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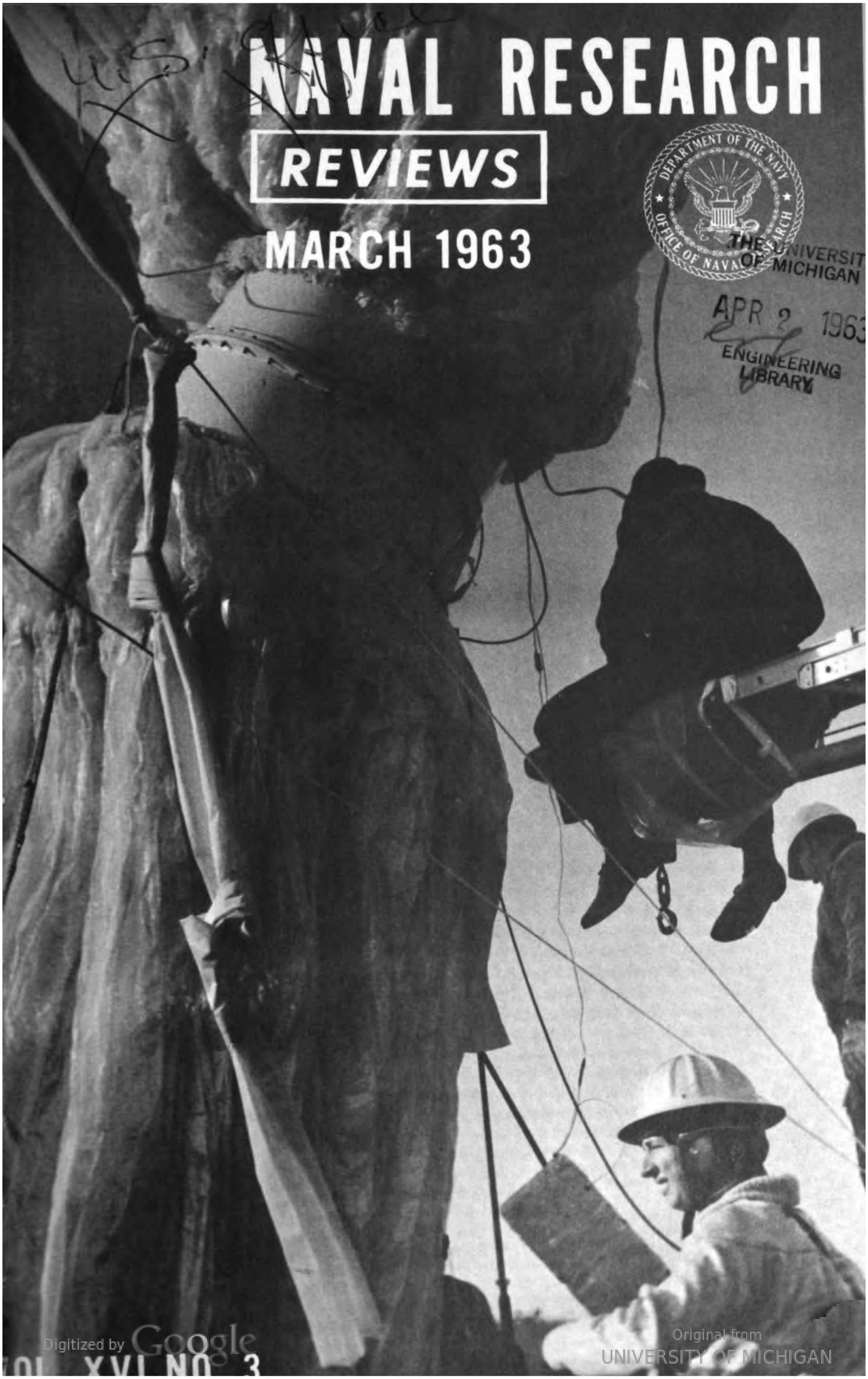
DEPARTMENT OF THE NAVY · OFFICE OF NAVAL RESEARCH



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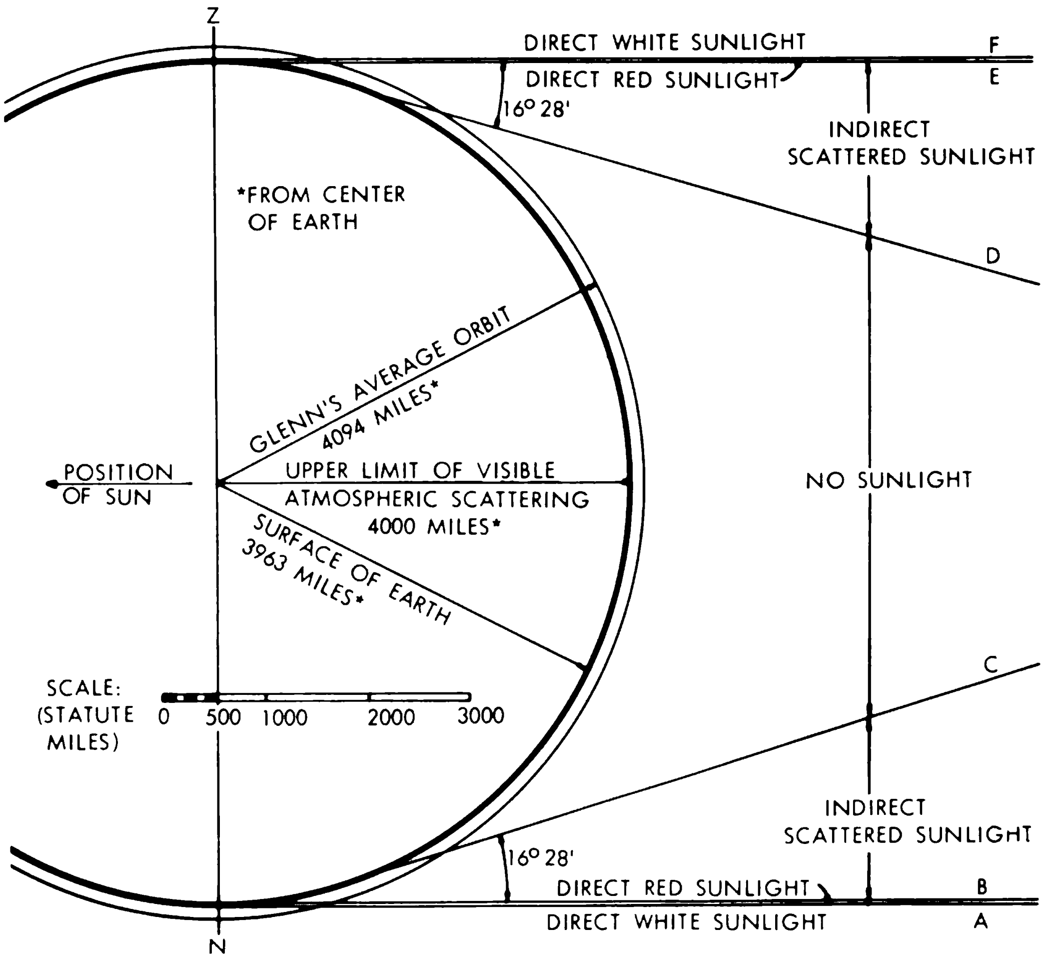

Analysis of light-scattering phenomena
observed from a terrestrial orbit.

An analysis, by the writer, of the most suitable of Colonel Glenn's color photographs in the National Geographic Magazine (see text) shows that the terrestrial atmosphere produces visually perceptible scattered light up to an altitude of 36.5 miles. This figure presupposes that the sensitivity to blue of the color film used is comparable to the blue sensitivity of the human retina and that the photograph was taken immediately after sunset. The outer blue band of this corona, to be attributed to pure Rayleigh scattering, starts at 18.3 miles (96,600 feet). Using the value of 36.5 miles for the maximum depth of the terrestrial corona and approximating Colonel Glenn's orbit by a circular orbit at a constant altitude of 131 statute miles, one arrives at the following conclusions: Considering only the fully drawn half orbit between Z and N, direct white sunlight is observed from the space capsule outside of the range extending from A to F. Between the intersections of the trajectory with the lines A and B and also with the lines E and F, brilliant red sunlight is received. Here, Rayleigh scattering eliminates blue and green preferentially from the white sunlight. These periods of "red daylight" last 18.1 seconds, based on the reported average capsule speed of 17,500 miles per hour. Between B and C and between D and E, the only light received during a period of 3.8 minutes is scattered light, emanating from the terrestrial corona. Finally, between C and D, no visible light originating from the sun is received for a period of 29.9 minutes. At a distance of 25,400 miles from the surface of the earth, darkness would be excluded, and the earth would be seen surrounded by a corona during the entire period of solar eclipse by the earth.

Radiation Scattering: Yesterday's Cinderella, Today's Primadonna

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In 1870 and 1871 the Franco-Prussian War was raging in Europe, and many Englishmen were deeply concerned about the effect of the outcome on the continental balance of power. One Englishman, J. W. Strutt, however, was concerned about an entirely different matter. He was wondering why the sky is blue during the day, for in absence of any reflecting matter in the atmosphere one would have expected it to be pitch black. While Wilhelm I and Napoleon III tried to make political history, Mr. Strutt made real history by developing a theory intended to solve the mystery of the sky's coloration. Now, 90 years later, one realizes how tremendous a breakthrough Strutt's theory represented. It is to the credit of Queen Victoria that, here again, she proved to be very far-sighted, because Mr. Strutt was soon to be knighted. He was allowed, in 1873, to assume the title of his father, Lord Rayleigh.

