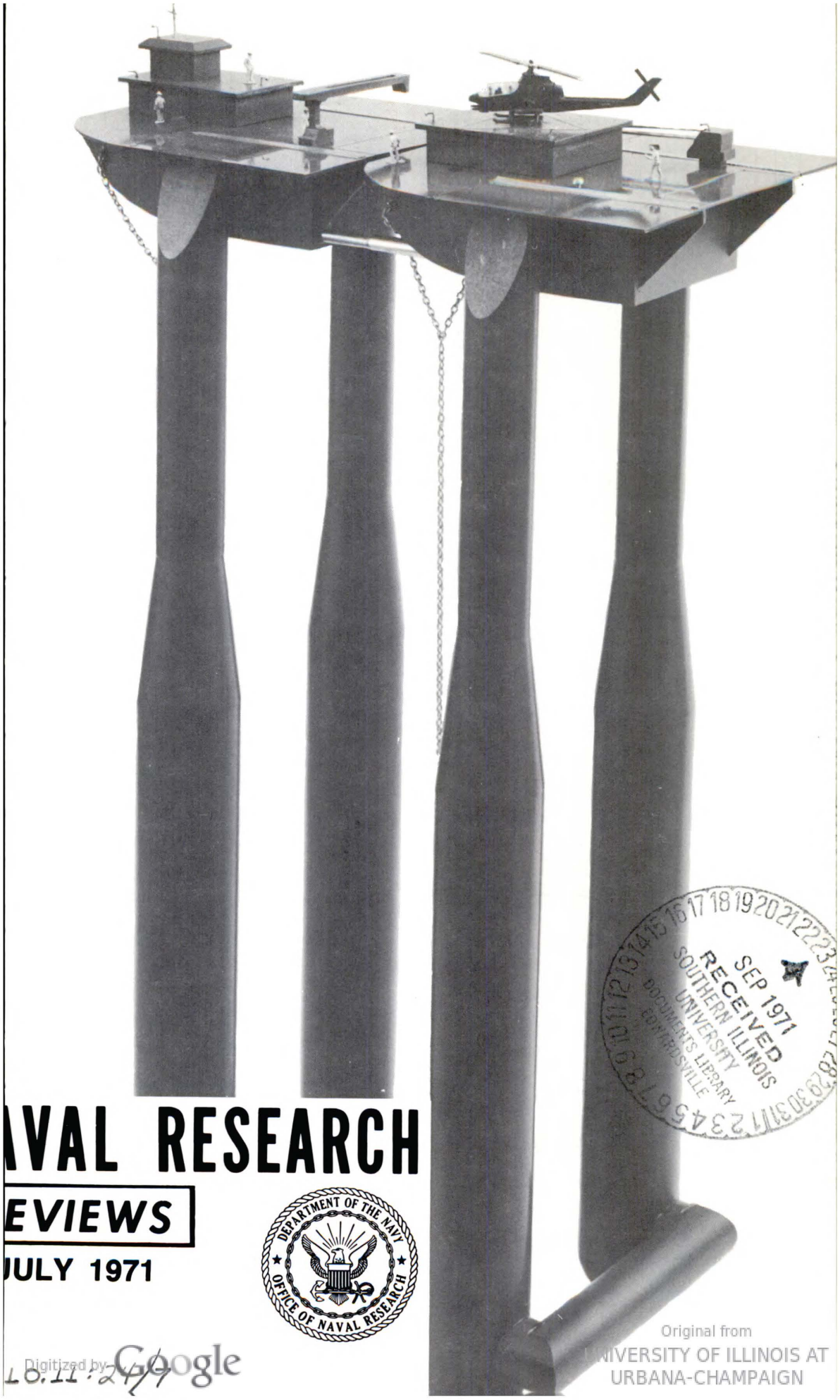

NAVAL RESEARCH REVIEWS

JULY 1971

PROFILE IN SCIENCE

Dr. Sidney Galler

Dr. Sidney R. Galler is the Deputy Assistant Secretary of Commerce for Environmental Affairs. Formerly he was Assistant Secretary (Science) of the Smithsonian Institution, and prior to that, 1950-1965, was head of the Biology Branch of the Office of Naval Research. Among his many awards, Dr. Galler received the Navy Distinguished Civilian Service Award for outstanding contributions in hydrobiology and biological orientation. His pioneering work in bio-instrumentation led to the first U.S. orbiting biological experiment launched in 1958. His designs in bio-instrumentation produced a series of radio telemetric devices which are being used to study the movements of birds as well as terrestrial animals to improve conservation practices. Dr. Galler's work has also resulted in the construction of the first underwater audio-video observatory, a remotely controlled system of underwater television cameras and acoustic devices for the study of marine life from a laboratory on land.

SOLRAD 10(C)

The National Aeronautics and Space Administration launched the Naval Research Laboratory's latest solar radiation (SOLRAD) measuring satellite on July 8 from Wallops Island, Va. at 6:58 P.M. DST.

The 260-pound spacecraft, SOLRAD 10(C) was boosted into a near circular orbit, about 370 miles (600 kilometers) above the Earth by NASA's all-solid propellant Scout launch vehicle (Figure 1).

There are 14 experiments aboard the NRL satellite, designed to monitor continuously solar electromagnetic radiation (X-ray and ultraviolet) and to measure, on command, stellar radiation (X-ray) from other celestial sources. Information gained by the satellite is expected to contribute to a better understanding of the physical processes involved in solar flares and other solar activity, and the potential effects of this activity on shortwave communications, as well as on future manned space travel.

Satellites contribute to studies of solar phenomena in three major ways. They make possible the study of the ultraviolet, X-ray and gamma

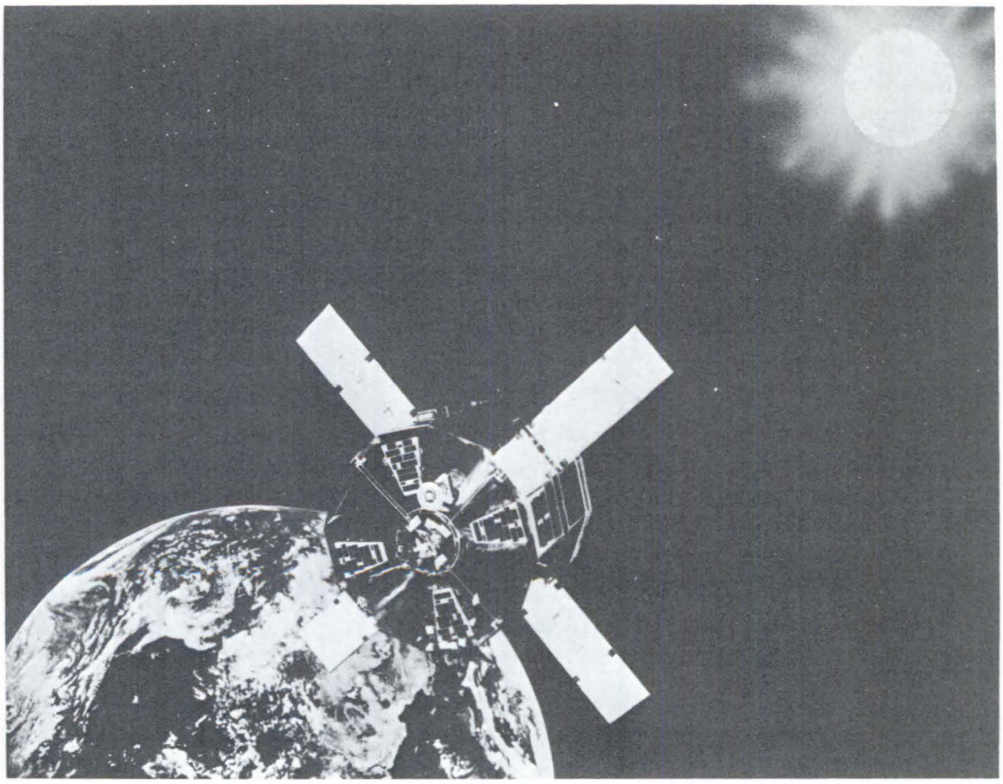

Figure 1 — In its earth orbit, SOLRAD 10's sensors are continually oriented toward the sun, monitoring its emissions and telemetering the measurements to earth stations. SOLRAD 10 is "on station" for the APOLLO 15 launch to warn of any unusual solar disruptions which may be hazardous to manned space travel.

ray radiation which is absorbed in the atmosphere; they permit continuous monitoring of this radiation during solar cycles of activity; and they provide higher resolution than ground equipment through the elimination of atmospheric scattering.

