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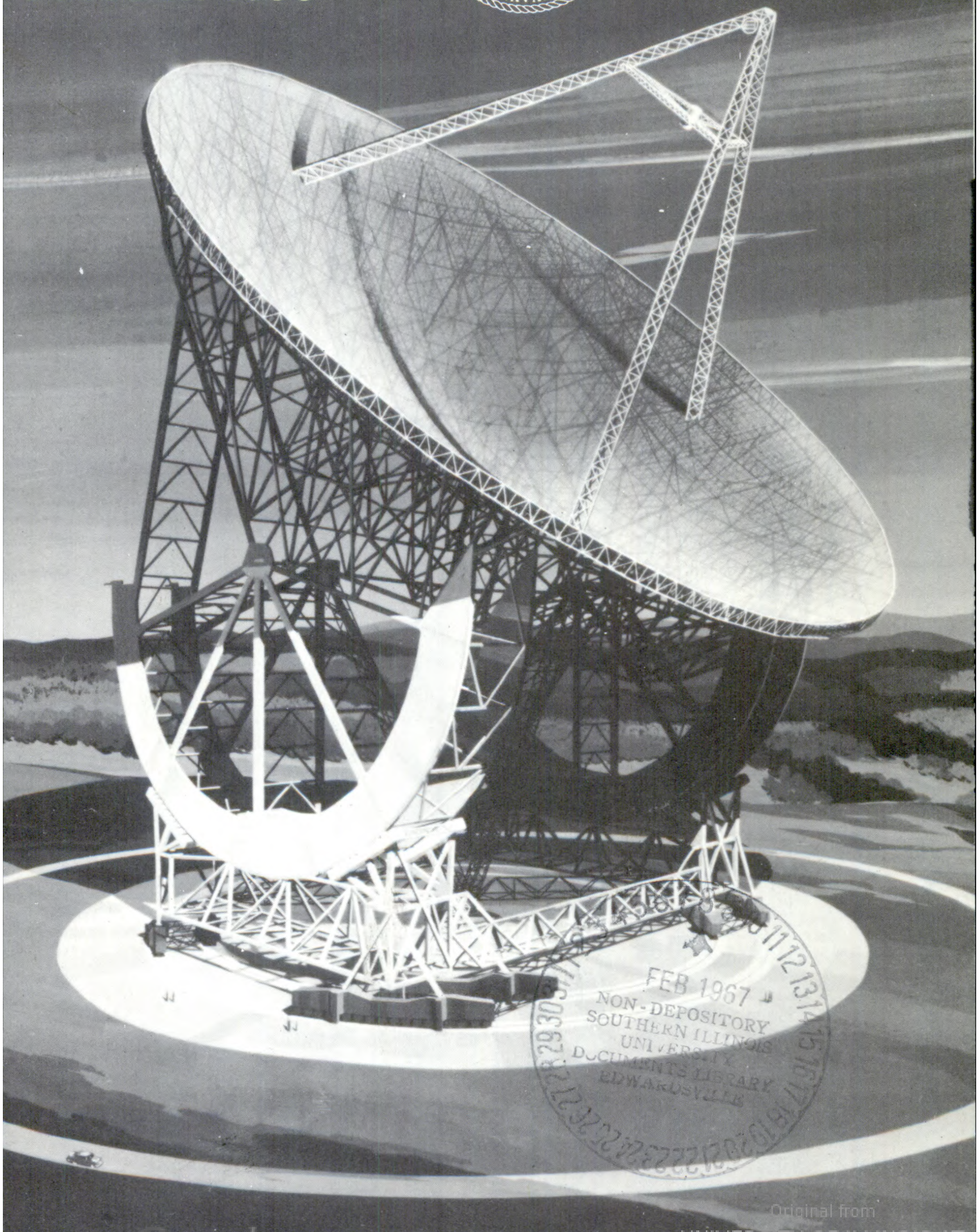

NAVEXOS P-510

Threat to Manned Space Flight

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Press accounts of the September Russian moon rocket were quite complimentary. On the assumption that Soviet announcements were correct, the glowing press reports were well justified. A tremendous technical capability in propulsion and guidance was reflected by the accomplishment.

Peripheral accounts indicated, however, by statement and inference, that manned flight to the moon--and manned space flight in general--is an event we should expect to follow soon as a logical "next step." This is not true.

Drs. E.P. Ney, J. R. Winckler, and P. S. Freier, of the University of Minnesota, have recently published information concerning a major new discovery of a "soft" radiation which, although not well publicized, may impose the most serious threat yet to manned space flight.

This new radiation, which tends to make the hazards of Van Allen radiation belts seem pale by comparison, is apparently associated with solar activity. Over the past few years it has been observed with different observational techniques by physicists at the State University of Iowa, the University of Minnesota, and the Geophysics Institute of the University of Alaska. At the time of a giant solar flare on the 12th of May of this year, several simultaneous unmanned balloon flights were made by the Minnesota group. These flights revealed a tremendous burst of protons, or hydrogen nuclei, from the sun, which resulted in unsuspected high amounts of this radiation at balloon altitudes in our atmosphere.

Subsequent balloon measurements during similar solar activity have been made which confirm the existence of this shower of solar cosmic radiation associated with events occurring on the sun. A maximum level of 10,000 times normal has been measured during one instance, and the over-all disturbed period (where the ionizing radiation exceeds normal background) appears to persist for durations of from 1 to 8 days. The work described here is part of a broad research program in high altitude physics conducted by the University of Minnesota, with support on a continuing basis by the Office of Naval Research.

In terms of manned space flight it is estimated that when one of these events occurs the intensity which might be received by an individual in space (in our solar system) is in the order of 1,000 Roentgens per hour. According to currently accepted tolerances, 30 minutes of this exposure would result in a dosage which would be fatal to about 50 percent of the personnel exposed. Even at balloon altitudes in our atmosphere the <u>measured rate</u> is 10 Roentgens per hour, a serious hazard for manned high-altitude flight. Shielding is an obvious solution; however, the amount of material required for adequate protection in extraterrestrial flight will impose a severe weight penalty and may not be a practical solution.

We must face facts regarding manned space flight. Technical problems can and will be solved as they occur. The major new radiation discovery, however, is a recurring natural solar phenomenon, the result of a mechanism and events on the sun which are not completely understood. Further, its occurrence cannot be forecast at this time, although work in this area is now in progress. This new radiation problem may also be solved in due time. But at the present it makes manned space flight appear quite unrealistic.

[The opinions expressed here are those of the author and do not necessarily represent those of the Department of the Navy.—Ed.]

An Explanatory Statement on Elementary Particle Physics

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During the years immediately following World War II, the Office of Naval Research was the leading contributor among government agencies to the study of elementary particles. Although the Atomic Energy Commission has borne the brunt of government support in the field since that time, ONR has continued to back a number of important subatomic investigations. What is the explanation for the government's interest in atomic particles? It is given in the following report, prepared by a special panel appointed by the President's Science Advisory Committee and the General Advisory Committee to the Atomic Energy Commission.

Elementary particle physics is the exploration of the subatomic world. It is concerned with phenomena remote from our immediate and familiar surroundings, but applications stemming from this branch of physics have had profound effects upon our technology, our national security, and even our daily living. And yet elementary particle research proceeds, not with any view toward useful application, but by pursuing discovery for its own sake. It is the very heart of modern physics, and the product of many centuries of effort to understand our universe. This statement seeks to convey something of the main ideas of elementary particle physics, its spirit, its methods, its results, and its value to our society.

The realm of the physicist is ever changing. Knowledge of the physical universe increases at an enormous rate, and the physicist—who explores the rapidly shifting border between the known and the unknown—continually departs from familiar areas and enters into new and unknown regions. Fifty, even twenty-five years ago the main branches of physics were quite different from present fields of investigation. Radio waves, electronics, the forces that bind molecules, the arrangement of electrons in the atom, the radiation and absorption of light—indeed, most of the phenomena which so strongly held the attention of physicists half a century ago—are now a part of the subject matter of other disciplines. Just as the mechanical physics of Galileo and of Newton have given rise to the separate professions of mechanical engineering and civil engineering, so these phenomena are now, for the most part, part of the domain of the electrical engineer, the physical chemist, and similar specialists. Even nuclear physics, the main focus of attention of physicists just ten or twenty years ago, has already given birth to the separate fields of nuclear chemistry and nuclear engineering. The frontier of knowledge, and with it the chief concern of physics, is moving into newer regions.

The exploration of the physical universe has proceeded in two directions, opposite but not unconnected. From the partial understanding by Newton and his contemporaries of the behavior of the familiar objects of our world, of the motions of bodies when forces are exerted upon them, of the flow of liquids, and of the changes in a gas when we heat or compress it, our knowledge has expanded to encompass phenomena which take place on a scale vastly different from that of our immediate experience.

Physicists now comprehend not only the structure of stars, the motion of our own and other galaxies, the curvature of space, the possible ways in which our universe has evolved, but also matter on a finer and finer scale: from familiar objects to molecules; then to the atoms of which the molecules are composed; the internal structure of the atom with its electrons orbiting around nuclei; the nucleus itself, made of protons and neutrons and the mesons which bind them together; and lately even something of a picture of the inside of the proton itself, complex and containing yet other particles. We are peeling an onion layer by layer, each layer uncovering in a sense another universe, unexpected, complicated, and—as we understand more—strangely beautiful.

ELEMENTARY PARTICLES

The basic particles out of whose interactions and combinations our whole universe seems to be formed are called elementary particles. It is a term whose significance has varied enormously as our view of the physical universe has become more detailed and precise; the changes in its meaning mirror the history of modern physics. In the time of Newton and for almost a century thereafter the connection between the structures of different materials was not understood and there were, in this view of our world, as many elementary particles as there were kinds of matter: water, salt, oxygen, iron, quartz, etc., an immense number. The uncovering of a finer structure to matter, mainly in the nineteenth century, revealed that all matter, with all its different sorts of molecules, was composed of fewer than 100 kinds of atoms; these became the elementary particles of last century's physicists. Shortly before the first world war we had our first look inside the atom. It appeared as a very small core, the nucleus, surrounded by one or more electrons whose configuration determined the chemical properties of the atom. More than two decades ago the tiny nuclei themselves were split open. Observations were difficult, fuzzy, approximate, but clearly showed that all nuclei were composed of combinations of protons and neutrons. And so, as we peeled our onion and looked to more infinitesimal distances we saw that our approximately 100 atoms were indeed not truly the elementary particles of our universe, but were themselves made up of a very few kinds: protons, neutrons, electrons. To this list we should perhaps add the light wave. It has had many aliases in our times: electromagnetic radiation, the X-ray, the gamma ray, the quantum, the photon. It has appeared in various guises, identified as different entities according to whether it had great energy, or very little energy, or was acting as a wave (such as a sound or ocean wave), or as a particle in the manner of a bullet or a speck of sand. It has been a triumph of modern physics to understand this dualism in the behavior not only of light but of all particles; physicists now realize that what are conventionally labeled as particles have wave properties, and conversely that the light wave is as much an elementary particle as the electron, or the proton, or the neutron. But the view that these four particles might be the ultimate elementary particles of our universe has been emphatically destroyed. Various elementary particles, when looked at with instruments which can resolve extraordinarily fine detail, have revealed a substructure involving a host of new and strange particles. Our onion has more skins.

WAYS AND MEANS

With our eyes we can distinguish objects whose size is as small as three thousandths of an inch. A microscope is used to see detail on a much finer scale. But the wave nature of light limits the sharpness of detail that can be observed. Theory predicts and experiment confirms that with even the most perfect optical instrument it is not possible to see anything smaller than the wavelength of light. For visible light this is about 0.00001 inch, a thousand times the radius of an atom, a hundred million times as large as a nucleus. And so in the conventional sense we cannot see an atom or a nucleus, nor can we ever hope to do so. The exploration of atomic and nuclear particles demands a different type of vision, different kinds of instruments.

One way to try to see to atomic distances and beyond is to use light of a wavelength much shorter than that of normal visible light, X-rays, or gamma rays. Such short-wavelength forms of light are emitted only by sources that can impart a great deal of energy to a single light wave; the higher the energy the shorter the wavelength and the more clearly we can see.

All the sources of very-short-wavelength radiation that are employed by physicists are based on the simple fact that when an electron hits a target it radiates light; the greater the energy of the electron the shorter the wavelength. Thus a beam of electrons is the source of radiation not only from an X-ray tube, but also from betatrons and electron synchrotrons, which use electrons many thousands of times as energetic and emit radiation whose wavelength is correspondingly many thousands of times shorter.

