installed 84-foot radio telescope, the Laboratory has older instruments varying in size up to 50 feet. With these, NRL scientists have discovered new discrete radio sources and, more recently, confirmed astronomical theories on the expanding universe.

.Chemists are investigating various aspects of the Navy's needs in the fields of physical, inorganic, and organic chemistry. In one of many projects, the whole theory of friction and wear is being reinvestigated as a new point of departure in the development of improved synthetic lubricants, designed especially to meet the rigorous requirements of modern warfare, as, for example, in new naval ordnance equipment and in aeronautical items, including jet engines and guided missiles.

Basic investigations on the chemical and physical properties of liquid metals are contributing to the theory of the liquid state as well as to nuclear-reactor technology. Other work in chemistry is concerned with improvements in high-energy fuels, protective coatings for materials, rubbers, and other elastomers for special applications, new foams for fire extinguishment, methods for analysis of atmospheric radioactivity, aerosol filtration, and paper made from synthetic fibers.

Work is in progress in the field of mechanics on shock and vibration, the development of light armor, studies in the failure of materials

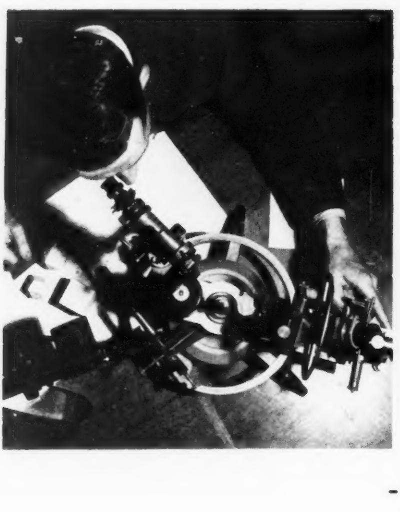


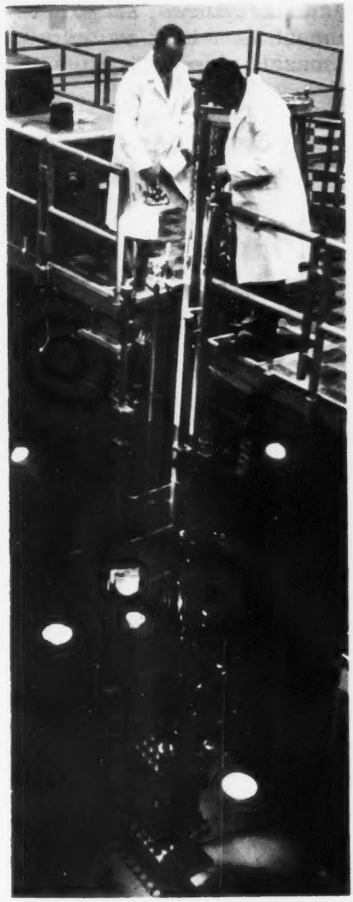
Top--An experiment in welding.

Center--Two unusual tubes being assembled for use on a research problem.

Lower left--The angles between the natural faces of a crystal are measured to determine internal arrangements of atoms.

Lower right--A device which records events in the hydrogen alpha line of the solar spectrum is readied for use.

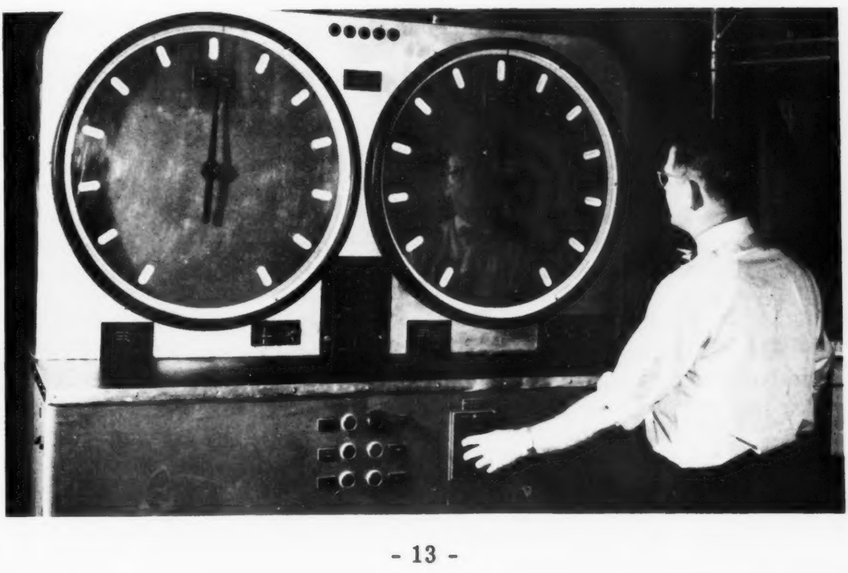




A low-temperature investigation underway in NRL's cold chamber.

Two technicians holding portable electric lamps light up reactor core submerged in tank.

At the control panel for NRL's three-million-pound testing machine.



and structures, and nonlinear and continuum theories. A recent development is a high-velocity gun capable of firing 3.0-gram projectiles at muzzle velocities up to 17,500 feet per second.

The program in the field of metallurgy covers studies of the electron theory of metals, crystal imperfections, phase transformations, reactive metals, high-temperature alloys, corrosion, welding, and casting. Depending on the nature of the problem, the research may be conducted by balanced teams comprising metallurgists, physicists, physical chemists, and chemists. As an example, a team of this type is engaged in studying the nature of liquid metals, to provide basic information required for the use of liquid metals in nuclear power plants.

Major contributions have been made in the fields of flow and fracture of metals, ranging from the problem of brittle fracture of steels at low temperatures to that of the high-strength alloys for service at elevated temperatures. Corrosion studies have resulted in the development of improved methods for the cathodic protection of ship hulls. Studies of the nature of the solidification of metal provided a basis for the development of improved procedures for casting of metals which have been widely adopted by industry.

The program of nuclear physics at NRL is a broad one. It includes theoretical investigations in energy ranges up to several million electron volts, in which are used the various particle accelerators available to nuclear physicists at NRL. Other studies are associated with the use of nuclear power for propulsion purposes. A program has been set up to use the new reactor as a source of low-energy neutrons for various studies. Cosmic radiations are being investigated through the use of nuclear photographic emulsions carried aloft in high-altitude balloons. Incidentally, NRL began its research program in nuclear physics back in 1942 with the separation of the isotopes of uranium by thermal diffusion in a liquid compound of uranium.