The primary reason for the solar studies is to expand human knowledge of space phenomena. While this is an exciting and important reason for the work, there are also practical benefits to be gained.

Knowledge of solar radiation and its effects on the terrestrial environment, together with continuous monitoring of the entire spectrum of solar radiation, should result in significant advances in the understanding of, and effective accommodation of human activities to weather conditions.

Significant advance signs of solar activity can be used to predict periods of high probability of solar flares. This service will become a major contribution to communications, meteorology and manned space flights.

One of the first missions in SOLRAD's anticipated three-year life span will be to aid the National Oceanic and Atmospheric Administration as a sentinel during the Apollo 15 mission. Since the emissions resulting from unusual solar distrubances, especially large proton flares, may be harmful to men outside the protection of the Earth's atmosphere, SOLRAD's continual monitoring of the Sun will supplement the existing Apollo warning system enabling scientists on Earth to detect solar eruptions severe enough to be a source of potential danger.

This is the third in a series of solar radiation spacecraft launched in a joint NRL/NASA program. The previous two were SOLRAD 8, the Solar Explorer launched in 1965 during the IQSY (International Quiet Sun Year), and SOLRAD 9 in 1968 (Solar Explorer B). The 30-by-23-inch SOLRAD 10(C), designed and built by NRL's Space Systems Division, will continue and expand the experiment capabilities of the earlier two. Unlike the previous satellites, its sensors will be continuously oriented toward the Sun. The sensitivity and accuracy of its sensors are also technologically improved over earlier versions.

The electronics aboard the 12-sided satellite are powered by four symmetrically placed 7-by-21-inch solar cell panels arranged like windmill blades. These panels also serve as the four elements of its "turnstile" antenna system.

The SOLRAD program is sponsored jointly by the Naval Air Systems Command and NASA's Office of Space Science and Applications (OSSA), with NRL providing project management for the mission. SOLRAD 10 is the most complex spacecraft in the SOLRAD series and extends the measurements of the Sun's emission spectrum into regions previously investigated only in short rocket flights.

Background

The Earth is a body immersed in the atmosphere of a star, the Sun. Radiation from the Sun controls the environment of the Earth, of other solar system planets, and of interplanetary space. Because most emissions of radiation from the Sun are variable, the environment of the Earth is variable.

There is a cyclic pattern of solar activity, with maximum and minimum occurring about every 11 years, and a similar cyclic variation is evident in certain properties of the Earth's atmosphere, especially in the ionosphere.

The present period is one of descending solar activity. The next period of maximum activity is expected to be in 1979-1980.

The solar flare appears to be the most important part of variable solar activity insofar as variable solar effects upon the environment of the Earth are concerned. In the red light emitted by the hydrogen atom, a flare is a sudden brightening of a part of the solar surface occurring in a few minutes and then slowly decaying over a period of tens of minutes to hours (Figure 2).

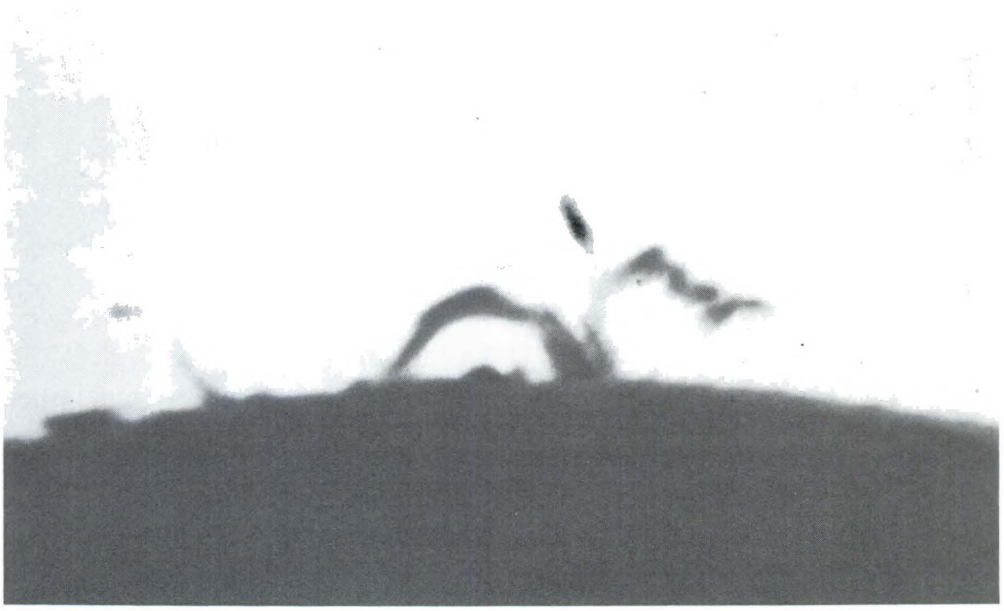

Figure 2 — In addition to giving off light and heat, the sun often billows forth clouds of gas and plasma particles of varying intensity. Most often, because of the sun's magnetic field, these energized streamers circle back to the sun, as shown above. However, when during flares they burst free of the sun on an earthbound course, they can dissipate more energy in the earth's high atmosphere than the most destructive hurricanes on record. The resulting electrical and magnetic disturbances can black out long range radio communications, cause airplane and ship compasses to shift erratically and trigger brilliant auroral displays. The continual monitoring of the sun by SOLRAD 10 will give earth scientists an early warning sentinel and will help predict the duration of these disturbances.

X-rays and intensified ultraviolet light emitted during the life of a flare increase the number of electrons in the Earth's lower ionosphere and thus disrupt short-wave radio communications by increased absorption.

The largest flares also emit great numbers of energetic protons which increase the radiation levels in interplanetary space and in the space over the Earth's poles. Greater knowledge of the radiations emitted by the Sun is required to understand these interactions between solar events and the Earth's upper atmosphere and ionosphere.

The Sun is an astrophysical object of prime interest to man. It is the only star whose surface characteristics we can resolve and study. Knowledge gained by studying the Sun will help us understand and interpret the data from other stars.

The techniques of space research permit scientists to expand solar studies in two ways: They can increase the resolving power of their telescopes through the elimination of atmospheric distortion, and they can observe over a very much larger part of the electromagnetic spectrum.

The Sun emits electromagnetic radiation covering the spectrum from radio waves through the visible and ultraviolet to X-rays and gamma rays. Only a fraction of the radiation is in the visible part of the spectrum that a human eye can see. Parts of the radio and the infrared portion of the spectrum can be observed on the ground. The rest of the solar radiation is absorbed in the Earth's atmosphere and can be observed only with instruments above the atmosphere.

Some of the absorbed portions of the spectrum are doubly important. They are the portions which vary with solar activity. To understand the mechanism of a solar flare, studies of the ultraviolet and X-rays emitted during a flare (both of which are absorbed in the atmosphere) must be made. Since the radiation is absorbed in the upper atmosphere, these portions of the solar radiation control the nature of the upper atmosphere.

In recent years, portions of the solar spectrum of radiations have been observed by ground-based monitors, balloon-borne instruments, high-flying aircraft, sounding rocket flights, deep space probes, and satellites. Scientists from industry, universities and several Government agencies have engaged in these efforts to unlock the Sun's secrets.

In 1949 the Naval Research Laboratory (NRL) began a program of observation of solar ultraviolet and X-ray emissions in which the V-2 and, later, Aerobee and other sounding rockets were used to lift sensitive instruments (spectrographs and photometers) above the absorbing layers of the atmosphere.

In 1956, NRL began trying balloon-launched rockets, ROCKOONS, in an attempt to test, by direct measurement, the theory that solar

X-rays were responsible for sudden ionospheric disturbances (SIDs) during solar flares.

A rocket fired during a solar flare July 20, 1956 indicated a surprisingly high intensity of X-rays between altitudes of 75 and 100 kilometers (47 to 62 statute miles). This X-ray flux was the first ever measured at such short wavelengths and at such a low altitude in the ionosphere.

Subsequent ground-launched sounding rockets gathered considerable new data on X-ray emissions during 1957 through 1959. Rocket measurements were made during three solar flares each of which was accompanied by a large sudden ionosphere disturbance.

