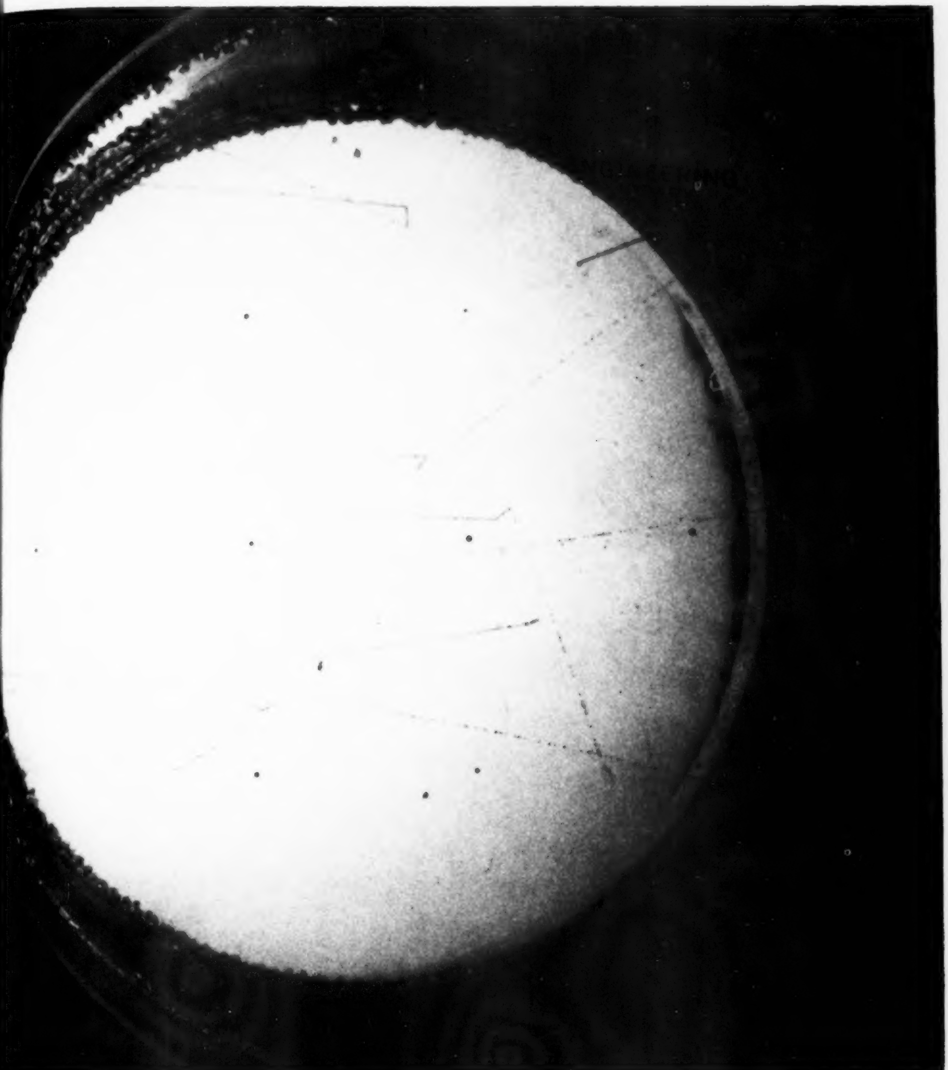
FFICE OF NAVAL RESEARCH DECEMBER 1957

ESEARCH REVIEWS



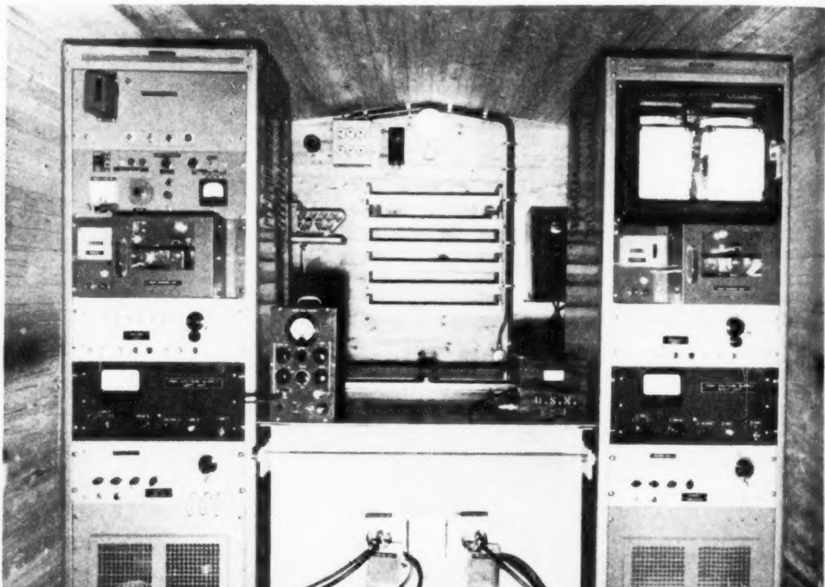
EPARTMENT OF THE NAVY

ASHINGTON, D. C.

NAVEXOS P-510

Cosmic-ray observatory mounted on boat deck of Swedish merchant ship.

Neutron monitor installation aboard the LOMMAREN



Sea-Going Cosmic Ray Observatory

Martin A. Pomerantz

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Although the external magnetic field of the earth is relatively weak, its influence extends for very great distances beyond the upper reaches of the atmosphere. As a result of this influence, electrically charged particles travelling towards the earth from distant sources, such as the sun, follow trajectories that are not straight lines. When these deflected particles pass through the ionosphere, they change its state, thereby affecting the quality of long-distance radio communication. Consequently, a detailed knowledge of the nature and properties of the external geomagnetic field is not only of intrinsic interest, but also has very important practical applications.

MEASURING THE EARTH'S MAGNETISM

Until recently, it has been possible to describe the external geomagnetic field only on the basis of measurements of magnetism obtained at or relatively near the earth's surface. Because these descriptions were based in part on local concentrations of magnetic materials in the earth's crust, which were thought to have negligible effect at great distances from the earth, they were considered inapplicable. A new way to describe the field at large distances is to measure the cosmic radiation. By now it is known that the primary cosmic radiation consists of protons (hydrogen nuclei), quite a large number of alpha particles (helium nuclei), and a few heavier nuclei. All have been stripped of their outer electrons and hence carry a net electrical charge. As the theory of motion of charged particles in magnetic fields is now well understood, it is possible, by counting the number of certain of these particles reaching the earth at many places, to locate the geomagnetic coordinates.

Surface measurements show that the earth's average magnetic field is equivalent to that which would be produced by a bar magnet (technically called a dipole) displaced somewhat from the geographic center of the earth. The magnet's north pole would point approximately to 80° N. and 83°W., and its south pole would intercept the surface at about 76° S. and 121° E. The magnetic field associated with this equivalent eccentric dipole affects the cosmic radiation in two important ways: First, it gives rise to a variation of intensity with latitude; that is, the number of particles recorded by a particle detector each minute is lowest at the geomagnetic equator and highest near the poles. Second, it produces a small change of intensity with longitude at a given latitude. This influence, which is greatest at the equator, is accounted for by the fact that the magnetic center is displaced about 340 kilometers from the center of the globe.

By measuring the cosmic-ray intensity as a function of latitude and longitude, it is possible to locate the magnetic equator and poles, and to determine the eccentricity of the dipole, that is, its distance from the center of the earth.

NEUTRON MONITOR PILE

Although techniques for obtaining the desired cosmic-ray data have existed for many years, they have been limited by the fact that they call for the measurement of mesons, particles which manifest only a small variation in intensity with latitude, particularly in the crucial equatorial region. The reasons mesons show little respect for latitude is that they are derived from nuclear collisions involving only the most energetic primary cosmic-ray particles, which are subject to the least deflection in the earth's magnetic field. Furthermore, because these particles are unstable, and disintegrate a short time after they have been produced, their intensity near sea level depends also upon the continually changing meteorological conditions that exist between that level and the high altitude at which they are produced.

Largely as an outcome of the excellent work of Dr. John A. Simpson and his group at the University of Chicago, a new method of measurement has been developed during the last several years. This method utilizes nucleons (combinations of protons and neutrons). Since a large portion of these units are produced by primary cosmic-ray particles having less energy than those producing mesons, their intensity at the surface of the earth varies more at different latitudes than the intensity of mesons does.