Rayleigh had postulated a new phenomenon to account for the blue of the sky: light scattering. He assumed that the individual molecules in the atmosphere, when illuminated by the sun, scatter a minute fraction of the radiation received, in every direction. Assuming that each molecule behaves, like a single induced dipole under the influence of incident radiation, he calculated the nature of the effect to be expected and found it to be essentially in agreement with the facts. According to his theory, which he later refined, the intensity of the light scattered from an incident light beam should increase with the inverse fourth power of the wavelength of the latter and it should increase with the sixth power of the radius of the scattering material (assuming it to be spherical in shape), and it should increase also with the refractive index ratio of the scatterer and its surroundings.

Because the sun emits a continuous spectrum (except for the Fraunhofer lines), the inverse fourth power law shows at once that scattered blue sunlight (4500 A) will be more than three times as intense as scattered red sunlight (6000 A)—assuming, for simplicity's sake, spectral invariance of the sun's brightness within these limits. The blue color of the sky was thus explained quantitatively. In addition, if anyone had asked Lord Rayleigh in 1871 what the earth would look like from outer space, he probably would have answered without hesitation that the earth must look like a ball surrounded by a very beautiful bluish-violet halo, whenever direct sunlight does not interfere with the observation. This observation was in fact made by Glenn on his orbital flight and by the other men who preceded and followed him. (The June, 1962 issue of the National Geographic Magazine gives on pages 808-810 beautiful color photographs of this halo as taken by Colonel Glenn; see also diagram on facing page).

An obvious corollary of this preferential blue scattering is the observation, well known to all of us, that the sun itself looks reddish during the sunset or sunrise, because it is viewed through thick layers of scattering material (through the maximal optical thickness of the atmosphere plus haze). This better penetration of long-wavelength radiation through haze is the simple reason for using infrared photography for objects obscured by haze or clouds. The strong increase of Rayleigh scattering with particle size explains readily why the relatively small amount of tiny smoke particles rising from the burning end of a cigar or cigarette viewed laterally in ordinary daylight gives rise to a relatively intense beam of scattered blue light, while, on the other hand, a tremendously large number of molecules of nitrogen and oxygen in the atmosphere—that is, an appreciable atmospheric thickness—are required to lead to the same effect on viewing the sky.

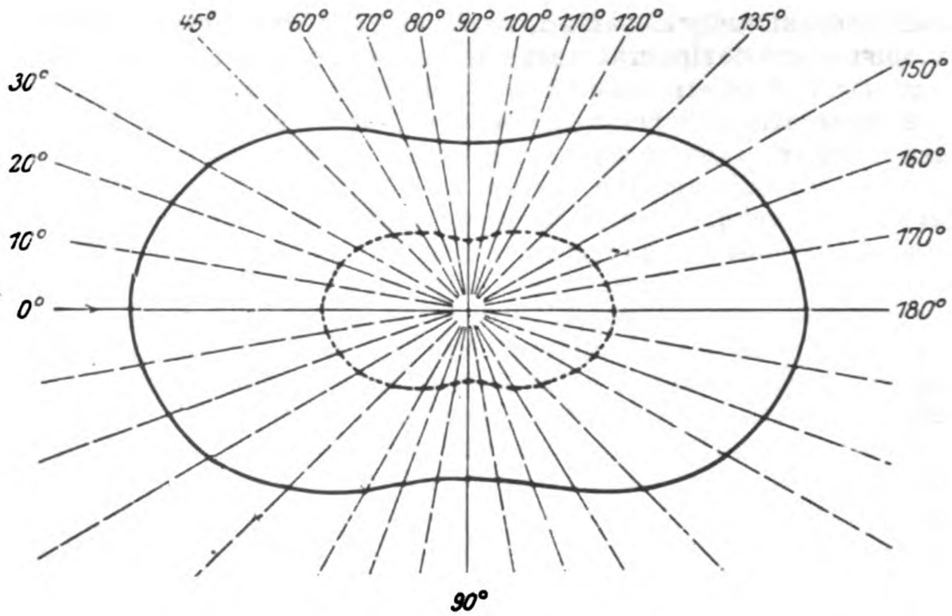
The importance of the refractive-index difference between scatterer and environment may also be demonstrated by a simple experiment which everyone of us has carried out, involuntarily, at one time or another. A sheet of typewriter paper soiled with a speck of butter from a sandwich becomes transparent where it has been touched. Typewriter paper is opaque because of the light-scattering effect of a dense network of fully transparent fibers. By substituting fat for air as the medium in which the fibers are embedded, the ratio of the refractive indices is reduced from 1.55 ± 0.03 to 1.06, which in turn reduces the scattering appreciably (the refractive indices involved are: cellulose, 1.55 ± 0.03; butterfat, 1.46; air, around 1.00). To be sure, the scattering process is far more complex here, the particles being very large, nonspherical, and intertwined, which causes interference phenomena. However, the refractice index effect is here, qualitatively, the same as in the simpler case of Rayleigh scattering. (See photograph showing light scattering by typewriter paper on inside back cover.)

Those who have performed, before reading this far, the scattering experiment with cigar or cigarette smoke may have noticed that the smoke coming from the end opposite to the burning end has a grayish or brownish color. Here again is an effect of light scattering, but one that does not fall within the range of the Rayleigh theory. The smoke particles in this instance are far too large to be considered as single dipoles. As a rule of thunb, one can say that the Rayleigh theory will fail if the longest dimension of the scatterers exceeds about 1/20 of the wavelength of the radiation used. While the blue smoke therefore consists of particles smaller than 1/1,000,000 of an inch, the particles in the gray smoke are probably of the order of 1/100,000 of an inch. (This is the result of particle aggregration during the transport of smoke through the tobacco).

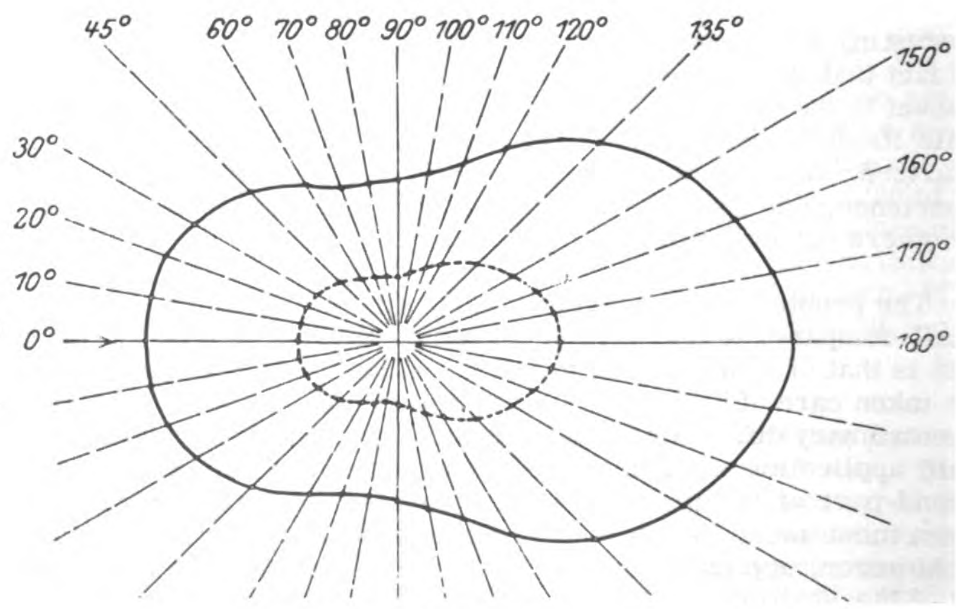
Another common example of scattering by relatively large particles is the grayish ray of light coming through a tall church window. Here, the scattering particles are dust particles. Although the scattered light generally is gray if the relatively large particles are present in various sizes, singularly striking colors of any hue in the spectrum are likely if they all have approximately the same size. Such uniformity, for instance, is the cause and the prerequisite of the beautiful multicolored sunsets occasionally observed, particularly if the lower layers of the atmosphere and peripheral areas around clouds contain a large amount of tiny water droplets of about the same size. These larger particles in the lower atmosphere are, of course, also responsible for the red, yellow, and gray bands which are seen from outer space between the blue Rayleigh halo and the boundary of the earth (see the photographs referred to above). It is fairly easy to anticipate that these non-blue bands will be more prominent over heavily populated areas than over desolate areas and oceans.

In addition to the complicated spectral variation of scattered light, relatively large particles exhibit several other characteristically different scattering properties (See diagram on the following page). First, the amount of light scattered in the forward direction—in the same direction traveled by the incident radiation—is greater than that scattered in the backward direction. This lopsidedness increases rapidly with particle size. (In contradistinction, Rayleigh scattering in the forward and backward direction are equal). The next time you are driving in misty weather up toward the crest of a hill you can verify this preferential forward scattering by the following simple observation: a car which is travelling toward you, but is still out of sight below the crest of the hill, sends up an impressively bright beam of light; a car travelling ahead of you in the same direction in which you are going will also send a beam of light up into the sky, but this scattered beam is much weaker. The second noteworthy difference in the scattering by relatively large particles is that the total amount of light scattered by a system of given concentration of scatterers per unit volume reaches a maximum value at a very specific intermediate particle size. For this phenomenon also one can cite a common experience: the brightness of a distant light source, or the visibility of a distant illuminated object, is minimal in fog but is considerably increased both in misty weather and in a heavy drizzle. The average water droplet size of fog is intermediate between that of mist and of light rain; it is just the right size to produce maximal hiding power. The implication for the production of smoke screens of maximum efficiency are obvious. The third interesting difference in the scattering by relatively large particles is the fact that the scattered light observed at an angle of 90 degrees with respect to the incident beam will be found to be only partially polarized, while Rayleigh scattering is, for the same angle of observation, fully polarized. This phenomenon is outside of the realm of easy everyday experience, but its practical significance and importance rank with the others enumerated.