Sounding rocket experience by NRL, NASA and others provided the brief glimpses of the Sun's spectrum necessary to guide development of satellite instrumentation.

In the study of such spasmodic events as solar flares, however, the sounding rockets have three handicaps: They cannot be launched quickly enough to see the early phases of flares; they cannot stay above the Earth's atmosphere long enough to measure time variations of solar X-ray and ultraviolet emissions; and it is difficult to keep instruments pointed at the Sun due to roll and yaw of the rockets.

Therefore, scientists turned to satellites capable of providing a stable platform for continuous solar monitoring.

In June 1960, the SOLRAD 1, designed and built by NRL, became the first successful solar X-ray monitoring satellite. Because X-ray monitoring could be conducted only when SOLRAD 1 passed over a telemetry station, the experiment depended on the extensive network of NASA tracking and data acquisition stations.

Previous SOLRAD Projects

Despite its modest capabilities, 577 telemetry records were obtained from SOLRAD 1 between June 22 and November 1, 1960. One hundred of these showed measurable X-ray fluxes.

The results were significant. SOLRAD 1 confirmed the hypothesis that solar X-rays cause sudden disturbances in the ionosphere during flares and determined the intensity necessary to trigger the changes.

It also established that active prominence regions, bright surges on the edge of the Sun, and certain solar edge (limb) flares have the same characteristics as major disk flares. The disk is the central portion of the Sun as viewed from the Earth.

Data from SOLRAD 1 showed that solar X-ray fluxes provide a very sensitive measure of solar activity and can change significantly within one minute. It was found that long-duration X-ray events of moderate intensity can accompany rising prominences on the solar limb. Prominences are streams of cool gas that surge into the hot corona.

The second satellite in the SOLRAD series failed to achieve orbit and the third, SOLRAD 3, launched in June 1961, went into a tumbling mode that made data reduction difficult. Nevertheless, some of the data from SOLRAD 3 have been reduced and found useful.

The experiments of SOLRAD 1 and SOLRAD 3 made it evident that X-ray emission spectra vary greatly from one flare to another, and vary with time during a single flare event.

A highly successful satellite of the SOLRAD series was launched in January 1964 and was designated 1964-01D. During periods of good alignment relative to the Sun, the satellite provided 200 minutes-per-day of direct solar observations with measurements of solar X-ray emissions in the spectral bands of 1-8, 8-12 and 44-60 Angstroms. (The Angstrom (Å) is a measure of wavelength: 1 A equals 10^{-10} meter, or about four one-billionth of an inch.)

The 44-60 Å wavelength band proved especially sensitive to even the smallest solar event and its observed flux has been correlated with plage phenomena. Plages are bright, hot areas that appear on the Sun's photosphere. The photosphere is the visible disk of the Sun.

SOLRAD 8 was a highly successful satellite of the series launched in November 1965 and was also designated Explorer XXX. It marked the first time that an attempt was made to use a data storage system in the series. Although the system malfunctioned after one month, the satellite continued to provide useful information in real time until November 1967.

SOLRAD 8 provided evidence that an increase in background solar X-ray emission can be interpreted as a precursor of flare activity and the subsequent disruption of radio communications. It also gave the best definition of the sizes of X-ray active regions thus far obtained. They were derived from observations made by Italian scientists with their instruments as the satellite passed through the May 1966 eclipse shadow across Greece.

In a recent advancement to the state-of-the-art for radiation satellites NRL's SOLRAD 9 (also designated Solar Explorer 37) was launched by NASA, March 5, 1968. The satellite, which weighs 195 pounds and is in the shape of a twelve-sided drum, is some 30 inches high and 30 inches across. Since its launching, SOLRAD 9 has continuously transmitted measurements of solar X-ray emissions as they are made and has stored selected measurements in a memory for special transmissions to NRL's ground station at Blossom Point, Md.

Short-term solar flare activity forecasts derived from information furnished by SOLRAD 9 during America's historic Moon landings in Apollo flights assisted in safeguarding the astronauts and their communication systems as it and SOLRAD 10(C) are expected to do in the future.

Scientists are "elated" over the long life of SOLRAD 9 which will continue to be used as a backup solar radiation monitor for SOLRAD 10(C).

Since NASA was established in October 1958, there has been a close working relationship between NRL and NASA personnel in numerous scientific projects of mutual interest. Vanguard II, the first satellite launched by NASA (February 1959), was developed by an NRL team that was transferred to NASA.

Solar Radiation Measurements

All radiant energy, including that from the Sun, is emitted in many diverse forms and over a tremendous range of frequencies, or wavelengths. All these forms of radiant energy are electromagnetic in nature, obey the same basic laws and travel through space at the speed of light (about 186,300 miles-per-second). They differ in wavelength, origin and the ways in which they manifest themselves and cover the entire electromagnetic spectrum.

Wavelengths corresponding to radio frequencies are usually expressed in meters; infrared in centimeters or microns; visible light, ultraviolet X-rays and gamma rays in Angstroms. X-ray and gamma photons are often described by specifying their energy in electron-volts.

Instrumentation on the SOLRAD 10(C) will make measurements in the X-ray and ultraviolet regions of the electromagnetic spectrum. Radiation measurements will be obtained by photometers, photomultipliers and Geiger tubes.

Spacecraft Description

The spacecraft is a 12-sided structure which measures 30 inches in diameter across the corners and approximately 23 inches in height. The spacecraft weighs 260 pounds. There are four symmetrically placed 7-by-21-inch solar cell panels, hinged at the center station of the structure, which are folded along the length of the structure and deployed after third stage burnout. These panels also serve as the four elements of a turnstile antenna system (Figure 3).

The electronic subsystems of the satellite include two nonredundant telemetry transmitters operating on separate frequencies of 137.710 MHz and 136.380 MHz, three spin replenishment and four spin-axis attitude control subsystems, and a command subsystem. The telemetry systems are under the exclusive operational control of NRL.

The spacecraft uses two separate telemetry subsystems for the transmission of data to the ground stations. Telemetry subsystem 1 is a

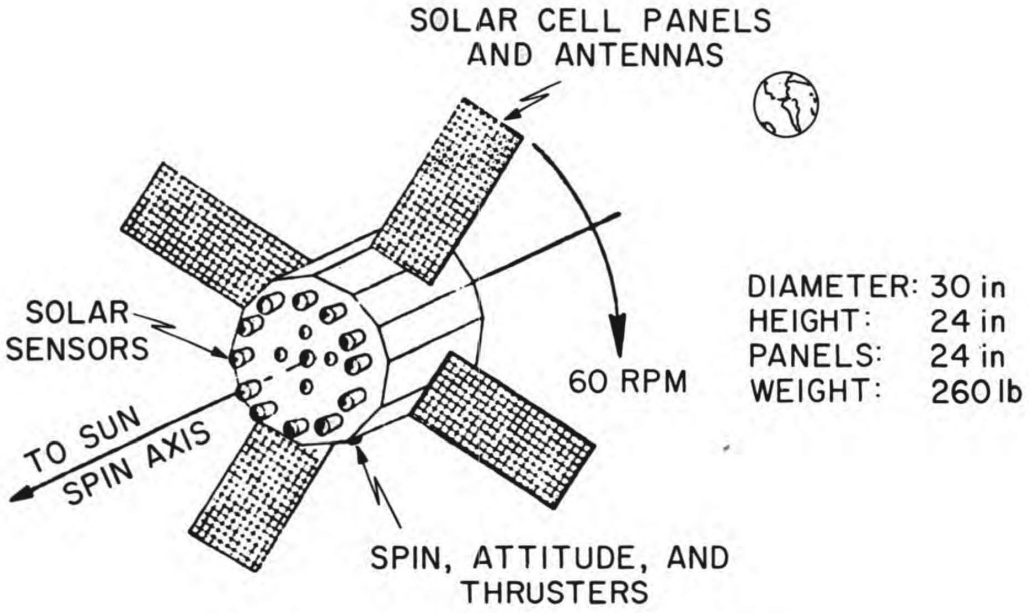

Figure 3 — The NRL/NASA SOLRAD 10 Satellite

realtime subsystem which uses the linearly mixed output of five voltage-controlled IRIG subcarrier oscillators (SCOs) to phase modulate the transmitter. The SCOs are frequency modulated by their individual inputs of Pulse Amplitude Modulation (PAM), analog and Pulse Code Modulation (PCM) data. Telemetry subsystem 1 will normally transmit on a continuous basis. Telemetry subsystem 2 is a Pulse Code Modulation/Phase Modulation (PCM/PM) system which radiates on a frequency of 136.380 MHz and power output of 3 watts. The system transmits the contents of a 54 kilobit memory store of experiment data upon ground command. It is anticipated that the subsystem will be read out several times a day by command from the NRL tracking station at Blossom Point, Md. The memory dump operation will require about five minutes of transmission time for the readout and the transmitter will remain off at all other times.