However, short-wavelength light is not the only tool used to explore down to nuclear dimensions and below, nor is it even the main one. A beam of particles itself can be used, like a beam of light, to probe the atom, the nucleus, and beyond. The astonishing discovery of wave-particle dualism means that particles of matter—electrons, protons, and all the rest—behave in many phenomena exactly like light waves. They too have associated with their motion a wavelength which decreases as their energy increases. And, as with light, this wavelength limits the detail that can be examined with a beam of particles. Thus an electron microscope, which uses an electron beam instead of a beam of visible light, resolves more detail because it utilizes electrons whose wavelength is smaller than that of visible light. The resolution increases with the electron energy. Of course a "look" with a beam of electrons gives a picture different from that obtained with visible light. Beams of high-energy protons furnish still another view of our submicroscopic universe. These various tools provide equally valid descriptions but differ in the precise information which they give. It is figuratively as if we have photographed our landscape with a variety of cameras, one of which films only the houses, another the trees, a third the streets.

The familiar objects around us are unaltered when we turn on a light in order to see them. The molecules and the atoms of a cube of sugar or a glass of water are not appreciably disturbed by visible light. However, if we increase the energy of the light or particle beam in order to decrease its wavelength and see to atomic dimensions, then the energetic light waves or particles seriously shake up the atoms and often break them up into their constituent electrons and nuclei. Beams of short enough wavelength to probe a nucleus also have high enough energy to split the nucleus apart by knocking out the tightly bound protons and neutrons of which it is made. A detailed observation violently disturbs the system that is observed; this is a quite general consequence of the laws of quantum mechanics (the description of the behavior of particles on the atomic and subatomic scale). In this way a sufficiently high-energy beam of light (particles) striking a proton or neutron or any other target particle has two associated consequences. It offers a partial view of the target's interior and it frees various new particles.

Conventional pictures and words are inadequate for the description of these subatomic phenomena; it is not sufficient to think of familiar analogies on a reduced scale. When a piece of wood is chipped from a table we have two new objects, a chipped table and a piece of wood. But occasionally some particles may be "torn" from a proton and still leave the proton intact. In this sense we may consider the new particle to have been "created" in a high energy collision. The "creation" takes energy, for we must still conform to Einstein's familiar relation $E = mc^2$ and supply the energy (E) which appears as the mass (m) of the new particle. An example of particle creation is the production of an elementary particle called the pion or pi-meson. When we probe the proton there is abundant evidence for such mesons in its structure; even their arrangement is in part known. But to "see" the tiny pion inside the proton requires a beam of very short wavelength, and hence high energy. It is a general consequence of the laws of quantum mechanics that the energy of the particles in the beam must be just high enough to create a pion, using the relation $E = m_{pion}c^2$. Thus the same beam which can distinguish the pion inside the proton can liberate (or "produce") pions. Separate measurements can then be made to determine the properties of these free pions. Moreover, freshly produced particles like pions can be focussed into secondary beams which are themselves used as probes to obtain a view of the submicroscopic universe different from, and complementary to, that obtained from the primary beams of light waves, electrons, or protons.

Thus the main tools of the physicist who explores the subatomic universe are the beams of high-energy particles which are his light, and the various devices to detect these particles which are his eyes.

High-energy particles exist in cosmic rays, but these are infrequent and uncontrolled. Our understanding of the ultimate structure of matter and energy depends upon the great particle accelerators, which take low-energy electrons and protons and impart to them the enormous energy necessary to "see" to distances which are to the thickness of a sheet of paper as that thickness is to the distance to the moon. The primary beams of electrons and protons are themselves useful probes, as also are the secondary high-energy beams of light, neutrons, mesons, etc., which they produce.

The various kinds of particle accelerators all work in a similar way. Electrical energy is imparted to an electron or proton by repeatedly "kicking" the particle, just as the electrons in a wire or a light bulb are "kicked" when the electrical switch is turned on. The total energy given to the particle is measured in terms of the necessary voltage difference to give an electron this same energy. For a giant accelerator this is some billions of electron volts (abbreviated Bev). The electron or proton may be given a few very hard kicks, as in the linear accelerator, or it may move in a circle and receive an enormous number of precisely timed small "kicks," as in the cyclotron and its sophisticated offspring, the Bevatron (6 Bev) and the Cosmotron (3 Bev). The design and construction of these accelerators is an enormous engineering feat which both taxes and expands our technological abilities. The voltage given to a proton by such accelerators equals that from a string of flashlight batteries about a million miles long. Equally sophisticated has been the development of particle detectors, the eyes of the elementary-particle physicist. These range from extra-sensitive photographic film, or specialized counters to detect particles of only a certain speed or charge or mass, through cloud chambers in which particles leave visible droplets in their paths (similar to the vapor trails behind jet planes), to similar giant bubble chambers already as large and complicated as cyclotrons. Like the building of accelerators, the design and use of these devices substantially contributes to our technological resources.

STRANGE AND SIMPLE PARTICLES

At present about thirty subatomic particles have been discovered. These are now the elementary particles whose number may grow or dwindle as we explore more deeply. Despite our basic ignorance about them, we already know many of their properties and systematic interrelationships. Many are known to be spinning like tiny tops.

Almost half of our elementary particles are a form of matter known as antimatter. Its existence was predicted by the theory of relativity applied to quantum mechanics and has been amply confirmed by experiment. Corresponding to every charged particle and almost every neutral particle there is a twin, identical in some properties, opposite in others: the electric charges are opposite, the masses and spins are identical, their interactions with other elementary particles are closely related. Whenever a particle and its twin come together they annihilate each other, with total conversion of their mass into rapidly moving lighter particles or even entirely into high-energy light waves. (Again $E = mc^2$ describes the mass-energy balance.) When mixed together, matter and antimatter instantaneously yield more than a thousand times as much energy per pound as an atomic bomb. Although we can create antimatter in collisions of sufficiently high-energy particles, the antiparticles almost immediately collide with neighboring particles and annihilate themselves and these new partners. Antimatter apparently cannot be stored on earth, but the possibility of its existence raises interesting and unanswered questions. Are there regions of our universe normally composed of antimatter just as our local surroundings are entirely normal matter? To what extent would the laws of physics in such regions be identical to our own?

We have come to know some peculiar beasts in our zoo of the elementary particles:

Neutrinos are emitted by radioactive nuclei whenever they emit electrons. Like light waves they have no mass at all and no charge, but, unlike them, almost no interaction with other particles. A beam of neutrinos is unaffected even when going directly through the earth itself. Our sun, whose energy is produced by nuclear reactions, emits an enormous flux of neutrinos. Every second, hundreds of billions of these neutrinos pass through each square inch of our bodies, coming from above during the day, and from below at night, when the sun is shining on the other side of the earth!

Muons are apparently in every way like electrons except that they are 215 times as heavy. A muon is not, however, a stable particle. It lives on the average a millionth of a second, after which it decays into an electron, a neutrino, and an antineutrino.

Pions, or pi-mesons, slightly heavier than muons, have been observed to play a vital part in the structure of protons and neutrons. It is the continuous exchange of pions between neutrons and protons that binds them together into a nucleus. The pions are the main constituent of the nuclear glue. But when free, each of the three kinds of pions—positively charged, neutral, and negatively charged—breaks up into other particles. The charged pions decay into muons (themselves unstable) and neutrinos in about a hundred millionth of a second. The neutral pion decays into two high-energy light waves (photons) in less than a millionth of a billionth of a second.

Strange particles are a group of eight newly discovered particles and their antiparticles. They are really no stranger than pions or protons but differ in various properties. They are significantly heavier, so that only giant Bev-accelerators can produce them and begin to illuminate the role they play in the structure of other elementary particles. Therefore, the detailed exploration of their properties has just begun. All the "strange particles" are unstable, and some decay into many different groups of particles. For example, the K meson is a strange particle more than three times as heavy as a pion. It usually decays into a muon and a neutrino, but it can also break up in many other ways. It was the observation of different decay modes for this particle that suggested that an important property known as parity was not conserved—an idea that has proved fruitful in explaining the emission of electrons from radioactive nuclei. Thus experiments that awaited the construction of giant high-energy accelerators have played a vital role in clearing away misunderstanding in a sixty-year-old branch of low-energy nuclear physics.

The more familiar protons, neutrons, electrons, and light waves (photons) complete the list of the known elementary particles. Besides the neutrino, only these four are stable. Even the neutron can be stable only inside nuclei; the free neutron decays after an average lifetime of 18.5 minutes into a proton, an electron, and an antineutrino. Neutrons and protons are the familiar building blocks of nuclei, which, together with electrons, form the atoms of the hundred different elements.

Because all other particles are unstable, "new" particles created by high-energy beams are always transient. The new particles quickly decay or—if they are antiparticles—are annihilated with suitable partners. The decay and annihilation products are themselves generally unstable, so the chain of degeneration of heavy particles into lighter ones proceeds rapidly. A residual electron or proton or neutron is always found to be a replacement for another such particle, originally present but annihilated by an antiparticle. The ultimate net result of the feeding of electrical energy into giant accelerators is its final dissipation into neutrinos, light (photons), or heat. It is the brief look between these events that, to the physicist, is priceless.

WHAT IS TO BE LEARNED?

We cannot know what will be discovered from deeper probings of the subatomic world. Our only guide is past experience, and here the lesson is evident that nature often turns out to be remarkably different from any expectation. But enough is understood about our physical universe to suggest specific questions whose answers may emerge from further exploration.

The classification of the elementary particles and their interactions is more than a mere catalog. Definite patterns have been recognized which are suggestive of the familiar ordering of the chemical elements in the periodic table. But the pattern of elementary particles is not yet so complete as that of the chemical elements, and there are numerous possibilities for new particles whose discovery would confirm those regularities which seem to be present.

Perhaps the most remarkable property of the elementary particles is their large number. The feeling of most physicists is that there are far too many for them all to be elementary. It is a situation reminiscent of the time when each of some 100 atoms, the chemical elements, apparently merited the label "elementary." Then a detailed probing within these atoms showed them all to be combinations of protons, neutrons, and electrons, and reduced the number of relevant elementary particles to three. Whether a detailed look at the structure of our present elementary particles will disclose a similar simplification is one of the profound and critical unanswered questions of the modern physicist. Present accelerators produce beams whose energy is on the borderline of revealing something of the internal structure of these particles, but their energy is still too low to permit such detail to be resolved. Giant accelerators whose energies are some tens or perhaps ultimately hundreds of Bev would be as welcome as powerful glasses to the near-blind.

Despite our ignorance of the answers to the most fundamental questions about the elementary particles, there is one area in which our understanding seems satisfactory. The electron and the light wave and their mutual interaction are a system for which the fusion of quantum mechanics, relativity, and the theory of electric and magnetic fields into the new theory of quantum electrodynamics, although certainly incomplete, has produced answers in fantastically good agreement with experiment. Therefore it has been the model for attempts to build theories to describe the other elementary particles and their interactions. It remains to be seen whether this single successful theory remains valid when higher energy beams of electrons and light become available.

Our various laws of physics generally do not remain unaltered as we seek to apply them to ever more diverse phenomena. We see them rather as approximations, accurate and sufficient only in limited domains. To preserve the law of conservation of energy, first heat and then matter had to be considered forms of energy. The epoch-making Newtonian laws of motion are now seen to be valid only for velocities much smaller than those of light. For the description of atomic particles, conventional mechanics is superseded by quantum mechanics. Physicists wonder whether relativity and quantum mechanics will continue to be correct descriptions of nature as we explore to smaller and smaller distances. Do signals always propagate at speeds smaller than that of light no matter how small the interval? Does the relation between energy and wavelength hold for arbitrarily small wavelenghts? Even if we learn that our present laws remain valid in this new region, the knowledge that this is true would be of enormous significance.

It may be that our very ideas of space and time may not be adequate for continually deeper exploration of the subatomic world. Is there perhaps a smallest distance inherent in space itself? Can ordinary Euclidean geometry continue to be applicable to such incredibly small lengths? We already know that it is not applicable to enormously large ones. Perhaps the answers to such questions may illuminate the long-sought connection between inner space and outer space, the submicroscopic and the astronomical universes.

Pure research, stimulated by curiosity and the satisfaction of accomplishment, has given us knowledge and understanding of many of the phenomena of our world. The rapid exploitation of such discoveries, especially in this century, has resulted in our present amazing technology. These tangible returns from pure research have been gigantic. From the brilliant investigations of nineteenth-century physicists on the nature of electric and magnetic fields have developed electric power, electronics, radio, television. Examples from the past are countless. Even in recent decades we have witnessed enormous application of discoveries merely incidental to research in elementary-particle physics: isotopes, nuclear fission and power, medical therapy with high-energy beams, a step toward controlled thermonuclear power—a list that continues to grow rapidly.