To determine the number of nucleons striking the earth at a given point, one could count the particles directly. But a far better determination can be made by indirect means, utilizing a device called a pile which was introduced by Professor Simpson. As shown below, it consists of two instruments called proportional counters, surrounded by a quantity of lead and paraffin. When a nucleon produced by cosmic rays collides with a nucleus of the lead surrounding the counters, the nucleus emits several neutrons, thus multiplying the number of neutrons that enter the counter. Lead is used as the "neutron multiplier," because its nuclei, being heavy, emit a large number of neutrons. Now, one of the properties of the neutron detectors is that they produce an electrical pulse for almost every slow neutron, but not for a large fraction of the

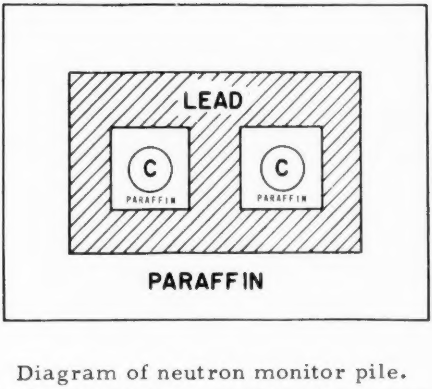


Diagram of neutron monitor pile.
"C" represents proportional counters.

Dr. Arne E. Sandström of Uppsala University, the author, and Captain Gunnar Runsten.

Lars Erikson of Uppsala University, observer on the first cruise, and the author.

more energetic neutrons. The purpose of the paraffin is to slow down the fast neutrons so as to increase the counting rate. The neutrons lose an average of half their energy in each collision with a hydrogen nucleus in the paraffin. Hydrogenous materials are also utilized in nuclear reactors to slow down neutrons, because slow neutrons are much more effective in causing uranium fissions.

Thus, by counting the nucleons in terms of the number of neutrons they set free in the pile, a higher count is obtained than would be if the nucleons were counted directly.

SHIPBOARD OBSERVATORY

As part of a long-range program which will ultimately result in the charting of a complete cosmic-ray map of the world, an apparatus of this type is now operating aboard the Swedish merchant vessel LOMMAREN, plying the waters between Sweden and South Africa. The neutron monitor, weighing about 3 tons, was constructed at the Bartol Research Foundation with support from the Office of Naval Research. It is being operated as part of the International Geophysical Year program in a collaborative effort involving the Bartol Research Foundation, the National Research Council of Canada, and the Fysiska Institution of Uppsala University, Sweden.

The apparatus is housed in a special prefabricated hut installed on the ship's deck on a structure bridging the engine room skylight (see inside front cover). The Transatlantic Company of Sweden has very generously made the ship available for these experiments, and the National Geographic Society is sponsoring the field operations. Funds from the U. S. National Committee for the International Geophysical Year have also aided the project.

An observer from Uppsala University, under the direction of Dr. A. E. Sandström, is accompanying the equipment. Except for certain routine inspections and maintenance procedures carried out in accordance with a series of check-lists, the entire device functions automatically and is essentially self-checking.

THE OBSERVATORY'S MISSION

The mission of this mobile station is to provide a continuous monitoring of the cosmic-ray intensity along many sea routes. The data being collected are similar to those being obtained by the "shore patrol"—the many fixed cosmic-ray stations distributed over the surface of the earth. By reference to them, a plot of isocosms—lines of constant cosmic-ray intensity—will be made.

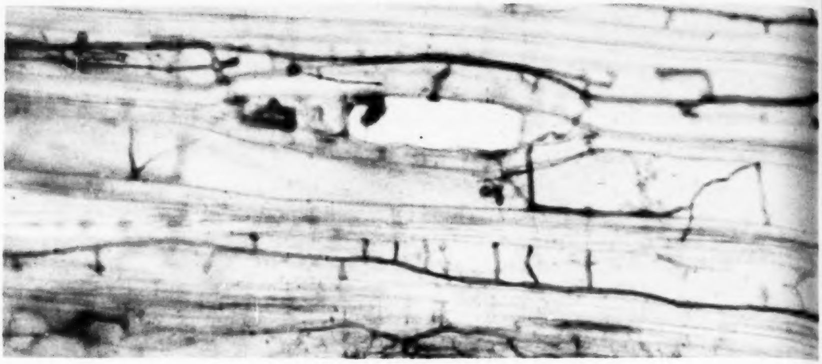
A neutron monitor responds to the progeny of the relatively low-energy cosmic rays, upon which the effects of magnetic conditions in the vicinity of the earth are most pronounced. A decrease in cosmic-ray intensity is often associated with magentic storms as a consequence of either a deflection or deceleration of these particles. Furthermore, the monitored primaries are in the band of energy which, as has been directly observed on a number of occasions, can be produced on the sun. Rapid increases in the cosmic-ray intensity sometimes occur simultaneously with eruptions on the solar disk. These coincide with other geophysical phenomena, such as sudden ionospheric disturbances which result in a blackout of radio communications. The most recent of the five large increases recorded to date was observed on February 23, 1956, at stations all over the world. This increase was much larger than any other that has been recorded, for its peak was 25 times the normal rate at some locations. Much useful information can be derived from comparisons of the data obtained at different points of impact on the earth.

The shipboard station provides coverage in a region where no other detector exists. It is of interest to compare any sudden changes observed en route with those detected elsewhere, particularly during the International Geophysical Year. For, during this period, which coincides with sunsport maximum, the probability of occurrence of large solar flares and other disturbances is especially high.

THE PROGRAM

Even before the present type of measurement was undertaken, there were experimental indications that the previously accepted geomagnetic coordinates based upon surface magnetic-field measurements were different from those based on cosmic-ray measurements. These differences have been confirmed by the recent results obtained from the monitor operated at sea.

Three round-trip voyages between Sweden and South Africa have been completed thus far and a fourth is in progress to determine whether any significant changes have occurred during a year characterized by an unusually high level of solar and geomagnetic activity. Although the analysis of the results is still in progress, it can be reported that the earlier cruises revealed that the position of cosmic-ray minimum intensity—the so-called cosmic-ray equator—is located at geographical coordinates $8° \pm 1°$ N., $14°$ W. This position differs appreciably from that of the geomagnetic equator based on surface measurements, the latter being $15°$ south of this point. However, it is interesting to note that the position of minimum cosmic-ray intensity actually lies very close to the isoclinic, or dip, equator, which represents a surface measurement of the inclination of the earth's field equal to $0°$. A comparison of the measurements in the northern and southern hemispheres also appears to suggest that perhaps the magnetic field at the surface of the earth plays a more important role in determining the trajectories of cosmic rays than had heretofore been supposed. The mathematical approximation which had previously been regarded as applicable at large distances from the earth, where the cosmic rays undergo the deflections which determine their ultimate impact points, evidently requires modification. The validity of this hypothesis must of course, await detailed verification on the basis of additional measurements, and the possibility that the position of the cosmic-ray equator is not permanent must be investigated. Indeed, it has now been established that the earth is actually immersed in a highly conducting interplanetary medium, which, as a consequence of possible outer-ring currents, has magnetic properties which affect the trajectories of all charged particles incident upon the earth. Whether or not these phenomena change with time, and the nature of the variations if they do occur, can be determined only by continuous observations of the type now underway in the long-term program which is contemplated.



A section of yellow pine infected by a marine fungus. The infected areas appear as dark lines

Marine Wood-Inhabiting Fungi

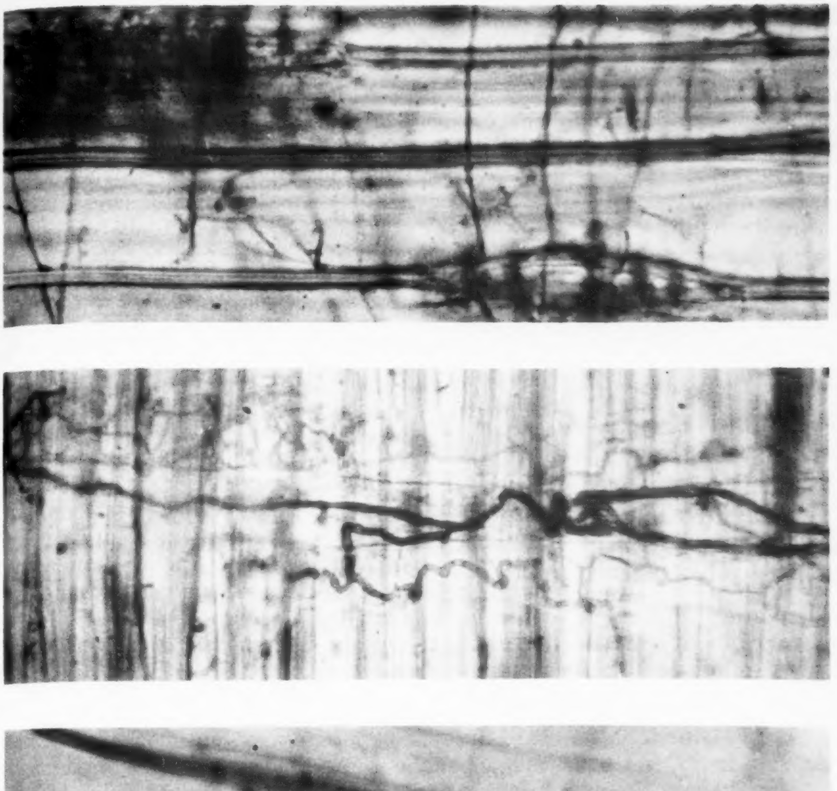
Ernest S. Reynolds
Samuel P. Meyers

Marine Laboratory
University of Miami

In order to reach a better understanding of the dynamics of the sea, scientists are intensifying their studies of the organisms that live there. For many years, men have known that the basic physiological processes of marine algae and bacteria have a lot to do with the maintenance of equilibrium in the ocean environment, just as their counterparts do on land. However, they have not known, until recent years, what effects the ubiquitous group of microplants called fungi have on this environment. On land, we know these plants well, their beneficial and harmful activities being of vast economic importance. But what about their activities at sea? What role do they play there?

