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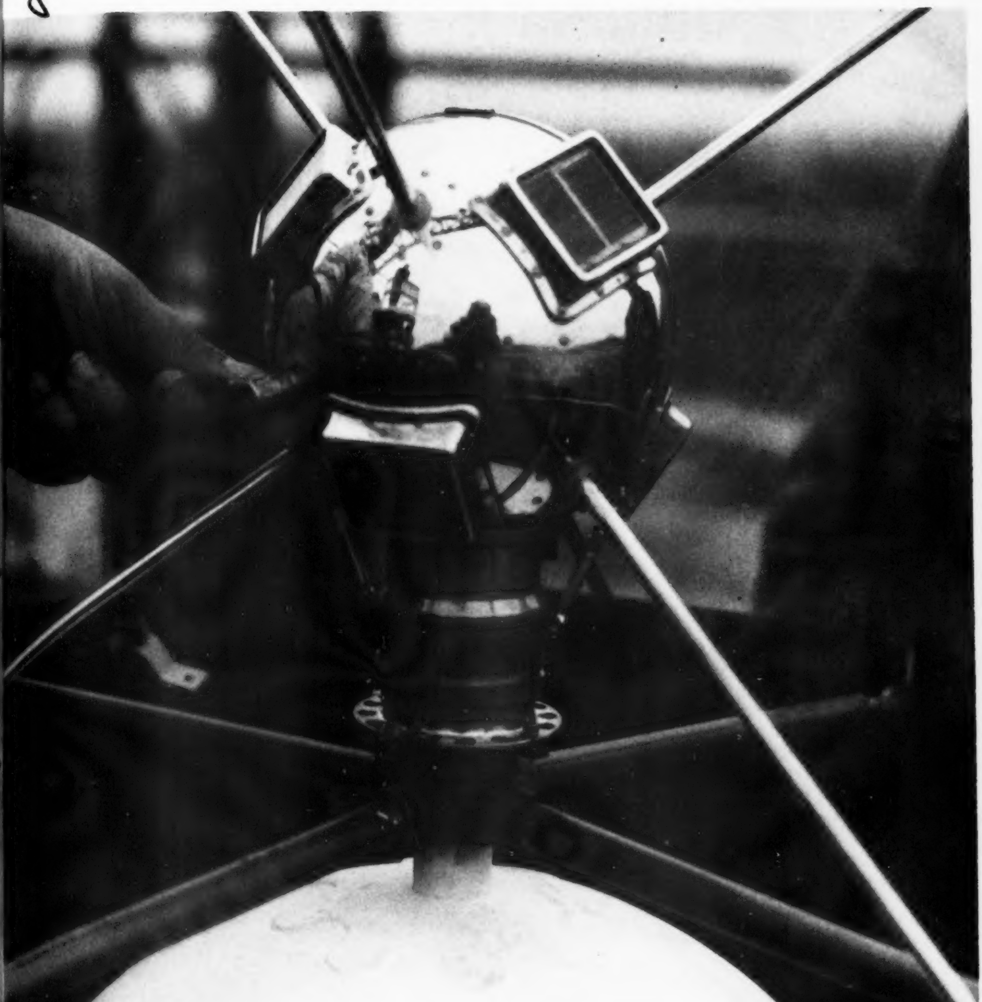
RESEARCH REVIEWS



DEPARTMENT OF THE NAVY

WASHINGTON, D. C.

NAVEXOS P-510

Angle-of-attack indicator being adjusted on the top of the plastic nose cone of the VANGUARD rocket in preparation for firing on March 17. See "Last Month With VANGUARD," inside back cover.

The Interactions of Electrons With Nuclei

Robert Hofstadter
Professor of Physics
Stanford University

The history of man's thinking shows us that as long as 2,000 years ago he was interested in understanding the fundamental composition of matter. The Ancient Greek philosophers thought that matter was made of indivisible atoms. We now know that matter is indeed made of atoms, which, however, are not indivisible but, on the contrary, do have parts. As is well known, the atom has an outer cloud of electrons, and within this envelope, at the very center, an unbelievably dense core, which we call the nucleus. This core, we have learned, is also divisible into smaller bodies—the neutron and proton (collectively called nucleons). Ninety-nine point nine percent of the mass of the atom is contained here. However, the size of the core is extremely small compared with the outer electronic cloud. Just how small is indicated by the fact that if the atom were magnified so that it encompassed an area as large as Washington, D. C., the nucleus would be about the size of a baseball.

During the past 7 years, determinations of the exact size and shape of the nuclear core and of the individual neutron and proton have been the object of studies made by a research group* at Stanford University. As a result of this work, done by means of electron-scattering experiments, we have established the sizes and the density distribution of the electric charge in a number of nuclei ranging from Helium to Uranium. We have also penetrated the smaller structures of the neutron and proton and have found the sizes of these particles. Furthermore, we have discovered the way in which the electric charges and currents are distributed within these particles.

Before describing the detailed findings of the past few years, it is appropriate to sketch briefly the basic experimental method. In essence, this method is similar to one employed about 40 years ago by Lord Rutherford and his associates in establishing that the atom has its presently known structure. The method consists of firing probe-particles at the structure we wish to examine. If the structure is very "soft," the probe-particles, especially if they move at high speed, will be deflected only slightly as they go through the structure. If the structure is dense, the probe-particles will collide with the hard centers and be sent back in the direction from which they came. In the latter case the action is similar to the recoil of a ball hitting a hard wall. By making a precise

*Associated with the author in this work are the following investigators: F. Bumiller, E. E. Chambers, H. R. Fechter, B. Hahn, R. W. McAllister, J. A. McIntyre, D. G. Ravenhall, M. R. Yearian, and D. R. Yennie. The work was supported by the Office of Naval Research, the Atomic Energy Commission, and the Office of Scientific Research of the Air Force.

study of the number of probe-particles deflected at all angles between the initial direction and the opposite direction (180 degrees), one can determine the kind of structure that the probe-particles pass through. In Rutherford's experiments, alpha particles, the nuclei of Helium atoms, were used as probes. But in our's, high-speed electrons are used. The great advantage of using electrons for this application is that they interact with nuclei only through electromagnetic forces, whereas protons and alpha particles interact with nuclei through nuclear as well as electromagnetic forces. The latter are well understood, but the former are not. Thus, one can calculate with confidence the angular pattern of the scattering of electrons; but not so for scattered protons and alpha particles, because of the unknown contribution of the nuclear forces.

To direct the electrons against the nuclei, we employ the 220 foot long Stanford linear accelerator. This is basically a wave guide which carries the electrons on a wave proceeding down the accelerator tube. All the while the electrons are going down the tube, an electric field is accelerating them. When they emerge, at characteristic energies of 200 to 600 million electron-volts, they are deflected by magnets, as shown in Figure 1, and made uniform in energy by a slit placed between the magnets. The electrons are then directed against the target, shown as a black line just beyond the electron monitor. After striking the target, which may be made of gold nuclei or hydrogen nuclei or whatever one chooses to study, the electrons are scattered in all directions. Some of the scattered electrons enter the port to the magnetic spectrometer, and these are the ones we study.

The magnetic spectrometer may be moved to any angular position about the beam line. This is achieved by mounting the instrument on a former naval 5-inch gun mount modified for our present use. Figure 2 shows the spectrometer mounted on our gun base. The large platform above the target area carries the detector element, a so-called Cerenkov counter. The massive 15-ton shield on the detector platform is required to keep undesired background events from registering in the detector. The whole assembly of spectrometer and shield can be rotated around the target center by remote control with a precision of better than 1/10th of a degree.

It is necessary to use a magnetic spectrometer to detect the electrons rather than just a counter telescope looking at the target, because the electrons bouncing off the target can do many things when they strike the target nuclei. In addition to merely passing through a nucleus and being deflected by its charge or current, they may excite the nucleus to a vibrational or rotational state, or they may even break up the nucleus. Just which of these processes occurs can be inferred by examining the energy of the electron after it has gone through the magnetic spectrometer and has been registered on the detector. The monitor indicated in Figure 1 tells how many incident electrons pass through the target.

With these instruments it has proved possible to examine in great detail just how the charge density varies in the different nuclei as a function of radius. We shall now try to describe these results, beginning