Other scientists are investigating the physics of the solid state. The properties of metals, semiconductors, and dielectrics are being explored, with studies in ferromagnetism, electronic resonance and transport phenomena, luminescence, and phenomena accompanying irradiation of solids.

Since the mid-1940's, NRL has been working in the field of engineering psychology, more popularly known as "human engineering," a program whose importance to the Navy has increased as the complexity of naval equipment has grown. This program is aimed at establishing basic principles so that engineers can better fit the naval machine to the Navy man.

In the course of their scientific investigations, NRL scientists have been sent on distant expeditions for observations in the tropics, polar regions, and on high mountains; they have taken part in several eclipse expeditions. In fact, there are few areas in the world where they have not been for the purposes of radio, optical, sonic, atmospheric, or oceanographic investigations.

Glimpses of NRL Research

As NRL enters its 35th year, its more than 1,000 scientists are hard at work on more than 400 research projects. Although all are important to the Navy and of interest to the scientific community, only a very few can be described here. These are a random selection. They do not necessarily represent the most significant work done at the Laboratory or indicate the scope of research underway. They serve, simply, as "keyholes" through which some of the work can be viewed.

Musical Atmospherics

The Laboratory is one link in a chain of 11 IGY stations, stretching from the Arctic to the Antarctic, for observing audiofrequency atmospherics—the so-called "whistlers" and "dawn chorus." In addition to its own equipment, which has been in continuous operation for several years, NRL supervises and is responsible for a station near St. George, Bermuda.

Whistlers are believed to be waves radiated from lightning strokes and propagated along the lines of the geomagnetic field to a conjugate point in the opposite hemisphere. Under certain conditions, they produce a semimusical tone normally descending in pitch. The dawn chorus is a separate, but possibly related, phenomenon named for its similarity to the sound of many birds chirping and its occurrence most frequently at dawn. Its origin has not been determined, but there is no direct connection with lightning, because it can occur at times when the regular atmospheric radio noise level is very low.

The latitude dependence of these phenomena is being studied and its effect correlated with geomagnetism, aurora, sunspot activity, properties of the ionosphere, and other geophysical phenomena. Of prime interest are the events occurring simultaneously at opposite ends of the earth's magnetic field lines. Simultaneous whistler trains have already been recorded at conjugate points and have supplied excellent confirming data for earlier theories.

Certain stations, including the one at NRL, record special events occurring between regular schedules and, if desired, at recording speeds differing from that normally used. These recordings of unusual emissions are needed to support theories now being developed concerning the origin of dawn chorus and other emissions not caused by lightning.

Results of whistler studies have already required that certain modifications be made in our conception of outer space. Additional modifications will be necessary to explain the various unusual types of activity occasionally observed.

Magnetic tapes from all stations are monitored regularly to distinguish the various types and degrees of activity. These data are disseminated regularly among interested investigators, thus providing a means of advising others of possible events that require further analysis and study. The original tapes are stored for future reference.

It is of interest to note that VLF transmissions from Annapolis have been received at Cape Horn by the whistler mode of propagation. Present data are meager, and further study is required to determine whether or not they could lead to a practical communication circuit.

Development of Methods for Trace Analysis

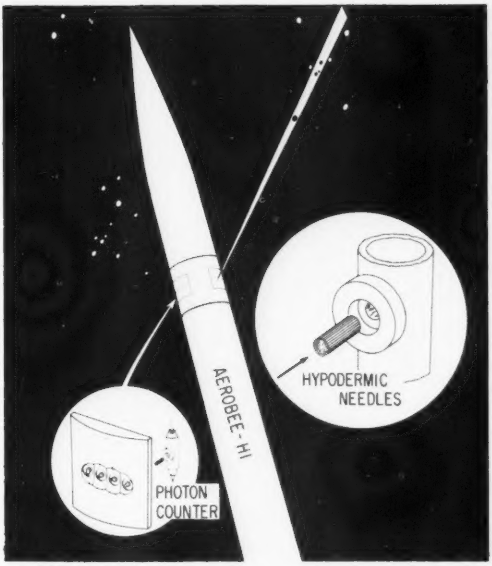
Among the more significant fields challenging the modern research scientist is that of high-purity materials. Mounting evidence indicates that many materials, when highly purified, exhibit behavior patterns strikingly different from those traditionally reported. The current outstanding example is semiconductor materials, which have made possible the transistor. As little as a few hundredths of a part-per-million of certain contaminants in these materials can practically extinguish the semiconductor properties required for industrial use.

The preparation and evaluation of high-purity materials lean heavily upon the ability of the analytical chemist to develop methods that are capable of detecting and determining lower and lower levels of impurity. NRL chemists have been successful in developing methods for exploring the purity of some metals in analytical panoramas comprising as many as 55 different potential contaminants in the parts-per-million level or lower. In each survey, analyses are performed for all of the possible naturally occurring contaminants, as well as those that may be introduced in processing, including interstitial elements such as atmospheric gases. This breadth of analytical scope and sensitivity to impurities has provided NRL metallurgists with data on research metals never before available.

The method developed at NRL for determining small amounts of oxygen in titanium has had an almost universal acceptance in industry. This method differs from conventional vacuum-fusion analysis techniques for gases in metals in that the reaction of the titanium-metal sample under test takes place in the presence of an excess of flake graphite rather than in a carbon-saturated molten-metal bath. The dry reaction permits the formation of titanium carbide with simultaneous reduction of the oxides to carbon monoxide, without the troublesome side reactions experienced when free titanium or titanium-rich alloys are present. It also permits the analysis of the full range of titanium alloys with oxygen contents as high as several percent, as well as of high-purity titanium iodide containing as little as a few thousandths of one percent.

Commercial high-vacuum analysis equipment, designed to accommodate the distinctive features of the NRL method, is being mass-produced by a leading firm to meet the industrial demands for oxygen-in-titanium control. In addition to a large number of analysis units built privately from data supplied by NRL publications, nearly 150 of the commercially produced units have been placed in laboratories in all parts of the world at a total market value of well over one million dollars.

Photon counters, mounted in Aerobee-Hi as shown here, serve as rocket "telescopes."



Rocket Astronomy

NRL scientists have taken a new look at the Universe by means of rocket astronomy. This has revealed that in far ultraviolet light—seen only from heights greater than 60 miles above the ground—our galaxy appears to be filled with extended gas clouds.