The practical results that must derive from continued exploration with larger accelerators cannot be guessed. If the past is a guide they will be numerous and fantastic. The one thing that we have leanred to expect from nature is to be surprised.

The M.I.T. Whirlwind I Computer

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The Whirlwind I computer, located in the Barta Building of Massachusetts Institute of Technology, was shut down on May 29, 1959, after nearly eight years (62,000 filament hours) of operation. This computer has played an historic role in modern computer technology and has been a vital part of many Lincoln Laboratory programs. The decision to halt operation of Whirlwind was based on practical considerations: commercial computers now available are faster and more economical to operate and employ programs which are interchangeable among computers of the same type, and developmental computers like the Lincoln TX-2 offer still more advanced capabilities.

Planning for Whirlwind began in 1946, and the machine went into full-scale operation late in 1951 as the largest, fastest digital computer in existence at that time. It was designed by the M. I. T. Digital Computer Laboratory, which subsequently became the Digital Computer Division of Lincoln Laboratory, a research facility supported by the three services. The design and construction was sponsored by the Office of Naval Research; costs for operation and further development were later shared by other users, notably the Air Force. It is estimated that the total cost to the government, from 1946 to final operation, was approximately 7.5 million dollars. Few investments have yielded larger returns in terms of technical achievement.

Whirlwind was originally intended for real-time simulation of the performance of an aircraft in flight, as part of a pilot training device for the Special Devices Center of ONR.* The need for a memory system of unprecedented speed and capacity, for this task and for other important applications, led to the development of the electrostatic storage tube. The rapid evolution of computer technology during the period 1946 to 1951, stimulated to a considerable degree by the development of Whirlwind itself, made possible widespread applications of digital computers to many broad problem areas. In the course of this expansion, Whirlwind became an important proving ground for trouble-location methods, computer logic, and circuit and component design. In late 1951, the Air Force became the principal user of Whirlwind, in research on urgent air-defense problems from which evolved the SAGE System, now going into operation all over the continental United States.

The feasibility of basic SAGE concepts, that a digital computer can semiautomatically process radar data, generate displays, and guide

*Now the Naval Training Device Center, a field activity of ONR, located at Sands Point, Long Island, N. Y.

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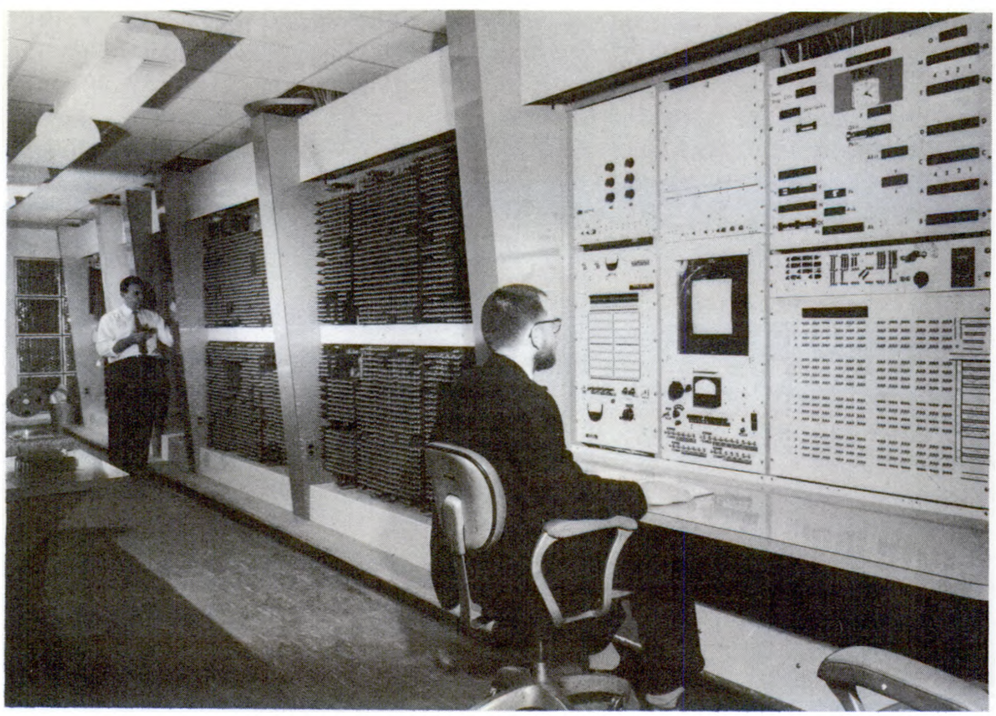
Figure 1--Central computer unit of Whirlwind I occupies 224 lineal feet of racks, ten feet high.

Figure 2--Lincoln TX-2 computer and control console. Central computer unit, including the large core memory (not shown), occupies 48 lineal feet of racks, six feet high.



defensive weapons, was first demonstrated with Whirlwind in 1951 and 1952. Lincoln Laboratory's initial air-defense-system task was the design and construction of a laboratory model system, comparable to a single SAGE sector, located in eastern Massachusetts and known as the Cape Cod System. This model system comprised one long-range radar, several gap-filler radars, data-handling facilities, and a ground-to-air communications system, and was built around the Whirlwind computer with an air-defense direction center facility set up in the Barta Building in Cambridge.

Experience gained from operation of the Cape Cod System from 1953 on was reflected in almost every aspect of the design and development of the SAGE System and subsystem components, including computer circuits and computer programs, data processing and transmission equipment, and communications systems. The Cape Cod System as a vehicle for SAGE development was supplanted by the Experimental SAGE Sector, with a prototype Direction Center at Lincoln Laboratory, but the Whirlwind computer continued to provide essential services for a variety of Lincoln projects and academically oriented scientific and engineering applications. Whirlwind applications during the last year have included such diverse topics as research on computer-aided civilian air-traffic control and machine recognition of hand-printed block letters.

Whirlwind was a primary test vehicle in early 1954 for the first magnetic core memory, a fundamental contribution by M. I. T. to modern digital-computer technology. The largest such memory in current use (approximately 2.5 million cores) was developed and built by Lincoln Laboratory; it was initially tested on the Lincoln TX-0 computer and is currently in use with the TX-2. This memory served as a developmental prototype for a large memory unit now being produced by I. B. M. for operational AN/FSQ-7 SAGE computers; the first such unit was installed last fall in the AN/FSQ-7 (XD-1) computer in the Direction Center of the Experimental SAGE Sector.

Automatic programming techniques developed on Whirlwind are now used almost universally, and indeed are essential to the effective application of the battery of commercial machines now in operation. The "Comprehensive System" pioneered at M. I. T. for use on Whirlwind is the origin of many present-day automatic programming techniques, such as the cooperative SHARE system for I. B. M. 704 and 709 computers. The Comprehensive System was the first successful attempt to reduce programming effort by using a versatile standard language of man-machine communication and to avoid redundancy by the establishment of a large library of common subroutines.

Three original types of programs were employed in the Comprehensive System. The assembly or compiler program, using the symbolic (floating) address technique, relieved the programmer of endless drudgery and enabled him to prepare complex practical programs in mnemonic and symbolic form. The interpretive program enabled the programmer to employ fixed and floating point arithmetic to obtain precision higher than the limit imposed by the word length of the machine itself, by simulating a computer with a longer word length. The diagnostic program used the computer to analyze and de-bug other programs by post-mortem analysis of operations and results. Such programming techniques, first developed with Whirlwind, have had a powerful influence on all modern computer applications.

Whirlwind has thus contributed to a very considerable extent to the rapid technological advances which have resulted in its own obsolesence. To illustrate the extent of the changes that have taken place in the past decade, certain characteristics of the central computer portion of Whirlwind may be compared with the corresponding characteristics of the Lincoln TX-2 computer, as follows (see also photographs on page 10):

Characteristic	Whirlwind	TX-2
Basic word length (bits)	16	36
Speed (average operations per second)	30,000	120,000
High-speed core memory (bits)	100,000	2,500,000
Cathodes	9,000	1,000
Diodes	17,000	700
Transistors	0	30,000
Power (kilowatts)	150	20

A Boston engineering concern is presently negotiating with the Office of Naval Research to lease the Whirlwind computer and associated equipment as a complete unit, planning to move it to a new location in Cambridge for use on research and development contracts.

BuMed has Enviable Record

The name is the same after 117 years, but the Navy's Bureau of Medicine and Surgery is synonymous with medical advancements. On August 31, 1842, Congress established the present Bureau, which is the only one in the Navy Department retaining its original name. The first hospital was established at Norfolk and began receiving patients in 1830. Others followed at Philadelphia in 1833, Boston in 1836, and Brooklyn in 1838. The title, Surgeon General, was not created until 1871, and is now held by Rear Admiral Bartholomew W. Hogan, recently re-appointed by the President to a second two-year term.

The first female nurses on record in the Navy were those of the Civil War. The Nursing Sisters, who volunteered only for service during the War, served aboard the hospital ship RED ROVER, a captured Mississippi sidewheeler. It was not until 1908 that the Navy Nurse Corps was established.

The Medical Department in the Navy today ranks high in the confidence of the men who know that the professional care available to them is second to none. The death rate in the Navy has fallen to its lowest point in history. This was two percent for Navy and Marine Corps personnel wounded in combat during the Korean conflict.

An Application of Photogrammetry to Radar Research Studies

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Litchfield Park, Arizona

During 1958, Goodyear Aircraft Corporation, in conjunction with the Applied Physics Laboratory of The Johns Hopkins University, carried out a radar-return research program sponsored by the Navy Bureau of Ordnance. Its purpose was to accurately identify and measure radar-return signals at various depression angles from different types of terrain: cultivated areas, forested areas, lakeland, desert areas, and grass- or meadow-land. To a lesser degree, identification of return signals from cities and other cultural centers was also included in the program. Relatively flat land was desired for the experimental radar mapping, as the many variations in slope and elevation of mountainous or broken terrain would have required intricate, if not impossible, data-reduction procedures.

For this study, Goodyear developed an accurately calibrated side-"looking," non-scanning, strip-mapping radar, which was installed in the nose of a P2V-3W "Neptune" aircraft. The radar antenna was preset to "look" perpendicular to the aircraft's desired heading. Since the antenna was gyro-stabilized, it maintained its setting within about 0.25 degree, despite normal variations from the flight path by the aircraft. Figure 1 shows the ground illumination pattern of the radar. At 10,000 feet above the ground, the radar illuminated the sector between depression angles of 10 and 70 degrees, or the strip lying between 0.6 and 9.3 nautical miles from the flight path of the plane. Figure 2 shows how the radar return was displayed in the aircraft on a cathode-ray tube, then photographed by a continuous-strip camera. The resulting strip map had a scale of, roughly, 20 miles to the inch.

How does a radar terrain photograph differ from a conventional aerial photograph? For one thing, a conventional photograph records almost everything that is visible but is normally obtainable only under certain conditions of light and weather, while radar, of course, is not subject to these limitations. However, radar will record only those features that reflect the transmitted microwave energy back to the antenna. Furthermore, the direction from which a radar scans an area will affect the intensity of the signal return. Despite these differences, remarkable visible similarity exists between Goodyear radar photographs and conventional aerial photographs, or other cartographic material. Figures 3 through 7 are radar maps made with a low-resolution radar system. GAC, Arizona, is also flight testing high-resolution radar systems.