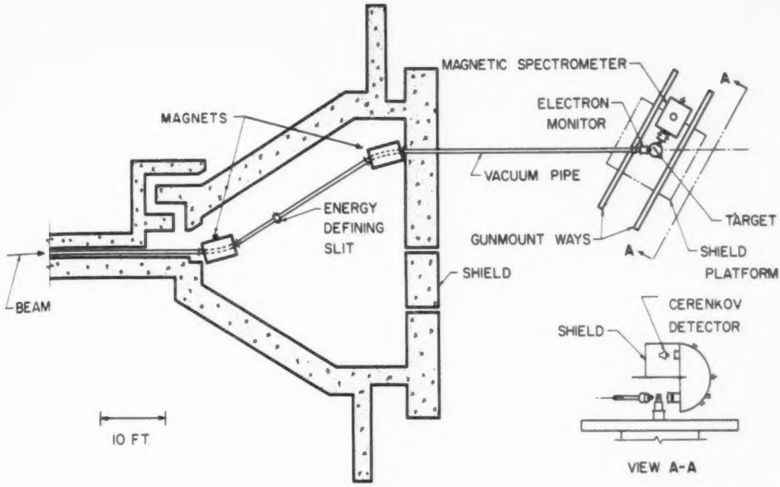
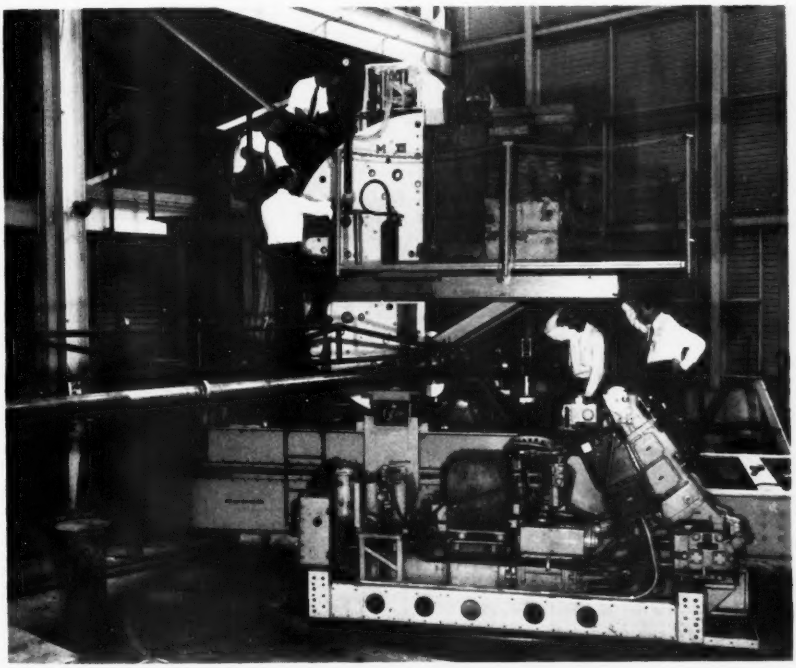


Figure 1 - Diagram of apparatus used for making electron-scattering measurements. The electron beam, indicated at left, is generated by the 220 foot long Stanford linear accelerator. The beam is focused on the target, at right, which scatters the electrons in all directions. Electrons entering the port to the magnetic spectrometer are the ones measured. Courtesy of Scientific American magazine.

Figure 2 - Shown here are the magnetic spectrometer (upper center), the gun base on which it is mounted, and the pipe through which electrons travel to the target.



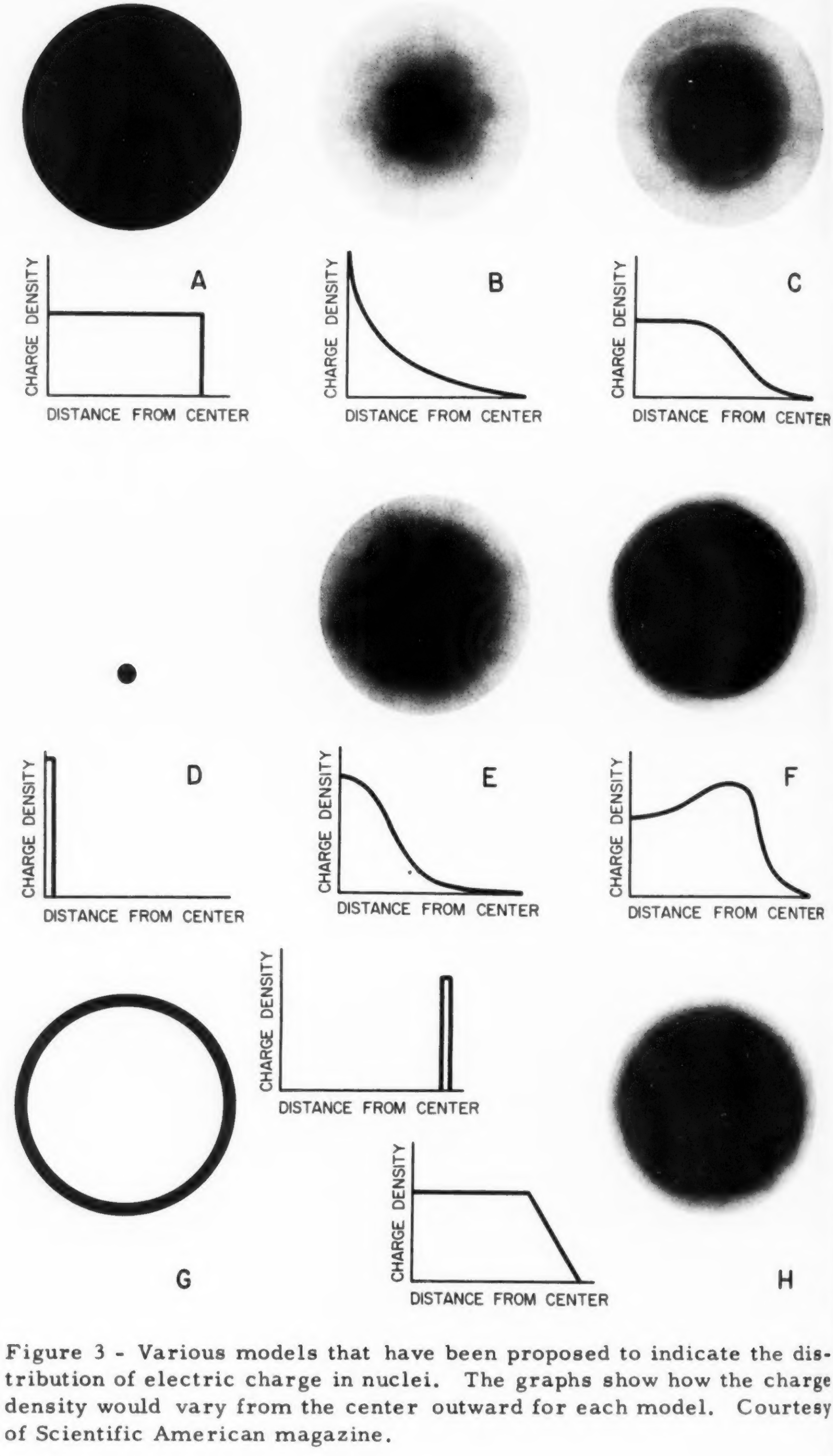


Figure 3 - Various models that have been proposed to indicate the distribution of electric charge in nuclei. The graphs show how the charge density would vary from the center outward for each model. Courtesy of Scientific American magazine.

with the medium and heavy nuclei, then going on to the proton and neutron.

Figure 3 shows various models that have been proposed for the distribution of charge in nuclei, and corresponding graphs which give the charge density as a function of radius. According to these conceptions, a nucelus might be spread throughout the nuclear volume uniformly, as at A; it might be highly concentrated, as at D; it might be so distributed as to form a shell, as at G; or it might have other configurations. It is our intention to find which of these models is the true one and determine what its dimensions are.

The way in which these results can be found is indicated by the graph of Figure 4. This graph shows two curves which represent the way in which the scattered intensity of electrons falls off as a function of scattering angle for two different nuclear models. The top curve shows how a point nucleus (a nucleus having a great concentration of charge; see model D in Figure 3) would scatter electrons. Because the charge is so concentrated, the intensity at large angles is still high. In the case of a spread-out nucleus, such as those represented by any of the models except D and G, the angular pattern of the scattered intensity resembles the lower curve of Figure 4. The dips at A, B, and C represent diffraction features which give further precise information about the size and density distribution of the nucleus. The figure shows that the spread-out structure gives 10,000 times smaller intensities at large angles than the point structure. Other nuclear models give correspondingly different intensities lying below the curve for the point nucleus. By comparing the experimental findings with such calculated curves, we can tell which model applies to any given nucleus.

Many experiments carried out over the last few years have shown that models C and H of Figure 3 best fit the data. Notice from the graphs of these two models that the charge distribution is characterized by a core of constant density with a fuzzy "skin"—a gradual tapering off of the density. Two remarkable regularities have been observed in the medium and heavy nuclei we have examined. They are—

- The skin thickness is a constant for all these nuclei. It has the value of 2.4×10^{-13} cm.

- The distance from the center to the point where the density is 50 percent of the core value (called the "c" distance) is directly proportional to the cube root of the number of nucleons in the nucleus (referred to as "A"). This rule may be stated in the formula

$$c = 1.07 A^{1/3} \times 10^{-13} \text{ cm.}$$

With these two rules we can describe many nuclei with a high degree of precision.

We now wish to describe our investigations of the fundamental constituents of the nuclei, the protons and neutrons. In the last 3 years we

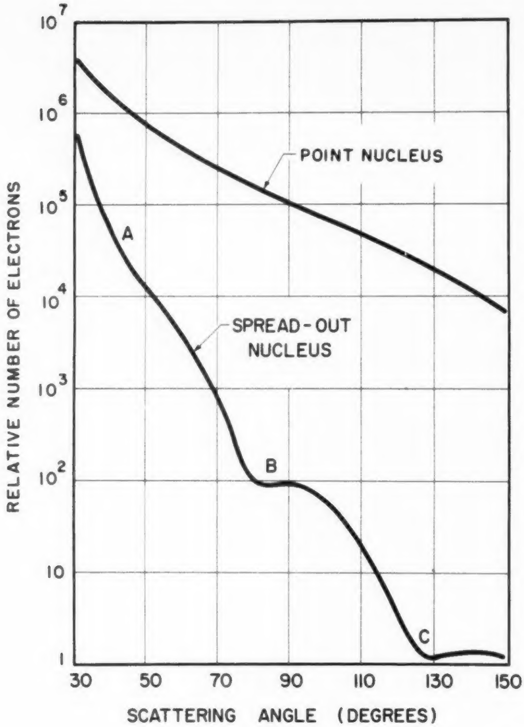


Figure 4 - Theoretical curves showing the electron-scattering patterns to be expected for two types of nuclear models. The vertical scale indicates the relative number of electrons scattered by each nucleus at the different angles indicated on the horizontal scale. Courtesy of Scientific American magazine.