These first attempts at rocket ultraviolet astronomy have been purely exploratory and relatively simple. Instead of using mirrors or refracting lenses, the rocket "telescopes" have been made of bundles of hypodermic needles about half an inch long, placed in front of ultraviolet sensitized photon counters. The view through these tubings is restricted to a field about 3 degrees wide, roughly what can be seen by looking through a bundle of common drinking straws. Such optics can be used because of the remarkable sensitivity of photon counters. (A photon counter is a Geiger counter sensitive to ultraviolet light.) The counters developed for the rocket experiments can detect almost every individual quantum of ultraviolet light that strikes them.

To scan the sky, use is made of the spin and precession motions of the Aerobee rocket. As the rocket rises vertically, the spinning motion causes the "telescope" to sweep out a ring of the sky, 3 degrees wide. If the rocket yaws and starts to precess, the plane of the ring tilts relative to the stars. In this way the combined spin and precession of the rocket serve to sweep out a large view of the celestial sphere.

Throughout the flight, the photon-counter telescopes transmit signals via radio telemetering to a ground station where the complete history of the flight is recorded. Reconstructing a map of the sky from the telemetered data is like solving a jig-saw puzzle. The problem of determining at each instant of flight exactly where each detector was pointed is called the "aspect" problem. Visible-light photocells provide the clues by detecting the bright stars and the air-glow horizons. The final solution is the one which puts all the known stars in the telemetering record in exactly the observed sequence. NRL scientists were able to solve the aspect problem with an accuracy of one degree.

When the first rocket-astronomy experiment was planned, it was expected that the ultraviolet sky would differ from the visible sky in that certain stars would be much brighter in the ultraviolet than in the visible. The sun, for example, is a rather cold star, classified as a yellow dwarf. Its color temperature is only 6000° K. By contrast, some early stars, such as the blue-white stars, have color temperatures as high as 50,000° K. These stars should look extremely bright in the far ultraviolet, whereas the sun should fade rapidly as the wavelength decreases.

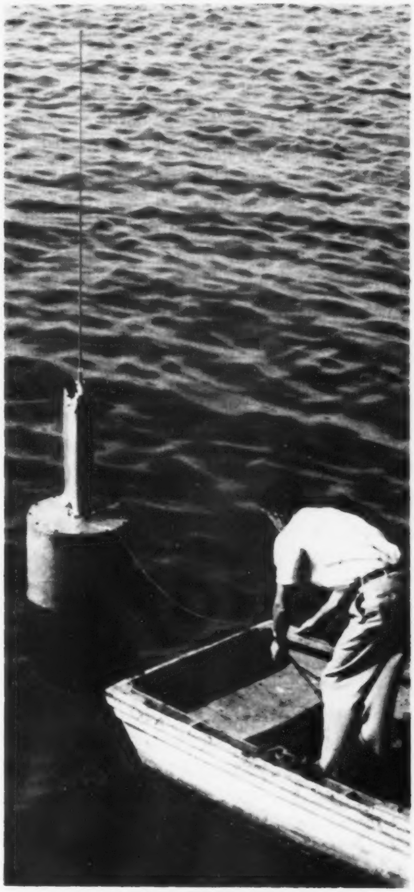
The results of the rocket ultraviolet survey were very surprising. For example, in Virgo, a region of bright ultraviolet nebulosity more than 20 degrees in diameter was observed surrounding the hot star Spica (28,000° K), even though no visible nebulosity can be seen with large optical telescopes. The ultraviolet glow about Spica was so intense that it masked the star itself, which is almost five times as hot as our sun. Within the narrow wavelength interval to which the photon counters are sensitive, about 100 angstroms, the ultraviolet flux from the region of Spica is 100,000 times as great as the total power radiated by the sun.

It is now well known that between the 100 billion stars of our galaxy there are present enormous clouds of highly rarefied gases and fine dust. In fact, it is estimated that as much as half the matter in the universe is in the form of gas and dust. Stars are probably being continuously formed out of this interstellar matter by a steady condensation process.

Ocean Weather Coverage

In an effort to obtain economically more information about ocean weather conditions, NRL has developed two new systems for meteorological data collection, both sponsored by the Bureau of Aeronautics. The first of these, called Transosonde, was put in operation this year. Basically, it consists of a balloon-borne station which transmits meteorological information as it floats above the ocean at a high altitude. The other system, called Transobuoy, employs a free-floating weather station designed to provide more detailed data from the ocean surface. The buoy is not yet in operational use, although field evaluations of it have been made.

The Transosonde weather station is designed to follow the upper-atmosphere flow of air along a constant pressure surface. While making its journey, it telemeters such information as atmospheric temperature, pressure, and humidity by high-frequency radio transmissions. These transmissions are also employed in tracking the balloons by means of direction-finder networks. The successively plotted positions provide a track representing the velocity and acceleration of the wind at balloon altitude from which the motion of the air at that level can be determined. Such information enables weather men to chart large-scale atmospheric flow patterns and thus to predict probable developments of major storms. The great advantage of the system is that it provides much needed weather data over large ocean areas at a fraction of the cost of obtaining comparable coverage by ship weather stations.



At present, the balloons are being dispatched on flights across the Pacific Ocean, one balloon being launched about every other day from Iwakuni, Japan. After reaching the United States, many of the balloons remain in flight, crossing the continent and moving well out over the Atlantic Ocean. The data obtained are used not only by meteorologists in the United States but also by those of other countries, for they are made available internationally.

The Transobuoy is a free-floating device designed to operate for as long as a year. During its "voyage" it will periodically transmit measurements of air and water temperature, wind speed and direction, and atmospheric pressure to shore-based stations. Since the buoy moves slowly, one position plot per day is considered sufficient. The system is an economical one not only because the buoy is free-floating, but also because it can be delivered by air. The air-drop also permits the buoy to be placed quickly and strategically in any ocean area. Present plans call for buoys to be placed in the general ocean area traversed by the Transosonde balloons. The two systems will thus be complementary, with the buoy station providing surface data and the balloon station providing upper-air data.

Plastic Flow and Fracture

The mild steels widely employed in cargo-ship construction have long been known to become more resistant to plastic deformation, such as bending, when rapidly loaded by some force such as an explosion or collision. Investigators are giving more and more credence to a theory that this resistance to bending, under a sudden stress, may be one of the main reasons the steels fracture brittlely in an accident, particularly where the metal plate has already been weakened by a notch or crack which provides a starting point for the break. Steels are known to be subject to many variables in their tendency toward notch-brittleness, but little is known about the ways these variables affect yield strength.