No special beacon or tracking equipment is provided on board the SOLRAD 10 spacecraft for tracking by the ground stations. Since the 137.710-MHz telemetry transmitter will be continuously transmitting, it will serve as the signal source for tracking assignment under control of the NRL. No tracking support will be required from the NASA Goddard Space Flight Center (GSFC) STADAN stations.

The spacecraft contains three spin replenishment and four spin-axis attitude control subsystems designed to maintain the spin rate at 60 rpm and the spin-axis within $\pm 2°$ of the Sun line.

Solar sensors determine the angle to the Sun and automatically apply control signals to the attitude spin subsystem. The spin rate is observed

on the telemetry signal and is corrected by commanding a low-thrust ammonia or hydrazine gas system.

Attitude control subsystems 1 and 2 are redundant and share a common toroidal tank containing 9.5 pounds of liquid anhydrous ammonia. Each attitude control subsystem contains a solenoid valve, a latching valve and a nozzle. The latching valves and power for the solenoid valves are controlled by ground command and operation of the solenoid valves is controlled by solar sensor pulses. Upon receipt of the solar sensor pulses, ammonia vapor passes through the two sets of valves and nozzles and precesses the spin axis to within $\pm 2°$ of the Sun line.

Spin replenishment subsystems 1 and 2 are also redundant and share the same tank as attitude control subsystems 1 and 2. Each spin replenishment subsystem consists of a solenoid valve, a latching valve and a nozzle. Both the latching valves and the solenoid valves are controlled by ground command when spin replenishment is desired.

Attitude control subsystem 3 and spin replenishment subsystem 3 share a pair of spherical tanks containing five pounds of hydrazine and pressurized to 130 psi. Each subsystem contains a latching valve, a solenoid valve, a catalyst bed and a nozzle. The latching valve and power for the solenoid valve of attitude control subsystem 3 are controlled by ground command; operation of the solenoid valve is controlled by solar sensor pulses. Both the latching valve and the solenoid valve of spin replenishment subsystem 3 are controlled by ground command. The hydrazine system is being tested for future application in high-altitude follow-on SOLRAD satellites.

Scout Launch Vehicle

Scout is NASA's only solid propellant launch vehicle with orbital capacity. The first-development Scout was launched July 1, 1960. Since the Scout was recertified in 1963, the launch vehicle has attained a 94-percent success record.

Scout B is a four-stage solid propellant rocket system. Scout No. S-173 and the spacecraft will be set on an initial launch azimuth of 90 degrees to obtain a 214 × 800-kilometer orbit with 2.9 degrees inclination and 94.8 minutes to complete one revolution.

The four Scout motors—Algol II, Castor II, Antares II, and Altair III—are interlocked with transition sections that contain guidance, control, ignition, and instrumentation systems, separation systems and the spin motors needed to stabilize the fourth stage. Control is achieved by aerodynamic surfaces, jet vanes and hydrogen peroxide jets.

The launch vehicle is approximately 73 feet (22.25 meters) long and weighs about 40,000 pounds (17,144 kilograms) at liftoff.

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Wallops Station Launching Site

NASA Wallops Station is responsible for project coordination relating to scheduling, reporting, launch vehicle and tracking and data acquisition, as well as the usual launch operations and pre-launch support provided for the Scout SOLRAD C launch.

The SOLRAD 10(C) satellite was launched from Launch Area 3A, and is the fifteenth satellite placed in orbit from Wallops Island. Nearly 8,000 rockets have been launched from Wallops Island since 1945. Wallops' efforts have assisted in obtaining scientific data about the Earth's atmosphere and its near-space environment, as well as providing support for programs such as space sciences and applications, aeronautics and Earth Resources. The Scout four-stage solid-propellant launch vehicle is the largest rocket launched from Wallops Island and is the only one with orbital capability from the island.

NRL Develops New Lubrication System

A long range research and development effort by the Naval Research Laboratory (NRL) has led to a new lubrication system which will increase the life and reliability of prelubricated precision instrument ball bearings from two to ten times that achieved with conventional bearing lubrication.

The new lubrication system consists of a fluoropolymer oil barrier coating to prevent oil loss through migratory spreading and a "tailor made" polyol ester oil with highly improved chemical stability.

The deverse and increasing use of the instrument bearing lubricant system, developed by NRL's Surface Chemistry Branch, has revealed that major cost savings have resulted from reduced repair requirements and reduced stockpile inventories.

An example of the savings possible through improved bearing life was demonstrated when the NRL lubricant system was evaluated in synchro bearings. It increased synchro life over ten times that normally obtained on an item that cost $50 million per year for replacements.

Another example of cost reduction was obtained from the operational evaluation of the NRL lubricant system in aircraft gyro equipment in which bearing life was more than doubled. There is $89 million worth of such gyro equipment in the Navy inventory with an annual repair cost of $9 million. Doubling the life of this equipment would save $4-1/2 million annually.

Since over 200 other types of rotating instruments have been identified for the application of the NRL lubricant system, it is anticipated that many more millions of dollar savings will accrue from the NRL research.

The NRL research was sponsored by the Naval Air Systems Command, the Naval Ordnance Systems Command, and the Strategic Systems Project Office of the Naval Material Command for bearing applications involving rotating electromechanical instruments used for navigation, fire control and missile guidance. All of the sponsoring activities have been adopting the use of the NRL lubricant system in instrument applications for aircraft, submarines, ships and missiles.

Modern Solid State Electronics

Donald J. Hanrahan
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So many advances have been made in the techniques and devices of solid- and surface-state electronics since the transistor gained widespread use in the Navy, that it is desirable to survey the underlying principles, performance characteristics and other features of the most important, recent, fast-evolving devices in this field.

Field Effect Transistor

The field effect transistor (FET) is a unipolar device (meaning involvement of only one type of charge carrier) that dates from the early days of transistors (1) but which has recently come into common use in micro-electronic and large-scale-integration circuits (2). Its advantages include high input-impedance, low noise-figure, and ease of fabrication by means of planar technology. Its important uses are as first stages in amplifying circuits, in stable oscillators, and as switching elements in logic circuits.

The main idea involved in operation of the FET is to vary the conductivity of a semiconductor wafer which serves as a channel between so-called source and drain electrodes. Figure 1 shows the most commonly used FET, namely, the insulated gate type (IGFET). (Another variation, known as the junction FET or JFET, controls the channel by ordinary reverse-biased diode action, the controlling voltage appearing between gate and substrate, the latter usually connected to the source.)

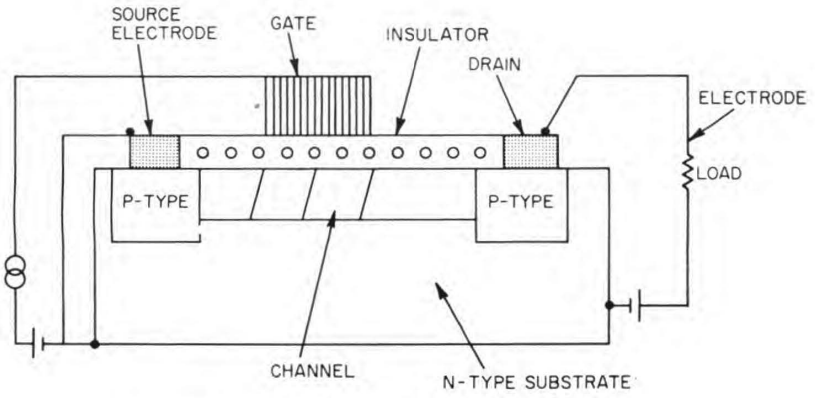


Figure 1 — Schematic diagram of an insulated gate field effect transistor (IGFET)

The IGFET, also called the MOSFET, (metal-oxide-silicon FET) or MISFET (metal-insulator-semiconductor FET) is built with a metal gate, oxide insulator, and semiconductor electrodes and substrate as shown.