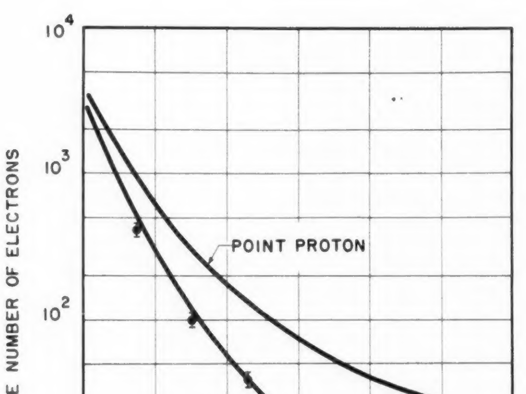


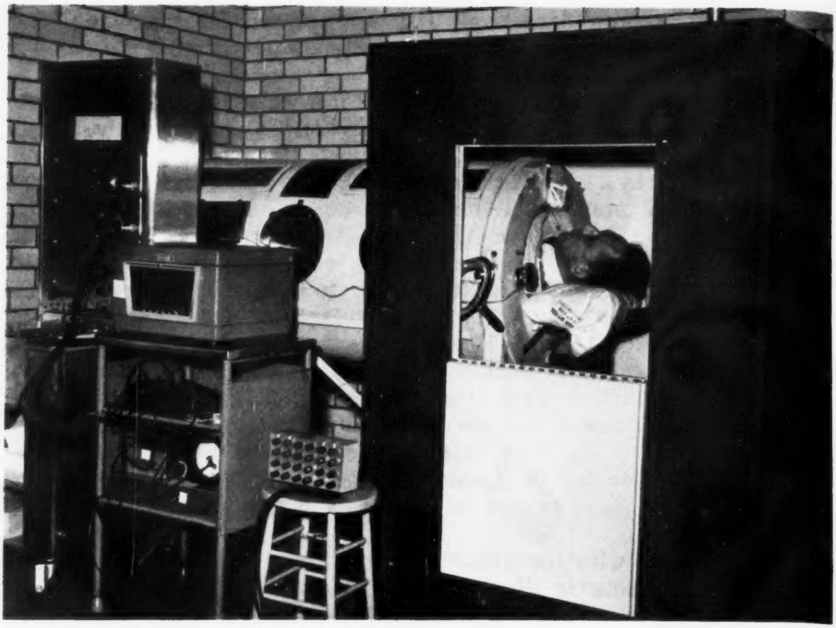
Figure 5 - Scattering pattern for the proton. The upper curve shows the pattern to be expected of a point proton, while the lower curve shows that to be expected of a spread-out proton. The experimental points (black dots) indicate that the lower curve best represents the actual structure. Courtesy of Scientific American magazine.

have concentrated on these basic and more primitive structures. The method used to examine protons and neutrons is basically the same as that described for the heavier nuclei. Corresponding to Figure 4, we show in Figure 5 a curve taken for the proton at a high energy. A point proton would give the upper scattering curve. The experimental points, shown as black dots, are far below the curve for a point proton. Thus, the proton itself is a spread-out structure. The solid line going through the experimental points is a theoretical curve corresponding to model B for the proton. This is evidence, therefore, of a higher concentration of charge in the center of the proton than in all other nuclei. However, the density at the center does not appear to have those extremely high positive values which physicists call singularities. On the contrary, the density appears to be finite. However, we should add that our scattering method has the smallest sensitivity at the center of the proton and has better accuracy farther away from the center. It is possible that future higher energy studies will reveal more detail in this region. At present it appears safe to say that, if there are regions of extremely high densities in the center of the proton, they must appear in oppositely charged pairs so as to cancel each other, leaving a finite result.

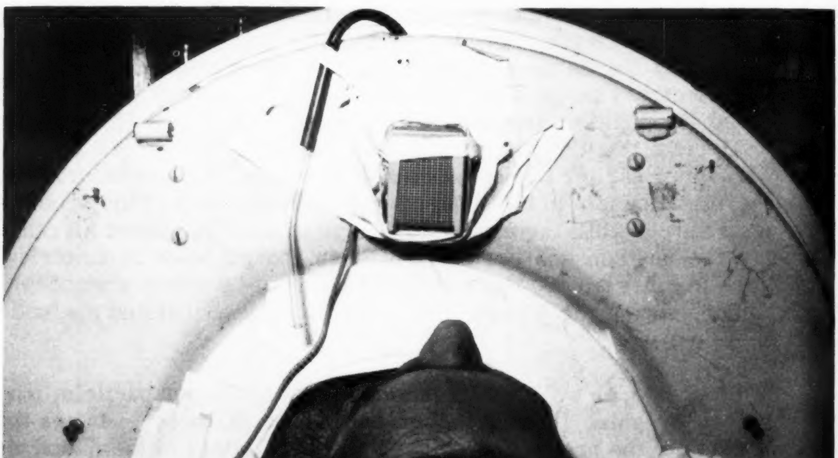
Associated with the charge in the proton are electric currents which produce magnetic effects. The magnetization inside the proton is also accessible to our method of investigation. We have found that the current is spread out in the same way as the charge in the proton. This is a result which has proved a surprise to many theorists.

We have also studied the other basic building block of nuclei, the neutron. This was done by working with the heavy isotope of hydrogen, called the deuteron. The deuteron contains one proton and one neutron. By comparing the scattering from the deuteron with the scattering from hydrogen (the proton), we can find the residual scattering coming from the neutron. Then we can apply our usual analysis to determine the density distribution. We have found that the neutron's electric current is spread out in virtually the same way as the proton's current. However, the neutron's electric charge is not spread out! The neutron has no total charge, so its positive and negative parts must cancel out throughout space. The fact that the neutron's charge cloud is not spread out was also discovered earlier by Fermi, Rabi, Hughes, and their collaborators. Thus there is a puzzle in the neutron-proton case: why is the proton's charge spread out while the neutron's charge is not? In almost all other respects the neutron and proton have been thought to be symmetrical particles—in other words, that which occurs in one particle also occurs in the other, except for a change of sign of the electrical and magnetic effects.

This puzzle, as well as a true understanding of each particle, may be resolved by going to still higher energies. At these energies the central parts of the proton and neutron will be exposed to view, and we may examine them to see if the detailed differences are really as we now suppose. A new large magnetic spectrometer of six times the weight of the present one will be used to help answer the questions presently posed by our experiments. This spectrometer will weigh 155 tons and will be ready in about 1 year. The future thus appears promising from the viewpoint of determining the structure of the nucleons.



A human volunteer enclosed in tank-type respirator designed to deprive him of the usual input to his senses. The photograph above shows the complete assemblage of equipment, including the screen (at right) and "polygraph" and tape recorder (at left). The photograph below shows the "head" end of the tank; a voice-activated microphone and self-feeding device can be seen mounted on the tank above the subject's head.



Sensory Deprivation and the Human Mind

Philip Solomon
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and
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Boston City Hospital

Man has been fascinated by his own mind since the dawn of recorded history. It is man's mind that has singled him out for supremacy over all living creatures. There are many other animals that are stronger, faster, better protected, more deadly, or naturally superior in adapting themselves to land, sea, or air. But only man has a mind capable of conquering the elements, transmuting matter into energy, exploring outer space, and perhaps eventually learning the secret of life itself. How does this mind work? Is it dependent on contact with the world around it or can it think successfully by itself after messages from the outside have been cut off?

Explorers, shipwrecked sailors, and prisoners-of-war have long been known to develop mental troubles after many days of isolation. Deafness and blindness can help bring on mental breakdown. Even during normal sleep, when little sensation occurs, the mind is lost in the vagaries of its dreams. Nevertheless, man has been loath to accept dependence on his senses for mental stability.

Very recently, psychologists put the question to test. They did this by blocking the usual sensory input to human volunteers, then observing how they behaved. D. O. Hebb, of McGill University, placed the volunteers in sound-proofed rooms, and John C. Lilly, of The National Institutes of Health, immersed them in tepid water. Both experiments brought on temporary mental abnormality, including loss of the sense of time and place, anxiety, and hallucinations.

Our own interest in this subject arose at the Boston City Hospital when it was noticed that patients with poliomyelitis, who had to be put in a respirator because of paralysis of their breathing muscles, often developed transient mental abnormalities. We wondered if just living in a respirator could bring about such a condition through the effect of sensory deprivation. It was easy to find out. We put adult male volunteers in the respirator for periods up to 36 hours.* Although we kept the vents open so that each subject breathed for himself, we darkened the room, and kept the observer silent behind a screen. We encased the subject's arms and legs in cardboard cylinders to limit touch sensation and mobility. The respirator motor made a constant monotonous sound.

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*The work was done in collaboration with Jack Mendelson, M. D., Donald Wexler, M. D., P. Herbert Leiderman, M. D., and Philip Kubzansky, Ph.D. It was supported in part by ONR and carried out under the auspices of The Harvard Medical School.

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Later we added a voice-activated tape recorder, and a "polygraph," a machine which registers electrical waves from the subject's brain, heart, and skin. We also arranged a self-feeding device, and collected urine specimens to measure the output of adrenalin and nor-adrenalin, related to stress. Before and after each experiment we gave the subject a variety of psychological tests.

What were the results? Much the same as the other experimenters', though the mental abnormalities usually appeared a little later than in Lilly's subjects, and earlier than in Hebb's. The advantage of our particular set-up was that it permitted greater possibilities of varying the experiment, thus giving us better opportunities to study what was going on.