Before 1944 we did not give much thought to the possible invasion by fungi of submerged wood, such as that of docks and pilings. In fact, many investigators believed that fungi could not decay wood saturated with sea water. Although it is true that terrestrial wood-destroying fungi are rendered inactive by salt water, fungi that are adapted physiologically to the sea can vigorously degrade wood. The time-honored phrase, "Wood in sea water will not rot," is indeed a myth!

Since 1952, the Marine Laboratory of the University of Miami has been studying marine fungi in Biscayne Bay, Florida, the Caribbean Sea, the Bahamas, the Gulf of Mexico, and at more than 63 stations throughout the United States, Canada, Alaska, Nova Scotia, Newfoundland, and the Canal Zone. Most of our attention is now being given to the marine



Sections of yellow pine infected by marine fungi. The infected areas appear as dark lines. Top--Passage of hypha through a series of tracheid cell walls. Center--Hyphal penetration of ray tissue. Bottom--Passage of hypha through a cell wall (note the constriction of the hypha as they pass through the wall).

wood-inhabiting fungi, which we are considering from taxonomic, physiologic, and ecologic points of view.

Although we have examined fungal infections on driftwood and pilings, most of our studies have been made of those occurring on specially prepared wood panels. The panels, most of which are yellow pine and basswood, are arranged in 2- to 5-layer "sandwiches," with spaces about 1/8 to 1/4 of an inch wide between layers. Several of these "sandwiches" are attached in a series to a plastic cord. After the wood has been submerged for the required period of time, it is shipped to our laboratory in special waterproof bags, which greatly reduce the chance of contamination by terrestrial fungi. Each panel is given a complete examination, then is placed in a humidity chamber, which enhances the development of latent infections present in the wood.

Infestations by marine fungi have been found at all of our test localities. Most of these were caused by Ascomycetes belonging to the genus Lulworthia and certain species of the genus Helicoma, which are Fungi Imperfecti. They not only attack wood at most of the stations, but also are among the first species to do so. During the winter at many of the Boreal and northern temperate test sites, species of Helicoma are either the sole or dominant fungi occurring on submerged wood, often completely infecting it. It is interesting to note that Helicoma includes 31 terrestrial species, most of which live on decayed bark and wood, and only two species that attack submerged wood.

To determine the wood-infecting abilities and nutritional needs of marine fungi, we have made pure-culture studies of seven genera of marine Ascomycetes. Infection of wood by these genera was demonstrated in culture in standing water, moving water, in water not artificially aerated, and in aerated water. Several species of one genus spread from an infected piece of wood to a new piece placed next to it, covering its entire surface within a few weeks. In thin sections of the infected wood, complete ramification of the fungi throughout the wood tissue can be observed.

The nutritional requirements for marine fungal growth appear to be comparatively simple. Several genera grow well on a medium containing glucose, thiamin, biotin, and asparagine. Wood flours and powdered cellulose can be substituted for the glucose, often with an increase in reproductive capacity. Pure cultures of various species, using single spore inocula, were passed through several generations on sea-water agar, with no added nutrients. Both vegetative and reproductive growth, the latter resulting in the production of viable spores, occurred through successive generations. One species was carried on this medium, via single-spore transfers, through six subcultures with no diminution in viability. Another species showed similar viability over a period of a year. Apparently, the small amount of organic nutrients within the sea-water agar medium is sufficient to sustain the fungus, at least for several generations.

Our studies indicate that marine fungi can tolerate a broad range of saline conditions. This capacity is not peculiar to them, however;

Dr. S. P. Meyers examines wood submerged in individual aquaria, each inoculated with a single species of fungi. This procedure enables mycologists to determine the time and rate of fungal infection of wood.

many organisms can grow normally in media containing high salt concentrations. But marine fungi have other features that characterize them as a natural sea-water population. In the Ascomycetes studied, these include appendaged spores (the appendages not only facilitate the dispersal of the spores, but also enable them to adhere to submerged surfaces), the capacity to grow and reproduce underwater; and the ability to infect submerged wood.

The role played by marine borers in the destruction of submerged wood is well known. But little is known about the factors affecting wood in the early stages of its submergence, before it is attacked by borers. These factors are often called "conditioning" phenomena. At Biscayne Bay, Florida, we observed that the dissolution of the outer cell layers of submerged wood was accompanied, in nearly all instances, by fungal colonization. Fungal infection, including extensive surface growth, occurred very shortly, often in less than one week, after the wood was submerged.

Dr. E. S. Reynolds exposes wood panels to sea water at the Marine Laboratory pier.

Dr. E. S. Reynolds inoculates flasks with pure cultures of marine fungi. The flasks contain wood in nutrient solution.

In order to study this activity more closely, numerous yellow pine and basswood panels were submerged in Boreal and northern temperate waters, primarily from October through February. As borer activity is negligible or does not occur during this period, we were able to examine fungal infestation independently of damage caused by the borers. We found that the fungi vigorously attacked the wood in both regions. In the subtropics, however, the period of fungal attack prior to borer infestation is much shorter. In Kodiak, Alaska, the period may be from 2 to 3 months, while at Key West, Florida, it is only from 2 to 3 weeks. The fungal infection that occurs before the borers attack the wood has interesting biological implications. In northern areas, especially, it may facilitate the activities of the borers, not only by making it easier for them to enter the wood, but also by providing them with a source of food.

In contrast to bacteria, fungi are able to invade the wood's inner tissues directly. The fungi gain entrance by means of their hyphal

Infected and uninfected wood panels. In the left hand--a wood panel that has been submerged for more than 1 month. In the right hand--new panels awaiting submergence.

system, which consists of thread-like growths that can penetrate the cells of the wood. Bacteriologists have noted that terrestrial bacteria are unable to attack wood directly, but must wait until it is in a state of fine division; therefore, some have postulated that on land fungal decay may be a precursor of bacterial decay. We believe that a similar situation may exist in the sea.

It is worthwhile at this point to consider some of the physiological activities of fungi that enhance the degradation of wood.

- Wood experimentally infected by fungi shows (a) surface and imbedded reproductive structures, (b) softening and disintegration of the outer tissues, often to a depth of several millimeters, (c) rapid reproduction of the fungal hyphae throughout the wood, and (d) direct penetration of the hyphae through the walls of the wood cells. In the latter process, the hyphae is noticeably constricted as it passes through the cell wall, a feature common also to terrestrial wood-destroying fungi.

- By the growth of their hyphae, fungi develop channels within the wood, thus facilitating the interchange of external and internal materials, including bacteria. Whether this condition also contributes to the leaching out of preservatives in treated wood is not known. Some species of fungi have been collected from old creosoted pilings, but the extent of their activities in this wood has not yet been studied.

- In their interactions with submerged wood, fungi may cause the breakdown of insoluble large molecules, such as those that make up cellulose and lignin. The fact that fungi can bore holes through the thickest cell walls of wood suggests that they are equipped with a mechanism of enzymatic action. The large pits produced by their reproductive structures, some as much as 500 microns in depth, are further evidence of their chemical destruction of wood.

- The possibility that the fungi themselves and the amino acids and other organic compounds which they produce are a source of food for other organisms, particularly the wood-boring animals, cannot be ignored. Fungi are known to be rich in organic compounds, especially protein. They may also provide other organisms with nitrogen, only a small amount of which occurs in wood and sea water. Scientists have shown that such relationships are not uncommon for many other groups of organisms.

A thorough evaluation of the role of marine fungi in the destruction of wood is not yet possible. Not enough is known about their physiological activities and their many interrelationships with other flora and fauna that inhabit submerged wood. Also, we don't know enough about the wood itself. While the ligno-cellulose complex constitutes most of its weight, other constituents, occurring in relatively small amounts, may be of much greater significance during the early period of infection.