The problem of the theory of scattering by particles which are not small compared to the wavelength can be divided into two parts. The first is that of spheres. All possible contingencies that may arise here are taken care of by a theory developed by Mie in 1908. However, the extraordinary difficulties arising in actual calculations delayed its full-scale application until electronic computers became available. The second part of the problem relates to nonspherical particles. Here also a most useful theory exists, again initiated by Rayleigh (1911). It is, however, applicable only in the limiting case that the refractive index of the scattering material differs very little from that of the surroundings. Very slowly progress is being made in developing theories



Scattering pattern of Rayleigh spheres and of large spheres. The upper diagram is the radiation diagram of "Rayleigh" spheres having a diameter of five millionths of an inch, while the lower one applies to particles with a diameter of ten millionths of an inch (relative refractive index: 1.25). The incident light comes from the left. The particle is assumed to be in the center of each diagram. The length of the dashed straight lines from the center to the intersection with the contour curves is a measure of the relative intensity of light scattered at various angles with respect to the 0° line. The fully drawn contour curve applies to green light, the dashed one to red light. The symmetrical upper diagram is characteristic of Rayleigh scattering. The preferential forward scattering in the lower diagram increases rapidly with further increase in size. For a diameter of five hundred thousandths of an inch, the 180° intensity of green light scattered has already increased to 2,800 times that along the 0° line. (Reproduced from data by H. Blumer, 1926).



in which this limitation will be reduced gradually. In the meantime, one must be satisfied with various approximating treatments.

The great importance of light scattering derives from the fact that it allows one to investigate quantitatively an amazingly large number of problems in many fields of human endeavor. This can be done without interfering in any way with the system investigated. One of the reasons for this unique position of the light-scattering method as an analytical tool is the fact that there is, in principle, no limitation as to the wavelength that may be used. The phenomena are the same no matter whether the radiation is that of visible light, or is of shorter wavelength (ultraviolet, x-rays, gamma radiation), or of longer wavelength (infrared, far infrared, radar, or broadcasting waves). This is because the absolute size of particles does not matter; only the size relative to the wavelength is important. Thus, hollow aluminum spheres one inch in diameter strewn into the atmosphere will scatter (attenuate) radar waves quantitatively in exactly the same manner as tiny aluminum spheres 1/10,000 of an inch in diameter will scatter visible light—provided the differences in the refractive indices at the two wavelengths are taken into account.

On reviewing the development of science, technology, and national defense, during the last 15 years, it is amazing to see how large a contribution the understanding and the application of radiation scattering has made in all these areas. The space available here allows one to give only a few significant examples. The amazing progress that has occurred in the fields of polymer chemistry and biochemistry is to a large extent the result of the fact that light scattering has provided a rapid, reliable, and precise method for determining molecular weights and approximate molecular shapes, and that it has allowed the kinetics of changes in these qualities to be followed in a way no other method is capable of doing. Noteworthy here is the pioneering work by Zimm and by Doty in the late forties. In all these areas, it is primarily Rayleigh scattering which has, at last, taken the place as a research tool it so fully deserves. A large part of the credit for this goes to Debye who, in 1943, put the final touches to a theory developed by Einstein in 1910. This theory, though based upon an entirely different approach, is fully equivalent to Rayleigh's theory. It has, however, the advantage that the final equations arrived at facilitate the practical application of the scattering effect and furthermore allow one to obtain, in addition to the primary information on molecular weights and shapes, information on the thermodynamics of the systems and processes studied.

In the field of colloid chemistry, which deals with particles too small to be seen in a microscope but larger than an average macromolecule, the growing exploitation of the Mie theory has put us just now on the threshold of a full understanding and control of the behavior of emulsions and of aerosols, to name only two important classes of systems in this area. (Experimentally, the work on scattering by aerosols was initiated in this country primarily by La Mer in 1943.) In various laboratories, extensive theoretical work is underway concerned with the quantitative evaluation of radar attenuation by tiny atmospheric ice crystals and by various types of cloud formations. Also, complete theoretical information is now available (results of the writer published thus far only in preliminary form) which makes it possible to predict the exact range of particle sizes which for a given wavelength—visible, radar, or broadcasting—will lead to minimum radiation transmission or maximum radiation reflection.

These and other developments in the science of light scattering hold the promise of a more fruitful investigation of fogs and smogs. If and when a full understanding is achieved, it certainly will be the decisive step towards eventual control or complete eradication of smogs. Fog and smog are the ultimate result of a large accumulation in the lower atmosphere of dust and debris from combustion which act as nuclei for water condensation. However, the conclusion that the upper atmosphere is pure and clean would not be justified. Light-scattering experiments quite recently showed that dust may be carried by eddy currents as high as 80,000 feet. This finding, incidentally, leads to a solution of the puzzling problem of why the sky is brighter than one would expect from Rayleigh's theory. Investigations by space probes gave exactly the same results on the pollution of the upper atmosphere, the only difference being that the light-scattering technique gave this information at a considerably smaller cost.

The sky, however, is not the limit for scattering enthusiasts. They already are busily engaged in wresting from outer space many of its secrets without having to take their feet off the ground. They hope to clear up, by scattering experiments, the unknown depth and concentration of the atmosphere of Venus, by studying the latter's atmospherics effect upon a beam reflected from the surface of the planet. It also is reasonable to expect that scattering may give useful information on the consistency of the surface of the moon which is now the subject of so much debate. No attempts in this direction seem to have been made thus far.

Light scattering work has also begun to extend beyond the reaches of our solar system. Particularly fascinating is the work of the Belgian astrophysicist, Dr. Swings, on the radiation which comes to us from comets. Superimposed upon the discrete emission spectrum of these bodies is a continuum which now has been found to be due to the scattering of sunlight by cometary dust. Moreover, this dust effect appears to become larger as the age of the comet increases. Therefore, one may be able before too long to tell the age of a comet from the amount of dust it has managed to collect in its tail. Where all this dust comes from has also been partially explained by light-scattering measurements. Thus, it has been found in England that the solar F-corona may be understood as the result of scattering by dust. The sun thus may turn out to be one of the dust generators, while the comets may belong to the class of dust catchers. The "cosmic dust," as it is called, often is present in space in such large concentrations that it partially obscures the radiation from distant galaxies. Several scientists are already making light-scattering measurements of those giant blobs in the hope of obtaining further information on their mysteries.

Returning now to earth and proceeding in the opposite directions—into the microcosmic world of the atmoic nucleus—it is common knowledge that much of the progress made here is due to experiments with the cloud chamber and, more recently, with the bubble chamber. Here light scattering convinvingly, though indirectly, makes visible the paths taken by α-particles, protons, electrons, positrons, and mesons, and allows us to follow the interactions of the so-called "strange particles" of nuclear physics. Phenomena such as neutron scattering also are treated by means of theories which, in many respects, are related to the scattering of electromagnetic waves. An application of scattering which is of particular concern to many of us is its use as a potentially powerful tool in medical diagnosis. One successful example dating back to the waning period of World War II is the examination of donor blood for the degree of non-sphericity of red blood cells by a rapid experiment on the deviation of lateral scattering from symmetry. Another example is the present, intriguing work by Boyle and associates who believe that the presence and development of atherosclerosis may be detected and studied by light-scattering measurements on blood serum.

Rapidly developing also is the theory and practical application of light scattering by transparent or translucent solids. Here light scattering may be due to a dispersion, within the solid, of gases or of liquids, or it may be due to the formation of tiny regions of molecular orientation within the matrix, or it may simply result from internal strain or from cavities. In all these cases, internal refractive index differences arise, and the resulting optical inhomogeneity leads to light scattering and, consequently, to more or less pronounced opaqueness.

A good example of a solid rendered opaque by the entrapment of tiny droplets of water is the pearl. Its delicate bluish-gray color originates exclusively from light scattering. (Therefore, you should never heat a pearl above the boiling point of water.) An example of light scattering due to differences in molecular orientation within a solid is the scattering by polymer films, studied in this country at present primarily by Stein and collaborators at the University of Massachusetts. The scattering by these films gives valuable information on their internal structure. A lesson learned from the fact that inhomogeneities in solids may make them opaque, due only to refractive index differences, is that one now can make glasses, particularly plastic glasses, more transparent than before by simply eliminating or matching refractive index differences. One has even succeeded in manufacturing translucent rubber tires by using exotic fillers instead of carbon black. Unfortunately, their mechanical properties still leave much to be desired. Once this bottleneck is overcome, translucent tires may well become the next fad of car owners, particularly since white side walls have already become so commonplace that they can no longer be used as a mark of personal distinction.

The radiation scattered by molecules, particles, or inhomogeneities has thus far been considered as being unaffected by that scattered by neighbors. Actually, there is an interference between the individual scattered wavelets, the more so the smaller the distances between neighbors, relative to the dimension of the wavelength. A whole host of phenomena that are of theoretical interest and practical importance can result from such interferences. Some of them belong in an area which the uninquiring mind may wish to classify as a part of the "twilight zone." We will limit ourselves to a brief outline of the latter which are particularly intriguing.