Our data are still being processed for significant correlations, and new data are being accumulated all the time. Certain findings, however, are already abundantly clear. The experimental situation acted as a severe stress on all subjects. Though they may have entered the tank thinking they would enjoy a good rest, it was not long before they were acutely uncomfortable. A vague restlessness, anxiousness, and feeling of oppression grew on them until, in some, a state of actual panic was reached. Only a third of the subjects were able to complete the experiment. Mental impairment included loss of time judgement, inability to think clearly or concentrate well, and, in about half the subjects, peculiar notions about their bodies, or the experience of having brilliant visions, often in technicolor. One subject reacted violently to a spot on the ceiling, thinking it was a spider descending on him. Another thought he saw a knight in shining armor with a coiled metal spoke shooting out from below his waist. Another thought the air around him was polluted and that gas was condensing on his skin.

Our psychological tests have been helpful. They indicate that the type of individual who tolerates the stress of sensory deprivation best is the one who is more motivated by a genuine interest in others and less by self-enhancement. It appears that the self-centered introvert, whom you might expect to be quite content in the respirator, holed up in his own little world so to speak, is precisely the one who breaks down soonest; whereas the extrovert, who is more strongly oriented to people and the outside world, can stand being shut off, if he has to, more readily. Sensory deprivation places a strain on the individual's hold on external reality, and it may be that those who are jeopardized most by it are those whose ties to reality are weakest.

Are there any practical applications of the work in this new field? We think there may be many. Take the field of clinical medicine, for example. If normal individuals can develop psychotic-like states under the stress of sensory deprivation, how much more likely it is that sick people, perhaps already near the mental breaking point, can be tipped into a delirious-like state by the curtailment of their usual sensory stimulation. On the wards of the Boston City Hospital we found a number of cases that fell into this category. The list includes the following:

- Patients treated in a respirator, whether for poliomyelitis or other neurological diseases.

- Patients severely confined in other ways, for example in orthopedic body casts, tongs, or complex traction apparatus.

- Patients recovering from surgery.

- Cardiac patients considered too sick to have visitors.

- Patients with cataracts just removed and with both eyes bandaged.

We found that the transient psychotic states experienced by these patients could be prevented by the avoidance of darkness, silence, and solitude. A night light, a radio or television set, or the presence of relatives and other persons could work wonders.

An understanding of the effects of sensory deprivation may have relevance in certain public health problems. For example, truck drivers, while making long hauls, often have visual hallucinations that may cause them to lose control of their vehicles. The drivers of passenger cars are also put in jeopardy when they travel the highways—particularly the new superhighways—because of the lack of stimulation, or sensory deprivation. Accidents of similar origin occur, in addition, to workers performing repetitive tasks on assembly lines. Military applications of our growing knowledge of sensory deprivation are obvious: consider the lonely guardsman at his post, the radar observer at his scope, and the pilot of the future in his interplanetary ship.

How does sensory deprivation work? No one knows. There are several theories, and a number of laboratories are actively engaged in research to find out. In June 1958 we hope to shed some light on this problem through some 60 investigators from all over the United States, as well as Canada and England, who will meet in Boston, Massachusetts, under the auspices of the Harvard Medical School, Boston City Hospital, and ONR in a two-day "Symposium on Sensory Deprivation." Among them will be distinguished representatives of the fields of psychology, neurology, psychiatry, psychoanalysis, internal medicine, military medicine, physiology, biochemistry, electroencephalography, biomathematics, and philosophy. It is hoped that this meeting of the minds will lead man further along the road at the end of which lies the solution to the enigma of the mind.

Professor Wins Highest Navy Science Award

The second annual presentation of the highest award for scientific achievement in the Navy—the Captain Robert Dexter Conrad Award—was made on March 11 to Dr. Charles C. Lauritsen, Professor of Physics, California Institute of Technology.

Dr. Lauritsen was chosen for the award because of his outstanding contributions to the Navy's research and development program in the field of rockets, nuclear physics, and tactical operations.

The Navy's Full-Pressure Suit

C. F. GELL, CAPT, MC, USN
Director

E. L. Hays
Superintendent, Safety Equipment Division

J. V. Correale, Jr.
Head, Pressure Suit Branch

Air Crew Equipment Laboratory
Naval Air Material Center

For a number of years now, man has been able to fly at high altitudes in surroundings as comfortable as those of his living room at home. He has been able to wear the same dress he wears to his office, take his meals as conveniently as he does at a buffet supper, and read, converse, or nap at will. He is able to enjoy these luxuries only because the plane's cabin is heated, comfortably furnished, and supplied with oxygen, and because the cabin pressure is kept about the same as that on the ground.

This high degree of security applies only to commercial flying. In military operations the situation is quite different, at least for planes flying high-altitude operational missions. Although the cabins of these aircraft are pressurized, they cannot be made bullet- or shrapnel-proof. If the cabin is punctured at high altitude, explosive decompression will occur, and, unless protective measures are taken, the pilot will be in serious trouble. Liquids in the tissues of his body will vaporize, and, along with the gases trapped in his lungs, digestive track, and abdomen, will follow the paths of least resistance to their expansion. His blood will not oxygenate, and thus will be unable to deliver oxygen to the parts of his body that need it. As a result, he will experience pain, perhaps shock, and his vision and muscular coordination may be impaired. He will also suffer the effects of rapid changes in temperature, which may, by themselves, incapacitate him.

The need for equipment to protect air crews against low pressure began to be felt during World War II, and it has increased sharply as each new high-altitude plane has rolled off the assembly line. As investigators began studying this need, two schools of thought emerged. According to one, pressurization was to be provided by means of a garment made to contract against the body, and according to the other, by a suit that would permit the pilot to be surrounded by a layer of confined pressurized air. In general, the Air Force has concentrated on the development of the former, called the partial-pressure suit, while the Navy has specialized in the latter—the full-pressure suit.

MANY GARMENTS IN ONE

In its present stage of development, the full-pressure suit system consists of the suit proper, the headpiece, a back pan containing controlling instruments and an emergency oxygen supply, and a source of pressurized air and oxygen located in the airframe. The latter is separated from the controlling instruments by a quick disconnect, used in emergencies when the pilot must eject himself from the plane. Emergency equipment built into the suit system permits this to be done without loss of suit pressure or breathing oxygen.

Next to his body, the pilot wears a ventilation-insulation garment, and over that, an anti-G suit. The pressure garment, which comes next, consists of a rubberized air- and water-tight coated fabric. The back pan containing the control instruments is located outside the suit adjacent to the parachute. Integrated with the back pan and parachute harness is the flotation gear, which keeps the pilot from submerging if he goes down at sea.

When pressurized, an airtight suit tends to increase in girth and length throughout the torso and limbs, the headpiece tends to rise, and the fabric becomes taut. To prevent headpiece rise, the helmet is attached by an external restraint to the lower torso of the suit. Bellows joints permit flexion at the knees, elbows, and neck, and two-way sealing ball-bearing joints allow rotation of the head, arms, and wrists. Metal restraints built into the palms of the gloves reduce ballooning and enable the wearer to close his fists.

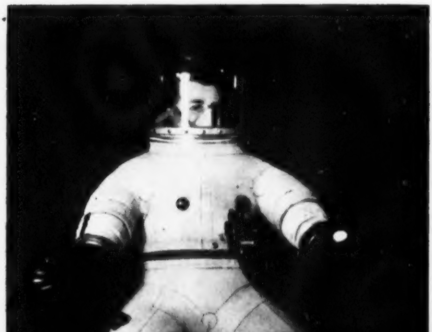
The headpiece has a retractable visor, which, when lowered, is sealed by an inflatable type pressure seal. The breathing regulator, located on the left side of the headpiece, includes an on-and-off oxygen valve and a button which deflates the visor seal. On the right side of the headpiece is a knob that controls the tension of the internal straps and pads, by means of which the face seal is effected. The face seal divides the headpiece into two sections—the forward compartment, which is pressurized with oxygen; and the back section, which is continuous with the rest of the suit. Oxygen enters the forward section through perforations in a circular tube installed at the perimeter of the visor; this prevents fogging of the visor visual area. The exhaled gases pass through special valves into the interior of the suit. A microphone and headphones are also built into the headpiece, and the entire assembly is carefully designed to provide maximum crash protection.

FROM THE BEGINNING

Obviously, such complex gear was not built or assembled overnight. Or were only a few years required to do the job. Rather, the Navy's role in the development goes back some 15 years, to World War II. And if one wants to trace the history of the suit to its very beginning, he has to backtrack 8 more years. At that time, 1934, an internationally known pilot, Wiley Post, was seeking to break the altitude record of 47,352 feet set by an Italian flier, Renato Donati, a year earlier. To increase his chances, the B. F. Goodrich Company built for him the suit shown in Figure 1. Although it was little more than a rubberized inflatable garment with a viewport, it was the first full-pressure suit ever made. According to Post it stood the test well, for he reported he flew to an altitude of about 90,000 feet. However, upon looking over the records of the flight, officials refused to acknowledge his claim.

Figure 1 - Wiley Post wearing a suit developed by The B. F. Goodrich Company about 1935.

Figure 2 - Experimental suit, developed by Navy and Air Force about 1942.



Little else was done to develop the full-pressure suit until 1942, when the Navy and Air Force built the suit shown in Figure 2. Achievements were slow to materialize, however, the first big step not being taken until 1949. At that time, the Air Crew Equipment Laboratory designed a respiration system that functioned completely independent of the pressurizing gas. This permitted use of a simplified breathing mask. Other noteworthy discoveries were made the next year, when a suit built for the Navy by the David Clark Company (Figure 3) was tested in a jet aircraft. The experiment brought to light two significant weaknesses in suit design up to that time. One was the suit's inadequate mobility, which made it almost impossible for the pilot to maneuver the plane, and the other was the impracticality and potential danger of the pressurization system, which had to be regulated manually.