A signal voltage, applied between gate and source contacts, moves charged particles into and out of the channel by means of field forces which operate through the insulator. As a result, modulation of the current which flows from source to drain and then to the load takes place. This modulation manifests itself either as a *depletion* or *enhancement* of charge in the channel, depending upon whether the substrate is P- or N-type material, and on the polarity of the gate voltage. If complete depletion occurs, the channel is said to be "pinched" (biased so that no current flows), in which event a small change in signal voltage can cause a large change in load current, and hence amplification.

The signal voltage, applied between gate and base substrate, actually pulls or pushes charges into and out of the semiconductor; this pulling or pushing is the "field effect," the field extending right through the insulator.

Avalanche Diode

Up until a few years ago the title of this section would have referred to the so-called Zener diode, used chiefly as a voltage reference because of its sharp break-down characteristic. (The usual Zener diode operates, not by the Zener effect, which is a tunneling process, but by impact ionization or avalanche.) Today the term avalanche diode more likely refers to the IMPATT (impact ionization avalanche transit time) diode, a new source of microwaves. An IMPATT oscillates by virtue of a negative differential conductance that involves "hot" carriers, *i.e.* carriers whose energy is large compared to the thermal energy of the lattice.

The IMPATT diode was proposed in 1958 by Read (3) but was not realized until 1964 (4), and then in a simpler structure. The structure and reverse–bias electric field distribution of a Read diode are represented in Figure 2. The electric field is high enough for avalanche to occur in a narrow region near the n^+-p (or p^+-n) junction. The rest of the depletion region constitutes a drift space in which the field remains high enough for the drift velocity to be saturated. A differential increase in diode voltage results in a differential current that lags the change in voltage for two reasons: the carrier population in the avalanche region increases with a delay time characteristic of the multiplication process, and the carriers in the drift space are delayed by the transit time. When the total phase lag exceeds 90°, the differential conductance is negative, and the diode is capable of oscillation. IMPATT oscillation has now been achieved in Read, PIN, p-n and metal-semiconductor diodes, but

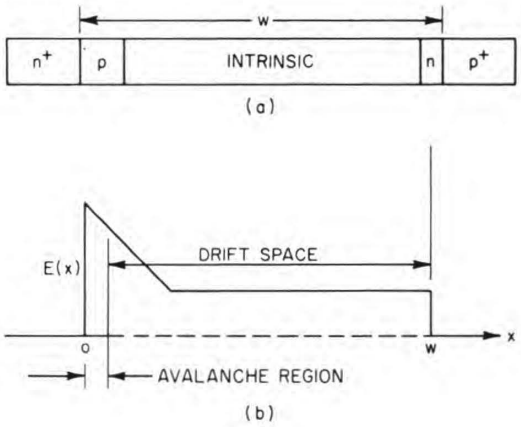


Figure 2 — Structure (a) and reverse-bias, electric field distribution (b) of a Read diode

analysis of the last three types is complicated by overlap of avalanche and drift regions.

Operation of an IMPATT diode in which there is essentially only one type of carrier in the drift region, as described by Read, is now called the fundamental IMPATT mode; it has a theoretical efficiency limit of about 30 percent. Efficiencies of over 40 percent have been reported (5),(6) in what is variously called the high-efficiency, "Chang," or TRAPATT (trapped plasma avalanche triggered transit) mode. This more complicated, multi-frequency oscillation typically gives one-third the frequency and three times the efficiency given by the same diode operated in the fundamental mode.

Most IMPATT diodes have been made from silicon because of its advanced technology, but diodes fabricated from germanium have proved to be much less noisy than either silicon or gallium arsenide oscillators (7). Any avalanche process tends to be noisy; the IMPATT diode is therefore generally more noisy than the bulk-effect devices to be described next. At the present time, however, avalanche diodes have a greater high-power, high-frequency capability than any other solid state source. (Commercially available IMPATT diodes for 4 watts cw at "C"- and "X"-bands were announced by Raytheon in February, 1971 (8).) The avalanche diode is, therefore, a very important contender for the active unit in a solid-state, microwave power source.

Gunn Oscillator

This is a so-called transferred electron or bulk-effect device (9) which generates coherent electromagnetic energy by application of a direct-current voltage across a slab of certain semiconductor materials, such as n-type gallium arsenide. The metal contacts, usually evaporated onto the ends of such slabs, are called source and drain electrodes. Typical applied voltages are about 200 volts, across slabs of about 200 microns length, generating energy in the 500 MHz region. The radio-frequency

signal is taken off the oscillator *via* a wave guide or other load in parallel with the diode, as shown in Figure 3.

Like the IMPATT, a Gunn device operates by means of hot carriers and a negative differential conductance, but the negative conductance comes about in quite a different way. It is due to a progressive increase in effective mass of electrons, over a range of electric field, as the field exceeds some threshold value. An increase in effective mass means a decrease in mobility and, therefore, a decrease in current density (at the same charge density) with increasing field, and vice-versa. The increase in effective mass is a result of the unusual Brillonin-zone structure of gallium arsenide which accounts for several minima in the conduction bands of the crystal.

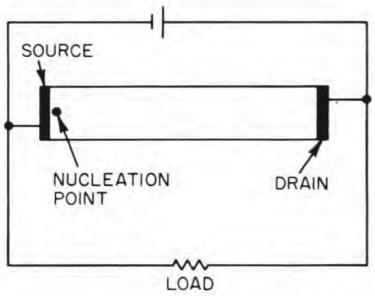


Figure 3 – Schematic diagram of a Gunn oscillator

When the electric field exceeds the threshold value, an irregularity of doping density (near the source electrode for minimum frequency of oscillation) serves as a nucleation site where the electric field grows rapidly, at the expense of the field elsewhere. This high field domain then propagates down the semiconductor slab to the drain electrode at a drift velocity of about 10^7 cm/second. Upon arrival at the end of the slab the energy of the traveling field is dissipated by the positive resistance of the load. The process then begins all over again at the nucleation point where the rapid growth in field had started in the first place. This cyclic phenomenon manifests itself as radio-frequency energy coming from the oscillator.

What we have described above may be called a transit-time, domain mode of operation. Besides other possible domain modes, there is a mode in which domains are avoided; this is called the LSA (limited space-charge accumulation) mode (10). The LSA mode permits operation at higher frequencies, or more power at a given frequency, than can be obtained with a transit-time device. Readily achievable peak powers exceed 100W in both C- and X-bands, with 100 mW average power and 8-10 percent efficiency.

Gunn devices have operated over a wide range, from UHF to the millimeter region of the spectrum. They are finding application as microwave generators for local oscillators, parametric amplifier pumps, doppler radar transmitters, altimeters and range finders, where both narrow and broad band electronically-tuned sources are required.

These are the most important of the many surface- and solid-state electronic devices that have emerged and come into use since the advent of the transistor. They have the usual solid-state advantages of reliability combined with small size, weight, and power requirements; and are capable of being mass-lubricated by simple, semiconductor techniques such as oxidizing, masking, etching, diffusion and ion-implantation profiling. These devices will find increasing use in naval data-processing, communications, IFF, and Weapon systems to assure quality performance in the functioning of such systems.