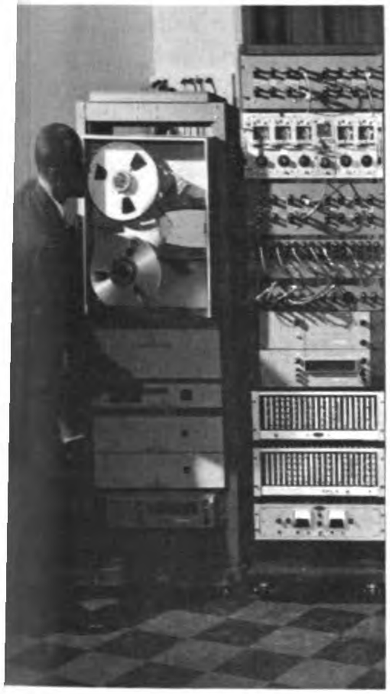
When you drive along a highway on a hot summer day, you may see dark patches on it in the distance which look just like water. Then, when you come closer, they vanish. The next time you make this observation, stop while you see these patches and wait until a car passes you and drives over those patches. You will be amazed to see that the car seems to lift itself a few inches off the ground and to travel in air. Moreover, you may see its understructure reflected on the patches. What is the reason? Immediately above the ground is a layer of thin hot air, above which the temperature drops 30 to 50 degrees. Because of the resulting refractive-index differences, refraction and reflection occur. Although this phenomenon is contrary to everyday experience, it shows that not only solid surfaces, but surfaces separating gases of different optical properties can produce perfect reflection.

Similarly, on driving across Utah's Salt Lake on a hot afternoon you may suddenly see one of the mountains on the horizon detach itself from its base, an experience which this writer will never forget. Flying saucers also belong in this category of phenomena, although here the diffuse reflection and refraction originate at the surfaces of vortices of the air which differ in density from the rest of the air. These vortices are generally circular and, according to Helmholtz, may be extremely longlived. They may, therefore, have travelled far from the place where they were generated—for instance, by a jet breaking the sound barrier. Unquestionably, photographs of this phenomenon could be taken if and when the density differences are large enough.

Another related phenomenon which turned out to be of extreme practical usefulness, is that of transhorizon wave propagation. This results from diffuse reflection on stratifications in the uppermost sections of the atmosphere.

Complicated stratifications caused by a succession of hot and cold air layers may also arise in the lower and intermediate atmosphere. Under the right conditions—one still knows very little about them—refractions and reflections of light rays coming from distant objects give rise to the very rare phenomenon of fata morgana. This phenomenon is so diversified, so changeable and so complex that its connection with simple radiation scattering is already quite remote. Yet this connection exists in view of the preceding discussion. In contrast to the mirage of flying saucers which produces apprehensions, fright, or adventurous curiosity, the psychological effect of fata morgana is far more gratifying. It is said to produce "a deep sense of happiness and an endless longing." Therefore, whoever has the rare chance of observing a fata morgana can consider himself lucky unless he finds himself, at that particular time, in a hopelessly precarious position.

We all have felt sympathy with the man lost in the Sahara desert who became elated on suddenly seeing the mirage of an oasis in the distant sky. Alas, we cannot control these phenomena yet, but eventually we may. If that happens, there is no way of predicting how real estate values in the Mojave desert will skyrocket, since real estate agents may then be able to include in their package deal a permanent fata morgana in the backyard, allowing a choice view of a selected section of Yosemite National Park.



Four Measurements of Sound Underwater

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Sound Division
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Laboratory

Information obtained on sound waves in the deep ocean is monitored in the laboratory by means of special equipment developed at the Naval Research Laboratory. Data on tape, at left, is reproduced on oscilloscope screen, at right. Processed data show up on a plotter nearby.

When compared with the inherent precision of radar in detecting aircraft, sonar is inferior as a means of detecting submarines. Obviously, then, much more needs to be known about the physical behavior of underwater sound and the acoustical characteristics of the ocean. Scientists at the Naval Research Laboratory have tackled the problem through research in four separate but related areas, with the ultimate aim of improved sonar systems:

- The speed of sound—how it is determined and how it is influenced by temperature, salinity, and pressure in the sea.

- The path of sound--the actual geometry of sound rays, how fast they spread, and how far they reach into the ocean.

- The strength of sound—how much is reflected from a target.

- The source of sound—the identification of underwater objects by the sounds they emit.

Speed of sound is the basis for determining the range to a submerged submarine. Variations in speed as the rays pass through the sea is the underlying cause of deflection and bending of the searching beam. To understand and control these characteristics, the measurement of the speed of sound as it is influenced by temperature, salinity, and pressure in the sea is being pushed to its ultimate limits of precision. Equipment now in use is built to yield a precision of 1 part in

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150,000. This means that under a typical sea condition, in which sound may be traveling at a speed of about 4,900 feet per second, a change in speed amounting to only 1 centimeter per second can be detected. Sound-speed tables of values are being compiled which reflect this precision and which show variations with temperature, salinity, and pressure.

The path along which a point on the sound wave proceeds through the ocean is called the sound ray. Knowledge of the actual geometric shape of these rays, how fast they spread, and how far they reach into the ocean is dependent upon two elements: accurate laboratory measurements of sound speed and precise determination of salinity and temperature in the ocean. Establishing the relationship which exists between these two elements is the major purpose of experiments now being carried out at sea. The results should permit more reliable predictions of the exact sound field impinging on any point in the ocean.

The sound that comes back to the searcher in the form of an echo indicates the position and some characteristics of the target in the ocean. Thus a complete understanding of the physical mechanisms in the reflection process is a vital link in our chain of knowledge. Many measurements have been made of the reflection properties of target submarines; sonar engineers refer to this as determining target strength. Many of these measurements are made far at sea, and the ever present motion and turbulence of the water cause the measured results to fluctuate wildly. To establish a sound physical basis for determining exact target strength, NRL is conducting a continuing program of reflection measurements under laboratory conditions. Targets which somewhat remotely resemble a submarine, such as spheres and spheroids, and which have precisely known physical properties are placed in a sound-radiation field of precisely known intensity and geometric configuration. Under these conditions, accurate measurements can be made of the sound reflected from the target.

Objects moving through the water produce sound which is independent of sonar echoes. An understanding of this phenomenon is vital in submarine-hunting operations, known as passive detection—that is, simply listening for submarines. Recent studies have revealed the physical details of vortex shedding as bodies of various shapes are moved through the water. These vortices are commonly observed phenomena in hydrodynamics. Under certain circumstances, they peel off a moving object in regularly ordered series and, in doing so, they impart to the object alternating forces, setting the object into vibration, which gives rise to sounds or disordered oscillations of noise. The magnitude of this phenomenon in exciting vibration in ship's plates has been determined for certain simple geometric shapes in the laboratory. This work contributes to the general fund of knowledge regarding the emission of noise from submarines and thus aids in the design of detection systems.

In order to make several of the types of measurements described here, very large, expensive equipment is required. In the following article, an important new Navy platform for testing and calibrating this Navy equipment is described.

The New Sounds in Seneca Lake

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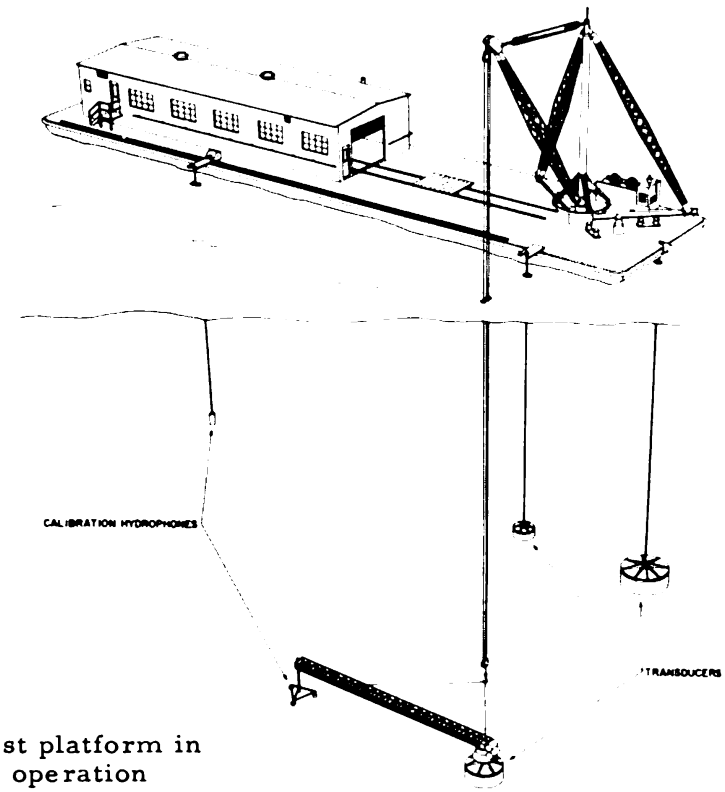


Test platform in operation

One of the difficulties experienced in measuring sound underwater in the several dimensions outlined in the preceding article arises from the sound-wave frequencies now used for sonar devices. For more than a decade there has been a sharp downward trend in these frequencies with a corresponding gain in detection at longer ranges. In attacking the problems which this trend has created, it is obviously more efficient and far more economical to test, calibrate, and debug transducers, hydrophones, and associated hardware before installing them at their operating sites.

An important factor in testing new sonars is water depth—because the characteristics of highly directive low-frequency transducers can be measured adequately only in very deep water. Compared with the high frequencies used in World War II sonars, which required depths of only five or six fathoms for testing, the frequencies used for modern sonars require depths roughly ten times greater. Indeed, in some cases, depths as great as 1,000 feet have been required. At the same time, the lateral dimensions of the testing site have had to be increased.

A second requirement for testing many transducers is the capacity for handling objects of large size and weight. The complete Artemis transducer, for instance, is so big it can be handled only from a special ship, and even preliminary testing of small segments of the transducer was precluded by lack of a deep-water platform which could support their weight. Other requirements are higher workload capacity, easy accessibility to the site, and availability of trained operating personnel.