To look for relationships between yield-strength characteristics and fracture criteria measured elsewhere, an investigation of rapid yielding and flowing properties of various steels has been carried on at NRL for several years. The recent development of a gunpowder-powered testing machine has permitted investigations in speed ranges not previously feasible. The high pressures which are rapidly developed by the burning of a propellant-type powder furnish a convenient means for rapidly deforming a specimen. This pressure is applied to a specimen through its action on a piston which slides in a thick-walled cylinder. Variation of from about 5 to 50 million psi per second in the pre-yield rate of loading is obtainable by interposition of differing restrictive orifices between the burning powder and the piston chamber. The stress on the specimen is measured with wire strain gages on a deforming anvil; similar gages detect the deflection of a beam, in contact with this anvil, as a measure of specimen deformation.

Among the more striking results of investigations utilizing this apparatus is a correlation of the sensitivity of yield stress to loading rate with the manganese content of the steel. Steels of low manganese content exhibit substantially greater yield strength for a given increase in loading rate than do steels of high manganese content. This observation is consistent with the tendency of steels of low manganese content to exhibit increased notch brittleness. Effects of carbon content and heat treatment (affecting the grain size) also have been studied by this method.

Automatic Recording and Reduction Facility

In the test and launch phases of Project VANGUARD, great reliance must be placed upon telemetry data for analysis of propulsion and vehicle performance. Early in the program it became apparent that the volume of data involved (over one million samples per firing) and the required speed of reduction demanded an automatic data-reduction facility. It is essential that the data be reduced as rapidly as possible in order that a consensus may be obtained on the basis of the telemetered data and placed in immediate use for evaluating future firings. Toward this end the Automatic Recording and Reduction Facility (ARRF) has been designed.

The new facility is a joint development of Radiation, Inc., of Melbourne, Florida, and NRL. Because the highly accelerated program precluded the development of new equipment, existing components were used whenever possible. The facility has been separated into two basic systems: The Data Recording System, trailer-mounted for mobile field use, and the Data Reduction System, designed as a hangar installation.

VANGUARD vehicles carry three distinct telemetry systems, each chosen for its particular capability commensurate with desired precision, capacity, and frequency response. The digital recording trailer can produce, at the rate of 25 inches per second, three compatible digital magnetic tapes for each VANGUARD firing. In addition to the telemetered data, coded timing signals are provided from the recording system's internal clock for later use in programming the data-reduction system.

The magnetic tapes are played back and reduced by the Data Reduction System at the rate of 60 inches per second, or 2.4 times the recording speed. Thus the data can be read, sorted, linearized, plotted, and finally tabulated in less than 72 hours. Formerly, weeks of painstaking analyses were required to reduce some of the data to usable form, even though they were radioed back from the rockets in a matter of seconds. Furthermore, as the ARRF plots curves of the data, it automatically reads the value involved and prints these readings beside the curves, in the proper units of measurement, to produce graphs and tables detailing the flight.

The entire ARRF has operated profitably since August 1957 in linearizing and reducing VANGUARD vehicle test data under operational conditions. Experience thus obtained indicates that the engineering solutions adopted are generally sound and are fulfilling the specified requirements of the data-reduction facility.

Corrosion of Steel in Tropical Environments

An extensive NRL investigation of the corrosion rates and characteristics of 50 different metals and alloys has been in progress since 1946 in the Panama Canal Zone. The metals have been exposed to five natural tropical environments: marine and inland atmospheres, freshwater immersion, and continuous and mean-tide sea-water exposure. As a result of an earlier study, it was considered necessary to make periodic measurements over a period of 16 years in order to predict with considerable accuracy the useful life in the tropics of the metals included in the study. Ten replicate panels of each metal were exposed in each environment so that two panels from each location could be removed after 1, 2, 4, 8, and 16 years.

The Canal Zone, fortunately, is one of the few tropical areas in the world for which accurate and long-term weather information is available. From this information, collected by the Panama Canal Department of Meteorology and Hydrography, it was a simple matter to assemble data showing monthly variations in temperature, humidity, rainfall, wind, and sunshine for an average year based on a minimum record of 20 years. For more precise local information, the atmosphere at each of the test sites was sampled during the period from May 1947 to November 1950, and chemical constituents of significance to corrosion were determined. Samples were taken continuously by aspiration methods in which distilled water was used as an absorbent to collect airborne material. Analysis of this absorbent water was made three times a year, representing periods from January to April inclusive (dry season), May to August inclusive (wet season), and September to December inclusive (wet season).

Of the ten structural steels evaluated for corrosion resistance to tropical atmospheres, four were proprietary high-strength low-alloy types; one was a 2-percent nickel boiler steel; one was a 5-percent nickel steel; two were high-tensile chromium steels, a proprietary of 3-percent and 5 percent chromium content; and two were low-carbon steels, one copper-bearing and the other unalloyed. The pedigrees of each steel had been so accurately documented that their constituents were known to small fractions of a percent.

Evaluation of data after eight years of exposure indicates that for Canal Zone atmospheric environments the 5 percent chromium steel was the most corrosion resistant of the group tested, although the 5 percent nickel and the 2 percent nickel steels were almost as resistant. The 2 percent nickel steel, considering its lower alloying cost, would seem to be a wise selection for atmospheric exposure in the tropics. The proprietary low-alloy steels could also compete on a cost basis, and in atmospheric corrosion resistance they are far superior to the low-carbon and copper-bearing steels.

Crystal Structure Determination

Most of the physical properties of metals, alloys, minerals, and even biological substances in the solid state are intimately related to their crystalline form. Where the structures are well known, as are those of simple ionic crystals, considerable progress has been made in understanding their many interesting solid-state properties. But when the number of atoms in the basic building block (unit cell) increases, it soon becomes almost impossible to solve the crystal-structure problem by conventional methods, and correspondingly, it is difficult to understand the properties of the material.

A significant advance toward the solution of problems involving large numbers of atoms in the unit cell has been made at NRL through the development of new procedures in algebraic and statistical analyses of data derived from X-ray and electron diffraction patterns. Heretofore, a unit cell of ten atoms appeared to present the most complex problem that could be solved by existing methods. The new theory of data treatment, adapted to high-speed computing machines, has recently solved a problem involving a 36-atom structure. It appears capable of extension to problems of structures containing as many as 1,500 atoms per unit cell.

Submarine Rescue Buoy

Every modern submarine must have some means for alerting rescue forces in the event it is seriously damaged while submerged. One solution is a rescue buoy which can be launched from the interior of the stricken submarine. This buoy would then rise to the surface and begin transmitting a distinctive radio distress signal, automatically and continuously, for as long as possible. Such a buoy was developed by NRL several years ago and is now in use. It has a three-hour operating life in the frequency range of 115 to 145 Mc. Since then a new requirement for rescue buoys has arisen—that they operate on the international VHF distress frequency of 243 Mc. NRL undertook the task of modifying its earlier model for operation on this new frequency.