AN ARRAY OF PROBLEMS

The first of these weaknesses—lack of mobility—was overcome in 1952, when the B. F. Goodrich Company reentered the program (Figure 4). This was done by means of airtight rotating bearings and fluted joints. Another improvement made at this time resulted from the application of vulcanization to suit fabrication. This not only strengthened the material but also reduced air leakage to an insignificant amount.

The second problem was solved not long afterward, when the Firewel Company and the Air Crew Equipment Laboratory developed an automatic suit-pressurization device, called the suit controller. The controller keeps the suit pressure the same as that at an altitude of 35,000 feet, no matter how high the pilot files. This particular pressure was selected for two reasons: First, the difference between it and the exterior pressure, no matter how low the latter may be, will not be great enough to adversely affect the suit's mobility, and second, it permits the pilot to breath 100 percent oxygen at all times. If the interior pressure were lower than that at 35,000 feet, oxygen would have to be delivered to the pilot under pressure in order to maintain the required

Figure 3 - David Clark Company's suit, developed about 1950.

Figure 4 - B. F. Goodrich Company's suit, developed about 1952.

supply. Breathing under pressure is undesirable because it results in a reversal of respiratory effort, which may lead to hyperventilation, and it is definitely fatiguing.

Although the suit was now functional for many purposes, it had to be refined in certain ways before it could be widely used. One of these changes—reducing its bulk and weight—was made by using improved coated nylon fabrics. Another—making the suit more mobile—was brought about by perfecting the already existing joints. And a third—providing better ventilation—was accomplished by preparing a special ventilation

Figure 5 - Ventilation garment.

Figure 6 - The "H" model suit.

garment (Figure 5). This latter article included a series of channels that led to the extremities of the body. As the channels were reinforced with Tri-lock, a three-dimensional material, they assured the flow of air to all parts of the body, even when the legs and arms were bent.

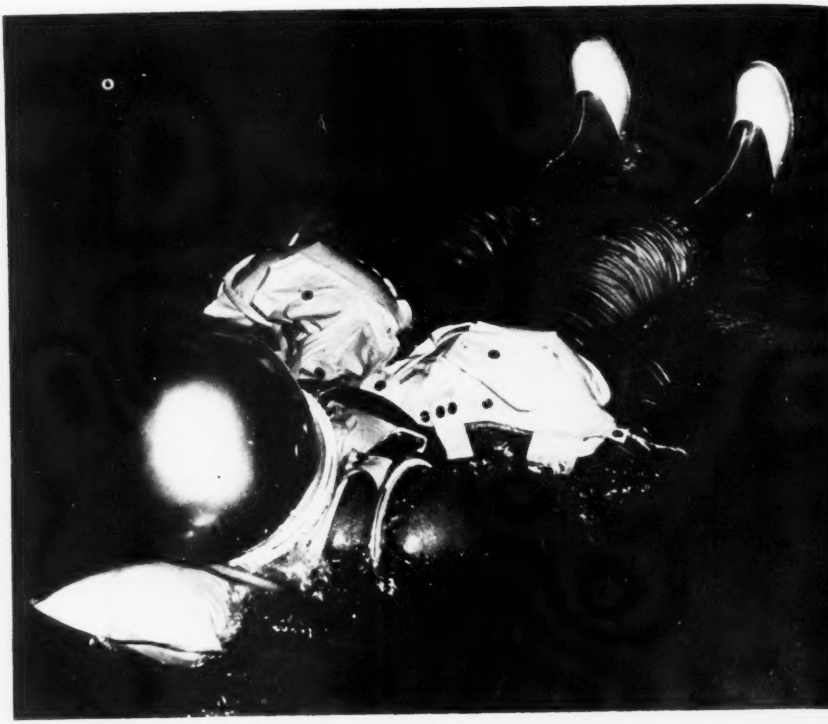
There were other problems, too. Ways had to be found to prevent the headpiece from rising under pressure, to make the suit watertight, to keep the visor from fogging, to enable the pilot either to sit or stand when the suit was pressurized, to retain body warmth and keep the pilot afloat if he went down at sea, to provide crash protection, to enable the pilot to disconnect himself quickly from accessory equipment in the aircraft, to assure that the suit would continue to function in the event ejection was necessary, and to reduce the size and weight of component equipment.

SIX PROTOTYPES

To resolve these many difficulties, the Bureau of Aeronautics let a contract to the B. F. Goodrich Company for the development of five suits, each to be an improvement over its predecessor, with the final model containing all the features desired.

The first suit to evolve from this work was called the "H" model (Figure 6). Its outstanding features were a retractable visor, a close-fitting headpiece with integrated crash-protection shell, an oxygen defogging device, a breathing regulator that was mounted on the facepiece, and an oral-nasal access port. Although the "H" model was not intended to fulfill all the requirements for an operational suit, it was found to be satisfactory for "constant wear" at high altitudes. This proof was given by Mr. McGowan of the Air Crew Equipment Laboratory while establishing a still extant record of 11 hours of flight simulated in a low-pressure chamber at altitudes between 60,000 and 80,000 feet.

Figure 7 - The "M" model suit.



igure 8 - Flotation test of the full-
essure suit.

Figure 9 - The "R" model suit.

Figure 11 - The "S" model suit.

Figure 10 - Cold water evaluation of "S" model suit. ←

The next suit developed was the "L" model, which introduced both a detachable headpiece and lacing adjustments that made it possible to fit the suit to individuals of different length sizes. This was followed, in 1954, by the "M" suit (Figure 7). Owing primarily to a miniature breathing regulator built for this garment, the "M" model was a milestone in full-pressure suit development. The regulator, mounted on the side of the headpiece, delivers 100 percent oxygen upon demand. In addition, the "M" helmet seals off the pilot's face from the rest of the headpiece cavity, thus rendering obsolete the oral-nasal breathing mask, which obstructs vision, is uncomfortable to wear, and is complex in construction. The face seal was accepted for use only after tests revealed that not enough carbon dioxide would collect in the larger oral-nasal cavity to be harmful.

A few other improvements, such as detachable gloves that enabled airmen to put on and take off the suit more easily, were also being developed at about this time. In addition, investigators were thinking about such questions as what injuries, if any, a pilot would receive from the suit when ejected from a plane, when his parachute opened, and when subjected to windblast. Seat-ejection tests made from a test tower at the Air Crew Equipment Laboratory, jump tests conducted by the Naval Parachute Unit, El Centro, California, and sled tests carried out at the Naval Ordnance Test Station, China Lake, California, showed that the suit would not, itself, injure the pilot. In many of these tests, the suit proved to provide superior protection to the current standard safety equipment.

Up to this time, little attention had been paid to the amount of space occupied by accessory equipment, such as that which keeps the oxygen supply and pressure at the required levels. This gear, which makes up the suit control system, had also to be modified so the pilot could disconnect himself quickly from the aircraft in an emergency and enter and leave it easily when on the ground. Thus a compact system that permitted instant "break away" was designed. This system was integrated with the flotation equipment and parachute harness, and a zipper front was provided so it could be donned like an ordinary jacket or vest (Figure 8). This garment held the complete pressurization system.

The control system operates in this way: Air is taken from the plane's air-conditioning system, passed through the pilot's manual control valve and the composite disconnect and into the full-pressure suit. It is then distributed by means of the channels in the ventilation garment to all parts of the suit so as to warm or cool the pilot and remove excess moisture from his body. The air leaves the suit on the opposite side, passing through the suit controller into the cockpit. In addition to ventilating the suit, this air also pressurized it, when required.

The "P" model suit incorporated only minor changes over the "M" suit. One of these—coverings for the sizing lacings—was intended to prevent snagging, but the coverings proved, instead, to be potential snaggers, themselves. Also, the "P" suit combined the upper-arm bearings and glove disconnects into one unit, which proved cumbersome. In order to avoid lacing snags and shorten the time required to size the suit, the Air Crew Equipment Laboratory devised zippered band inserts.

The last model developed before the nod was given for limited production was the "R" model (Figure 9). In this garment, the wearer, for the first time, was able to change from a sitting to a standing position while under pressure. The suit included the zippered band inserts, so it could be adjusted quickly to size, and, in the headpiece, a supplementary tinted lens, which cut down on eye strain. The gloves were modified by installing wires in their palms to reduce ballooning and permit the wearer to close his hands easily.

Although the full-pressure suit was now being used operationally to some extent, the job of refining it had not ended. One of the questions raised at this point was how to protect the wearer from the effects of cold, if he were forced down at sea. Such protection had not been guaranteed previously because of the type of bearings being used in the suit. Although these bearings prevented the escape of air, they did not stop water from entering. Thus a new bearing was designed, and its utility demonstrated by Mr. McGowan of the Air Crew Equipment Laboratory. Clad in the suit, Mr. McGowan remained in a +29° F. water bath, with the air temperature at -40° F., for 45 minutes without suffering ill effects (Figure 10).

Also, headpiece lift was still a thorn in the side, as it had been throughout the development program. The "R" suit utilized an internal harness, which was unsatisfactory because once it was adjusted and the suit donned, it could not be readjusted; also, to do the job it was intended for, it had to be cinched up so tightly it was quite uncomfortable.

The "S" model (Figure 11) was developed by the B. F. Goodrich Company to overcome headpiece lift and to add a few extra features. The tie-down system devised—a figure eight arrangement of steel cables passing from the helmet through the crotch—prevented the helmet from rising under pressure, but created too much tension over the buttocks. Other features of the "S" model were detachable boots, which reduced suit donning time, and new deterioration-resistant materials. In addition, streamlined fittings were used, giving the suit a more esthetic look.