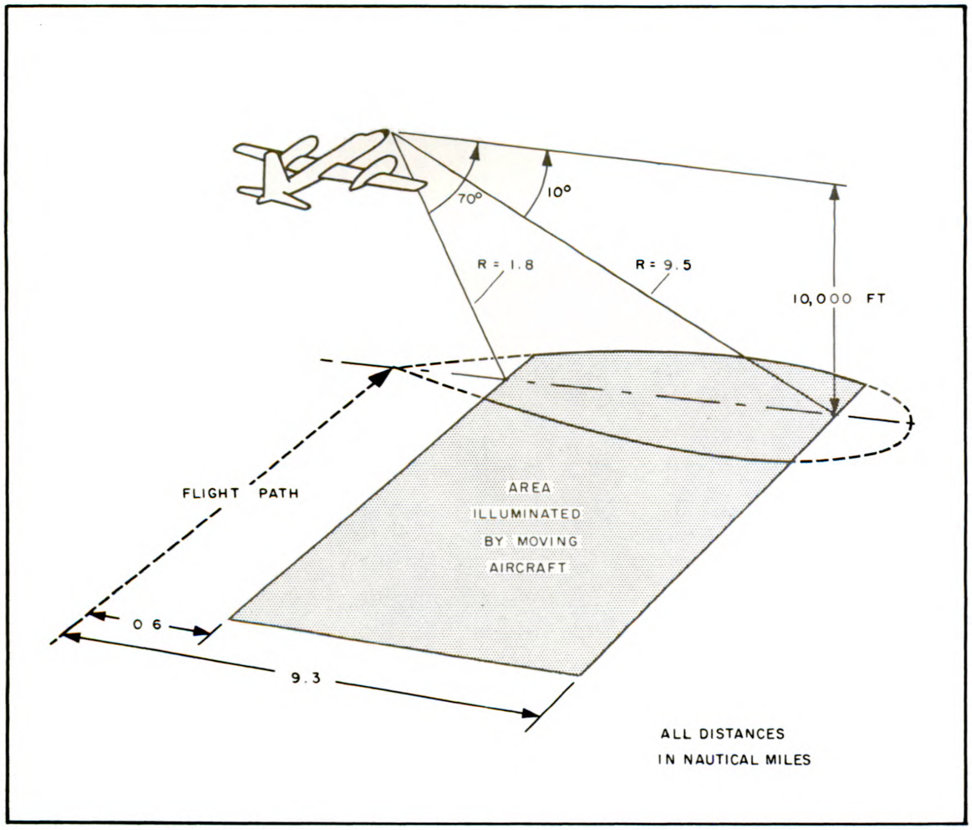


Figure 1--Radar antenna coverage.

Figure 2--Formation of radar strip map.

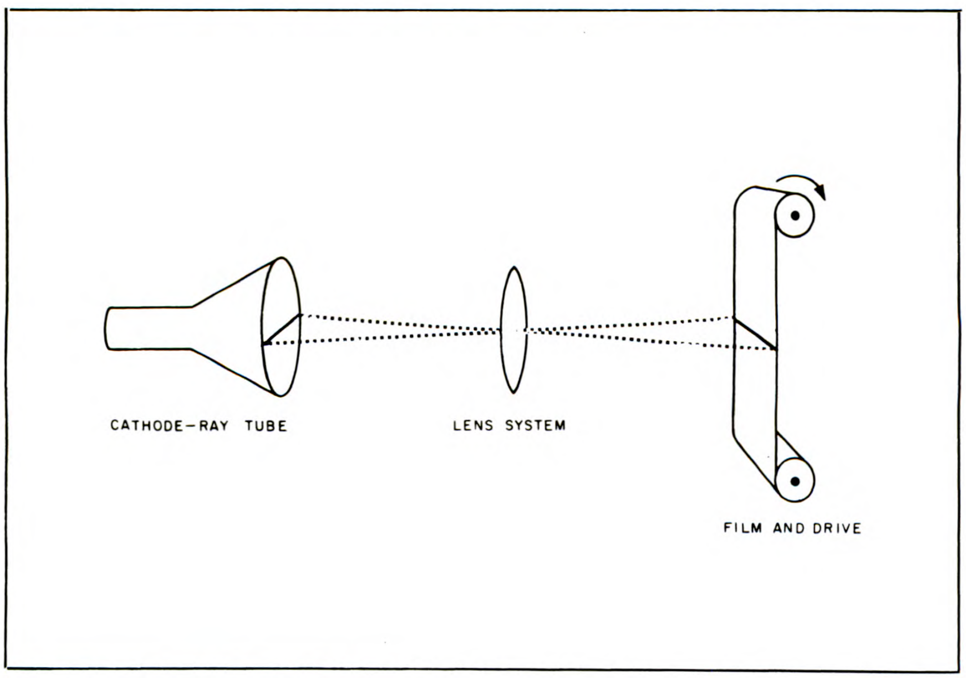


Figure 3 is a radar map of New York City. Central Park on Manhattan Island lies in the center; the Hudson River and New Jersey shore appear on the left, the East River and Queens on the right. While the area below Central Park on Manhattan has the larger buildings (such as the Empire State Building and other skyscrapers and the buildings around Times Square) it does not show as strong a signal return as the bright area of Queens, with its smaller buildings.

The difference in signal return can be explained as follows. In both Queens and Manhattan, the city blocks are solidly built-up rectangles; but, in Manhattan, the narrow side of the rectangle faces the radar beam, while across the East River in Queens, the long side of the block is so oriented. The long side of the block presents a larger reflecting surface to the radar beam and thus appears as a brighter image, or target, on the radar map. The orientation of the blocks can be verified by consulting large-scale topographic maps of the area.

Figure 4 is a radar mpa of cotton fields near Chandler, Arizona. The differences in the strength of returned signals are due to the same phenomenon observed in regard to the buildings in Figure 3. The cotton rows parallel to the radar beam present a larger reflecting surface than the rows perpendicular to the beam and, hence, appear brighter. The black areas on the map represent plowed or fallow fields.

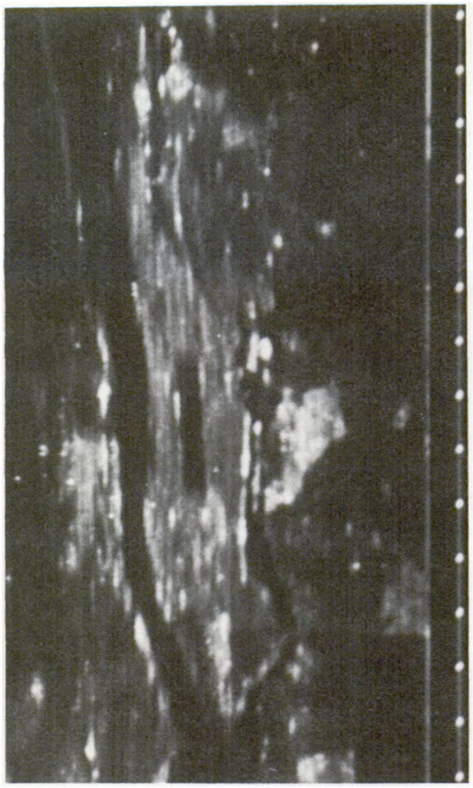
Figure 5 shows a radar photograph of a mountain range in southwestern Arizona and part of a photo index mosaic of the same area. Note the general conformity between them.

Figure 6 shows a radar map and a topographic map of lakes and forests northwest of Duluth, Minnesota. Identification of specific lakes is relatively easy. When large-scale topographic maps are used for comparison, forests and open areas can be identified on the radar maps.

Figure 7 shows a radar map and a nautical chart of the Florida Keys area. Note how the causeway connecting the various keys is sharply defined on the radar map.

In the photographic and photogrammetric work for the Goodyear research program, a Maurer 70-millimeter format camera with a 38-millimeter lens was used. It was mounted vertically in a Steinheil gyro-stabilized camera mount. An exposure was made every 20 seconds—about once every nautical mile, assuming an aircraft speed of about 180 knots. The pulse that triggered the camera placed a reference mark on the radar map and the other data-recording systems that were part of the entire installation.

To obtain the flight path of the aircraft, the principal points of the photographs were plotted on large-scale topographic maps. Since the gyro-stabilized camera mount kept the camera to within about 0.5 degree of arc of the vertical, the use of the principal points proved to be a sufficiently accurate method for locating the flight path.



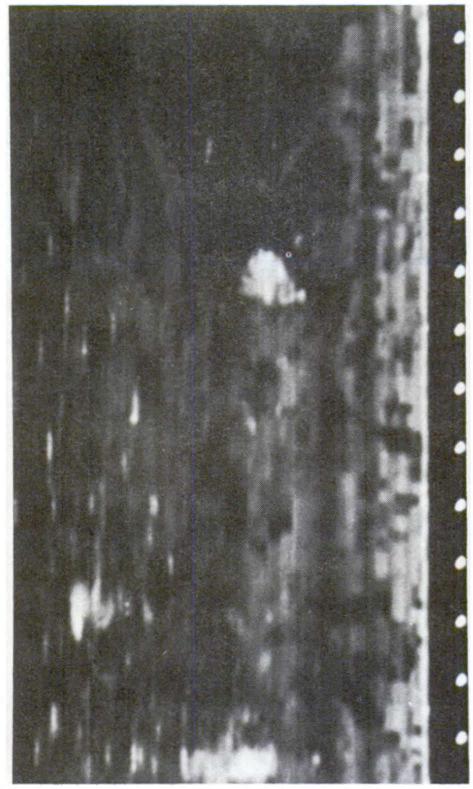
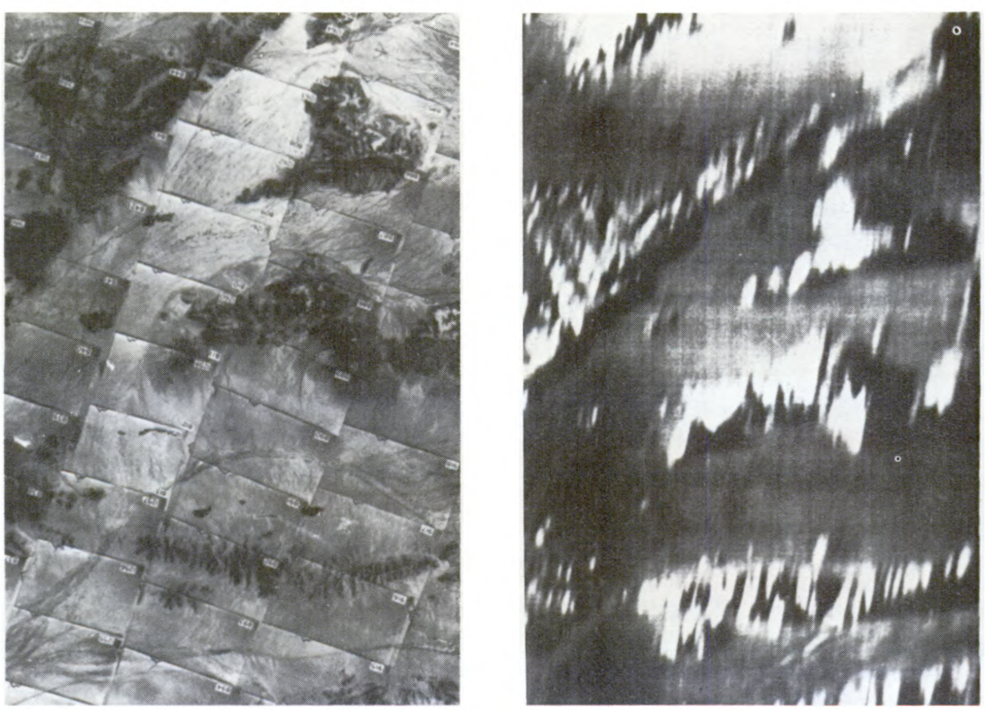


Figure 3--Radar map of New York City.

Figure 4--Radar map of cotton fields in central Arizona.

Figure 5—Radar map and photo index of mountains in southwestern Arizona.



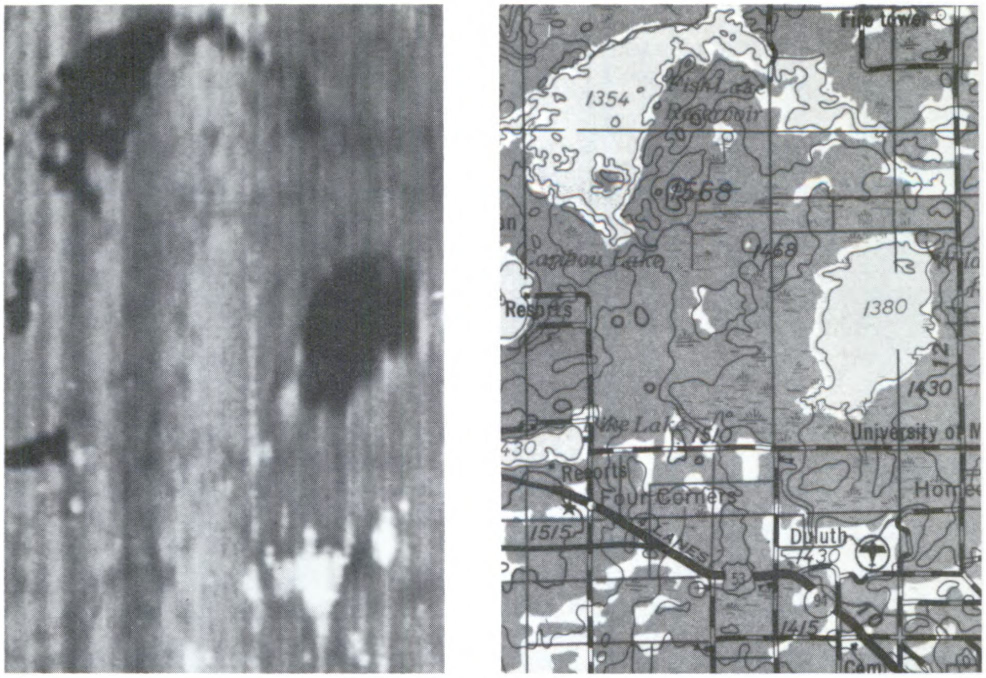


Figure 6--Radar map and topographic map of lakes and forests in Minnesota.