Three prototype models of the new buoy have been completed, and comprehensive drawings have been prepared for use by contractors in the manufacture of service-test or preproduction models. The buoy is cylindrical and has the dimensions (3 inches in diameter by 39 inches in length) to permit launching through one of the signal-flare ejector guns of the submarine. The source of power is a magnesium silver chloride battery, which is activated immediately upon contact with sea water. The transmitter has an amplitude-modulated radio frequency output of 500 Mw and occupies a 40-kc bandwidth, centered on the required operating frequency of 243 Mc. At time of launching the antenna is folded along the body of the buoy, but upon release it springs erect. The buoy rises to the surface and automatically starts transmitting its distress signal, the international Morse Code for "SOS SUB SUNK SOS." Other improved features include increased battery life (9 to 10 hours) and a reduction in weight from 8 to slightly less than 7 pounds.

Precision Measurement of Nuclear Particle Energies

Many experiments in nuclear physics require a precise knowledge of the energy of nuclear particles in a beam. During the past year, NRL scientists have put into operation an extremely precise instrument designed to measure the energy of particles accelerated by the 6-million-volt Van de Graaff generator. This instrument consists essentially of two parallel plates that are separated by about 4/10ths of an inch and curved in a 90-degree arc having a radius of about 6.5 feet. When a voltage is applied between these plates, only those beam particles having a particular energy are able to traverse the entire length of the arc. The selectivity is such that any particles whose energies are 0.005 percent more or less than the energy of the particle being measured are discarded.

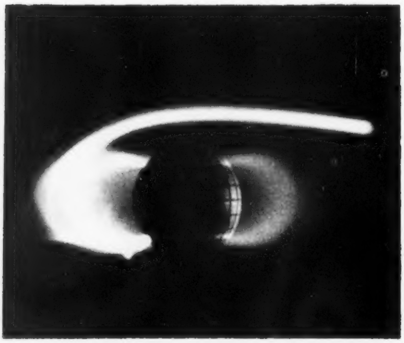
Initial results show this instrument to be better in many respects than any similar apparatus known to exist. Important contributions have been made in the determination of standard nuclear calibration energies, in the determination of nuclear masses, and through the measurement of narrow resonances associated with certain nuclear reactions.

Reproduction of Aurorae in the Laboratory

The aurorae—those beautiful displays of luminescence that appear at intervals in the night sky, particularly in Arctic and Antarctic regions—have mystified humanity for centuries. Only recently has man begun to understand them. It is now believed that aurorae occur when streams of charged particles coming from the sun are deflected into the upper atmosphere by the earth's magnetic field. The importance of knowing more certainly the cause of aurorae can be appreciated when one realizes that they are closely related to problems in radio-wave propagation, of which the prediction of radio blackouts is currently of much concern.

In an attempt to explain the cause as well as the various physical forms and time variations of aurorae, a laboratory model of the earth with its magnetic field has been assembled at NRL. When a beam of electrons representing hydrogen ions from the sun is directed toward this model earth, a variety of stream forms are produced. Under certain conditions, ion rings may completely gird the earth.

The model has demonstrated very effectively various features of the aurorae and has thus assisted immensely in achieving a more complete theoretical understanding of the phenomenon.



Equatorial view.

View of north magnetic pole.

Models of the earth subjected to a beam of electrons representing hydrogen ions from the sun. Typical stream patterns, ring current, and northern and southern auroral zones appear in the photographs.

High-Velocity Impact Studies

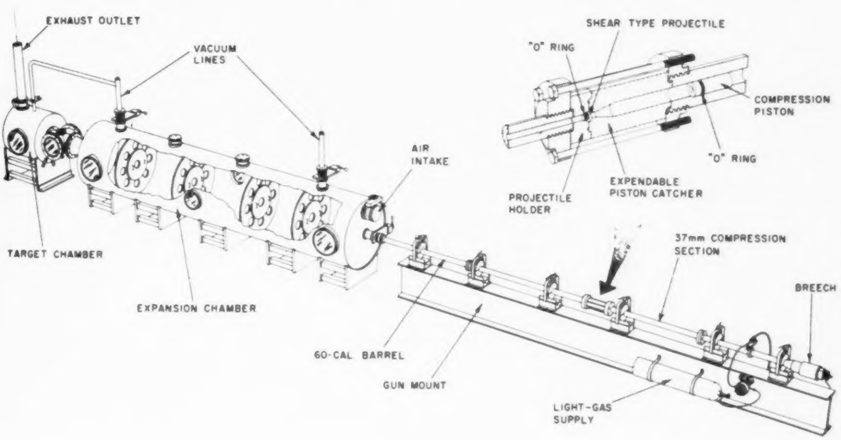
As our new missiles travel toward their targets at speeds faster than 10,000 feet per second and our new aircraft up to speeds of mach 4 or higher, they may be struck by fragments ejected by enemy missiles or they may be struck by meteors. A knowledge of the kind and degree of damage resulting from such impacts is urgently needed in our quest for greater missile and aircraft capability, both offensively and defensively. Therefore, studies aimed at devising a rational basis for the design of such vehicles which takes impact vulnerability into consideration are constantly being conducted at NRL.

One of these studies utilizes a special hypervelocity evacuated ballistic range built at the Laboratory. This chamber, which reduces the loss in velocity of a projectile due to air drag, has an over-all length of 54.3 feet, and consists of a 25-foot gun mount, a 20-foot gas-expansion tank, and a 3-foot target chamber. Four ports are available for use in ballistic studies and one port for viewing the target. The entire system can be evacuated to a pressure of 0.2 millimeters of mercury (corresponding to an altitude of 225,000 feet) in about 20 minutes.

The fragment or projectile is accelerated by an improved model of NRL's light-gas gun. This apparatus has interchangeable pump sections varying from 75 to 30 inches in length and barrels ranging from 0.22 to 0.60 calibre. Velocities of 17,300 and 16,500 feet per second have been achieved for projectiles of 3.3 and 6 grams, respectively. This exceeds the minimum mass and velocity required for missile studies by a considerable margin.