References

1. Shockley, W., "A Unipolar 'Field Effect' Transistor," *Proc. IRE*, Vol. 40, pp. 1365-1376, Nov. 1952
2. Wallmark, J. T., and Johnson, H., *Field Effect Transistors, Physical, Technology, and Applications*, New York:Prentice-Hall, 1966
3. Read, W. T., "A Proposed High-Frequency Negative Resistance Diode," *Bell System Tech. J.*, Vol. 37, pp. 401-446, Mar. 1958
4. Johnston, R. L., De hoach, B. C., and Cohan, B. G., "A Silicon Diode Microwave Oscillator," *Bell System Tech. J.*, Vol. 44, pp. 365-372, Feb. 1965
5. Iglesias, D. E., and Evans, W. J., "High Efficiency CW IMPATT Operation," *Proc. IEEE*, Vol. 56, p. 1610, Sept. 1968
6. Johnston, R. L., Scharfetter, D. L., and Bartelink, D. J., "High-Efficiency Oscillations in Germanium Avalanche Diodes Below the Transit-Time Frequency," *Proc. IEEE*, Vol. 56, pp. 1611-1613, Sept. 1968
7. Rulison, R. L., Gibbons, G., and Josenhans, J. G., "Improved Performance of IMPATT Diodes Fabricated from Ge," *Proc. IEEE*, Vol. 55 pp. 223-224, Feb. 1967
8. Hardeman, L. J., "Microwave Diodes," *Microwaves*, Vol. 14, pp. 30-34, Feb. 1971
9. IEEE special issue on Semiconductor Bulk-Effect and Transit-Time Devices, *IEEE Trans. Electron Devices*, Vol. ED-13, pp. 4-136, Jan. 1966
10. Copeland, J. A., "A New Mode of Operation for Bulk Negative Resistance Oscillators," *Proc. IEEE (Letters)*, Vol. 54, pp. 1479-1480, Oct. 1966; also "CW Operation of LSA Oscillator Diodes," *Bell System Tech. J.*, Vol. 46, pp. 284-287, Jan. 1967

ONR History Being Prepared

Professor Harvey M. Sapolsky of the Massachusetts Institute of Technology is preparing a history of the Office of Naval Research. The study will cover the period from ONR's origins as the Office of Research and Invention through 1966 and will emphasize the formulation of ONR's research program and its impact upon both the development of naval technologies and the growth of science. Persons who would like to contribute to this history are invited to contact Professor Sapolsky at the Institute of Public Policy Studies, the University of Michigan, Ann Arbor, Michigan, 48104, where he will be on research leave from August 1971 through July 1972.

A New Floating Platform for Oceanographic Research

Construction will begin on a 15,000-square-foot stable floating platform complete with steel superstructure and concrete vertical legs that pivot up to the horizontal to permit towing to an ocean station. This project, which culminates nearly three years of design study, including model testing in San Diego Bay, is under the joint technical management of the Advanced Research Projects Agency and the Office of Naval Research.

Subsequent phases of this new technological breakthrough call for assembly and outfitting of the first module and construction of a second module, both of which, when joined together, will comprise the ultimate platform (Figure 1).

The studies for and subsequent design of both an operational, eighth-scale, three-legged model and a second, two-legged, eighth-scale model follow naturally from the experience of Scripps's Marine Physical Laboratory in designing and operating Scripps's successful stable floating platform, FLIP. Both scale models were built by MPL personnel (Figures 2 and 3).

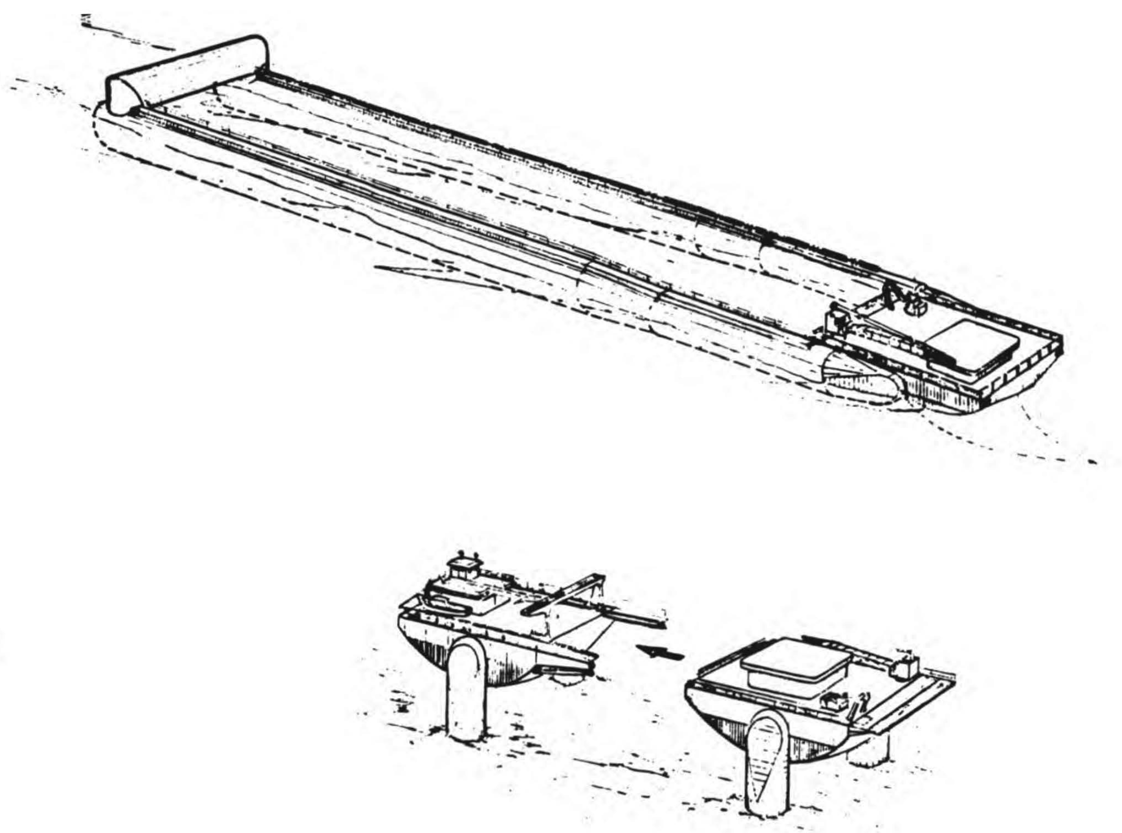
The single-spar, 355-foot, tubelike FLIP is towed to her ocean station then upended for underwater acoustic research by flooding ballast tanks. FLIP's vertical stability has been demonstrated in 78 deep-ocean operations. MPL personnel designed and operate not only FLIP but also ORB, a special platform used in lowering heavy operational equipment to the ocean floor and recovering it.

Working with the naval architectural firm of L. R. Glosten and Associates, Seattle, Dr. Spiess, the principal scientist for the project, formulated and guided the concept of the revolutionary new floating platform to its ultimate design and model testing. The newly conceived floating platform, incorporating FLIP's flooding principle for the operation of the legs, will be useful in at least four of our current research areas.

- Underwater acoustics and sonar signal processing
- Sea-floor work, such as the inspecting, planting, and retrieving of equipment and the support of vehicles (submersibles, bottom-supported vehicles, and remote controlled equipment) to do work in the sea and on the sea floor
- Investigations of the ocean's water column; for example, studies of the deep scattering layer, optical properties of the ocean, and internal waves
- Above-water research on air-sea interaction and other aspects of surface waves and marine meteorology

The principal areas in which the new technology would be developed and embodied are in the use of post-tensioned concrete for the slender, highly stressed legs; the hinging of the laboratory, or superstructure, sections relative to the legs; and the joining of the independent modules at sea to form the operating platform. This latter point is particularly important since it will demonstrate the feasibility of making very large platforms by connecting a number of modules.

In effect, each of the two proposed modules would utilize two, FLIP-like, 350-foot concrete legs to provide operating stability at sea when the legs are in the vertical position. As the two original modules are towed to their work



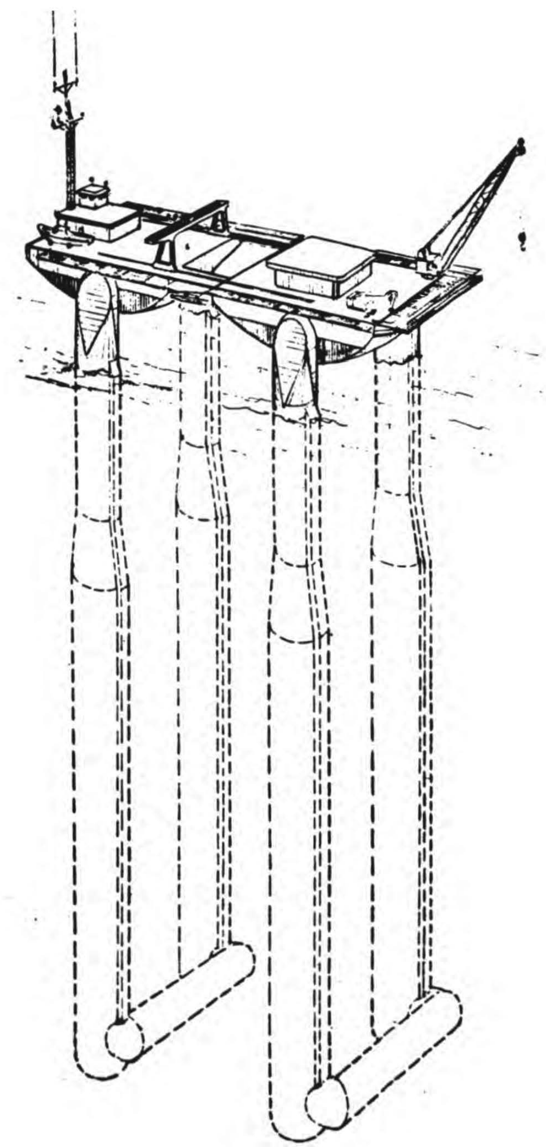


Figure 1 — Engineering sketches of proposed stable floating platform for open-ocean operations show how a module, at left, is towed to work station, its concrete legs horizontal with sea surface and platform. Water pumped into legs will cause them to pivot to the vertical to provide stability. In center, two modules as they would appear, legs down, just before being locked together. At right, two modules form a completed platform. Any number of modules could be joined to provide platform of any size.