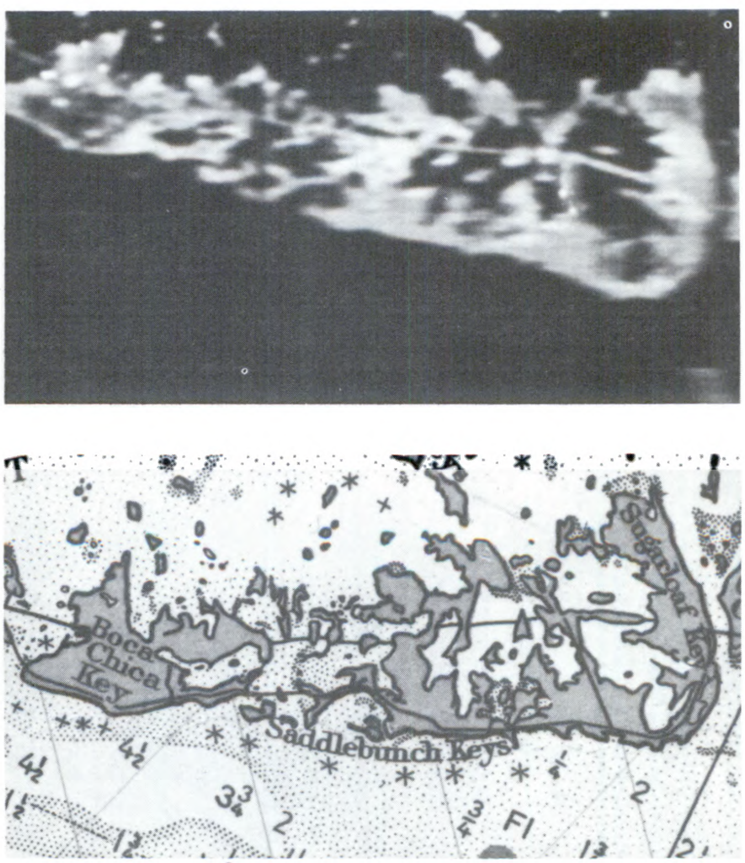


Figure 7--Radar map and nautical chart of Florida Keys.

The altitude of each exposure was computed. With this information it was possible to plot the exact limits of radar coverage on the topographic maps, since these limits were directly dependent on the altitude of the plane. Also, at each exposure station a profile was prepared of the ground covered by the radar beam. Where necessary, profiles were prepared at intermediate points. On occasion, a profile running the length of the radar map at a specified range from the aircraft was prepared to determine the exact ground elevation of the target and, thus, the exact depression angle, as the depression angle is a function of ground range to the target and the height of the antenna above the target (see Figure 1).

While these operations were being performed, 20X enlargements of the radar maps were prepared for use in target identification. The identification was accomplished by map study, stereoscopic study of conventional photographs, and field trips. On the field trips, an actual field check was performed; in other words, the radar map was marked to indicate such things as type of crop, direction of planting, height of vegetation, whether the vegetation was narrow- or broad-leafed, size and orientation of farm buildings, type and height of trees, whether the trees were deciduous or coniferous, and the size of meadows or clearings.

As many ground photos were taken of these features as seemed necessary. For example, on a four-day trip to Minnesota in August 1958, the author took about 90 photographs, half of which were in color.

All data-recording systems of the complete installation were then subjected to a comprehensive electronic and mathematical analysis. The data obtained by photogrammetric and cartographic methods—antenna altitude, range from antenna to target, ground elevation of target, and target identification—were included in the analysis. The validity and accuracy of these photogrammetric operations influenced the accuracy of the interpretation of the final results. For instance, the signal return from a cotton field will vary with its depression angle, and photogrammetric computations were necessary as part of the system analysis resolving this and other parameters.

Photogrammetry is proving to be a valuable tool in radar research; at the same time radar, because of its varied needs, is expanding the potential of photogrammetry. These present contacts will benefit both technologies and will provide the stimulus for increasingly fruitful relationships in the future.

Dr. Matthew H. Schrenk has been named Research Coordinator of the Office of Naval Research. He succeeds Dr. Immanuel Estermann, who was recently appointed Scientific Director of the ONR Branch Office, London. Dr. Schrenk began his Government career at the U. S. Naval Research Laboratory and worked for more than 20 years there, most of the time as Head of the Aircraft Section of the Radio Division. He moved from the Laboratory to ONR in 1955, when he was appointed Deputy Development Coordinator of the Office.

Research Notes

Navy Research on Color Vision

In Stars and Stripes for August 5, 1959, is an article on the research on color vision conducted by CDR Dean Farnsworth of the ONR Branch Office, London. The article describes work done by CDR Farnsworth from 1943 to 1957 while he served as Chief of the Visual Engineering Branch, U.S. Naval Medical Research Laboratory, New London, Conn. During this period one of his principal aims was to convince the Navy that color-blind servicemen need not be disqualified from general service. Today he is still working on this same problem, so that a "great manpower talent pool will not be wasted."

His investigations have resulted in recommendations concerning the habitability of atomic submarines; the determination of the most suitable color for livesaving equipment; the development of standard aircrew sunglasses for the Navy and Air Force; the use of control codes that do not rely on color; and a test that enables the Navy to use some color-blind men in the specialized services, such as aviation and submarine operations.

In 1944, CDR Farnsworth and his colleagues began research on a more precise test for degrees of color blindness than had existed previously. This led to the development of the Farnsworth Lantern, the first model of which was built in 1945. After four model changes, the Lantern became standard equipment in 1955. It has revealed that of the eight percent of servicemen who are color blind and who have therefore been disqualified for the special services, three percent can be salvaged for these services. Although this saving is a significant one, the five percent still lost to the special services is, in Farnsworth's words, "an enormous waste of manpower."

One of Farnsworth's aims has been, and continues to be, the elimination of color codes on equipment, such as control panels. This would permit utilization of the five percent of servicemen now disqualified for the special services. But if it can't be done, "then we hope the engineers will at least use the few colors that color defectives can determine. They are black, white, gray, yellow, blue, and brown."

Another major contribution made by Farnsworth and his colleagues was the determination that red is the best color for survival gear used at sea. "Yellow has always been thought of as the best color," Farnsworth says. "But we discovered an interesting peculiarity of the eye in 1943—the very center of the eye is yellow and blue blind. If you're looking at a speck of something in the water. . .a man in a lifejacket. . . believe me, he looks like a speck of white foam."

After several years of exhaustive research, the Farnsworth group recommended that all sea-air rescue equipment be colored red. When a permanent fluorescent was developed, "we recommended, in May 1955, that all survival gear be ordered in fluorescent red." The red color—particularly the fluorescent red—gives a man confidence. "If he's out there in the sea, he thinks, 'They can't fail to see me.'"

Sun Spots Photographed from High Altitude

More than 1,000 of the sharpest pictures ever taken of sun spots were obtained during the past three months by a balloon-borne telescope-camera from an altitude of 80,000 feet over Minnesota. At the time this was written, the special photographic equipment had been sent aloft three times—on July 11 (see Naval Research Reviews, August 1959), August 17, and September 4, and a fourth flight was scheduled for October 2. The director of the photography project, Dr. Martin Schwarzschild of Princeton University, says he believes that "these pictures will help substantially in the understanding of the motions which we observe in the strong magnetic fields of the sun spots." The processes occurring in sun spots are known to occasionally cause magnetic storms here on earth and also to seriously interrupt long-distance radio communication.

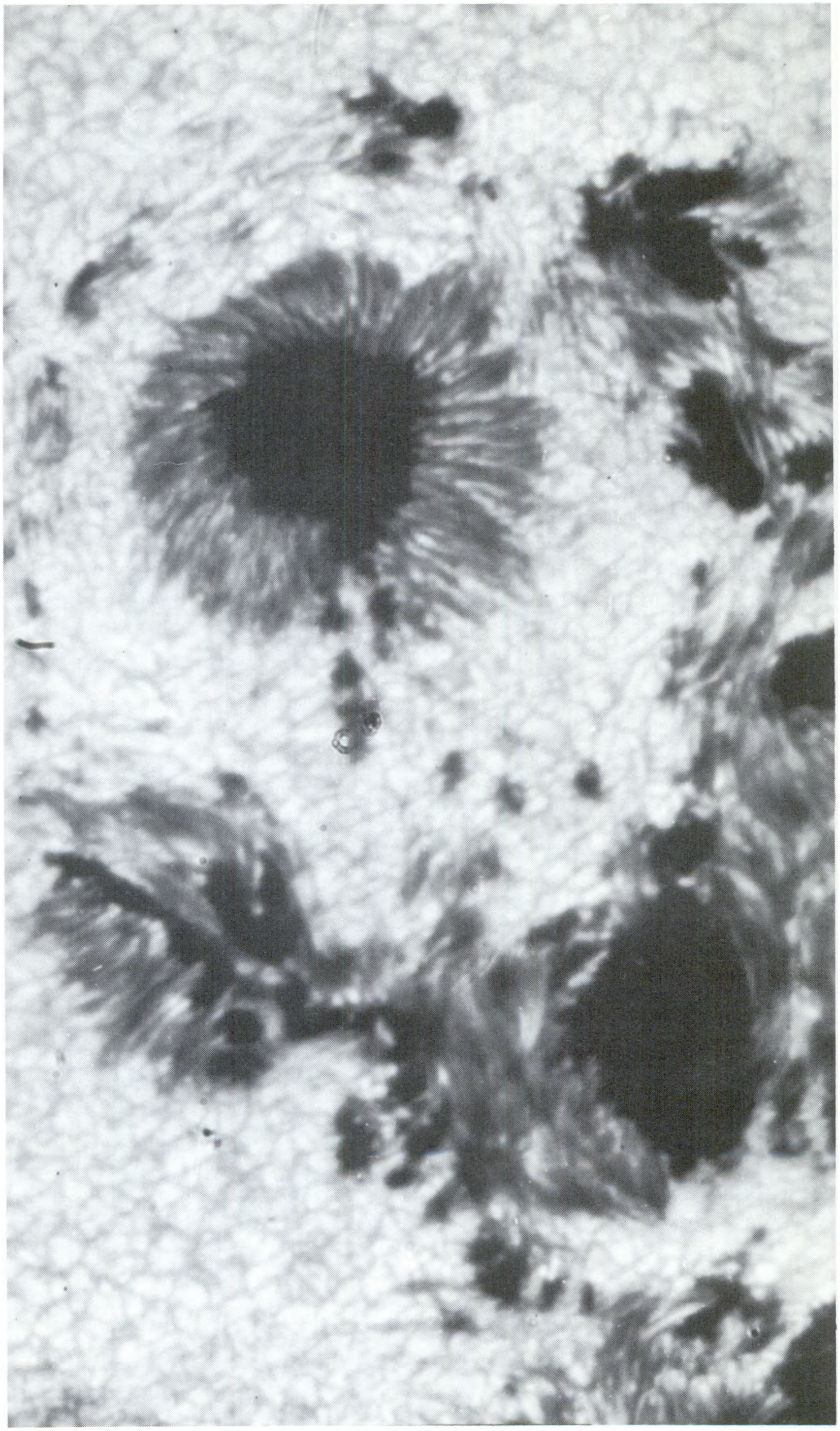
The 12-inch telescope-camera which obtained the pictures was equipped with a closed-circuit television camera and a remote-control mechanism which enabled the research team to guide it at will and at the same time to see on the TV screen the area under observation. Furthermore, it enabled the scientists to follow a specific event on the sun continuously, which has not been possible with the isolated photos obtained previously from such altitude.

The series of four flights, called Project STRATOSCOPE I, was sponsored by the Office of Naval Research and the National Science Foundation.

This active group of sun spots was photographed by a balloon-borne telescope-camera at an altitude of 80,000 feet on August 17. The spots consist of a dark core of relatively cool gases embedded in a strong magnetic field. The cores are surrounded by envelopes made up of wispy filaments of outward-moving warmer gases. The whole spot group is embedded in a cellular pattern of heat convection in the hot gases which cover the entire surface of the sun. This particular spot group produced a magnetic storm here on earth the day before the flight, causing major disturbances in long-range radio communications and a brilliant aurora throughout the night.