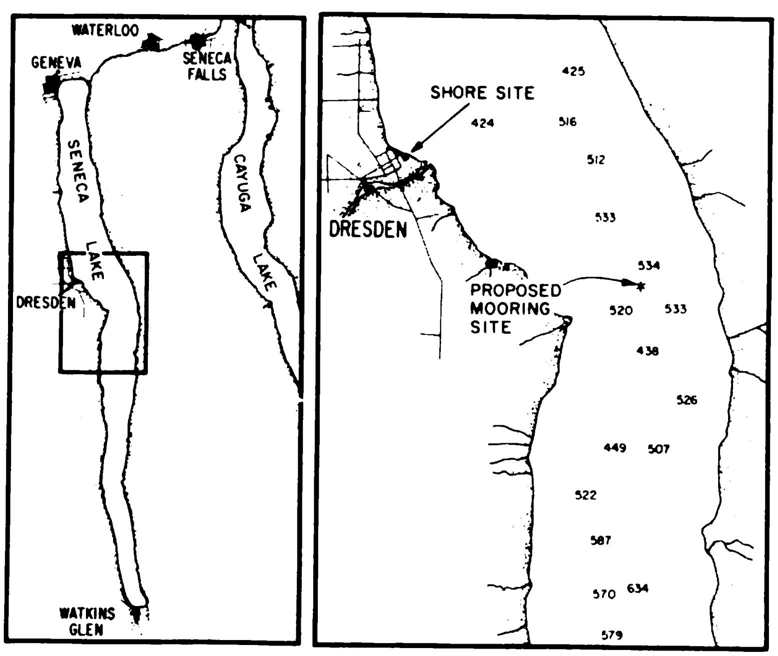
At the present time, no Navy facility exists which meets all of these requirements. The one that comes closest to doing so is the Navy

Electronics Laboratory's calibration platform located on Lake Pend Oreille in Idaho. Its drawbacks are its distance from Navy laboratories doing acoustics work—particularly those on the east coast—and its overloaded test schedule. What has been needed for a long time, therefore, is a similar station in the eastern part of the country.

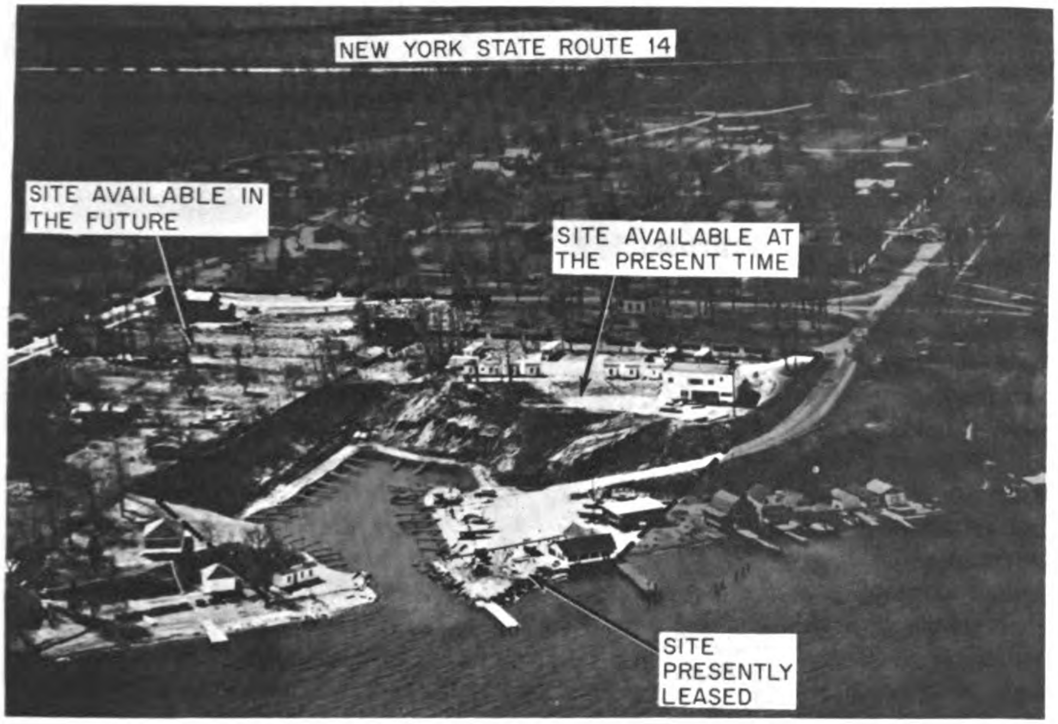
Ideally, such a station would be situated on a body of water at least 500 feet deep over an area of not less than one square mile. Natural shelter would prevent the occurrence of high winds and waves. Little noise would be produced in the area. The surrounding terrain would be of such a character that it would absorb most unwanted noise. The climate would be sufficiently mild to permit year around operation. And the site would be accessible to all major east-coast laboratories carrying out underwater research and development programs.

After an extensive survey of water bodies in the east, made by the Naval Research Laboratory, a site was chosen and work was begun on a new calibration platform. The body of water found to satisfy best all of the requirements was Seneca Lake, located in the Finger Lakes region of central New York. The lake is about 36 miles long and from one to three miles wide. Over an area approximately 20 miles long by one mile wide it is more than 500 feet deep, and in one locality—about 2-1/2 miles long by 1/2 mile wide—it is from 600 to 634 feet deep. The western part of the lake is free of ice and protected from high winds by lofty ridges. Over a two-year period (1952-53) the annual mean wind speed was 9.1 miles per hour, and the mean low temperature, 31.7°F.

As pleasure-boat traffic is usually concentrated at the ends of the lake—near Geneva and Watkins Glen—the central, deepest portion of the lake—the part selected as the operating site—is relatively quiet. Also, the shores in this area are not heavily populated, so few noises are produced to interfere with the acoustic studies.



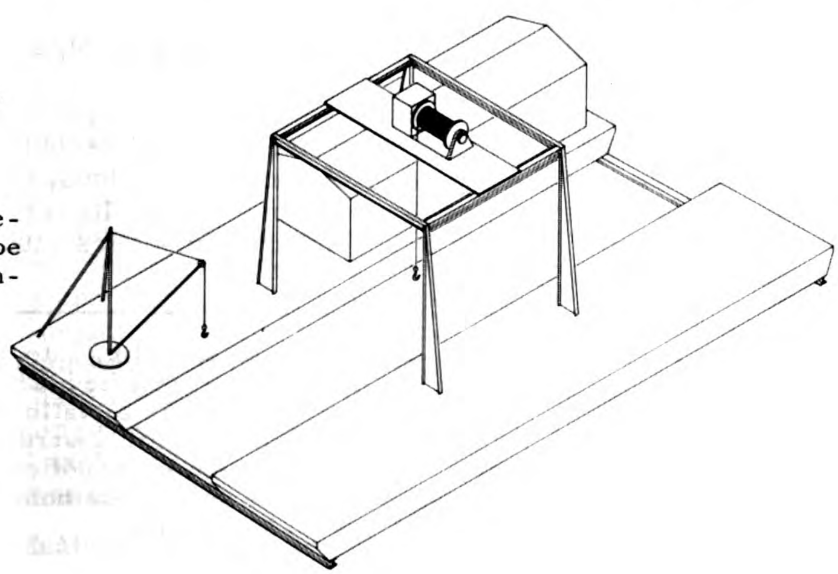
Map of Seneca Lake, New York, showing location of shore site at Dresden and proposed mooring site of test platform. Numbers indicate water depth (in feet).



Aerial photograph of Dresden, showing property now leased for shore site, area immediately available for expansion, and area eventually available.

The shore installation is being set up on leased property at the Dresden Marina, on the western side of the lake, about 12 miles south of Geneva. Office, storage, and work-shop space, as well as a staging area and dock are located here. Test equipment will be unloaded from trucks directly onto a landing craft. This vessel, which is 50 feet long, 14 feet wide, and has a capacity of 60,000 pounds, will carry the equipment to a large platform moored on the lake. Here the experiments will be

Sketch showing how present platform could be enlarged to accommodate larger loads.



conducted. If the gear is too large or heavy for the landing craft to handle, the platform will be brought to the dock for loading. In this case, the landing craft will be used to tow the platform.

The platform is a converted Navy barge of steel construction, 150 feet long and 34 feet wide, with a 250-ton capacity. The barge can handle a load of up to 40 tons in weight and 20 cubic feet in size. In addition, it can move such a load through 180 degrees from the bow to a point on the main deck 52 feet aft of the bow, and can lower it to a depth of 600 feet. Along the starboard side of the platform is a monorail track from which a monitoring or calibrating hydrophone, supported on sectionalized pipe, can be positioned precisely and lowered to a depth of about 200 feet. A tracked dolly of 10-ton capacity facilitates movement of equipment from the main open deck area to the interior of the deck house. Davits and power winches are positioned as required for handling electrical cable over the side.