Serendipity and the Second Nuclear Navy

Sol Krasner
Physical Sciences Division
Office of Naval Research

If you visit the Nuclear Physics Branch of ONR, one of the first things you'll notice is the word SERENDIPITY printed in big red letters on our blackboard. Since we learned the word we've used it again and again, because it provides one of the key arguments for the sponsorship of speculative research by the Navy.

What is serendipity?

In 1922, while two Navy scientists—Drs. A. H. Taylor and L. C. Young of the Naval Research Laboratory—were experimenting with short-wave radio equipment with the objective of improving communication, they noticed that ships plying the Potomac River obscured their signals. Then began a series of experiments that led to radar. That was serendipity.

In 1939, Professors Hahn and Strassmann were investigating the intriguing problem of what happens when you add neutrons to the heaviest of all the known nuclei, uranium. They and other investigators had found that several types of unstable (radioactive) nuclei were produced, some of which had the chemical properties to be expected of elements just beyond uranium in the periodic table. Not all of the radioactive nuclei had such chemical properties, so Hahn and Strassmann designed an experiment to prove that these anomalous products were radium nuclei which must have been the result of a series of radioactive decays by the transuranic elements. When, to their surprise, the experiment proved instead that the unusual radioactive nuclei were not radium, but barium whose nuclei are roughly half the size of uranium nuclei—that was serendipity. This splitting of the uranium nucleus into two medium-weight nuclei is called fission. Because of that bit of serendipity, the oil-burning engine will soon take its place beside sails in naval museums!

By now you get the idea. Serendipity is the discovery of an effect neither sought nor anticipated. Many, perhaps most, of the great scientific discoveries have been made in this way. Furthermore, it is self evident that the frequency of such discoveries will be higher in a research project probing for the laws of nature at the frontiers of man's knowledge, rather than in a project aimed at developing a device operating according to known laws. It is, therefore, imperative for the Navy to encourage pure research and to be up to date on its progress.

Now I should like to tell the story of a discovery made within the past year which came very close to having a more profound effect on the Navy and on mankind than even radar and fission have had. The story consists of two sub-plots—seemingly unrelated—but that's where the moral comes in. . . .

The first sub-plot deals with basic research done on the indivisible entities that make up the atom—the elementary particles.

Shortly after the end of World War II, there were thought to be only a few basic elementary particles. In addition to a few that play no role in our story, there were the neutrons and protons, which when packed closely together constitute the nucleus; and the electrons, which circulate about the nucleus just as the planets circulate around the sun in our solar system. In the true solar system, gravitational attraction keeps the planets in their orbits, while in the atom, the attractive force is caused by the opposite electrical charges of the protons and electrons. You probably are thinking now, "Yes, opposite charges attract, but like charges repel." Why, then, does not the nucleus fly apart because of the mutual repulsion of its protons? The answer, it was clear, was that there was an attractive force between them, one strong enough to completely overcome the electrical repulsive force. This is called the nuclear force. The fact that it takes about a million times more energy to dislodge a proton or neutron from a nucleus than it takes to dislodge an electron from an atom, points up the awesome strength of the nuclear force and, at the same time, explains the fundamental reason that nuclear bombs go off with a bigger bang than chemical bombs.

Some of the features of this force were accounted for, theoretically, by the prediction that the nucleus contained, in addition to the proton and neutron, a third particle, named the meson. Among the required properties of the meson are that it interact strongly with neutrons and protons and that it be 200 times as heavy as an electron. There was known to exist in the cosmic radiation a particle having roughly the required mass, but not the other expected properties. For example, it could pass through thick lead plates without interacting with any nuclei.

This, then, was the situation when ONR began to sponsor nuclear-physics research in 1946. The principal aims of the scientists were to solve the meson mystery and to learn the properties of the nuclear force. But, alas, serendipity reared its head, and not only was the meson mystery cleared up by the discovery of another meson that had the desired properties, but whole families of other elementary particles were discovered. The nucleus turned out to be a cornucopia of curious particles! There were times when published lists of the elementary particles were as variable as stock market quotations! There are now thought to be about 30 fundamental particles, most of them very strongly bound within the nucleus. To dislodge them it is necessary to bombard the nucleus with protons that have been accelerated in very large multi-million dollar accelerators. There are at present only three such instruments capable of producing most of the newly discovered particles in useful numbers, and one of them (the most powerful of the three) is in Russia.

In addition to being difficult to produce, the most interesting of these particles live for extremely short times—from about 10^{-15} seconds to about $2(10)^{-6}$ seconds—after which they decay into the "old fashioned" types. In spite of these difficulties, the challenge to understand the role that these unexpected particles play in the construction of matter, and to understand the laws of nature in the subnuclear domain, has attracted many of the world's most brilliant minds. Elementary-particle research is now one of the fastest moving, most exciting branches of physics. New discoveries and new ideas come at a furious pace. Elementary-particle research has already led to the abandonment of a previously universally held assumption about the symmetry of the laws of nature (the conservation of parity) and has thus profoundly affected all of physics. Indeed, this writer will be surprised if more applications to science and technology do not come out of this hotbed of activity.

We now come to the second-sub-plot of our story.

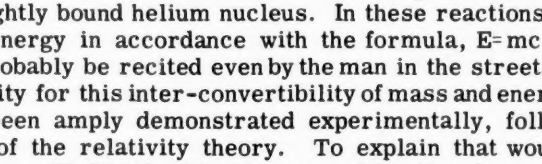
Today, almost every major country of the world is conducting large, expensive research projects aimed at tapping the ultimate power source—controlled fusion. Man has already achieved uncontrolled fusion in the hydrogen bomb. The remaining problem is how to release this vast amount of energy at a slow, controllable rate—just as the uranium reactors that will power our first nuclear navy slow down the processes occurring in an "old-fashioned" uranium atomic bomb. When and if man succeeds in developing a useable fusion reactor, his power requirements will be satisfied as far into the future as anyone would care to look, and the second nuclear navy will draw its power from the sea water in which it floats!

Now, let's find out what a fusion reaction is, and how to go about building a reactor, so we can get the second nuclear navy underway.

In their efforts to understand the nature of the powerful forces that hold the nucleus together, nuclear physicists have for years been studying the transformations that nuclei undergo when they collide with each other. Among the large number of nuclear reactions that have been observed to date are about a half dozen in which light nuclei "fuse" to form the very tightly bound helium nucleus. In these reactions mass is converted to energy in accordance with the formula, $E = mc^2$, which these days can probably be recited even by the man in the streets of Skid Row. The necessity for this inter-convertibility of mass and energy, which has certainly been amply demonstrated experimentally, follows from the postulates of the relativity theory. To explain that would take us too far off course. We'll take Einstein's word for it and proceed.

Let's look at a typical fusion reaction—the collision of two deuterium nuclei to form a helium nucleus and a neutron.

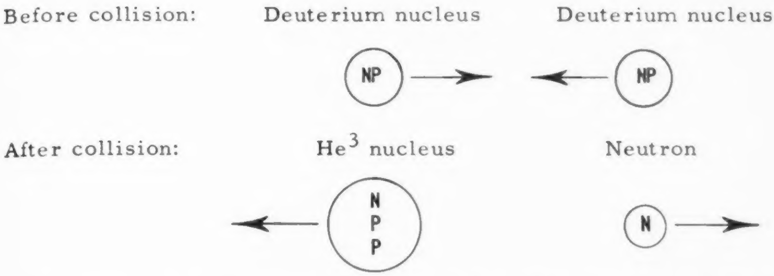
Deuterium, a natural impurity of hydrogen, is also called heavy hydrogen, because its chemical properties are practically identical to those of hydrogen, although its mass is about twice as large. The larger mass is explained by the fact that it contains both a proton and a neutron, whereas the hydrogen nucleus contains only the former. In the free state, and at ordinary temperatures and pressures, the deuterium atoms are held together in pairs by electrons. A pair, or molecule, looks like this:



When these two nuclei fuse, helium (He^3) is formed, a neutron is set free, and considerable energy is released. The reaction can be represented as follows:

$$D + D \longrightarrow He^3 + n + \text{energy}$$

or



The sum of the masses of the particles after the reaction is less than the sum of the masses of the particles before the reaction; so, as required by $E=mc^2$, the end products have more kinetic energy. This means that the He^3 and neutron are moving at higher speeds than the deuterium atoms were moving. As they collide with other particles, they share their extra kinetic energy, so that the net effect of the fusion is an increase in the average kinetic energy of all the nuclei in the neighborhood. But this is just another way of saying that the material has been heated. Essentially, then, the fusion reactor, as here described, is a furnace, as is the uranium reactor. In the case of the latter, some of the mass of a uranium nucleus is transformed into kinetic energy of the two fragments when the uranium nucleus fissions. In the nuclear submarine NAUTILUS the reactor "furnace" heats water to make steam.