Measuring Variations in Sky Brightness

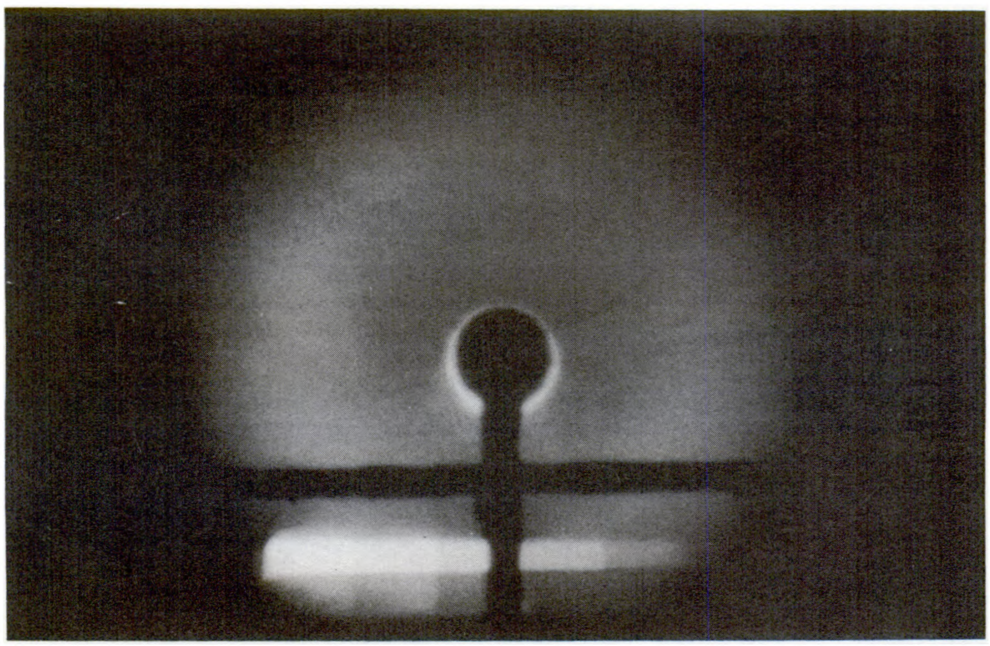
The August 1957 issue of Naval Research Reviews carried a report of an open-basket balloon flight made to an altitude of 38,000 feet by Malcolm D. Ross of the Office of Naval Research and Robert H. Cooper of the High Altitude Observatory, Boulder, Colo. On the flight the sun's corona was observed for the first time with an instrument called the "Flying Coronagraph." With this device a solar eclipse was simulated, enabling the observers to study variations in sky brightness near the sun as a function of balloon altitude.



Since that account was written, some of the flight results and a photograph of the sky near the sun as viewed through the coronagraph have become available. The photograph is reproduced below.

Preliminary measurements made by the project sicentist, Dr. Gordon Newkirk of the High Altitude Observatory, show that the sky brightness at an altitude of 38,000 feet is about five times as great as it would be if the earth's atmosphere were completely free of contaminating dust. During the coming months, Dr. Newkirk and other personnel at the High Altitude Observatory will make a detailed study and evaluation of the exposures made on the flight. Analysis of the data is expected to yield valuable information about particulate matter (aerosols) in the earth's atmosphere at altitudes ranging up to 38,000 feet. Little data are now available to describe accurately the distribution of these aerosols. The chief value of such information lies in the relationship that may exist between atmospheric contaminants and weather conditions. It has been suggested, for example, that a relationship exists between meteoric dust and rain.

The first flight has demonstrated the feasibility of the balloon and the Flying Coronagraph for obtaining exposures at relatively high altitudes. So successful was the experiment, in fact, that it now appears that scientists may be able to use this technique, with certain modifications, for photography of the solar corona in a region which cannot be studied from the ground with conventional techniques.



A photograph of the sky at 38,000 feet obtained by the "Flying Coronagraph." The sky near the sun is the smooth bright area above the horizontal dark bar. The sun is eclipsed by the dark disk in the center of the frame, while the bright ring of light immediately surrounding the disk is caused by instrumental diffracted light. The support for the occulting disk is seen as a vertical, dark bar. At the bottom are light references against which the skybrightness is compared.

On the Naval Research Reserve

West Coast Methodology Seminar

The West Coast Methodology Seminar was held in San Francisco, Calif., for a two week period ending August 28. The meeting, which was sponsored by the Office of Naval Research Branch Office, San Francisco, under the command of CAPT R. B. McLaughlin, USN, was attended by 87 reserve officers. Of this number, 64 were of the Naval Reserve, 12 of the Army Reserve, 10 of the Air Force Reserve, and 1 of the Coast Guard Reserve.

The seminar was opened with a welcoming address by CAPT E. J. MacGregor, USN, Deputy Chief of Staff for Naval Reserve, Twelfth Naval District, who represented the Commandant. Greetings from the Chief of Naval Research were delivered by CAPT John P. Aymond, USN, Special Assistant for the Research Reserve. CAPT Aymond also spoke on the following day, his subject then being "Mobilication Concepts for the Research Reserve." The Deputy and Assistant Chief of Naval Research, CAPT A. B. Metsger, USN, addressed the seminar group later in the week.

The two-week period of discussions was devoted to the following subjects: research administration, research evaluation, methodology in electromagnetic discrimination, controlled thermonuclear research, peaceful uses of nuclear explosives, methodology of inorganic materials research, ionic and nuclear propulsion, studies of metabolic pathways, man in space, machine in space, radiation sickness, advanced areas of computer research, transuranium elements, and research information transmission.

CAPT MacGregor, CAPT McLaughlin, and LCDR Todd during the course of the latter's remarks in opening the West Coast Methodology Seminar.

In the course of the seminar the conferees also made some highly interesting tours. These included the Lawrence Radiation Laboratory and the main campus of the University of California at Berkeley, the Navy's Radiological Defense Laboratory in the San Francisco Naval Shipyard, and the Electronic Research and Microwave Research Laboratories of Stanford University.

Among the presentations made during the seminar were the following: Mr. Robert M. Underhill, Secretary and Treasurer of the Regents of the University of California spoke on "The Organization of the Los Alamos Laboratory;" Dr. Homer E. Conzett, Research Physicist of Lawrence Radiation Laboratory, University of California, discussed "The Relativistic Time Paradox and Space Flight;" Professor Emeritus Joel H. Hildebrand, of the University of California, talked on "Production of Scientists;" and Dr. D. G. Willis, of the Missiles and Space Division of Lockheed Aircraft Corp., discussed "Advanced Areas of Computer Research."

The host company for the seminar was Naval Reserve Research Company 12-5, Berkeley, Calif., LCDR Paul F. Deisler, Jr., USNR, commanding. LCDR David B. Todd, USNR, a member of NRRC 12-5, served as seminar chairman. Assistance on the programming was furnished by the other three Research Reserve companies of the San Francisco Bay region: NRRC 12-1, San Francisco; NRRC 12-2, Livermore; and NRRC 12-3, Stanford.

Seminar Held at NRL

The Seventh Annual Naval Reserve Research Seminar was held at the U. S. Naval Research Laboratory, Washington, D. C., from August 17 to 28, 1959. After the checking-in process on the first day, the 45 officers who attended were welcomed to NRL by the Laboratory's Director, CAPT A. E. Krapf, USN, who introduced the Chief of Naval Research, RADM Rawson Bennett, USN. RADM Bennett gave the officers a review of the latest naval research projects and their applications.

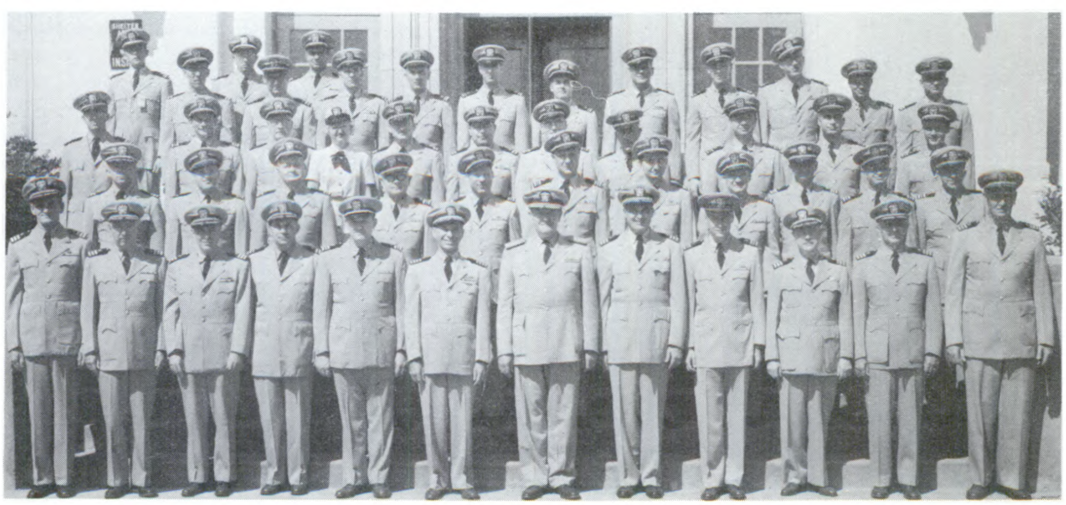
At noon on the first day Naval Reserve Research Company 5-9 of NRL was host at a luncheon given for the officers attending the seminar. CDR Walter C. Avery, USN, Training Officer, representing the Research Reserve Office of ONR was the guest speaker, answering questions on promotion and training within the Research Reserve.

Presentations were given by the following divisions of the Laboratory during the two-week period: Engineering Services, Sound, Chemistry, Nucleonics, Radar, Atmosphere and Astrophysics, Applications Research, Metallurgy, Mechanics, Optics, Radio, Radiation, Solid State, and Electronics. These presentations included talks, demonstrations, and tours. A special tour was arranged to the Chesapeake Bay Annex, where the Reservists saw some of the practical applications of NRL research.

The officers, all with backgrounds in the various disciplines of science, came from Naval Reserve companies throughout the nation.

RADM Rawson Bennett addresses NRL seminar.

Participants in the 7th annual Naval Reserve Research Seminar held at NRL. First Row: CDR Robert J. Bobber, CDR Richard C. Foley, CDR Sidney F. Wexler, CDR Hubert M. Tatum, LCDR Eugene R. Stroup, CAPT Arthur E. Krapf, RADM Rawson Bennett, CDR Walter C. Avery, LCDR Richard C. Reed, CDR Joseph E. Reegan, CDR Robert R. Brewin, CDR Joseph E. Rausch. Second Row: CDR Charles F. Lewis, LCDR Elza F. Tate, LCDR Charles L. Kleder, LCDR Robert J. Billingsley, LCDR Charles P. Cardani, LCDR Franklin R. Crow, LCDR John B. Hart, LCDR James F. Haggerty, LCDR Garland L. Thomas, LCDR Acton R. Brown, LCDR Jack T. Spencer. Third Row: LCDR Leonidas H. Roberts, LCDR Moody L. Coffman, LCDR William H. Coppedge, LT (W) Leola A. Sharp, LT Calvin B. Koesy, LT Sidney F. Mason, LCDR Joseph N. Raudabaugh, LCDR Raymond W. Kimm, LCDR James A. Buck, LCDR Wilfred E. Baker, LCDR Clarence C. Clarke. Fourth Row: LTJG H. King McGee, LT Harold J. Jobse, LT Robert H. Dinegar, LT Roy C. Stout, LT John A. Jones, LT David C. Hughes, LTJG Frederick J. Almgen, Jr., LTJG William C. Mickelberry, LTJG James G. Graham, LT Thomas C. Kerr, LT Alvan J. Hoffman, LT Glen Wagoner, LT John W. Hagan, LT Clarence G. Westendorff, Jr.