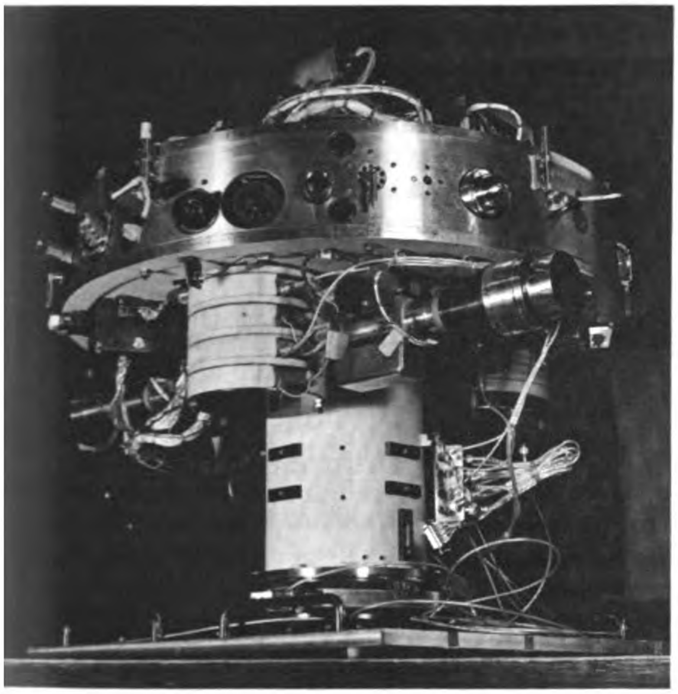
The deck house will contain the necessary test equipment—amplifiers, equipment racks, oscilloscopes, signal generators, counters—and a main power-distributing board, office space, and sanitary facilities. Below the deck will be three diesel generators and tanks for diesel fuel and fresh water. Four ballast tanks are provided for controlling list when the crane load makes such control necessary.

The operating site for the platform is located approximately two miles southeast of the shore site, where the water is 500 feet deep. A three-point moor prevents changes in the barge's position, yet does not seriously restrict the use of the water beneath the barge.

Although the NRL test platform is not yet in operation on the lake, the groundwork has already been laid for the expansion of the Seneca station, possibly into a facility to be placed under general Navy management. The platform itself can be expanded either by pontoon construction or by connecting it to another, similar platform—catamaran fashion—and leaving a well between the two structures. A traveling crane bridging the well might also be cantilevered over the bow for handling loads weighing up to 100 tons. To increase the work capacity of the platform, experiments might be conducted both night and day.

Considering the important contribution being made by acoustics research to the improvement of devices and techniques used in antisubmarine warfare and other undersea operations, the establishment of the Seneca Lake station is a welcome event. Its further enlargement—and the stimulus which it will bring to acoustics studies—should prove equally significant.

The Naval Oceanographic Office is putting into operation a flying oceanographic research laboratory in a modified EK-121C Super Constellation aircraft. The plane will serve as a platform for the evaluation of experimental airborne oceanographic instruments and will be used in fleet exercises to provide data on short notice over areas which are not normally covered by surface ships. Its home base will be the Naval Air Station, Patuxent River, Maryland.



The Injun Satellites

B. J. O'Brien
Department of Physics
and Astronomy
State University of Iowa

Part of the Injun III satellite, showing extensive array of scientific instruments.

The Office of Naval Research has supported high-altitude cosmic ray studies by Dr. James A. Van Allen and his group at the State University of Iowa since 1952. The early studies were with balloons and balloon-launched rockets, called rockoons. In the past few years the support has been extended to include the design and construction of the series of satellites called "Injun." The generic term "Injun" was devised by Van Allen on relatively short notice, and has no significance other than to identify the particular series of Iowa satellites.

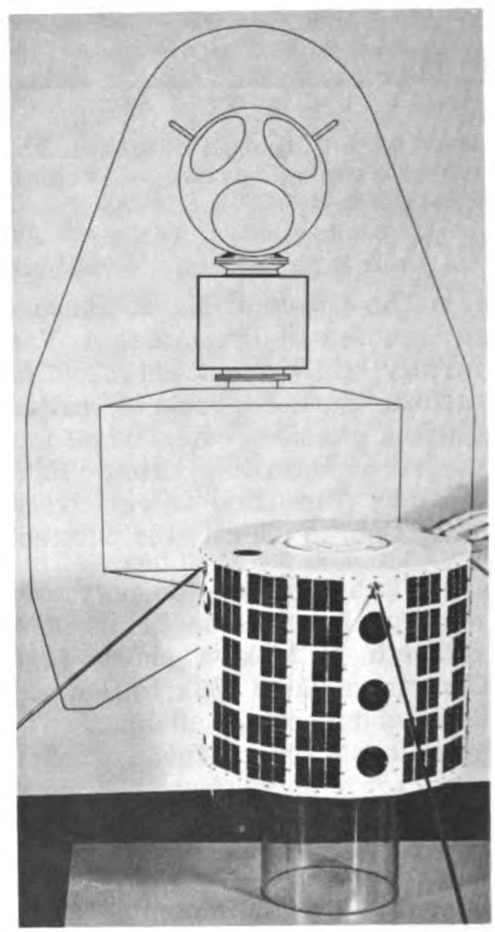
The Injuns are the only satellites which have been built at a University. Injun I was launched June 29, 1961 and is still operational, although it took a short rest period—stopped broadcasting—from Christmas Day, 1962 to January 17, 1963. Injun II was destroyed in the launch attempt on January 24, 1962, but Injun III is also operating now after a successful launch late in 1962.

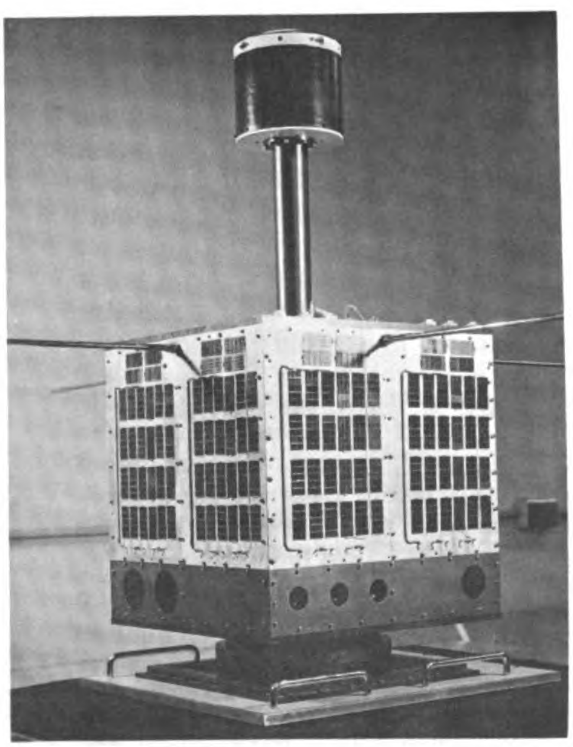
Because the Injuns have been put into relatively low-altitude orbits reaching to high latitudes they have been used for studies of the Van Allen belts, auroras and airglow, and other geophysical phenomena of interest. Our main object has been to design integrated research payloads that are custom-tailored to achieve the specific aims of each flight. I believe we have been successful in those aims because we have been able to make compromises and thus achieve compatibility between scientific aims and technical capabilities. This was possible because only a small group was involved.

A fundamental feature in the design of the Injuns has been the use of a permanent magnet to align one axis continuously parallel to the

The Injun III satellite. Left to right, Curt Laughlin, payload manager; Dr. Brian J. O'Brien, scientist in charge; and Don Gurnett, project engineer. The VLF loop is at the top of the payload. The antennas are shown in the folded position for launch.

The Injun I satellite and a sketch of its location at launch between Transit IV A at the bottom and Solar Radiation III at the top. Injun I and SR III did not separate at launch, as intended, and they are still attached.





Satellite Injun II, a 16-inch cube. Two magnetometers are located in the boom at top.

magnetic field of the earth, so that this axis is continually oriented as the satellite moves around the earth. Thus the axis should be "horizontal" when the satellite passes the equator, and it should point "down" over the North Pole and "up" over the South Magnetic Pole. Injun I was not very well oriented because the Naval Research Laboratory satellite Solar Radiation III and Injun I failed to separate after launching. Consequently, the little magnet in Injun I cannot orient the composite mass fast enough to keep up with the continually changing direction of the magnetic field. On the other hand, Injun III is orienting to within better than five degrees, even though its orbit differs considerably from that intended.

The effort to orient the satellites magnetically was made because the charged particles, protons and electrons, which exist in the Van Allen radiation zones and in auroral fluxes are guided solely by the magnetic field of the earth, and their intensity is cylindrically symmetrical about the field lines. Consequently, if we measure particles moving at right angles to the magnetic field at Injun's altitude we know they are truly trapped—held in a belt. If we measure particles moving parallel to the field lines we know that they are on their way down to be absorbed in the atmosphere, there to create perhaps an aurora. If we point a photometer parallel to the field lines we can then measure the intensity of the auroral light emitted. If we also (as in Injun III) orient a loop antenna appropriately, we can detect very-low-frequency (VLF) electromagnetic waves which are guided along the path of the field lines, and which may be associated with the acceleration of the particles causing the aurora. Obviously it is best to have all this apparatus on the same satellite so that whenever a rare auroral event is detected it can be studied extensively.

Injun I weighed 40 pounds at take-off and carries 13 particle detectors and an auroral photometer. Injun III weighed 114 pounds and carries three photometers, a VLF experiment, and 18 particle detectors including a scintillator built by Dr. Carl McIlwain of the University of California and a proton spectrometer built by Dr. Carl Bostrom of the Applied Physics Laboratory. With the particle detectors we can determine the intensity, angular distribution, and energy spectrum of electrons with energy between 5 kev and 6 Mev and of protons with energy between 50 kev and 100 Mev. These are the energy ranges of greatest interest in studies of auroras, of the natural Van Allen radiation and the artificial radiation belts produced by high-altitude nuclear explosions, and of protons from the sun.

Not only does the Injun apparatus enable us to carry out relatively pure physics research, but it also measures for us radiation which can cause deterioration of the solar cells which power many satellites. It was Injun I, for example, which showed that the cessation of transmission from the Navy satellites Traac and Transit IVB and the British-U. S. Satellite Ariel, in July and August 1962, was consistent with the hypothesis that their solar cells had been severely degraded by the after-effects of the U. S. high-altitude nuclear test on July 9, 1962.