Projectiles having a mass of from about 5 to 10 grams have been fired. In these experiments, various materials were used for projectile and target. Also, the shape of the projectile, its obliquity of attack, and the thickness of the target were varied. Damage has been assessed in terms of penetration depths and in terms of volumes and shapes of

Hypervelocity evacuated ballistic range.



craters. As a result, new penetration formulae are being derived to express the results and to estimate probable damages for velocity ranges unattainable with laboratory equipment used previously. This should have direct military application to our missiles program. It should also be applicable to the design of a fragmentation-type non-nuclear warhead for defense against high-speed enemy missiles.

Controlled Fusion Research

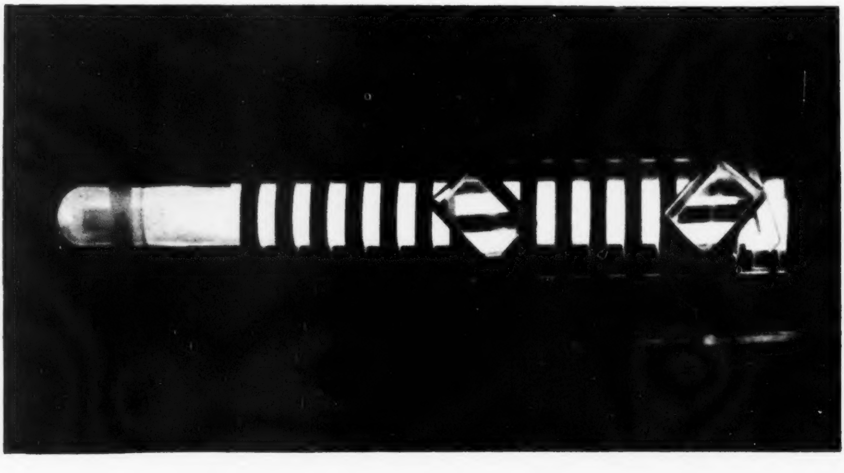
Research leading toward the control of thermonuclear reactions on a laboratory scale and, hopefully, later on a large, economic power-producing scale is being pursued in many countries throughout the world. One approach to the solution of this problem has been under experimental investigation at NRL for the past several years.

The basic idea behind these experiments is to use high-speed shock waves to preheat a tube containing deuterium gas and then to compress the resultant plasma by strong magnetic fields. The compressing field is along the axis of the shock tube while the magnetic forces are radial. These radial forces drive the plasma away from the tube walls toward the tube axis.

The experimental arrangement is shown in the accompanying photograph. The coils which generate the axial field surround the quartz tube. At two points on the tube, image rotators are positioned to facilitate optical observations of the compression.

These experiments are being conducted with a high current condenser bank capable of producing currents in excess of five million amperes in times of the order of 6 microseconds. With this apparatus it is possible to generate pulsed magnetic fields in the 500,000-gauss range.

Shock tube used for research on thermonuclear reactions.



Testing Nuclear Propulsion Equipment

Nuclear-powered propulsion plants designed for shipboard use must be especially rugged to withstand the severe motions caused by rough seas and noncontact underwater explosions, as well as the steady-state vibrations from the ship's machinery during prolonged operation. One of the steps being taken to meet this need is an NRL program for testing various components of such equipment to determine their performance characteristics under all conditions expected to be encountered.

Under the program, sponsored by the Bureau of Ships, NRL conducts shock and vibration tests on developmental and preproduction models with the aim of establishing design criteria which lead to better performance and greater safety. During the past year, numerous equipments have been subjected to shock and vibration tests to determine their suitability for shipboard use. When failures or damages occur during the tests, modifications in the equipment are made, where possible, to preclude their recurrence. At the end of each series of tests, a complete report is issued which describes the test procedures, damages inflicted, corrective measures to be taken, and recommendations for improvements. These reports form the bases for establishing military test specifications and point up factors to be considered in the design of improved equipment.

Tape Scanner and Analyzer

To the scientist studying recorded data from magnetic tapes, a "long-look" visual display of signals is often more meaningful than the product of automatic read-out devices. Until the advent of NRL's scanner, photographic film reproduction was the only means of obtaining such a "long look." But this method is costly and time consuming, especially when an abundance of data is involved. For instance, 4,000 feet of film, at a cost of $152, is required for each 1,000 feet of tape. With the new scanner, filming is no longer needed. Accurate data acquisition is afforded even for very low signal-to-noise conditions.

The machine accepts standard reels of one-half-inch tape containing up to seven tracks of recorded signals. Threading of the tape is as simple as on any standard recorder, and no tape-cutting or loops are required. A rapid search of a recording is achieved by automatically advancing the tape while simultaneously scanning. A search can be stopped at any given point, and scanning will continue. About 20 inches of tape are scanned per cycle at a speed of 30 inches per second. With the incorporation of a ranging-type oscilloscope, an operator can search for and analyze any desired data channel in a matter of minutes. Furthermore, data accuracy of better than 1/10th of 1 percent is easily obtainable.

An experimental commercial tape has undergone more than 75,000 scans without interruption. No deterioration of the signal or tape was observed, and it is apparent that there are many thousands of plays still obtainable from this sample.

The machine was originally produced specifically for analyzing magnetic recordings of satellite data, and the design considerations were dictated chiefly by the 48-channel telemetering code planned for use in satellites conducting X-ray and Lyman-alpha experiments. But its application is by no means restricted to this. Because of its scan-rate stability, tape life, and great ease of operation, it is an excellent tool for most types of data analysis.

Self-Luminous Gear for Fueling at Sea

A difficult and often dangerous test of seamanship arises when a ship must refuel at night during military operations. The ship to be refueled and the tanker must be brought alongside each other while underway, distance lines must be established, heaving lines and fuel hoses need to be passed from one to the other, and the hoses must be kept from sagging into the waves—all in total darkness.

As a result of recent experiments with phosphorescent paint at NRL, this task has been made somewhat easier. The paint is applied to the weighted end of the heaving line and excited by an ultraviolet light. Thereafter it glows with visible green light for a considerable length of time. Although the glowing paint cannot be seen at a distance great enough for detection by unfriendly eyes, it is clearly visible from one ship to the other.

The self-luminous heaving line was immediately successful in tests at sea, and it has been officially adopted by the Fleet for use on all seagoing replenishment vessels. Phosphorescent and fluorescent materials have also been applied experimentally to distance lines, refueling hoses, hose saddles, and operating machinery.

The Effects of Solar Flares on the Ionosphere and Radio Communications

A solar flare is a peculiar excitation phenomenon or magnetic storm in the sun's upper atmosphere that is frequently accompanied by a huge outburst of material from within the sun. The mechanism responsible for this activity is of considerable interest as a subject of study because large masses of matter are given extremely high velocities in the process. Consequently, they travel out through space and impinge on the earth, often disrupting shortwave radio communications.