THE MILESTONES AHEAD

Although great strides have been made in the bioengineering development of the full-pressure suit, work is still going on to improve it. Ways are being studied to eliminate the shoulder bearings, lighter weight materials are being sought, a "goldfish-bowl" helmet is under study, and systems are being considered for feeding the occupant and removing his body wastes when the suit is worn for long periods.

In the future, as planes are sent farther and farther beyond the earth, the full-pressure suit is sure to play an increasingly important role. This fact is clear when one considers its many protective features. It provides a 35,000-foot atmospheric environment at any altitude above that level. It guards against the effects of explosive decompression. It supplies the occupant with more than 25 minutes of bailout oxygen. Its skin is tough enough to withstand the rough treatment given it when ejected from a sled moving at a speed of mach 1. It is well ventilated. It will keep the occupant afloat if he goes down at sea and give thermal protection. It provides the mobility a pilot needs to operate his plane. And it is comfortable to wear.

Thus, the full-pressure suit takes care of virtually all of man's needs on his flights high above the earth. When it is provided with an inbuilt galley and head (and as mentioned above, these are planned) it will, indeed, be an ideal protective garment.

NOTE: The progress reported herein dates to January 1957. Subsequent developments which have led to the light weight high-altitude protective system now in limited operational use are not included.

The Application of Printed-Wiring Techniques to Electronics

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H. H. Levy
C. J. Creveling
Electronics Division
Naval Research Laboratory

Two-dimensional versions of conventional electric circuits can now be obtained through relatively new techniques by which conducting patterns are printed or etched on the plane surfaces of thin plastic laminates. Despite their popularity in production, it is not generally appreciated that these techniques can produce, in a rather subtle fashion, unexpected benefits in the design and developmental stages of complex electronic equipment. One of the most important of these is the breadboarding of the circuits in printed-wiring form. The Electronics Division of the Naval Research Laboratory has employed these techniques, not only in the miniaturization of components but also in speeding the transition from breadboarding to production prototypes.

The advantages of the new circuit techniques can be impressively demonstrated by comparing conventional hand-wired prototype components with those employing printed-wiring circuitry. Figure 1 shows a binary-sexadecimal radix changer mounted on an interconnecting board which has been wired laboriously by a skilled technician. Figure 2 shows the same functional unit produced by printed circuitry. The simplicity of the latter is readily apparent. Other advantages--reduced construction time, superior performance, ease of reproduction, and ready standardization—make it a suitable point of departure for production design.

CONSTRUCTION

Conventionally, such components as tubes and resistors are mounted in a way that bears no close relationship to the layout they are expected to have when engineered for production. This breadboard is then wired by hand and the circuits tested to determine whether or not they will perform the required function. Once the circuits are judged to be satisfactory, a preproduction model of the equipment is constructed. (In general, this step cannot be undertaken until the breadboard is judged satisfactory.) Whenever the physical layout changes radically, there follows a delaying period of "debugging" and modifying; other requirements, such as cabling, also can cause considerable delay. Not until the preproduction model is complete can the equipment be engineered for production. These successive stages must be repeated for each interconnecting board incorporated in any equipment. When it is considered that every board prepared in the conventional way requires an equivalent amount of time and effort on the part of a technician, one can appreciate the revolution taking place in the design of electronic equipment as the result of the application of printed-wiring techniques.

At NRL it has been found that printed-circuit breadboarding can be undertaken expeditiously in the laboratory and that engineers and technicians can quickly learn the process. The simplicity with which a developmental printed circuit can be laid out and processed is indicated from the following abbreviated account of the procedures and materials employed:

1. The circuit elements (four times full scale) are arranged on clear plastic.

2. The pattern is overlaid with another sheet of clear plastic on which the parts are connected by the use of different colored china-marking pencils to simulate the wiring.

3. A third plastic sheet with grid lines underneath is placed over the second, and the front wiring pattern is laid out accurately with 1/8-inch dull-black masking tape.

4. Captions to be printed on the circuit boards are applied with commercial "stick-on" lettering.

5. The same steps are followed in laying out the reverse side of the board. Registration marks on both sheets will ensure accuracy of alignment. The two master negatives (front and back) are now complete. (These should be kept as permanent records in the event changes must be made later.)

6. Front and back masters are set side by side for uniform photographic reduction (to one-fourth original size).

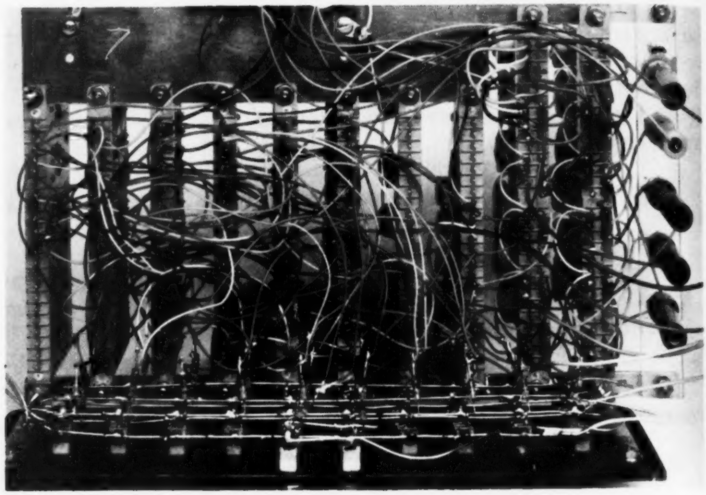
7. A selected copper-clad laminate sheet is photosensitized with a light-sensitive acid-resist emulsion and exposed on both sides through the two negatives.

8. The images are developed on the laminate, and the circuitry is dyed black. Washing removes unexposed emulsion, leaving a black acid-resistant image of the circuit. At this point the image is inspected visually for flaws, and any necessary corrections are made.

9. The circuit board is then etched in ferric chloride to remove all copper not covered by the acid-resist pattern.

10. The acid-resist and black dye are removed from the circuit pattern, leaving the copper circuit wires on the board.

All of the steps listed above can be performed in the laboratory, in ordinary incandescent light, with the kind of equipment found in most home photo-hobby workshops. Minor changes in wiring can be made by soldering on small or short-length electrical connectors. Permanent changes can be made on the original master with only a small amount of work. Furthermore, when the design of the developmental circuits has been proved, it closely approximates the final configuration, and thus the circuits are almost ready for production.



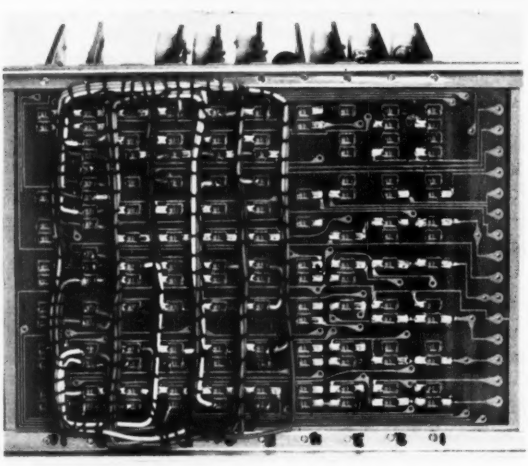


Figure 1 - Hand-wired interconnecting board so complex as to be obviously unsuited to production. Compare with the simplicity of the printed-wire circuit of Figure 2.

Figure 2 - Interconnection board, identical to that of Figure 1, which has been produced in the laboratory by printed-circuit techniques.

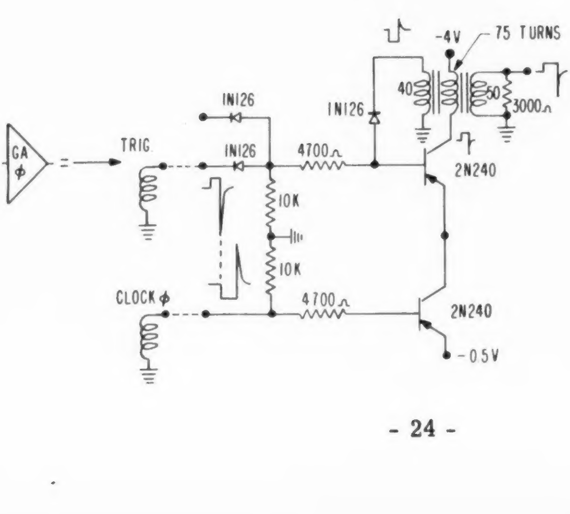


Figure 3 - Circuit diagram of a gated amplifier.

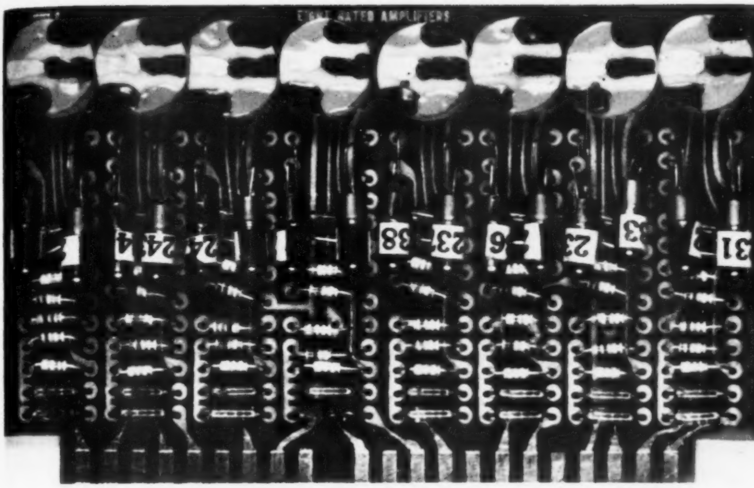


Figure 4 - Eight of the circuits shown in Figure 3, constructed on a printed-wire module.