The discovery of the artificial radiation belt from the July 9, "Starfish," explosion was perhaps the most spectacular of the many findings of Injun I. The satellite was a venerable one year old when the 1.4 megaton bomb was exploded 400 kilometers above Johnston Island in the Pacific, and we had to control its duty cycle of active transmission fairly carefully to conserve its batteries and allow them to be recharged adequately by the solar cells.

The very fact that Injun I had made millions of measurements of the radiation environment before "Starfish" meant that we could distinguish clearly the natural from the artificial radiation. It also meant that we could carry out very rapidly the complex logistical operation of scheduling telemetry, receiving and decoding telemetry tapes, reducing the data with our I.B.M. 7070 computer, calculating the orbit in appropriate "magnetic" coordinates, checking the satellite clock time against the time signals of Station WWV, and sorting the data for convenient analysis. The latter proceeded so smoothly that the author, Curt Laughlin, and Dr. James Van Allen were able to circulate privately—only about three weeks after the burst—a report on the intensity, spatial extent, and time decay of the artificial belt.

The artificial belt is composed of high-energy, very penetrating electrons. These electrons are the products of the rapid radioactive decay of fragments produced by fission in and around the bomb. About ten hours after the explosion in the heart of the belt, at an average altitude of about 800 miles and extending about 20 degrees north and south of the magnetic equator, there were about one billion fission electrons crossing each square centimeter each second. The artificial belt after six months still dominates the radiation environment in the lower fringes of the inner Van Allen belt, and it will be years before it is completely worn away.

There have been more than a dozen scientific papers written on the findings from Injun I. Most of these are concerned with the composition and dynamics of the radiation zones, but one concentrates on solar protons—those nuclei of hydrogen which are blown out in a violent flare on the sun and travel through interplanetary space at speeds comparable to the speed of light. Using two Injun I detectors which were designed and built by Dr. G. Pieper's group at the Applied Physics Laboratory of Johns Hopkins University (there are similar A.P.L. experiments on Injun III), a joint A.P.L.-S.U.I. study was made of the time history of several of these solar proton events in July 1961. Such phenomena are of importance in radio-communication at high altitudes, because an intense solar-proton bombardment of the ionosphere can produce enough ionization to cause a radio "blackout."

We were also able to study with Injun I the particles which bombard the atmosphere, both in magnetically-quiet and -disturbed times. On one occasion during the local (Iowa) day we received a report of electrons being dumped into the atmosphere in intensities sufficiently great to produce an aurora which would have been visible had it been night-time. We therefore found, from this and other events, that the beams of electrons which cause auroras must originate in mysterious accelerating mechanisms high above the altitude of Injun I (in other words, above 600 miles) and that these mechanisms can happen in the daytime as well as at night.

Another of our studies with Injun I showed that the average "dripping" of particles from the outer Van Allen zone was so large that one should discard the "leaky bucket" model. This model was suggested by Van Allen and others in 1959 as follows: consider the outer Van Allen belt as a "bucket" which is continually replenished by particles from the sun. If the sun is particularly generous (such as at times of solar flares which lead to geomagnetic storms) the bucket may "slop over" and the outrushing particles might cause an aurora below. In 1961, however, we found with the NASA satellite—Explorer XII—that the early estimates of the number or intensity of energetic electrons in the outer belt were a factor of 1,000 too large. Thus the average "dribble" seen by Injun I could empty the outer zone in a few hours unless new sources added to it.

So the author suggested that we should turn our thinking right around, and regard the outer zone not as a primary source of particles which later cause auroras, but as a secondary sink, which happens to catch a few electrons produced by the violent (and unknown) mechanisms which accelerate electrons, most of which plunge into the atmosphere to cause auroras. The outer zone, we suggested, is not so much a "leaky bucket" as it is a "splash catcher." Recently, data obtained from Injun III confirmed that our speculation is valid.

Ground is Broken for NRDL Cyclotron

Construction has already begun on a $3 million 70-inch cyclotron at the Naval Radiological Defense Laboratory in San Francisco. The new equipment--to be named the Neutron Radiation Facility--will be used to investigate the damaging effects of sub-atomic particles, particularly neutrons.

To house the accelerator, a 60- by 145-foot building will be erected containing a large, high-ceiling room serviced by a 15-ton crane. The accelerator will be placed near the center of this room in a heavily shielded cave. One wall of this enclosure will be 12 feet thick and the others 9-1/2 feet thick; the roof will be 6 feet thick. A unique feature of the shielding will be a moveable concrete wall which can be set up quickly when additional protection is needed. A staging area, machine shop, animal holding room, chemistry laboratory, offices, control and counting room, physics laboratory, and electronics laboratory will also be located in the building.

The cyclotron beam will be brought through ports in two walls of the cave into the compartments in which the experimental work will be done. Particles accelerated--chiefly protons and deuterons--will be employed not only to bombard targets to produce neutrons, but also to cause a variety of other nuclear reactions. Studies of the effects of high-energy protons as well as of high-energy neutrons will be possible.

Unlike the neutrons produced in reactors--which have random energies--those produced in the NRDL cyclotron will have specific energies. Furthermore, these energies will be controllable over a wide range, covering the entire area of interest of the applied radiation-effects program.

Research Notes

E. O. Hulburt Center for Space Research

A new space center was established last month at the U. S. Naval Research Laboratory, in Washington, D. C., under the joint sponsorship of the Office of Naval Research and the National Science Foundation. Called the E. O. Hulburt Center for Space Research, it is named for one of the pioneers in upper-air physics, who devoted almost his entire career to Navy science and was the Laboratory's first Director of Research. The Center's location is also singularly appropriate, because the Nation's space program began at NRL with the use of V-2 rockets for upper atmosphere research. Since those early experiments, NRL scientists have compiled an impressive record of space research, including the first ultraviolet spectrograms of the sun below 3000A, the first measurements of the Lyman-α line of hydrogen and of x-rays in the solar spectrum, and the first Lyman-α and x-ray spectroheliograms of the sun.

The purpose of the Hulburt Center is to provide a continuing, expanded program of space research in which graduate students, post graduates, and visiting faculty members of academic institutions may participate. In the main, the program is based primarily on the study of x-rays and ultraviolet radiation from the sun and stars and their interaction with the earth's atmosphere. Experimental probes are designed to be carried in sounding rockets and in small satellites flown pickaback with other satellites.

The center is permanently staffed by members of the Atmosphere and Astrophysics Division of NRL, under the direction of Dr. Herbert Friedman. Normally, National Science Foundation fellowship tenures will be for up to one year, during which the scientist will be required to reside within commuting distance of NRL, where his work will be carried out. Participants may either propose new research projects that can be performed with the Center's facilities or participate in the continuing space research program now being conducted by the Center's staff.

Cold Weather Clothing that Floats

For many years the Navy has been doing research on extreme-cold-weather clothing, toward the end that standing watch in a winter gale will be reasonably bearable and not a form of slow torture. Excellent cold-weather gear has been developed, but to provide the necessary warmth the jackets and trousers have become unavoidably bulky. And bulky clothing can be lethal if the wearer falls into the sea, dragging him under and hampering the movements of swimming.

Consequently, the Chief of Naval Operations established a requirement that the bulk material used in winter clothing must be buoyant, providing flotation as well as warmth. Development of a suitable material was assigned to the U. S. Naval Supply Research and Development Facility at Bayonne, N. J. Experimenters there, after testing many materials, have found that a closed-cell plastic foam called polyvinyl chloride (PVC) is an effective insulating material and provides positive buoyancy over sustained periods.

Two standard Navy items, the A-1 extreme cold weather jacket and the A-2 intermediate cold weather jacket, have been redesigned and tested in prototype. The A-1 is impermeable, consisting of an outer layer of waterproof cloth and two 1/8-inch layers of PVC. As the clothing does not "breathe," it is intended to be worn primarily by watchstanders, in situations where exposure is extreme and physical activity is limited. The intermediate (A-2) gear is permeable; the outer layer is water repellent cotton, and the insulating filler is a double layer of 1/8-inch PVC that has been perforated throughout with 1/8-inch holes. Perforating the closed-cell foam allows perspiration to be transferred from the body to the atmosphere during active work periods.

Both types have been tested in the station swimming pool. The A-2 (intermediate) jacket provides enough buoyancy to keep the wearer's head above water and to keep him from sinking. When the A-1 is worn as an outer covering, the wearer floats like a sea-bird. Neither garment, however, is considered as a substitute for a life preserver.

Now the Facility is working toward an added improvement—making the clothing fragment-resistant as well. Investigation of a fibrous batt that provides armor protection as well as buoyancy and insulation has shown sufficient merit to encourage further effort in this direction.

A Kudo for Laboratory Management

Last January 11, an award of merit for group achievement was presented to nine members of BuShips' Laboratory Management Division. Pictured below from left to right are CAPT J. H. McQuilkin, Assistant Chief of the Bureau for R&D, who made the award, and the recipients—David Hughes, Jack Cusack, William Hoagland, William Powell, Mary Charlotte Crook, Kathleen Ewers, Ted Huang, John Giblin, and at far right, CAPT D. C. Campbell, USN, Director of the Division.

BuShips has eight laboratories, employing 6,000 people all told and handling over 100 million dollars in RDT&E funds every year. The Laboratory Management Division was created with the object of getting the utmost out of every research dollar. By fostering economy in expenditures, by implementing thorough technical evaluation of programs, and stressing the "Lead Lab" concept, and by reducing or removing restraints on the laboratories, the management program has achieved an enviable record of increased performance over the entire BuShips research effort.

roup achievement ard is presented members of Bu- ips Laboratory anagement Divi- on.