Now, you might say, it's simple to build a fusion reactor—just fill a bottle with deuterium gas! The molecules of any gas are flying through space at high speed and continually colliding with each other; some of these collisions ought to cause fusion reactions. Unfortunately, this reactor, if operated at ordinary temperature and pressures, would produce an immeasurably small power output, because in essentially none of the collisions between the molecules will the nuclei approach closely enough to interact with each other. Recall that the nuclear force is felt only at short range. Unless the deuterium nuclei approach each other within a distance of about 10^{-13} centimeters, the force is not felt by either.

There are two types of repulsive forces that come into play when the molecules overlap, which prevent the nuclei from coming sufficiently close together. The first, which brings about a complicated interaction between the external electrons, can be explained only in terms of quantum mechanics. The second is the electrical repulsion between the like-charged deuterium nuclei. As you might guess, the faster the molecules move toward each other, the more the penetration and the closer the nuclei come to each other.

The next step has probably occurred to you. Yes, the thing to do is heat the gas. The higher the temperature, the faster the molecules move; therefore, just heat the gas to a temperature at which a significant fraction of the deuterium nuclei will collide.

However, before you run down to the basement to build your reactor, let me point out to you that rather simple calculations show that in order to generate a useful amount of power and to keep the reaction going, temperatures of about 100 million degrees are needed. Now, you may go down to the basement to start building—provided you know how to heat a gas to this temperature, and can build a bottle to hold it. Tungsten, which has a higher melting point than any other known substance, turns to liquid at 6,100° F.!

Temperatures of the order of magnitude required to start a fusion reaction exist only in the interiors of atomic-bomb explosions and stars. Use is made of the former fact in the construction of hydrogen bombs. The trick is to confine a large number of deuterium (or other fusionable nuclei) in the core of an exploding uranium bomb. Fusion reactions like the one discussed here are also the source of energy radiated by the stars.

Despite the seeming impossibility of the task, some progress is being made in achieving astronomical temperatures in confirmed volumes of gas without resort to nuclear explosions. The techniques being tried are based on the fact that at high temperatures the molecules of a gas are ionized—that is, the electrons are knocked out of their orbits by collision. The resulting bare deuterium nuclei can then be "handled" by means of externally applied electric and magnetic fields. Various arrangements of these fields can accelerate the nuclei, thereby serving as "ovens;" and they can support streams of the particles in vacuum, thereby serving as non-material, non-vaporizable "bottles" that will contain the reaction.

Most of the work being done in this field of research is secret, but even to describe the unclassified work in progress would require many pages, so we must reluctantly leave this fascinating subject. The important points for us to note are:

(1) All-out efforts to achieve controlled fusion power are being made by most major countries, and rightly so. It is estimated that if man's power consumption continues to increase at its present rate the known reserves of coal and oil will be used in less than a century, and uranium in several centuries. In contrast, there is enough deuterium in the oceans to satisfy our power requirements for a billion years!

(2) A perusal of the unclassified literature on the subject shows that all attempts to build a controlled fusion reactor are variations on a single theme. That theme is to heat a gas to a high temperature and simultaneously confine it by means of electric and magnetic fields.

We have now taken brief glimpses at two dynamic fields of research in physics today. In one field there is a practical objective in mind. The other field is pure, undirected, "long-haired" research whose main motivation is simply to understand the nature of matter. Until recently, there was no apparent connection between the two fields. Work in one was being done independently of work in the other. But last December a discovery was made that completely changed this picture.

At that time, Professor Luis Alvarez and his collaborators at the University of California were studying the properties of the K-mesons, one of the recently discovered families of elementary particles. The experiments were being performed at the University's Bevatron, which accelerates protons to such a high energy that, when they strike a nucleus, K-mesons and other elementary particles are spewed out. By means of specially designed magnets, the K-mesons were focused into a beam. This was then passed through a bubble chamber, an ingenious device for recording the trajectories of charged atomic particles. The chamber consists of a liquid kept at such a temperature and pressure that it will boil at the slightest provocation. When an electrically charged atomic particle passes through, it provides sufficient excitation to initiate boiling. If a photograph is taken before the boiling spreads, it will reveal a line of small bubbles—the track of the particle. By studying many of these photographs, physicists can determine how the elementary particles interact with nuclei, how long the particles live, and what their decay products are.

Prof. Alvarez was interested in learning what happens when a negatively charged K-meson is captured by the simplest of all nuclei—that of hydrogen. To do this, he had to use a liquid hydrogen bubble chamber. Of course, this made it necessary for him to conduct the experiment at the very low temperature at which hydrogen liquifies—400° below zero, Fahrenheit.

For a variety of reasons it is not possible to produce a pure beam of K mesons, and in this particular case among the impurities in the beam were mu-mesons. This meson, which you may recall was first observed in the cosmic radiation, does not experience the nuclear force. It seems to have all the properties of electrons with two notable exceptions: first, the mu-meson is 207 times as heavy as an electron; and second, it is not stable. It lives an average of $2(10)^{-6}$ seconds and then decays into an electron and another particle. A striking manifestation of this similarity is the mu-mesic atom; that is, an atom in which one of the electrons has been replaced by a mu-meson. For the past few years, physicists have been producing these short lived hybrid atoms for study. The essential difference between a mu-meson orbit and an electron orbit in an atom is that the former is 1/207th as far from the nucleus as the latter. It can be shown quite generally that the shapes of the orbits will be the same, but corresponding distances are inversely proportional to the masses.

Now, in order to accurately identify the tracks made by the K-mesons, Prof. Alvarez and his group had to examine all tracks, including those made by the mu-mesons. In so doing, they observed a strange phenomenon: a few mu-mesons, after coming to rest, reappeared a short distance beyond, rejuvenated with more energy. For a while, the investigators thought perhaps the second track was made by a new particle. However, after further consideration, they were convinced that it indicated that the mu-meson had effected fusion between hydrogen and deuterium nuclei! (Deuterium, you may recall, is a natural impurity of hydrogen.)

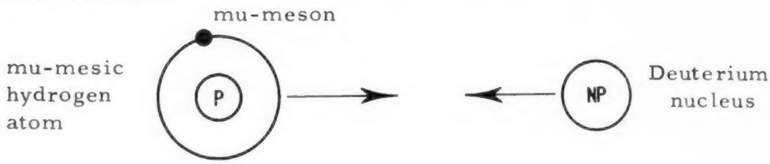
The sequence of events goes something like this:

- At the end of its first track, the negative mu-meson collides with a hydrogen molecule, breaking it into two hydrogen atoms and displacing the electron of one atom. Thus, a mu-mesic hydrogen atom is formed. As this atom is neutral, it does not produce a line of bubbles as it moves through the chamber. This explains the gap in the track recorded on the photograph.

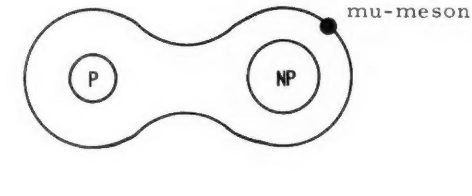
• The mu-mesic hydrogen atom then picks up one of the contaminating deuterium nuclei to form a hydrogen-deuterium molecule-ion, around which a mu-meson, instead of an electron, whirls. (An ion is an atom or molecule with one or more electrons removed. An ordinary hydrogen-deuterium molecule has two electrons.)

• As we mentioned earlier, the orbits of mu-mesons are smaller than those of electrons by a factor of 207, so that our pictorial representation of the hydrogen-deuterium-mu-meson molecular ion looks exactly like that of the ordinary molecular ion except that all distances are reduced by a factor of 207. The mu-meson has squeezed the two nuclei closer together than an electron can. But the nuclei in molecules are not motionless; they are vibrating about their equilibrium positions continually. This motion is universal and never ceases. The important point here is that the mu-meson, in bringing the equilibrium positions of the two nuclei closer together, has enormously increased the probability that they, in their oscillations to and fro, will come close enough so as to interact. When this happens....bang! You have catalyzed a fusion reaction! It looks like this:

Before reaction:



Mu-mesic molecule ion is formed:



After fusion:

This explains why the mu-meson reappears with more energy. Note the important fact that the rejuvenated mu-mesons can now go on and catalyze other fusion reactions, so the probability exists for starting a chain reaction. This is analogous to the situation in uranium reactors, where the chain reaction is maintained by neutrons.

Think for a moment of the beautiful irony of the situation. While many groups all over the world were seeking ways to achieve temperatures of millions of degrees in order to activate fusion reactions, some "longhairs" studying "impractical" things like sub-nuclear elementary particles stumbled upon a way to do it at 400° below zero, Fahrenheit!