During 1957, measurements were made of the high-energy X-rays and ultraviolet rays produced during solar flares by means of push-button rocketry utilizing the DAN rocket system (a DEACON rocket attached to a NIKE booster). The rockets were fired from the Naval Air Missile Test Center on San Nicolas Island near Point Mugu, California, upon notification by radio from observers at astronomical observatories at Sacramento Peak, New Mexico; Climax, Colorado; and Mount Wilson, California; that a flare had appeared on the sun.

Although the Point Mugu range is restricted to shipping, 30 seconds were allowed before firing to permit a rapid radar search of the area to detect the presence of any vessels that might have strayed on the firing line. If no halt was ordered by the radar crew within that period, rocket instrumentation was energized and the vehicle launched at the end of another 30-second interval.

Measurements obtained in this way reveal that the largest flare observed produced X-rays of about 2 angstrom units in wavelength, considerably shorter and more penetrating than X-rays from the normal quiet sun. This information indicates that the temperature in the flare region was several million degrees. These short X-rays penetrate deep into the atmosphere and produce ionization below the lowest normally present layer of the ionosphere. Thus they are adequate in intensity and penetration to cause major absorption of short wave radio waves below the normal ionosphere.

Nuclear Research Reactor

The nuclear reactor and its associated facilities for research were designed to meet the needs of a wide variety of investigations in the physical sciences. Its principal function is to provide a powerful source of neutrons required in many aspects of the Laboratory's research programs in such fields as nuclear physics, solid-state physics, metallurgy, chemistry, mechanics, electronics, and reactor technology.

The reactor is of the "modified pool" type, so called because it uses a large volume of water to moderate and cool the reactions of the fuel: 90-percent enriched uranium. Individual fuel plates consist of a 20-mil-thick layer of uranium-aluminum alloy clad with 20 mils of aluminum. Eighteen of these plates, each separated from its neighbor by 0.01 inch, are assembled to form a fuel element. The core is built up by mounting some 25 of these elements on a grid plate suspended below a core bridge. The movable bridge spans the reactor pool, permitting operation of the core at any position along the center line of the pool.

The pool is 40 feet long, 26 feet wide, and 20.5 feet deep. A water gate divides it into two sections, so that operation is possible in one part while the other is being drained for purposes of maintenance or for setting up a new experimental arrangement. The pool is placed above floor level, permitting beams of radiation to be brought out for experimental use through a high-density shield at one end. Seven experimental beam ports, one through-port, and a thermal column are available.

Also included in the facility are a control room, a "hot cell" capable of handling radioactive sources equivalent to several pounds of radium, a chemistry laboratory, a well-shielded counting room, a dark room, several general-purpose laboratories, and limited office space.

During its initial period of operation in 1957, the reactor was run at low power. Flux patterns, power calibrations, and various other reactor engineering studies were made at that time. Since then, routine operation of the reactor at its licensed 100-kw power level for a 40-hour week has been achieved.

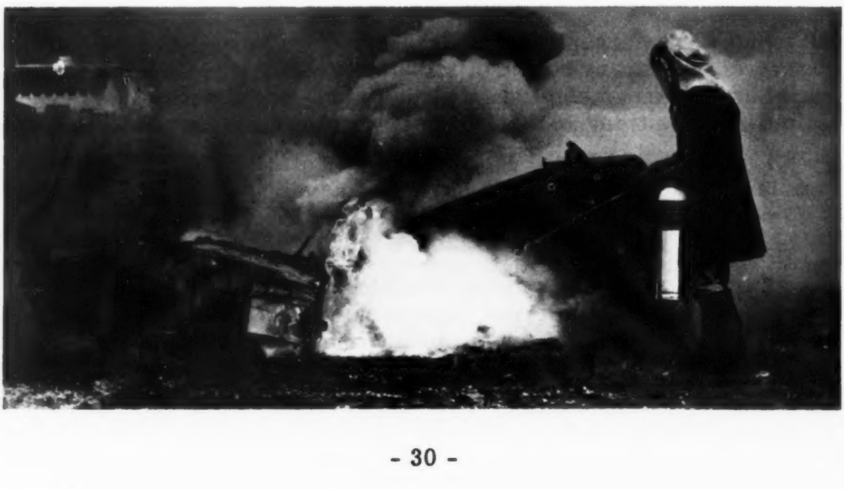
In addition to conducting its own experiments, the Laboratory has cooperated with other government agencies desiring to utilize the reactor radiation. All told, irradiation services have been performed on more than 100 items ranging from blood and tissue in the medical field to ceramic cements and magnetic circuit elements in the physics and engineering fields.

Extinguishant for Metal Fires

An unexpected outgrowth of one of the Navy's fuel programs has been the application of a new boron chemical, trimethoxyboroxine liquid, for the control and extinguishment of magnesium fires in aircraft. Discovered and developed by a research team in the Chemistry Division at NRL, the new nontoxic agent has been placed in use at over 200 Naval air stations around the globe by the Bureau of Aeronautics.

By spraying this chemical liquid (called "TMB" by the industry) on the brilliant white fire of burning magnesium airframes and parts, Naval fire fighters can now for the first time extinguish these fires without fear of explosions and flying hot metal. The stream of syrupy liquid works by decomposing in the fire to a molten sticky mass of boron oxide which coats the burning metal, excluding oxygen and halting further ignition. Cooling water and foam are then applied, and the metal fire is out.

Several dramatic rescues of men in burning aircraft have been made through its use in the past year. One was at NAS, Cherry Point, N. C., where a helicopter fire was fully extinguished and the four occupants of the plane rescued by expeditious use of TMB extinguishers and foam. Recent tests by the Atomic Energy Commission, in which the NRL extinguishing liquid was used on titanium, zirconium, and uranium metal fires, have shown that TMB is the only available agent that extinguishes these fires successfully. In spite of the drawback that the presence of boron "poisons" a reactor, the Commission is considering its use at its installations.



On the Naval Research Reserve

Tenth Annual ONR Reserve Research Seminar

The Naval Reserve Research Seminar, held annually by the Office of Naval Research, convened at Washington, D. C. on June 16, 1958, for a two week period. During the meeting, 80 reserve officers were brought up-to-date on current research and development activities in the Navy. Thirty-nine of these officers were in the Naval Reserve, 21 in the Army Reserve, 19 in the Air Force Reserve, and one in the Coast Guard Reserve.