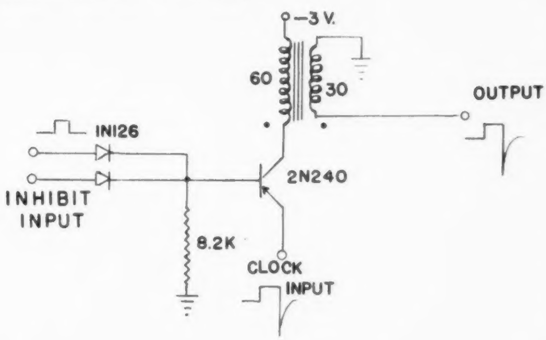


Figure 5 - Circuit diagram of a complementing amplifier.

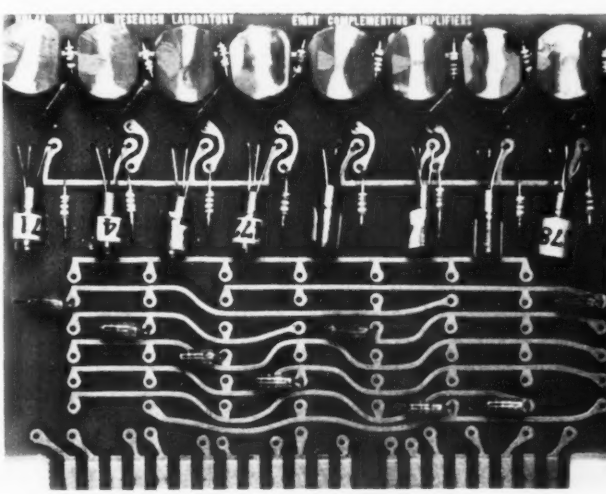


Figure 6 - Eight of the circuits shown in Figure 5, constructed on a printed-wire module.

PERFORMANCE

Electronics Division scientists, working on the development of a specific communications system, found that printed circuits usually work better than those which have been wired with flying leads. On many occasions it was observed that a circuit laid out and wired conventionally had some undesirable electrical characteristics which disappeared when it was converted to a printed circuit. Once it became evident that unnecessary time and effort were being used in relieving these defects which probably would not exist in the final form, it was concluded that the breadboard model, with its long leads and their associated reactances and inductive and capacitive couplings, should be eliminated whenever possible.

APPLICATIONS

Along with the saving of time and space that printed-wiring techniques have achieved have come other advantages which may have far-reaching effects on the design of new equipment. One important factor is that such circuit elements as amplifiers, blocking oscillators, and flip-flops can be standardized.

Figure 3 is the circuit diagram of a gated blocking oscillator having wide applicability in digital-computer logic circuits. Figure 4 is a photograph of eight of these circuits constructed on a printed-wire module, which will occupy a total volume of about 6 cubic inches. Figure 5 is the circuit diagram of a complementing amplifier, and Figure 6 is a photograph of a printed circuit board containing eight of these amplifiers. These units, together with "AND" gates, "OR" gates, and other circuits of similar complexity, can be printed and stocked for later use in the building of more complex circuits. It is only required that the units be compatible. The use of printed interconnecting boards will eliminate hand-wiring altogether.

Another important advantage is the ease with which printed circuits can be reproduced. Once the circuit or interconnection board is designed, it is a simple matter to reproduce it photographically as many times as desired, whereas reproductions of hand-wiring take almost as much time as was required originally.

The successful applications of printed-circuit techniques reported here suggest an important means of reducing circuit development time, and thus cutting down the time required to carry an electronic system from the design stage to the production stage. Even if facilities are provided only for producing printed-wiring boards in small lots, they will help expedite the design and development work in any electronics laboratory.

The Sea as a Depository for Atomic Wastes

Last month the National Academy of Sciences published a 137-page report on its study, "The Effects of Atomic Radiation on Oceanography and Fisheries," sponsored by the Rockefeller Foundation. The following article is adapted from an introductory chapter written by Dr. Roger Revelle, Chairman of the Academy's Committee on Effects of Atomic Radiation on Oceanography and Fisheries, and Dr. Milner B. Schaefer, Director of the Inter-American Tropical Tuna Commission.

As the use of atomic energy becomes more and more a part of our daily life, it is essential that thoughtful attention in broad perspective be paid to the often subtle but profound effects of this new technology on man and his environment. So far, the record of the control and monitoring of the disposal of atomic pollutants has been excellent. We are, however, at the threshold of a tremendous growth of the atomic energy industry, and it behooves mankind to make sure that as much caution is exercised in the future as has been in the past.

ACCIDENTAL CONTAMINATION OF WATERS

Nuclear power plants are already in use in naval craft, and it is almost certain that before long they will be extensively used in merchant vessels as well. This raises an important problem: Serious hazards may arise if, as the result of ship collisions or other accidents, reactors are damaged and their fuel elements and the fission products they contain are lost in the water. Suppose, for example, that a 50,000-kilowatt reactor has been in service without refueling for 1 year on a freighter that has spent half its time under way. About 10 kilograms of fissionable material will have been used up, resulting in the accumulation of fission products in the amount of 10^7 curies. If, owing to a collision, the reactor is lost in a harbor—say 8 miles long by 3 miles wide by 50 feet deep—and the fission products become uniformly distributed, the water in the harbor would contain 10^{-2} curies per cubic meter. This would give an almost constant radiation dose of about 0.5 roentgens per day on the surface. Dock pilings, ship bottoms, and other structures covered with fouling organisms would accumulate a much higher level of radioactivity, and local concentration in the water might be extremely high.

PLANNED DISPOSAL OF FISSION PRODUCTS

A much larger and more complicated problem than accidental contamination of waters arises when we consider using the sea as a dumping ground for atomic wastes.

The quantity of fission products that can be deposited safely depends on the concentrations that reach man's food sources. The quantity will be greater if sites of introduction are chosen that will serve to isolate the wastes for long periods or that will result in high dispersion (and thus low concentration) of the fractions that come into the environment (both physical and biological) of human organisms.

By analogy with results from genetic studies on laboratory animals it may be inferred that significant genetic population effects will occur in marine organisms at much lower levels of radiation than will produce somatic effects. These genetic effects might be related to the increase in amount of total body radiation above the natural background. It has been shown that the normal radiation background of organisms in the deep sea is very low, so that appreciable quantities of radioactive wastes would significantly increase the radiation received by them. The deposition of 1,000 tons per year of fission products in the deep sea would eventually almost triple the average radiation level in the deep water. This could, conceivably, result in genetic effects in the marine populations in these waters, which might seriously upset the ecological system of the oceans.

Although we cannot say at this time how much reactor waste material can be safely deposited in the deep sea, it certainly appears safe to dump up to a few tons a year in careful experimental studies. Perhaps as many as 1,000 tons a year of fission products can be safely disposed of in deep, isolated basins where the residence time is much greater than the 300-year average estimated for the deep sea generally. But for quantities of the order of 100 tons or more a year, effects on the animal populations of the deep sea, and resulting effects on the whole ecology of the sea, could become important.

CHARTING FUTURE RESEARCH

Our knowledge of most of the processes in the oceans is too fragmentary to enable us to say exactly what the effects will be if we dump a given quantity of radioactive material at any particular place. To build a proper background for making such predictions requires a long-range program of research on the physics, chemistry, and geology of the sea, and on the biology and ecology of its contained organisms.

Some of the major basic problems that should be included in the research program can be briefly outlined as follows:

Dispersion in the upper mixed layer.—Attempts have been made to describe the diffusion of materials in the upper layer of the oceans, but the detailed physical principles involved are so poorly understood, we cannot use them as a basis for making predictions. More basic research on the turbulent motion of water in the upper layer is needed.

Circulation in the intermediate and deep layers.—A similar gap exists in our knowledge concerning the turbulent motion and the currents that occur in the sea below the surface layer. Thus in our research we need to steer a course that will lead to the charting of these movements and to an understanding of the physical principles controlling them.

Exchange between the surface layer and deeper layers.—It is important to determine the average rate of exchange of water between ocean layers, particularly in different areas and at different depths. We know that the vertical exchange is much more rapid in some parts of the oceans than others, but we can describe it quantitatively only in a very sketchy manner. Data on this subject are required as one basis of estimating the amount of atomic wastes that can be deposited safely in specified parts of the deep sea.

Sedimentation processes.—The processes by which sediments are laid down on the ocean floors constitute an important mechanism for removing atomic wastes from the waters of the oceans. In order to evaluate their role, however, we need to measure the average times that different elements remain in the sea before being deposited, the rates of sedimentation in different parts of the deep sea, and the ability of sediments to capture and retain various fission products.

Effects of the biosphere on the distribution and circulation of elements.—Marine organisms profoundly modify the distribution and circulation of elements in the sea. It is vitally necessary, therefore, that detailed studies be made of the flux of various elements through different marine habitats; the variations in different ecological realms, such as inshore coastal waters, offshore surface waters, and the deep sea; the effects of vertical and horizontal migrations of organisms on the redistribution of elements; and the effects of the uptake, modification of the physical state, and elimination of elements by marine organisms on their subsequent distribution in the sea.

Uptake and retention of elements by organisms used as food for man.—Related to the foregoing is the study of the quantities of radioactive elements deposited in different situations in the sea that can be expected to be taken up by organisms harvested for food, the length of time such elements are retained in the food organisms, and the levels of concentration. Some parts of some organisms are not eaten by man, but are discarded or used for other purposes. The sites of accumulation of different radioactive elements in the organisms must therefore be determined.

Effects of atomic radiation on populations of marine organisms.—In order to determine how much atomic waste can be safely deposited without upsetting the ecology of the sea, research is needed on the somatic and genetic effects of atomic radiation on marine populations. This is especially important for organisms of the deep sea, where high concentrations of radioactive elements will occur if deep-sea disposal proves feasible in other respects.