Since the discovery was announced, much experimental and theoretical work has been done on this phenomenon with a view towards considering the feasibility of a fusion power source based on it. Unfortunately, the mu-meson does not exist free in nature except in the cosmic radiation, where there are too few of them arriving to make a useful power source. The only way we can produce them is by building a large accelerator, such as a cyclotron. When one calculates the energy produced by the fusion reactions catalyzed by mu-mesons, one finds that at best only one-fifth of the power that is fed to the accelerator can be recovered. Although improvements are conceivable, such as the design of more efficient accelerators, it appears unlikely that a factor of five improvement can be made without a major breakthrough.

However, this is not the end of the story. Several years ago a prominent Russian physicist claimed to have discovered, in the cosmic radiation, a particle similar to the mu-meson but having a mass about 500 times that of the electron. His evidence is so convincing that many physicists all over the world are searching for particles of this type. No less than four ONR contractors now have experiments in progress designed to detect particles of this mass in the cosmic radiation and at accelerators. Recall that the heavier the particle, the more closely the nuclei in the molecule are brought together, and therefore the more probable it is that a fusion reaction will be produced. Other desirable attributes for such a particle are (1) that it should not interact with the nuclei, because that reaction would occur before the molecule could be formed, and (2) that the particle live a long time, so that it can catalyze many fusions before it dies. The mu-meson can catalyze about 10 fusions in liquid deuterium in the $2(10)^{-6}$ seconds that it lives.

Even if this method of catalyzing fusion reactions should not lead to the development of a practical power source, it reminds us once again that technological breakthroughs of vast importance can come from basic research appearing to have no practical value. It happens that this particular phenomenon could have been predicted from the little that is known about the properties of the particles. The fact that it was not anticipated by the people doing the experiment is just a reflection of the fact that we poor mortals cannot conceive of all that is implied by the laws of nature that are already known.

Thus we see that in elementary particle research serendipity has a bright future for two reasons: First we don't know all the basic laws—we're not even sure we've found all the particles yet! In the second place, we can't foresee all the things that can happen in accordance with the laws we know. There can be no doubt that many new phenomena, both predictable and unpredictable by what is now known, are yet to be observed in the fabulous world of the elementary particles. Whether or not any of them will ever find practical application, only time will tell. However, if past history be our guide, it behooves us not only to keep close watch over this and all other exploratory research, but also to stimulate it if we want the U.S. Navy to continue being second to none.

Research Notes

Navy Roster of Key Scientists and Engineers

The Office of Naval Research has prepared a roster listing all civilian scientists and engineers, GS-13 and above, employed by the Department of the Navy. The list includes agronomists, architects, astronomers, bacteriologists, biologists, cartographers, chemists, electronic scientists, engineers, entomologists, geophysicists, hygienists, mathematicians, medical officers, metallurgists, meteorologists, microbiologists, naval architects, navigators, parasitologists, physicists, physiologists, physical science administrators, psychologists, statisticians, and technologists.

Naval activities submit information on new appointments, promotions, or separations to their Management Bureau for transmittal to ONR. Thus the list, initially prepared in the spring of 1956, is maintained on a current basis.

The roster provides a central source of information on qualified scientific and engineering personnel in the Naval Establishment. Therefore, it facilitates technical liaison and coordination.

Bureau chiefs, commanding officers, and technical directors of laboratories use the list to locate qualified individuals for consultation or for unique assignments.

The list supplements the roster of scientific and technical manpower maintained by the National Science Foundation. Special lists of scientists and engineers can be prepared easily from the roster.

The roster includes the names of about 3,000 persons. IBM cards contain 24 items of information about each person. Forty-five items are included in the questionnaire completed by each scientist or engineer. Special runs of IBM cards have been made to obtain an alphabetical listing of all persons included, and alphabetical listing by naval activity, scientific specialty in which most competent, and by profession.

About one-seventh of the group have doctoral degrees. Three have two or more doctoral degrees. Psychologists and chemists lead in the number of these degrees held, with mathematicians, physicists, and geophysicists following in that order.

Based on a bachelor's degree or higher, the 10 ranking professions are: physicists, chemists, psychologists, mathematicians, geophysicists, chemical engineers, aeronautical engineers, ordnance and armament engineers, mechanical engineers, and naval and marine engineers.

One objective of the roster is to facilitate professional recognition of Navy scientists and engineers by nominating them for possible inclusion in certain biographical directories. Editors of American Men of Science, Who's Who in America, Who's Who in Engineering, and Chemical Who's Who consider for inclusion in their editions persons nominated by the Navy. The name, professional field, and home address of each person is given. The editors send their questionnaires to these persons and on the basis of the criteria peculiar to each directory determine those to be included. ONR informed each person of his nomination. This has proved a definite morale builder for naval scientists and engineers.

Only authorized Navy personnel are permitted to use the roster. Job offers may be made to the individual only through the Commanding Officer of the activity.

Many uses have been made of the roster. One activity, after determining that all available Navy candidates for Marine Power Plant Development Engineer were being considered, promoted a member of its own staff. Another used the roster to obtain names of suitable candidates for Technical Director. Still another obtained a list of possible candidates for Chief Scientists to replace its retiring Chief Scientist.

The Inter-Service Committee on Technical Facilities used the questionnaire form to prepare a professional talent brochure. A Bureau chief obtained names and qualifications of both electronics and aeronautical-equipment specialists.

One activity obtained the number of mathematicians and statisticians in the field and departmental service of each bureau and office and the number in each grade, GS-13 through GS-16. The data were used in a three-day conference of mathematicians and statisticians.

Another naval activity found candidates for a Technical Director. Still another found four candidates for a Chief Scientist vacancy. The roster questionnaire was used as a guide for a questionnaire used by the Research Reserves to establish their roster. Staffing of the ONR Development Coordinator's Office was facilitated by use of the roster.

A study of the age distribution of Naval and Marine Engineers has been made which showed that 13.5 percent are now 62 or older and 14.7 percent will reach age 62 within 5 years. This means that 28.2 percent of all Naval and Marine Engineers are eligible for retirement within the next 5 years.

Although the roster has been in effect a comparatively short time, it is being used extensively for a number of purposes. It is considered a significant accomplishment.

Small Radars for Small Boats

The Navy has awarded a contract for 133 small-boat radars to the Raytheon Manufacturing Company, Waltham, Massachusetts. The new equipment, a modification of Raytheon's commercial radar, "Mariners Pathfinder," permits the Navy for the first time to economically place radar on small amphibious landing craft. The new Navy model proved very accurate, rugged, and easy to operate and maintain during recent tests at the Naval Amphibious Base, Little Creek, Virginia.

At present, the Navy plans installation in only a small percent of its landing craft. First deliveries are scheduled for the end of this year.

Raytheon's Navy radar differs from the commercial model in two respects. A variable range marker and range counter has been added which tells the target's exact distance. And a true-north indicator has been included, so that an amphibious craft's position may be computed either in relation to true north or to its relative bearing from the target.

The equipment can detect the smallest navigational markers, such as buoys, only 18 inches in diameter and as close as 50 yards from the vessel. Land can be detected as far away as 32 miles. For target scrutiny, the radar can be switched to any of six separated range scales. Thus the radars will enable small craft to navigate safely through uncharted or dangerous waters by providing needle-sharp, high-definition targets on a 10-inch radar scope. During an invasion landing, radar-equipped squad leaders can check not only their own positions but can monitor other craft as well.

Since it is compact and simply designed, the new radar can be installed in a limited space and within a few hours. Should the landing craft be damaged, the radar can be quickly transferred to another vessel.

The Navy's new small-boat radar came through with flying colors during recent tests at the Naval Amphibious Base, Little Creek, Virginia.

Future Artillery Shells May Have Plastic Cases

A light-weight, low-cost, plastic cartridge case for artillery shells has been developed and successfully tested by Navy scientists, under an Army contract, at the Naval Ordnance Laboratory, Silver Spring, Maryland. Except for a steel base, the cartridge case is of styrene copolymer material, especially developed for NOL by the Borg-Warner Corporation.

The Army will now make operational and cost studies. If these prove favorable, the new case probably will replace the traditional one of brass which has been used for more than a half century, as well as the steel case developed during the Korean conflict.

The new plastic case weighs less than half as much as the metal one. For instance, the NOL prototype cases made for the 105-millimeter field gun in use by the Army and Marines show a weight saving of 3 pounds. This will cut down on shipping costs and provide for easier and faster handling. Other advantages are a saving of vital materials like brass and steel and reduced production costs. Ease of manufacture seems to be another advantage. The conventional injection molding processes will permit many commercial plastic firms to do the work, which should result in lower contract costs through a broadened supply base and increased competition.

Some of the test cases have been fired by NOL scientists several times without reconditioning, emerging undamaged from the test gun after being subjected to extremely high temperatures and high pressures. The new cases have also passed weather tests calling for external temperatures ranging from -65°F. to 160°F.