Roster of Research Reserve Companies

ALABAMA

AUBURN
NRRC 6-2
Room 318, Ross Chemistry Laboratory
Alabama Polytechnic Institute
1900, 1st and 3rd Monday
LCDR James E. Land

HUNTSVILLE
NRRC 6-17
Naval Reserve Training Facility
Canal and Barnett Street
1900, 2nd and 4th Tuesday
CDR Hubert M. Tatum

ARIZONA

PHOENIX
NRRC 11-6
USN&MCRTC, 2042 W. Thomas Road
2000, 2nd and 4th Thursday
(No meetings in June and July)
LT Robert G. Wolfson

TUCSON
NRRC 11-7
USN&MCRTC, 1100 South Alvernon Way
2000, 1st and 3rd Thursday
(No meetings in July and August)
CDR Albert E. Hamilton

CALIFORNIA

LOS ANGELES
NRRC 11-1
USN&MCRTC, 851 Chavez Ravine Road
2000, 1st and 3rd Tuesday
CDR James R. DeBaun

PASADENA
NRRC 11-2
USNRTC, 2727 Paloma Street
2000, 1st and 3rd Thursday
CDR Arthur J. Imm

LOS ANGELES
NRRC 11-3
Room 2147, Life Science Building
University of California at Los Angeles
2000, 1st and 3rd Monday
CDR Joseph Cryden

COMPTON
NRRC 11-4
USN&MCRTC, 600 North Alameda
2000, 2nd and 4th Wednesday
CDR Howard F. Dostal

SAN DIEGO
NRRC 11-5
USNRTC, Camp Decatur
1930, 2nd, 3rd, and 4th Tuesday
LCDR Richard B. Woolley

POINT MUGU
NRRC 11-8
Building 351, Pacific Missile Range
1645, 1st and 3rd Wednesday
CDR Elmer M. Holk

AZUSA
NRRC 11-9
Aerojet-General Corporation
2000, 2nd and 4th Wednesday
CDR Donald D. Snodgrass

VENTURA
NRRC 11-10
Room 6, Building N
Ventura College
1930, 2nd and 4th Wednesday
(No meetings in July and August)
CDR James V. Iliff

SANTA MONICA
NRRC 11-11
USN&MCRTC, 3400 Airport Avenue
2000, 1st and 3rd Monday
CDR Lehman M. Rosholt

SAN FRANCISCO
NRRC 12-1
1000 Geary Street, 3rd Floor
1930, 2nd and 4th Monday
CAPT Ray H. Parker

LIVERMORE
NRRC 12-2
Radiation Laboratory
University of California
1645, every other Wednesday
CDR George A. McCormack

STANFORD
NRRC 12-3
Room 126, Electronics Research Laboratory
Stanford University
2000, every other Wednesday
CAPT Robert M. Fincher

FRESNO
NRRC 12-4
Room 119, Agriculture Building
Fresno State College
2000, 2nd and 4th Thursday
(Varied dates, 1st quarter)
LCDR Lewis A. Follansbee

BERKELEY
NRRC 12-5
Room 147, Cory Hall
University of California
1930, 2nd and 4th Wednesday
LCDR Paul F. Deisler, Jr.

DAVIS
NRRC 1206
Room 1006, Haring Hall
University of California
2000, 1st and 3rd Tuesday
(Varied dates, 1st quarter)
LCDR Charles E. Stokes

MONTEREY
NRRC 12-8
Room 530, Building 235
USN Postgraduate School
2000, every other Wednesday
(Varied dates, 1st quarter)
CDR Gilbert F. Kinney

COLORADO

FT. COLLINS
NRRC 9-12
Room 220, Chemistry Building
Colorado A&M College
1900, 2nd and 4th Thursday
LCDR Harry C. Hepting

BOULDER
NRRC 9-12
University of Colorado
1900, 1st and 3rd Tuesday
CDR Lowell P. Riggs

CONNECTICUT

HARTFORD
NRRC 3-5
Hartford Electric Building
176 Cumberland Avenue
Wethersfield, Connecticut
2000, 1st and 3rd Thursday
CDR Kenneth I. Boone

NEW LONDON
NRRC 3-12
USNRTC, Building 137
US Naval Submarine Base
2000, 2nd and 4th Tuesday
LCDR John A. Wheeler, Jr.

DELAWARE

WILMINGTON
NRRC 4-5
USNRTC, Foot of Madison Street
2000, alternate Mondays
CDR Donald MacCreary

DISTRICT OF COLUMBIA

NRRC 5-8
National Academy of Sciences
2102 Constitution Avenue, N.W.
2000, 1st and 3rd Thursday
CDR James W. Smith

NRRC 5-9
Building 28, NRL Auditorium
4555 Overlook Avenue, S.W.
July: 1630, 2nd & 4th Wednesday
Aug: 1630, 1st and 3rd Wednesday
Sept: 1st Wednesday and 3rd Thursday
2nd, 3rd, and 4th quarters:
1630, 1st and 3rd Friday
CDR Ernest W. Peterkin

FLORIDA

GAINESVILLE
NRRC 6-4
USNRTC, 1300 N.E. 8th Avenue
1915, 1st and 3rd Tuesday
CDR Robert S. Bolles

ORLANDO
NRRC 6-8
USNRTC, West Livingston Avenue
1930, 1st and 3rd Tuesday
LCDR Percy F. Hurt

CORAL GABLES
NRRC 6-10
Room 523, Building 521
University of Miami
2030, 1st and 3rd Thursday
CDR Norman R. Buchan

FT. WALTON BEACH
NRRC 6-15
Library
Choctawhatchee High School
Shalimar, Florida
1900, 1st, 3rd, and 4th Monday
2nd quarter: 2nd and 4th Tuesday
CAPT Carl Kyselka

MELBOURNE
NRRC 6-16
Conference Room, Building 425
Patrick Air Force Base
1630, 1st and 3rd Tuesday
CDR Charles A. Hoffman

GEORGIA

ATLANTA
NRRC 6-1
Conference Room, Engineering
Experimental Station, Georgia
Institute of Technology
2000, 1st eight Thursdays of 2nd,
3rd, and 4th quarters.
CDR James D. Baer

ATHENS
NRRC 6-9
U.S. Navy Supply School
1930, 1st, 3rd, and 4th Monday
(Some months all four Mondays)
CDR Carroll Downes, Jr.

IDAHO

IDAHO FALLS
NRRC 13-6
Army Reserve Training Center
Ucon Road
1930, 2nd and 4th Thursday
CDR Thomas J. Wadsworth

ILLINOIS

CHICAGO
NRRC 9-1
Navy Pier Campus
University of Illinois
1900, 2nd and 4th Tuesday
LCDR B. J. Jaskoski

URBANA
NRRC 9-2
"E" Law Building, University of Illinois
1930, 2nd and 4th Tuesday
CDR Walter C. Jacob

PEORIA
NRRC 9-2
Library, Northern Regional Research Laboratory
1930, 2nd and 4th Monday
LCDR R. G. Dworschack

DECATUR
NRRC 9-2
USNRTC, Decatur
2nd and 4th Wednesday
LCDR Clarence E. Taylor

FOREST PARK
NRRC 9-23
Naval Ordnance Plant
7500 West Roosevelt Road
1930, 2nd and 4th Wednesday
LCDR Ramo Puricelli

INDIANA

LAFAYETTE
NRRC 9-7
Purdue Memorial 318
Purdue University
1900, 2nd and 4th Tuesday
CDR William J. Stadelman

IOWA

AMES
NRRC 9-5
NROTC Building
Iowa State College
1900, 1st, 2nd, and 3rd Wednesday
LT Leroy E. Everson

DES MOINES
NRRC 9-13
USN&MCRTC, Ft. Des Moines
1930, every Wednesday
LCDR John V. Gebuar

IOWA CITY
NRRC 9-19
East Lawn 116, University of Iowa
1930, every Monday
LT Marvin S. Thostenson

WATERLOO
NRRC 9-24
USNRTC, 200 Riverside Drive
1930, 1st and 3rd Wednesday
CDR Warren W. Klos

KANSAS

LAWRENCE
NRRC 9-20
104 Military Science Building
University of Kansas
1930, every Monday
CDR William P. Albrecht

LOUISIANA

NEW ORLEANS
NRRC 8-1
NROTC Building
Tulane University
1930, alternate Tuesdays
LT Arthur J. Rhodes

MARYLAND

FREDERICK
NRRC 5-3
Building 426, Fort Detrick
1930, 2nd and 4th Tuesday
LCDR William G. Roessler

BALTIMORE
NRRC 5-4
School Board Administration Building
3 East 25th Street
2000, 1st and 3rd Thursday
CDR Lloyd E. Rozeboom

BETHESDA
NRRC 5-10
Auditorium, NMRI
Naval Medical Center
2000, 2nd and 4th Tuesday
CDR Urner Liddel

ANNAPOLIS
NRRC 5-11
Auditorium
USN Engineering Experiment Station
2000, 1st and 3rd Tuesday
(No meetings during July and Aug.)
CDR Warren F. Anderson

MASSACHUSETTS

CAMBRIDGE
NRRC 1-1
Room 4-270, M.I.T.
77 Massachusetts Avenue
1930, 1st and 3rd Monday
CDR Paul H. Flint

AMHERST
NRRC 1-3
Room 10-11, Gunness Laboratory
University of Massachusetts
1930, 1st and 3rd Tuesday
CDR Sidney F. Wexler

WORCESTER
NRRC 1-5
Stratton Hall
Worcester Polytechnic Institute
2000, 1st and 3rd Monday
(No meetings in July and August)
LCDR Samuel H. Coes

WOODS HOLE
NRRC 1-8
Woods Hole Oceanographic Institution
1930, 1st, 2nd, and 3rd Thursday
CDR Robert J. Tilden

MICHIGAN

ANN ARBOR
NRRC 9-3
112 North Hall, University of Michigan
1930, 1st and 3rd Monday
(Varied dates in July, August, and September)
LT Harold W. Sherman

MIDLAND
NRRC 9-15
Midland Library
1900, 2nd and 4th Tuesday
LCDR Walter C. Broad

EAST LANSING
NRRC 9-16
Room 313, Electrical Engineering Building
Michigan State College
1930, 1st and 3rd Wednesday
(Oct: 2nd and 4th Wednesday)
CDR Marshall B. Burt

MINNESOTA

MINNEAPOLIS
NRRC 9-6
Room 321, Mechanical Engineering Building
University of Minnesota
1930, 2nd and 4th Monday
LCDR Neil B. Coil

MISSISSIPPI

GULFPORT
NRRC 6-5
USN&MCRTC, Broad Avenue
1930, 1st and 3rd Wednesday
LCDR Paul C. Lightle

MISSOURI

ST. LOUIS
NRRC 9-8
Webster Groves Public Library,
Webster Groves, Missouri
2000, 2nd and 4th Wednesday
LCDR Earle F. Palmer

ROLLA
NRRC 9-9
Room 302, Rolla Building
Missouri School of Mine & Metallurgy
1900, Mondays
(No meetings in July and August)
LT John M. Brewer

NEBRASKA

LINCOLN
NRRC 9-22
208 Plant Industry Building
University of Nebraska
1930, Wednesdays
LT Norris P. Swanson

NEW HAMPSHIRE

HANOVER
NRRC 1-7
Wentworth Hall, Dartmouth College
2000, 1st and 3rd Tuesday
(No meetings in July and August)
CDR George Z. Dimitroff

NEW JERSEY

PORT NEWARK
NRRC 3-13
USN&MCRTC, Building 213
Naval Reserve Industrial Shipyard
1930, 1st and 3rd Wednesday
LCDR Norton L. Jeffers

PRINCETON
NRRC 4-1
10 Guyot Hall
Princeton University
2000, alternate Wednesdays
CDR Charles W. Logan

NEW MEXICO

ALBUQUERQUE
NRRC 8-7
USN&MCRTC, 1805 Yale Avenue, SE
2000, 1st and 3rd Wednesday
LCDR Jack M. Houston

LOS ALAMOS
NRRC 8-9
Lecture Room, Administration Building
Los Alamos Scientific Laboratory
1700, 1st and 3rd Tuesday
CDR Alvin R. Lyle

NEW YORK

NEW YORK
NRRC 3-1
Room 301, 30 East 42nd Street
1900, 2nd and 4th Thursday
CDR Frank E. Kulman

KINSTON
NRRC 3-14
I.B.M. Conference Room
1930, 1st, 2nd, and 3rd Thursday
LCDR Jerome L. Krumpelman

NEW YORK
NRRC 3-15
90 Church Street
1845, 2nd and 4th Thursday
CDR P. M. Randazzo

LONG ISLAND
NRRC 3-2
Engineering Building
USN Training Device Center
Sands Point, Port Washington
1930, 2nd and 4th Monday
CDR Alphonse A. Chester

BUFFALO
NRRC 3-3
USN&MCRTC, 3 Porter Avenue
2000, 2nd and 3rd Monday
LT Eugene S. Hiller

ROCHESTER
NRRC 3-4
Harkness Hall
University of Rochester
2000, 1st and 3rd Tuesday
LT Kenneth W. Kimpton

SYRACUSE
NRRC 3-6
General Electric Company
Electronics Park
2000, 1st and 3rd Monday
LCDR John B. Simeone

SCOTIA
NRRC 3-7
USNRTC, Scotia
2000, 2nd and 4th Thursday
CDR Thomas J. Gair

NEW YORK
NRRC 3-8
Room 301, 30 East 42nd Street
1900, 2nd and 4th Tuesday
CDR Edgar O'Neil

UPTON
NRRC 3-9
Brookhaven National Laboratory
1930, 2nd and 3rd Wednesday
CDR Jere C. Austin

MASSENA
NRRC 3-10
Court Room, City Hall
1930, 1st and 3rd Monday
LCDR Lucius M. Hale

NORTH CAROLINA

CHAPEL HILL
NRRC 6-6
105 Abernathy Hall
University of North Carolina
1800, 1st, 2nd and 3rd Monday
(No meetings in July, Aug., and Sept.)
LCDR Quentin W. Lindsey

OHIO

COLUMBUS
NRRC 4-7
Ohio State University Research
Foundation, 1314 Kinnear Road
1930, alternate Thursdays
(No meetings in Aug. and Sept.)
LCDR Daniel Howland

CLEVELAND
NRRC 4-8
USNRTC, East Ninth Street
2000, alternate Mondays
CDR Viktor Schreckengost

DAYTON
NRRC 4-9
USN&MCRTC, 410 Gettysburg Avenue
1930, 2nd and 4th Monday
LCDR Henry D. Colson

CINCINNATI
NRRC 4-11
Room 54, Albers Hall
Xavier University
1900, 2nd and 4th Tuesday
LCDR Louis J. Pecora

OKLAHOMA

BARTLESVILLE
NRRC 8-8
American Legion Building
1930, 1st and 3rd Tuesday
CDR E. O. Box, Jr.