Scripps Institution of Oceanography, University of California, San Diego, has been awarded contract to construct a platform complete with steel superstructure and concrete legs.

Figure 2 — A two-legged, one-eighth scale, operational module, some 42 feet long, is tested in San Diego Bay by UCSD's Scripps Institution of Oceanography personnel during feasibility studies. Eventual construction of a full-scale module whose 350-foot concrete legs, when extended vertically in the ocean, would provide stability for a floating platform. Additional modules could be linked to form platforms of any size desired for oceanographic research in the deep ocean.

stations with their hulls in the water, the two legs of each module would remain in the horizontal position, trailing along with their portion of the superstructure.

Upon the modules' arrival at the ocean station, the ballast compartments in the legs of each module are sequentially flooded to cause them to swing down into a vertical position. The hull is then locked to an upper trunion to prevent its rotation. The uppermost ballast compartments are then blown free of water to make the hull rise and thus provide desired clearance above the sea surface. The two modules are then brought together and joined.

The legs will be built in sections of pre-stressed concrete joined together by steel members. They will be some nine inches thick, 18 and a half feet in diameter at the top, and 28 feet in diameter at the bottom. Concrete legs require very little maintenance in contrast to legs of steel. Also concrete legs gain strength with time, exhibit excellent strength in compression from ocean pressures, and cost "significantly" less.

By the sequential flooding of FLIP's tanks, it can be tilted, or flipped, from the horizontal to the vertical so that it floats rather like a harbor navigational spar or buoy, though of much greater size.

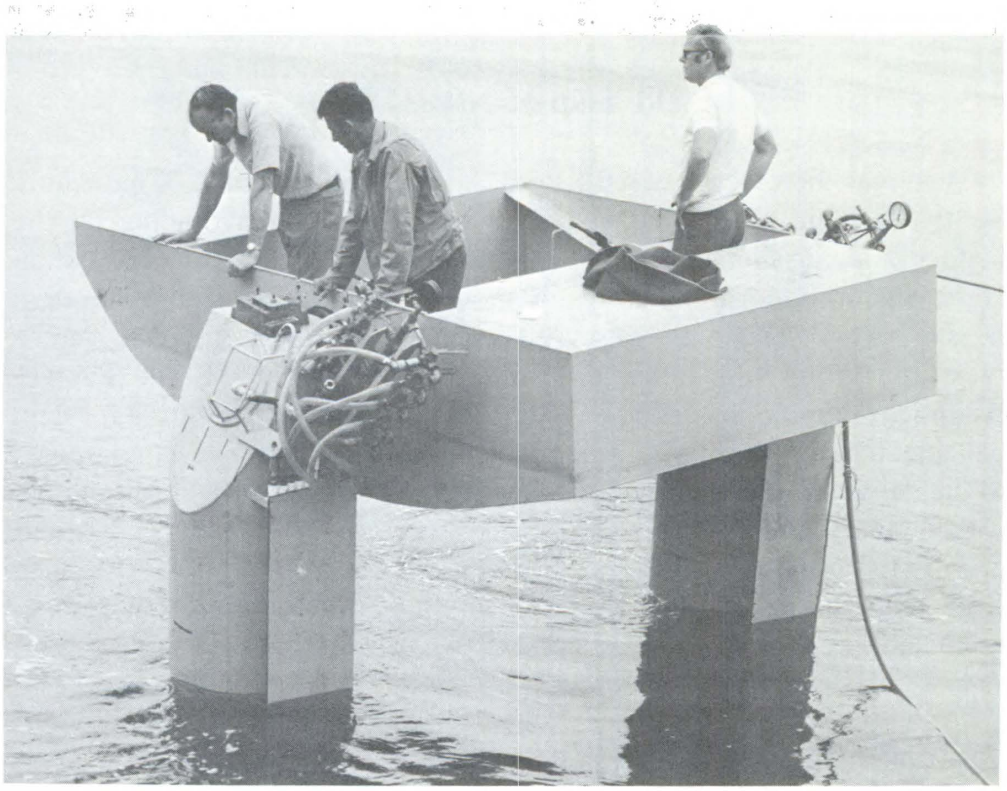


Figure 3 — A two-legged, one-eighth scale, operational module floats on its 42-foot-long legs in San Diego Bay as personnel from UCSD's Scripps Institution of Oceanography conduct feasibility studies for a full-scale version that would have concrete legs 350 feet long. In the vertical, the legs provide stability for the module in the deep ocean. Several modules linked together could form a stable floating platform of any size desired from which to conduct many types of oceanographic research. Legs would be in horizontal attitude as modules are towed to and from the ocean work station, and become vertical when water is pumped into ballast tanks.

FLIP, in effect, represents just one of a grid of such stabilized points between which would be built the floating platform's structure.

Such platforms are likely to become an increasing civilian feature of the ocean environment in years to come, perhaps as an oil-drilling rig, as a mining facility, or as a site for a nuclear power station, a fishing-fleet station, or a weather station. The mobility of such platforms in conjunction with their possible military uses makes them extremely advantageous.

New IR Detection Method Suggested

High-field instabilities in cadmium sulfide studied by Professor K. W. Bőer at the University of Delaware have been suggested as a new method to detect infrared radiation. High electric fields applied to these samples remove trapped charge from centers active in reducing electrical conductivity. Thus for certain ranges, an increase in field may bring

(Continued on Page 23)

On the Naval Research Reserve

Field Trip of NRRC 5-10

This year the officers of 5-10 Bethesda, Maryland went to Charleston, South Carolina where the visitors were first given a briefing on the history and mission of the U.S. Naval Weapons Station, Charleston. Here was an opportunity to examine at close hand one of the Standard missiles which had been observed earlier being fired at White Sands. Next the group was taken on a tour of the Polaris Missile Facility Atlantic, the mission of which is to operate a facility responsible for fleet ballistic missiles from the receipt of unassembled missile components to the delivery of new or repaired complete missiles to a FBM submarine.

Completing the Navy program was an afternoon tour of the nuclear powered, Poseidon submarine USS DANIEL BOONE (SSBN). The ship, built at the Mare Island Naval Shipyard, was the first Polaris firing submarine in the Pacific Fleet.

"NRRC 6-1 Discovers Rift in Mid-Atlantic Ridge"

This headline could have been written in July 1952. Present NRRC 6-1 Commanding Officer, CDR James Neiheisel, USNR, was then serving aboard USS THOMAS E. FRASER (DM-24). He was taking fathographs 70 miles north of the Azores when the moving needle distinctly showed the rift which was not officially announced for another year. CDR Neiheisel still uses a reproduction of the original fathogram as a teaching aid in his geology course at Georgia Tech.

Personal involvement such as this has spiced the past year's intensive study of oceanography by members of NRRC 6-1. A review of last summer's Oceanographic Seminar at Rider College gave the company a base for further study. Following a deeper review of some of the classic topics, such as marine topography, marine geophysics, and marine biology, the program series turned to the specialized topic of harbors, bays, and estuarys on the Atlantic coast. Included in this series were reports of recent research by the Army Corps of Engineers into channel and shoaling problems in the Delaware estuary, Chesapeake Bay, and Charleston harbor areas.

NRRC 6-3 Tackles Environmental Problem Solving

"War Gaming" technique has found new application. Members of Naval Research Company 6-3, Oak Ridge, Tennessee are veterans of a

new instructional experience in environmental problem solving called Enviro County. Developed by The Cooperative Science Education Center of Oak Ridge, with support of the National Science Foundation and Oak Ridge National Laboratories, Enviro County is a simulation game designed to stimulate participants to confront and better understand the total environmental problem.