Further tests by the Army Ordnance Corps will determine if the cases are strong enough to stand the rough handling of world-wide shipping and actual use in the field under battle conditions.

Stanley P. Prosen, NOL scientist, displays sample plastic cartridge case. Present steel case weighs down the scale. On the left is an assembled 105-millimeter artillery shell, the plastic case of which has been test-fired six times at NOL.

Scientsts Traverse Ross Ice Shelf

The first of several traverses of Antarctica to be undertaken by scientists during the IGY is now underway on the Ross Ice Shelf. The journey will be about 1,500 miles long and will cover an area roughly comparable to California in size. Five IGY scientists and two Navy men comprise the travelling party. Albert P. Crary, chief scientist at Little America and Deputy Chief Scientist for the IGY Antarctic Program, is leading the long trek.

The purpose of the traverse is to gather detailed information about the formation and present character of the floating ice sheet that makes up the Ross Ice Shelf as well as to determine ice thicknesses and water depths by seismic methods, using man-made earthquakes set off by detonating dynamite charges. Ice surface elevations will also be determined. Other measurements will be made of the strength of the earth's magnetic field and of magnetic compass variations. Gravity studies will be made throughout the traverse, as will meteorological measurements of temperature, pressure, humidity, wind, and wind-drift patterns. In addition, the party will survey mountain peaks and ranges along the route of travel.

Support for the traverse is being provided by Navy Task Force 43, commanded by RADM George Dufek. The scientists intend to set up about 50 temporary stations about 30 miles apart on the trail. Three Sno-cats, each towing a 2-1/2-ton sled loaded with equipment and supplies, are being used. The party plans to return to Little America about mid-February, allowing 25 days for bad weather and another 8 days for special observations at Ross Island and in the Beardmore and Shackleton Glacier area.

More Balloons in the Stratosphere

The feats accomplished by means of SKYHOOK balloons have been very much in the "news" recently in Research Reviews. But there is good reason for this, because the giant polyethylene bags are being used more and more to carry important scientific payloads above the earth. The most recent flights—a series of four—were made in October from Brownwood, Texas, to obtain more data on cosmic radiation. In addition to carrying out their scientific mission, two of the balloons soared to the highest altitudes ever reached by polyethylene balloons—138,000 and 134,000 feet. The balloon reaching the higher altitude remained at ceiling for about 8 hours. The flights, sponsored by ONR, were made for the Naval Research Laboratory, the National Research Council of Canada, and the University of Minnesota. Raven Industries, of Sioux Falls, South Dakota, was responsible for building, launching, and tracking the balloons and for recovering the equipment.

The purpose of the series of flights was to attain high enough altitudes to enable the emulsion detectors, carried by the balloons, to record data on primary cosmic rays, particularly the heavier primary cosmic rays. As the extremely high altitudes reached are above all but about 3/10ths of 1 percent of the earth's atmosphere, which causes the primary rays to disintegrate, the instruments were put in position to make very accurate measurements.

All of the balloons were 3/4-mil plastic (0.00075 of an inch thick). The balloon reaching the record altitude had a capacity of 3 million cubic feet and weighed 383 pounds. It carried a payload of 40 pounds of scientific instruments. The total weight of the balloon and its load was 510 pounds.

The entire series of flights was made in connection with the International Geophysical Year.

What's in a Name

A recently discovered minor planet has been named "Norc" for the Navy's fastest and most powerful electronic computer, the Naval Ordnance Research Calculator, located at the Computation Center of the Naval Proving Ground, Dahlgren, Virginia. By custom, the privilege of naming minor planets goes to their discoverers. In this case, the planet was discovered by S. Arend at Uccle, Belgium, in 1953, but its orbit was established entirely on the basis of computations made on the NORC by Dr. Paul Herget, Director of the Cincinnati Observatory. In recognition of the valuable contribution made by this unique machine, Dr. Herget arranged with Arend for the naming of the minor planet in its honor.

Under Dr. Herget's direction and the sponsorship of the Office of Naval Research and the National Science Foundation, the NORC has also provided a vast amount of computation of orbits of other minor planets, and has computed a precise orbit of the earth from 1920 to 2000 A.D. According to Dr. Herget, the researchers used 9 hours of running time of the NORC during May 1956, completing more computations than had ever been done at one time in the history of astronomy.

The NORC was built for the Bureau of Ordnance by the International Business Machines Corporation, and it was put in operation at the Naval Proving Ground in 1955. Performing computations at the rate of more than 15,000 complete operations per second, including automatic self-checking, it is one of the most powerful electronic calculators now in existence. It is used mainly by scientists at the Naval Proving Ground in the study and design of new weapons systems. Extensive calculations are carried out in the course of development of many types of guided and ballistic missiles and their associated control equipment and for basic research in aeroballistics and hydrodynamics. The computer has also been used by other agencies of the Defense Department in their programs—for example, in the development of nuclear reactors for ship propulsion, in other atomic energy applications, in cosmic ray research, and in the analysis of fleet exercises.

An important feature of the machine is its unique arithmetic unit, which produces a 26-digit product in 31 millionths of a second. It can store 3 million numbers, each consisting of 16 decimal digits, and transfer them to and from the main computing unit at a rate of 4,000 per second. The machine also possesses an internal memory from which it can recall any piece of information in 8 millionths of a second.

On the Naval Research Reserve

Attention Reserve Officers on Active Duty

If you are qualified in the scientific or technical fields you are eligible for association and may participate in the Research Reserve Program upon release to inactive duty. Members of the Naval Reserve of any designator are eligible for membership subject to the following standards:

1. Research: Be qualified and currently engaged in the conduct or administration of scientific research. Those qualified to conduct research are individuals having, or working toward, advanced degrees in fields of interest to the Office of Naval Research. Practical work as a substitute for formal education will be evaluated by the Office of Naval Research. Individuals qualified to administer research can be adjudged as to both educational and practical qualifications primarily on the basis of current occupation. Such personnel are interpreted to include engineering and technical personnel qualified to evaluate research from the standpoint of application.

2. Training Devices: Aeronautical, mechanical, electronic, and electrical engineers with knowledge of the application of their field to synthetic training devices; statisticians; educators in technical fields qualified to coordinate and supervise the use of synthetic training devices and training aids in the Navy's training programs.

3. Contract Administration and Patent Law: Lawyers with experience in either field; individuals with experience in Government research contract administration; individuals specializing in patent, trademark, or copyright matters.

Participation in the Research Reserve Program offers you an opportunity to perform active duty for training in many of the Navy's Research and Development Commands. You will also be considered from a priority aspect for attendance at Office of Naval Research sponsored seminars in the nuclear science field, training device field, aviation and submarine medical fields, research methods, and the Navy's current research programs. The objective of the Program is to train you for mobilization billets in the Naval Establishment requiring scientific and technical skills. In accomplishing this objective, the Research Reserve Program aids you in preparing yourself for promotion.

There are 111 Research Reserve companies located throughout the United States. Most of these companies meet twice each month and are generally located adjacent to or on the campuses of universities or colleges. The locations and the names of the Commanding Officers of Research Reserve companies are as follows:

Alabama

Auburn (LCDR J.E. Land)
Huntsville (LT H.F. Thames)

Arizona

Phoenix (LCDR Max Kaslo)
Tucson (CDR A.E. Hamilton)

California

Los Angeles (LCDR J.B. Slocum)
Pasadena (CDR C.V. Armstrong)
Los Angeles (LCDR J.T. McGill)
Compton (LCDR L.L. Whiteneck)
San Diego (LCDR E.C. Buffington)
Point Mugu (CDR M. S. Jones)
Azusa (CDR J.C. McConahay)
Ventura (CDR J. V. Iliff)
Santa Monica (CDR L. M. Rosholt)
San Francisco (CDR P.M. Klein, Jr.)
Livermore (LCDR R.G. Preston)
Stanford (CAPT R.M. Fincher)
Fresno (CDR F.D. Brown)
Berkeley (LCDR H.L. Williams)
Davis (CDR A.H. Smith)
Monterey (CAPT L.E. Kinsler)

Colorado

Ft. Collins (LCDR H.E. Troxell)
Boulder (LT W.F. Utlaut)

Connecticut

New London (LCDR J.A. Wheeler, Jr.)
New Haven (CDR J.H. Goldman)
Hartford (CDR K.I. Boone)

Delaware

Wilmington (CDR Donald MacCreary)

District of Columbia

(CDR W.M. Smedley)
(CDR A.J. Hiller)

Florida

Gainesville (LCDR L.N. Henderson)
Orlando (LCDR W.E. Radford)
Coral Gables (CDR N.R. Buchan)
Ft. Walton Beach (CDR H.W. Hoyt)
Melbourne (LT J.R. Petters)