The findings of the Committee on Effects of Atomic Radiation on Oceanography and Fisheries are based on research sponsored and carried out by many government and private organizations. Prominent among the sponsors, of course, is the Office of Naval Research, which has been a leader in the field of oceanography since its inception more than ten years ago.

The current study is slated to continue for many more years. Knowledge gained from it, plus that derived from studies of the sea that will be undertaken in the future by this country and many others throughout the world, should help us dispose of the atom's "Mr. Hyde" as we gear our economy for large-scale use of atomic power.

On the Naval Research Reserve

Reservists Selected for Promotion

On March 14 the Chief of Naval Personnel released the list of line officers of the Naval Reserve who were selected for promotion to the grades of Captain and Commander by the fiscal 1958 Inactive Reserve Selection Boards. Fifty Reserve officers were selected for the rank of Captain and 992 for the rank of Commander. Of this number, 30 were Research Reservists, three being selected for the rank of Captain and 27 for the rank of Commander. Congratulations are extended to these officers, who are listed below along with their respective companies.

SELECTED FOR CAPTAIN

Charles W. ALLEN	3-2
Richard H. BATES	11-2
Donald C. GOOD	12-3

SELECTED FOR COMMANDER

Sidney F. WEXLER	1-3
James H. CANNING	3-2
Harry H. STUART	3-2
Robert H. BROWN	3-10
Herman W. VERSEPUT	3-12
Raymond R. GOLDBERG	4-1
James H. HORTON	5-8
Malcolm D. ROSS	5-8
Ernest J. ZELLMER	5-8
Ernest W. PETERKIN	5-9
Raymond H. WILSON, Jr.	5-9
Nathan L. SMITH	6-4
Norvel M. McCLUNG	6-9
William G. MILLER	6-11
John A. BALLARD	6-17
Matthias STELLY	8-2
Nelson E. SPURLING	8-7
Frank J. DUNN	8-9
L. B. RICHARDSON	8-12
Robert C. HAVEN, Jr.	9-3
John R. MALONEY	9-13
Walter F. JOHNSON, Jr.	9-16
John T. McGILL	11-3
Roger G. PRESTON	12-2
Alexander L. LONDON	12-3
Raymond P. MURRAY	12-8
Hubert M. REISENAUER	13-3

New Reserve Assistant Reports to ONR Chicago

LT Christopher S. Lardis, USN, has reported for duty as Assistant to the Commanding Officer for Research Reserve at the ONR Branch Office in Chicago. LT Lardis relieved CDR Hiram F. Cromer, USNR, who returned to civilian life.

LT Lardis, a native of Ohio, studied for two years at Kent State University, then entered the U. S. Naval Academy. He graduated from the Academy with the class of 1953.

His first assignment after he was commissioned was aboard the Navy cruiser USS NEWPORT NEWS (CA-148), where he served as Electrical Officer. After he was promoted to the rank of Lieutenant (jg), his billet was changed to Assistant Navigator.

In August 1955 LT Lardis was transferred to the destroyer escort USS DELONG (DE-684), where he served as Chief Engineer until February 1958.

CAPT George J. Higgins, USNR, Retires

CAPT George J. Higgins, USNR, a member of NRRC 12-8, Monterey, Calif., has received notice of his transfer to the Retired Reserve as of August 1, 1957.

The Naval service of CAPT Higgins dates back to 1917, when he was a fireman in the Michigan Naval Militia. During World War I he served on active duty at Great Lakes, the USS YANTIC, the Aviation Mechanic-Aerial Gunner-Engineer's School, and squadron duty at Pensacola. In 1937 CAPT Higgins received his first commission in the USNR as a Lieutenant Commander, A-V(S). In January 1942 he was called to active duty and reported to the Navy Postgraduate School, then located at Annapolis. He was promoted to the rank of Commander in July 1942 and to the rank of Captain in November 1945.

After his release from active duty CAPT Higgins joined the faculty of the Navy Postgraduate School in a civilian capacity and was designated Professor of Aeronautics, the position he now holds. Before World War II, he was an aeronautical engineer with the National Advisory Committee for Aeronautics, Associate Professor and later Director of the Department of Aeronautical Engineering at the University of Detroit, and instructor at a Reserve squadron at Grosse Isle, Michigan.

CAPT Higgins received his engineering degrees (Ae.E.) from the University of Michigan. He is a Founder Member and Associate Fellow of the Institute of Aeronautical Sciences and also has been active in the Society of Automotive Engineers.

CAPT Higgins has been active in the Reserve program since his release from active duty. In 1952 when the Naval Postgraduate School moved to Monterey, Calif., he formed NRRC 12-8 at that place and was its first Commanding Officer (1952 to 1955). In 1954, this company received a commendation from the Chief of Naval Personnel.

LAST MONTH WITH VANGUARD

On 17 March, at 7:15:41 a.m., VANGUARD TV-4 took off from its launching pad at Cape Canaveral. Ten minutes and 40 seconds later its 6.44-inch, 3.25-pound, satellite test sphere went into orbit as "1958 Beta."

This occurred just two years, six months, and eight days from the day the Navy was assigned the management responsibility for Project VANGUARD. The development was rapid beyond precedent, and with a remarkably small number of test flights. At the same time, the frontiers of the rocketry art were thrust out in several directions. The credit goes to all who participated: the Naval Research Laboratory, the Martin Company for the overall rocket, the General Electric Company for the first stage engine, Aerojet-General for the second stage, Grand Central Rocket Company for the third stage, and many others. Large measures of credit go also to the Air Force for extraordinary cooperation on the missile range and to the Army for support of the tracking complex.

The VANGUARD rocket, which weighs only 22,000 pounds, placed 50 pounds in orbit, including both the satellite and the burned-out third stage. Other rockets capable of placing a comparable satellite in orbit weigh about three times as much. Major components of the VANGUARD rocket are planned for use in the nation's longer range space program.

Below is a table comparing certain features of the four artificial satellites which have been placed in orbit:

	VANGUARD I	EXPLORER I	SPUTNIK II	SPUTNIK I
Speed (miles per hour)	18,000-19,000	18,000	17,800	18,000
Height (miles):				
Perigee	403	227	150	170
Apogee	2,466	1,575	1,200	580
Weight in orbit (pounds):				
Satellite sphere	3-1/4	No separation	No separation	184
Total, including final stage	About 50	30.8	1,120	Unknown
Orbit time (minutes)	135	115	103.5	96
Lifetime in orbit (years)	5-10	2-4	About 1/2	About 1/4

1958 Beta is the first satellite to be equipped with a long-lasting source of power in the six solar cells provided by the U. S. Army Signal Engineering Laboratories. This will permit long-term radio tracking of the satellite and, during the gradual shrinking of the orbit, will provide information on the density of the fringes of our atmosphere. It is likely that the satellite will continue to transmit until erosion of the cells by interstellar dust cuts signal strength to inaudible levels.

U. S. GOVERNMENT PRINTING OFFICE : 1958 O - 460495

The satellite has a second transmitter powered by conventional mercury batteries. By studying shifts in the radio frequency of the two transmitters, we can learn of temperature changes inside and outside the satellite as it circles the earth.

It was planned as part of the program that the full-scale satellite launchings would be preceded by a series of progressive tests. Here is a tabulated history of the **VANGUARD** test flights:

DATE	VEHICLE	TEST
Dec. 8, 1956	TV-0 (Viking 13)	Launching facility and range check-out: completely successful.
May 1, 1957	TV-1 (Viking 14)	Flight test of third-stage prototype: completely successful.
Oct. 23, 1957	TV-2	Flight test of first stage: completely successful.
Dec. 6, 1957	TV-3	Burned on launching stand after rising about two feet.
Feb. 5, 1958	TV-3 Backup	Failed after 60 seconds of flight.
Mar. 17, 1958	TV-4	Completely successful; high-performance orbit achieved.

Four separate satellite arrangements have been prepared for the full-scale (20-inch satellite) flights. There is some possibility (but low probability) of achieving four satellites in the seven tries, but intuitive opinion based on general rocket experience suggests that the most probable number may be something like two. If so, this would be a remarkable performance indeed, considering the small number of tries and the original understanding to put up just one satellite sometime during the **IGY**.

VANGUARD having progressed well beyond educated expectations, one asks where it will go from here. So far, there has been no program expansion beyond the number initially authorized, which provides for seven more launching tries. Assuming reasonable room for performance growth, one would conclude that the **VANGUARD** system could accomplish a great deal of scientific satellite exploration with relatively reasonable costs because of the small size and high efficiency of the launching rockets.

Those of us directly associated with the project consider the momentum built up in the able and experienced **NRL/Industry VANGUARD** Team a valuable asset in the nation's pool of competence in space operations.

In This Issue

COVER PHOTO: A flick of the switch on the side of the little VANGUARD test sphere and its voice is ready to be heard as it flashes through space. See "Last Month With VANGUARD," inside back cover.

RESEARCH REVIEWS endeavors to report briefly highlights of tec ical progress in research by Navy laboratori and contractors and the development of important naval research faci ities. Articles which meet these broad criteria and possess a go degree of readability are welcomed. Manuscripts and changes of addre should be sent to Code 740, Office of Naval Research, Washingto D. C. . . . Research Reviews is listed for sale by the Superintendent o Documents, U. S. Government Printing Office, Washington, D. C. Sub scription price: $1.50 per year in U. S. and Canada; $2.00 per yea foreign; $0.15 per individual copy. Use of funds for printing this publica tion was approved by the Director of the Bureau of the Budget, Februar 12, 1958.