STILLWATER
NRRC 8-13
Room 2, Union Building
Oklahoma State University
1930, 2nd, 3rd, and 4th Thursday
CDR Roy W. Jones

OREGON

PORTLAND
NRRC 13-4
USN&MCRTC, Swan Island
2000, 2nd and 4th Tuesday
LCDR Edward J. Warchol

CORVALLIS
NRRC 13-5
Room 132, Food Technology Building
Oregon State College
1930, 2nd and 4th Monday
CDR William J. Kirkham

PENNSYLVANIA

PHILADELPHIA
NRRC 4-2
Franklin Institute
20th Street and Parkway
1930, alternate Thursdays
(No meetings in July and August)
CDR John C. MacFadyen

PITTSBURGH
NRRC 4-3
Room 1112, Engineering Hall
Carnegie Institute of Technology
2000, alternate Thursdays
CDR Frank M. Fellows, Jr.

STATE COLLEGE
NRRC 4-4
Room 200A, Engineering "E"
Campus, Pennsylvania State University
1900, alternate Mondays
LCDR Robert E. Clark

BETHLEHEM
NRRC 4-6
USNRTC, Spring Garden and Rodgers Streets
1900, 2nd and 4th Tuesday
LCDR William A. Green

WILLOW GROVE
NRRC 4-12
Technical Training Building
US Naval Air Station
1930, alternate Tuesdays
(No meetings in July and August)
CDR Bradley C. Algeo, Jr.

RHODE ISLAND

KINGSTON
NRRC 1-2
University of Rhode Island
1930, 1st and 3rd Wednesday
LCDR Peter F. Merenda

SOUTH CAROLINA

CLEMSON
NRRC 6-11
Room 103, Physics Building, Clemson College
1930, Wednesdays
CDR Marshall C. Bell

AIKEN
NRRC 6-13
Red Cross Building, Laurens Street
1900, 2nd and 4th Thursday
CDR Loren T. Palmer

SOUTH DAKOTA

BROOKINGS
NRRC 9-11
Room 330, Agricultural Hall
South Dakota State College
2030, 2nd and 4th Wednesday
(Varied dates in July and August)
LCDR Gerald B. Spawn

RAPID CITY
NRRC 9-11
Chemistry Building
South Dakota School of Mines
1600, 1st and 3rd Tuesday
LCDR Willard J. Martin

TENNESSEE

OAK RIDGE
NRRC 6-3
Room 225, Oak Ridge High School
1930, 2nd and 4th Wednesday
CDR Richard B. Martin

TULLAHOMA
NRRC 6-12
Conference Room, Arnold Engineering
Development Center
1930, 2nd and 4th Tuesday
LT Arthur H. Hinners, Jr.

NASHVILLE
NRRC 6-18
Physicol Education Department
George Peabody College
21st Avenue South
2000, 1st and 3rd Monday
CDR S. B. Sudduth

TEXAS

COLLEGE STATION
NRRC 8-3
Biological Science Building
Texas A&M College
1930, 2nd and 4th Monday
CDR Norman F. Rode

HOUSTON
NRRC 8-4
Science Building
University of Houston
1945, alternate Wednesdays
CAPT Robert W. Talley

AUSTIN
NRRC 8-5
Room 223, Experimental Science Building
University of Texas
1900, Mondays
LCDR Richard B. Eads

DALLAS
NRRC 8-12
USN&MCRTC, 9638 Bachman Boulevard
2000, 1st and 3rd Tuesday
CDR Daniel W. Wildfong

UTAH

LOGAN
NRRC 12-7
Faculty Lounge
Utah State Agricultural College
2000, 2nd and 4th Thursday
(Varied dates in 1st quarter)
CDR Dean F. Peterson

VIRGINIA

NEWPORT NEWS
NRRC 5-1
USN&MCRTC
73rd Street and Warwick Road
1930, 1st and 3rd Tuesday
CDR Charles M. Cox

BLACKSBURG
NRRC 5-2
310 New Agricultural Building
Hutcheson Hall
Virginia Polytechnic Institute
2000, Mondays
LCDR James B. Eades, Jr.

RICHMOND
NRRC 5-5
2 North Conference Room
Department of Biology and Genetics
Medical College of Virginia Hospital
1700, 2nd and 4th Monday
CDR Charles M. Preston

WASHINGTON

SEATTLE
NRRC 13-1
Fisherman's Terminal, Department of Fisheries, 4015 20th Avenue West
1930, 1st, 2nd, and 3rd Monday
LCDR Clarence F. Pautzke

RICHLAND
NRRC 13-2
Court Room, 2nd Floor, Headquarters Building
Camp Hanford
1900, 2nd and 4th Tuesday
LCDR Roy S. Peterson

PULLMAN
NRRC 13-3
Room 39, Holland Library
Washington State College
1930, 2nd and 4th Monday
(Varied dates in 1st quarter)
CDR Claud C. Lomax, Jr.

WEST VIRGINIA

SOUTH CHARLESTON
NRRC 5-6
USNRTC
1930, 1st and 3rd Thursday
LCDR Irving H. Bowman

WISCONSIN

MILWAUKEE
NRRC 9-4
USN&MCRTC
2000, 2nd and 4th Tuesday
CDR Robert A. Hoehne

MADISON
NRRC 9-14
119 Babcock Hall
University of Wisconsin
1930, alternate Mondays
CDR Marshall W. Keith

Super-Accurate Gyroscope

A gyroscope that is suspended electrically in a vacuum and thus can rotate at high speeds, unassisted and for long periods of time, has been demonstrated by aeronautical engineers of the Minneapolis-Honeywell Regulator Co. The Company has been conducting research on electrically suspended gyros for the Navy Bureau of Ordnance and Bureau of Ships since 1956. Recently it received a contract from the Air Force for a study of possible airborne applications of the new device.

C. L. Davis, vice president and general manager of the Aeronautical Division of the Company, says the concept of electrically suspending a gyro rotor was originally suggested by Dr. Arnold Nordsieck, professor of physics at the University of Illinois' Coordinated Sciences Laboratory. The M-H gyroscope embodies a wholly new approach to the original idea and represents a "distinct advance in the art of navigation."

Electrically suspended gyros now being developed at Honeywell contain a beryllium-sphere rotor machined to tolerances more accurate than 15 millionths of an inch (see facing photograph). Pointing out that gyroscope accuracy is the key to inertial guidance and control in space, Davis says, "Space missiles and naval vessels of the future will require guidance so precise that even the extremely accurate gyros of today may be inadequate. The electrically suspended gyroscope has the potential of far greater accuracy."

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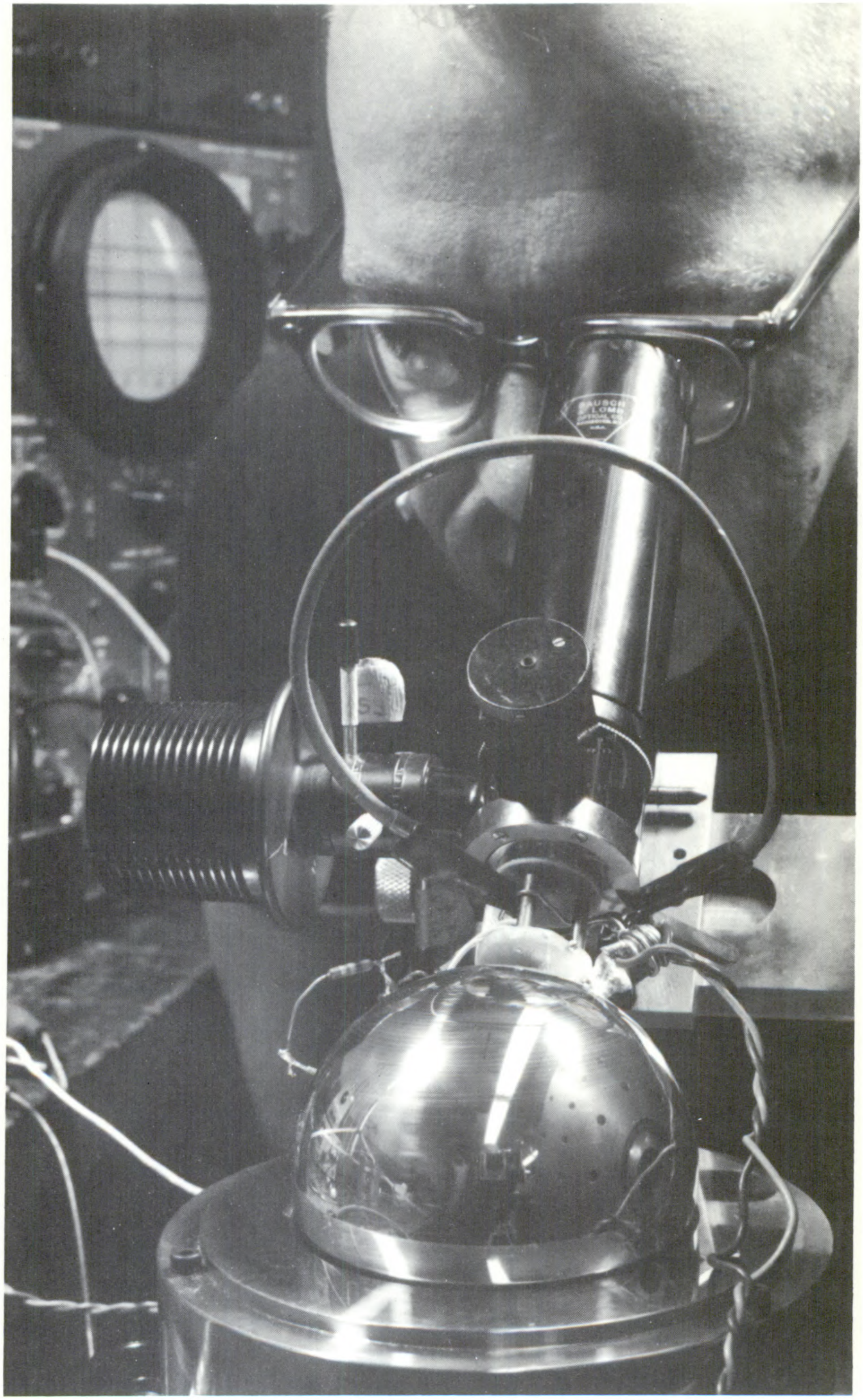

IN THIS ISSUE

NAVAL RESEARCH reports highlights of technical progress in research by Navy laboratories and contractors and the development of important naval research facilities. The magazine is listed for salé 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. Changes of address should be sent to Code 740, Office of Naval Research, Washington, D. C. Use of funds for printing this publication was approved by the Director of the Bureau of the Budget, February 12, 1958.

ON THE COVER: Scale drawing of 600 foot steerable antenna being erected for the Navy at Sugar Grove, W. Va. Research planned for the giant instrument was described in the August and September issues.