Georgia

Atlanta (CDR J.D. Baer)
Athens (LCDR A.R. Robertson)

Idaho

Idaho Falls (LCDR Mark Baum)

Illinois

Chicago (LCDR B.J. Jaskoski)
Urbana (CDR E.T. Curry)
Peoria (LCDR R.G. Dworschack)
Decatur (LT J.E. Housiaux)
Forest Park (LCDR L.H. Fuchs)

Indiana

Lafayette (LCDR A.E. Bell)

Iowa

Ames (LT L.F. Simmering)
Des Moines (CDR H.M. Golden)
Iowa City (LT S.M. Fahr)
Waterloo (CDR J.O. Chellevold)

Kansas

Lawrence (CDR W.P. Smith)

Louisiana

New Orleans (LT R.J. Demint)
Baton Rouge (LT A.B. Watts)

Maryland

Frederick (LT R.E. Beldon)
Baltimore (LT G. de Socio)
Bethesda (LCDR R. Trumbull)
Annapolis (CDR E.N. McWhite)

Massachusetts

Cambridge (CAPT R.W. Hart)
Woods Hole (CDR Mary Sears)
Amherst (LCDR A.L. Hepworth)
Worcester (CDR R.F. Burke)

Michigan

Ann Arbor (LCDR J.E. Lesch)
Midland (LCDR W.C. Broad)
East Lansing (LCDR C. Pedrey)

Minnesota

Minneapolis (CDR A.O. Hoistad)

Mississippi

Gulfport (LCDR J.S. Luter)

Missouri

St. Louis (CDR W.L. Wilkins)
Rolla (LT J.M. Brewer)

Nebraska

Lincoln (LT H.J. Ball)

New Hampshire

Hanover (CDR F.J. Boyle)

New Jersey

Port Newark (CDR R.H. Heartel)
Princeton (CDR E.W. Stitt)

New Mexico

Albuquerque (LCDR J.M. Houston)
Los Alamos (CDR A.R. Lyle)

New York

New York (CDR Frank Kulman)
Long Island (CAPT D.S. Little)
Buffalo (LT E.S. Hiller)
Rochester (CDR I.G. McChesney)
Syracuse (LCDR P.M. Engle, Jr.)
Scotia (CDR Thomas Gair)
New York (CDR Leo J.C. Murphy)
Upton, L.I. (CAPT J.S. Medd)
Massena (LCDR L.M. Hale)
Ithaca (LCDR A.F. Sherf)

North Carolina

Chapel Hill (CDR C.F. Milner)

Ohio

Columbus (LCDR Daniel Howland)
Cleveland (CDR V. Schreckengost)
Dayton (LCDR W.E. Kremer)
Cincinnati (LCDR L.J. Pecora)

Oklahoma

Bartlesville (CDR C.C. Cruzan)
Stillwater (CDR D.E. Howell)

Oregon

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Kingston (LTJG W.M. Hagist)

South Carolina

Clemson (LCDR W.G. Miller)
Aiken (CDR Loren Palmer)

South Dakota

Brookings (LCDR G.B. Spawn)
Rapid City (LCDR W.J. Martin)

Tennessee

Oak Ridge (LT W.A. Pryor)
Tullahoma (LT A.H. Hinners, Jr.)
Nashville (CDR S.B. Sudduth)

Texas

College Station (CDR N.F. Rode)
Houston (LT C.S. Brooks, Jr.)
Austin (CDR Atwell C. Lagow)
Galveston (LCDR Lauro Gutierrez-Vela)
Dallas (CDR L.F. Connel, Jr.)

Utah

Logan (CDR O.B. Cope)

Virginia

Hampton (LTJG S. Salmirs)
Blacksburg (LCDR J.L.W. West)
Richmond (CAPT R.D. Hughes)

Washington

Seattle (LCDR Raleigh Moreland)
Richland (CDR L.D. Weir)
Pullman (CDR C.S. McNeil)

West Virginia

S. Charleston (LT A.C. Bowbeer)

Wisconsin

Madison (LCDR T.J. Brevick)

If you desire a copy of this article for your own file and reference, or if you desire additional information on the Research Reserve Program, send a government postcard request or letter request to: Chief of Naval Research (Code 120), Navy Department, Washington 25, D.C.

Research Studies Underway

Several interesting scientific and technical studies are underway in various Research Reserve companies. These studies have been undertaken either as a part of, or in addition to, regular company drills.

• NRRC 4-2, Philadelphia, Pennsylvania, has initiated a study on camouflage for ships. CDR Edmund Thelen, USNR, is the project leader, and all members of the company, which now includes 18 officers, are participating in this study.

• Another investigation has been undertaken by NRRC 8-1, New Orleans, Louisiana, concerning the Iberian peninsula. The resources and peoples of Spain and Portugal will be studied in order to determine the desirability of using these countries as military bases. CDR John M. Scott, USNR, is the project officer. All members of the company will participate in the study.

• Under the direction of CAPT LeRoy D. Fothergill, MC, USNR, the members of NRRC 5-3, Frederick, Maryland, have begun a research project entitled "Navy's Role in Anti-Food Biological Warfare." A completion date of July 1958 is anticipated.

• Members of NRRC 5-10, Washington, D. C., engaged in a research study during the first quarter of fiscal year 1958 which involved a utilization of the situational performance materials developed by the American Institute of Research for the Bureau of Naval Personnel. The purpose of this study, which was conducted at the request of the Bureau of Naval Personnel, was to provide additional information regarding the reliability and validity of situational performance tests.

Other scientific and technical studies which are pending were listed in a letter dated April 18, 1957, from the Chief of Naval Research to Research Reserve companies. This letter also included a list of areas of interest to the Research Group, Office of Naval Research. The procedures established for the conduct of a research study, whether undertaken by a company or by individuals on appropriate duty order, are outlined in ONR Instruction 3920.2A, which recently superseded ONR Instruction 3920.2.

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[Articles are arranged chronologically under the ONR Division having cognizance of the research described or under other categories.]

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* Written by Eleanor Kehoe, Training Specialist, Research Reserves.
† Written by the editorial staff of Research Reviews.

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Last Month With "Vanguard"

On November 8th, the Secretary of Defense directed the Department of the Army to proceed with preparations for launching a scientific satellite by use of a modified JUPITER-C test vehicle. This program will supplement the present VANGUARD program to place an earth satellite into orbit in connection with the International Geophysical Year.

All of the Project VANGUARD test firings to date have met or exceeded the predicted performance. As we go to press, there is every reason to expect that Project VANGUARD will meet the announced schedule to launch a small test satellite before this year ends and a fully instrumented scientific satellite in March. The decision to proceed with the additional program was made to provide a second means of putting into orbit, as part of the International Geophysical Year program, a satellite which will carry radio transmitters compatible with Minitrack ground stations and scientific instruments selected by the National Academy of Sciences.

The Assistant to the Secretary of Defense for Guided Missiles, Mr. William M. Holaday, will be responsible for coordinating the Army Project as a part of the U. S. Scientific Satellite Program.

The Raising of SMITH, JONES, and BROWN

Recently, at Woods Hole, Massachusetts, site of the well-known oceanographic institution, a large bugeye schooner sank at her moorings while her owner was away. Salvaging such a vessel generally requires that one or more pumps be put into operation to remove the water from her holds. As the water is sucked out, the boat regains her buoyancy and rises to the surface. But in the case of the SMITH, JONES, and BROWN, this expedient failed to remove the water fast enough. Every available pump in the area was brought into play, but the schooner refused to budge from the harbor bottom.

A couple of days passed while the "experts" scratched their heads wondering what to do next. Then, one of the old timers who had been watching the proceedings, suggested a salvage remedy utilized many years ago to raise old ships with open seams. It required, first, that a load of horse manure be brought to the scene. After a long search for this material (horses are becoming scarcer than ever these days) enough was found to do the job. While the many pumps were trying to gain on the inrushing water, the material was sprinkled liberally around the sunken hulk and pushed down outside the bilges. It was then sucked into the cracks in the seams. Thus caulked, the SMITH, JONES, and BROWN rose almost immediately to the surface.

We don't know what this proves, except, perhaps, that science isn't everything.

In This Issue

COVER PHOTO: Tracks made by elementary particles moving through a bubble chamber. See article beginning on page 12 for a discussion of an important discovery made by means of this device.

RESEARCH REVIEWS reports highlights of technical progress in research by Navy laboratories and contractors and the development of important naval research facilities. Articles which meet these broad criteria and possess a good degree of readability are welcomed. Manuscripts and changes of address should be sent to Code 740, Office of Naval Research, Washington, D. C. Research Reviews is listed for sale by the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. Subscription price: $1.50 per year in U. S. and Canada; $2.00 per year, foreign; $.15 per individual copy. Approved by the Bureau of Budget, February 28, 1955.

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