RADM R. Bennett, USN, Chief of Naval Research, who delivered the opening address, said that this tenth seminar was being held in an atmosphere completely different from previous ones. "Whereas a decade ago the significance and value of basic research was but dimly recognized," he noted, "events of recent months have alerted our country to the vital necessity of research in providing us with a strong national defense. Today the public looks to the scientist and the engineer to lead us across new frontiers, dealing with possibilities that were in the realm of fantasy when this annual seminar was inaugurated ten years ago."

Other high-ranking officials who addressed the opening public session were the Honorable J. B. Macauley, Deputy Assistant Secretary of Defense for Research and Engineering, and CAPT K. M. Gentry, USN, Deputy Director (Research and Development), Office of the Chief of Naval Operations.

As was done so successfully for part of last year's seminar, the participating officers were divided into groups according to research interests for half of the meeting. The program and tours for each group were arranged by the group leaders, all of ONR. These were Undersea Science and Technology, chaired by CDR G. Thomas, USN, Undersea Warfare Branch; Frontiers in Electronics, with Dr. A. Shostak, Head, Electronics Branch, as Group Leader; Missile and Upper Atmosphere Science and Technology, led by LCDR M. R. Clement, USN, Surface Branch; Human Factors of Naval Systems, under the leadership of CAPT C. P. Phoebus, MC, USN, Special Assistant for Medical and Allied Sciences; and Advances in Information Systems, with Dr. M. C. Yovits, Head, Information Systems Branch, as Group Leader.

This year's program was planned and conducted by NRRC 5-8. CDR W. M. Smedley, USNR, served as commanding officer of this company, and CDR J. R. Patton, Jr., USNR, was the seminar chairman. The meeting was one of ten of its kind held throughout the country and sponsored by the Office of Naval Research during fiscal year 1958 to provide active-duty training for reserve officers.

During the program the reservists heard classified talks by RADM R. L. Johnson, USN, Director, Long Range Objective Group, Office of the Chief of Naval Operations; BGEN S. R. Shaw, USMC, Deputy Chief of Staff (Research and Development); Dr. A. K. Brewer, Basic and Technical Intelligence Branch, Office of Naval Intelligence; RADMs

W. F. Raborn, USN, and W. K. Mendenhall, Jr., USN, also addressed the group. The latter are Director, Special Projects Office, Bureau of Ordnance, and Commander, Operational Development Forces, U. S. Atlantic Fleet, respectively.

Also included in the list of speakers were a number of ONR scientific personnel and representatives from two of its field activities—the Naval Research Laboratory and the U. S. Naval Training Device Center. The Office of the Chief of Naval Operations and the Navy's bureaus also furnished speakers. Other government agencies represented on the speakers' list included the Army, Air Force, the Atomic Energy Commission, and the National Academy of Sciences.

In the course of the seminar, tours were arranged for the research groups to various activities in the Washington area. Two evening meetings were held: conferees attended a company meeting of NRRC 5-8, Washington, D. C., and a dinner meeting held at the Officers Club of the Naval Gun Factory.

Staff Corps Reservists Promoted to Lieutenant Commander

As reported in the June issue of Research Reviews, 103 members of the Research Reserve were selected for promotion to the grade of Lieutenant Commander by the Fiscal Year 1958 Inactive Reserve Selection Board. In the past months selections for Lieutenant Commander have been made by this year's board in the various staff corps. The 10 Research Reserve officers selected for promotion and their respective companies are as follows:

ADINOLFI, Roechina N.	3-1
BRYANT, John D.	3-10
HENDRICKS, James T.	3-10
SAMUELS, Reuben	3-13
THORNTON, John L.	5-5
ROSS, Sherman	5-10
COLQUITT, Vergie	6-2
HANSEN, Margaretha E.	9-5
ROESSLER, Robert B.	11-1
RUPPEL, Henry D.	13-6

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NRL's Research Associates

July 1 marked the beginning of the fourth year of a fellowship program calling for the appointment of up to ten "Postdoctoral Research Associateships" per year at both NRL and the National Bureau of Standards. Although initiated and funded by NRL and NBS, the associateship appointments are made by the National Academy of Sciences—National Research Council. Under the provisions of the program an able young man who has earned the Ph.D. degree may be selected to work in his own field of research at NRL under a scientist who is doing research in the same field. The tenure (GS-11 rate) is for one year, although this may be extended an additional year if the associate wishes and the work underway appears to warrant it. No commitment on the part of either the associate or NRL with regard to permanent employment is made.

The main object of the program is to increase the general fund of scientific knowledge in the United States. As a springboard for achieving this aim, NRL is particularly well suited. This is indicated by the breadth of the research program set up for the associates at the Laboratory. In charting their postdoctoral studies, prospective associates can choose between 39 separate areas of research encompassed by the following broad fields of investigation:

Applied mathematics	Nuclear Studies
Chemistry	Physics
Electronics	Engineering Psychology
Metallurgy	Solid-state physics

So far, 12 associates from schools as distant as the University of Hawaii have been chosen for research at NRL. Of these, five have undertaken, or are slated to undertake, work in nucleonics, two in metallurgy, two in solid state physics, one in chemistry, one in physics, and one in engineering psychology.

The program can now be evaluated as an unqualified success. Although not a recruiting device, it has served to direct some highly talented men into the regular research program at the Laboratory as permanent employees after they have completed one or two years as associates. All of the others have gone on to universities where they have become "ambassadors of good will" for the Laboratory. Furthermore, the brochure issued by NAS-NRC to publicize the program has been made available to graduate students in about 400 universities throughout the country. Whereas previously many of these men had only a vague notion concerning NRL's research program, they now have a good understanding of it, and are thus in a position to advise many other possible recruits of the opportunities it offers.

Both NRL and NBS plan to continue the associateships, and recently several other agencies have indicated a desire to establish them.

Further information concerning the program can be obtained from Dr. Claude Lapp, Fellowship Office, National Research Council, Washington 25, D. C.

In This Issue

RESEARCH REVIEWS endeavors to report briefly highlights of technical progress in research by Navy laboratories and contractors and the development of important naval research facilities. Articles which meet these broad criteria and possess a good degree of readability are welcomed. Manuscripts and changes of address should be sent to Code 740, Office of Naval Research, Washington, D. C. ... Research Reviews is listed for sale by the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. Subscription price: $1.50 per year in U. S. and Canada; $2.00 per year, foreign; $0.15 per individual copy. Use of funds for printing this publication was approved by the Director of the Bureau of the Budget, February 12, 1958.