On the Naval Research Reserve

New Research Reserve Curriculum

The Curriculum for Research Reserve companies has been revised and was recently published by the Bureau of Naval Personnel. The Curriculum, NAVPERS 92469A, consists of 16 training periods on the mission, organization, and function of the Office of Naval Research. Its stated purpose is "to provide members of the Research Reserve Program with a common background of knowledge concerning methods and procedures of the Office of Naval Research and its relationship to other agencies of the Government."

The new Curriculum is a revision and updating of the original Research Reserve Curriculum published in 1957. A new feature is the provision for the use of slides for some of the training periods in order to portray the subjects under consideration in a graphic manner. Also, the Bureau of Naval Personnel has provided a set of six books—one set for each company--as part of the bibliography for the training periods.

The mission of the Naval Reserve Research Program specifies four broad areas of qualification for its membership--research, training devices, research contract administration, and patent law. The mobilization requirements for officers having these backgrounds may be established not only by the Office of Naval Research but also by other activities of the Naval Establishment.

Although there is considerable diversification of qualification among the members of the Reserve Research Program, an area of common interest is believed to exist for all--the operations of the Office of Naval Research, the organization within whose framework of interest Research Reservists may be assigned upon mobilization.

The curriculum is made available to Research Reserve companies for flexible inclusion in their training schedules. It is effective upon receipt, and the subject matter is required to be presented in three fiscal years.

Seminars Planned for Fiscal Year 1964

Eleven Research Reserve seminars are planned by the Office of Naval Research for fiscal year 1964. Final approval on these seminars must be given by the Bureau of Naval Personnel. Further information will then be promulgated officially in the BUPERS Instruction 1571.4 series. This Instruction is expected to be available in May 1963. The titles, places, and dates of the seminars presently planned are as follows:

Naval Research Laboratory, Washington, D. C.	July 14, 1963
Aerophysics, Denver, Colo.	August 4, 1963
Biological Defense, Fort Detrick, Frederick, Md.	August 11, 1963
Electronic Computers, College Station, Tex.	August 25, 1963
Electronic Computers, Newburgh, N. Y.	October 6, 1963
Submarine and Diving Medicine, New London, Conn.	October 6, 1963
Space Science, San Francisco, Calif.	October 20, 1963
Nuclear Sciences, Oak Ridge, Tenn.	December 1, 1963
Research Reserve Seminar, ONR, Washington, D. C.	June 7, 1964
Training Device Center, Port Washington, N. Y.	June 14, 1964
Science and the Seas, Seattle, Wash.	June 14, 1964

Reserves Selected for Promotion

Five hundred and thirty-nine Naval Reserve line officers have been selected for promotion to captain and 224 to commander by the Fiscal Year 1963 Reserve Selection Boards. Of this number, 32 Research Reservists were selected for captain and 9 for commander. Congratulations are extended to these officers.

FOR CAPTAIN

	NRRC		NRRC
Charles V. Armstrong	11-2	Alvin R. Lyle	8-9
John H. Avery	13-1	John E. Masterson	11-8
Lewis Bernick	6-16	Lee D. McChesney	6-2
Robert J. Bobber	6-8	Daniel O. Price	6-6
Thomas B. Dowd	1-1	James D. Quale	3-14
John F. Gill	11-9	George R. Rae	4-2
Svend T. Gormsen	5-2	Harold C. Ries	12-5
Alonzo C. Hare	9-9	Hugo A. Schweers, Jr.	8-5
Merlin C. Herold (C.O.)	6-8	John L. Simons	4-13
Edward M. Herrmann	5-11	David C. Sloan	5-12
John J. Holoubek	11-8	Ernest R. Steele	4-12
John J. Horan	4-13	Albert T. Steelman, Jr.	4-13
Marshall L. Hunt	5-12	George B. Strother	9-14
Walter C. Jacob	9-2	George Vaux	4-2
Robert J. Lanter	8-9	Thomas R. Warrick	8-1
Claude C. Lomax, Jr.	13-3	Roger Wright	12-3

Statistics based on the records of the Research Reservists selected for promotion are as follows:

Date of Rank		Designator		Year of Birth	
Earliest	1-1-52	1105 - 15	1405 - 4	Earliest	1908
Latest	12-1-56	1315 - 2	1455 - 7	Latest	1921
Median	1-1-56	1355 - 3	1535 - 1	Median	1917

All officers selected for captain were in Ready Reserve status. Twenty-eight of the 32 selected were in the zone for the first time, with 4 being selected from the old field.

FOR COMMANDER

	NRRC		NRRC
Wayne V. Burt	13-5	Edwin D. Sayre	13-2
Fred E. Horvath	11-3	Gorden N. Selby	3-14
William W. Lang	3-14	Robert C. Whitten, Jr.	12-3
Henry B. Latimer	3-6	James C. Wiltse, Jr.	5-4
Dean E. McFeron	13-1		

Statistics based on the records of the Research Reservists selected for promotion are as follows:

Date of Rank		Designator		Year of Birth	
Earliest	3-1-52	1105 - 4	1405 - 2	Earliest	1917
Latest	7-1-58	1315 - 1	1635 - 1	Latest	1926
Median	4-1-58	1355 - 1		Median	1925

All officers selected for Commander were in Ready Reserve status. Six of the 9 selected were in the zone for the first time, and 3 were selected from the old field. The education levels of the officers selected were as follows: Doctor's degree - 6; Master's - 2; and Bachelor's - 1.

REMINDER

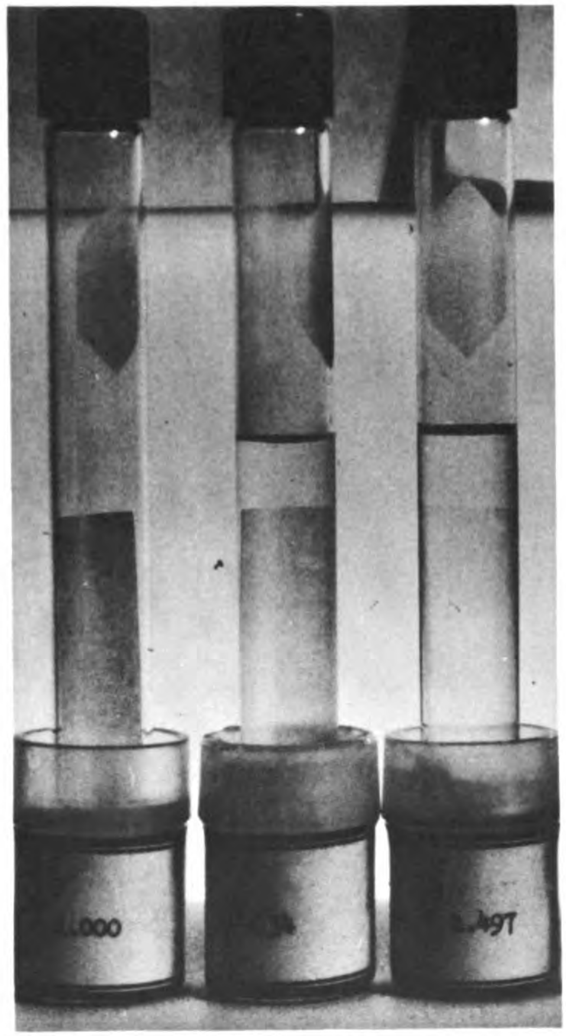
It is to the advantage of the officers selected for promotion to qualify for promotion within one year from the date on which the President approved the report of the selection board (5 Feb. 1963 for the Captain list and 21 Feb. for the Commander list). By qualifying within this year these officers will be entitled to pay and allowances of the new grade for that year. However, if more than a year is taken to qualify, the entitlement for pay and allowances of the new grade will date from appointment in that grade. The maximum time limit for qualifying for promotion is one fiscal year following the fiscal year in which selected.

Remember also that the physical examination for promotion may now be taken as soon as the official letter of notification of selection has been received, even though the officer may not have completed the professional requirements at that time.

In photograph at right, CAPT E. L. Knapp, USN (right), Commanding Officer and Director, Training Device Center, Port Washington, New York, presents flag to RADM J. D. Hardy, USNR (left), upon his recent completion of a two-week tour of active duty for training at the Center. Admiral Hardy made a staff study of mobilization requirements of the Training Device Center with particular emphasis on their relationship to the Research Reserve.

Light Scattering by Typewriter Paper

In a discussion of radiation scattering (pages 1-8), light scattering by typewriter paper is explained. At right, the phenomenon is illustrated. Strips of typewriter paper are enclosed in test tubes and illuminated from behind by a diffuse light source of large area. The strips are surrounded by a medium which has the refractive index indicated on each label. The medium in the tube at the left is air. The figure shows that the transparency of the paper increases, because of a decrease in light scattering, as the difference in the refractive indices of paper and medium become smaller (see page 2).



IN THIS ISSUE

NAVAL RESEARCH Reviews publishes highlights of research conducted by Navy laboratories and contractors and describes important Naval experimental facilities. Manuscripts submitted for publication, correspondence concerning prospective articles, and changes of address, should be directed to Code 740, Office of Naval Research, Washington 25, D. C. The magazine is listed for sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. Subscription price: $1.50 per year in the U. S. and Canada; $2.00 per year, foreign; $0.15 per individual copy. The issuance of this periodical approved in accordance with Department of the Navy publications and printing regulations.

EDITORS: A. T. Drury and Richard D. Olson

View of collar separating two balloons that lift 36-inch Stratoscope II telescope high into stratosphere for astronomical observations. Underway here is final test launching of the system, made last December. First scientific flight was scheduled for this month.

NAVEXOS P-510