The agenda for the game addresses five situations:

1. A request by Voltate Chemical Company for rezoning of prime riverfront property to permit construction of a fertilizer plant.
2. Development of "inner city" property for: low cost housing development, a city park, or a corporate headquarters building for Voltate Chemical Company.
3. Improving the water supply and its quality by: constructing a purification plant, pumping water overland from a distant source, digging city walls, constructing a reservoir, or implementing pollution penalties for industrial, commercial, and residential offenders.
4. Improvement of traffic flow from suburban areas to downtown business areas by: constructing an interstate highway, constructing suburban bypasses in congested areas of the existing state highway, or development of a mass transit system.
5. Providing additional electrical power sources by constructing: additional fossile-fired power plant, installing a hydrogenerator and siphon tube at a nearby damsite, or constructing a nuclear power generating station.

The value of the exercise is to review consequences of decisions and to gain insight into the impact that these decisions have upon social, economic, and environmental resources. By developing more concerned, sensitive, and knowledgeable attitudes, the larger objective is achieved in the real world when these attitudes are translated into more rational and constructive decisions about the management of these resources.

Drilling Program of NRRC 6-6

The officers in NRRC 6-6 Chapel Hill, North Carolina, comprise a rather unique research team when they gather on Monday evenings on the campus of the University of North Carolina.

The professional diversity of the members allows for discussions on a wide variety of topics. Programs on the economic effects of air pollution, advances in lasers and nuclear energy and the side-effects of deep water dives elicited the contributions of each of the members to understanding the problems that affect both the Navy and society.

Field Trips by NRRC 6-9

Field trips have been the "order of the day" for the recent drills of NRRC 6-9, Athens, Ga. The reservists toured the University of Georgia where they investigated the Soil Testing and Plant Analysis Laboratory and School of Veterinary Medicine, the U.S. Department of Agriculture's Richard B. Russell Agricultural Research Center, and the Georgia Mental Retardation Center. A special program was conducted on recent findings of "ice age giants" in Georgia in the Geography-Geology Building of the Science Center.

NRRC 6-17 Reports

Naval Research Reserve Company 6-17 in Huntsville, Alabama, has access to the NASA Marshall Space Flight Center and the Army Missile Command and their supporting contractor complexes.

As past technical advisor to the MSFC Saturn V Program Manager, CDR Chereek of NRRC 6-17 recognized the management challenge in the early days of the program and began to investigate the philosophies of System Engineering Management practiced by the military weapon system developers. He took these ideas and translated the pertinent features into documented recommendations for implementation on the Saturn V Program, including definition of a full life cycle program. Shortly afterwards, NASA began sponsorship of System Engineering Management courses at five universities—Kansas, Purdue, Cornell, Georgia, and Stanford.

CDR Chereek later developed Systems Engineering Management curriculum for NRRC 6-17. The curriculum is divided in three parts: (1) The first part deals with applications of Systems Engineering during the life cycle phases of a major program; (2) The second part deals with the tools and discipline of Systems Engineering; (3) The third part is a description of an academic program leading to qualifications as a Systems Engineer. Many other excellent programs have been made possible by proximity to MSFC.

NRRC 6-18 Visits the Naval Air Station Memphis

Members of Naval Research Reserve Company 6-18, Nashville, Tennessee toured the facilities of the Naval Air Station Memphis during Armed Forces Weekend, 13-15 May. The visit included a tour of meteorological and communication facilities, flight line, parachute

loft, survival gear repair and maintenance area, and the control tower where flight operations of attack aircraft and a C-9 Med-Evac were observed.

NRRC 6-19 Holds Weekend Seminar in Chattanooga, Tennessee

NRRC 6-19 sponsored a weekend seminar in Chattanooga, Tennessee on "Nuclear Power in the Seventies." Combustion Engineering Company, a major manufacturer of nuclear power equipment, and the Tennessee Valley Authority provided facilities and expert assistance. Thirty eight officers from Research Companies in Chattanooga, Atlanta, Oak Ridge, and Huntsville attended.

(Continued from Page 19)

about a decrease in current. Such a negative resistance leads to the formation of movable field domains within the crystal.

It has long been known that electrical conductivity in photoconductors could also be reduced when long-wavelength light emptied certain impurity centers in the crystal and allowed them to play an active role in reducing the number of current carriers. Recently Bőer studied his moving domains caused by high fields under the simultaneous influence of such infrared radiation.

Bőer himself considered *detecting* infrared this way by observing optically its effect on the domains. These domains are visible because cadmium sulfide is less transparent where the field is high. A NASA scientist at Langley Research Center has now proposed to increase the sensitivity of the process by increasing the electrical conductivity transversely across a domain and its change when the infrared radiation is applied. Infrared detectors based on new principles and which could operate without cooling would be a great improvement for air and shipboard applications.

Helicopter Lift Instrument

Under an ONR program, co-funded by Naval Air Systems Command and the Army Electronics Laboratory, Fort Monmouth, New Jersey, a simple helicopter lift margin indicator has been developed and flight tested.

The purpose of the device is to aid the pilot in preventing types of accidents (ground crashes) which occur in take-off and landing at restricted sites where vertical flight segments are required. Under this constraint the lift capability in translating in and out of ground effect *must* exceed the effective gross weight of the vehicle. The device provides the pilot with continuous up-dated information on his lift-margin based on actual engine performance efficiency, ambient air temperature, air pressure, and other variables. Each helicopter would be periodically calibrated by an easily accomplished flight test. The device has been tested on two UH-1B helicopters at Fort Eustis, Virginia, and, over a period of many flights, demonstrated an average accuracy of about 200 pounds. Minor improvements in instruments will enable this lift error to be reduced to 100 pounds.

Research Notes

Navy Study Sheds New Light on "Red Tide"

A Navy research study has confirmed that the so-called Red Tide is the source of a lethal poison, which periodically causes the death of large masses of fish. The study has also developed a promising theory on what leads to the sudden appearance of the phenomenon.

The Red Tide consists of a body of plankton containing organisms that suddenly spurt into rapid reproduction or "bloom," staining the water usually a red color. Research is being conducted by the University of Southern California under a contract with the Office of Naval Research, which supports a continuing research program on poisonous and dangerous sea life.

Investigators at USC, under the direction of Dr. B. C. Abbott, have succeeded in isolating the organism responsible for Red Tides in the Gulf of Mexico and southern Florida. The organism is called *Gymnodimium breve,* and experiments have been carried out on it. It was found that this organism contains a powerful toxin. When the toxin is only partially purified and injected into animals, it produces instantaneous effects on the heart muscle, respiratory centers, and the central nervous system.

This research study has particular importance for the Navy since naval personnel operating out of future undersea habitats could be affected. Although serious incapacitation is unlikely, the possibility also exists that the health and efficiency of men operating surface craft can be impaired through inhaling the spray from waters containing the toxin.

Through its studies the USC has developed the theory that the blooming of this organism into a Red Tide can be triggered by certain hormones known to stimulate growth in plants. Such growth hormones are believed to be present in plant residues that may be released into the sea water through the disposal of food wastes.

To test this theory, the investigators learned to produce mass cultures of the *G. breve* organism totally free of extraneous bacteria and fungi. This has enabled them to conduct laboratory experiments on the reproduction of the organism. Tests with one particular plant hormone, giberellic acid, have resulted in sudden flurries of growth activity similar to the blooming responsible for Red Tide episodes.

They are now seeking to determine just how the giberellic acid causes this spurt in growth. They also hope to learn in later experiments what other hormone materials can stimulate reproduction in *G breve* as well as in other organisms responsible for Red Tides elsewhere. If the action of the hormones can be properly understood, it may be possible to suggest methods of controlling the phenomenon and preventing its harmful effect on both fish and man by means of appropriate inhibitory compounds.

Later plans call for USC to monitor the effluents from its own research vessel and its marine installations on Catalina Island to determine whether chemical compounds capable of triggering a Red Tide are actually being introduced into the sea. The results of this work are of high potential impact on the Navy and maritime agencies.

Breaking the "Helium Barrier"

There is continuing interest in trying to determine the depth limitation of Helium/Oxygen breathing mixtures in diving. Dr. T. D. Langley of Ocean Systems, Inc. has concluded a series of four exceedingly deep simulated dives using squirrel monkeys as subjects.

Earlier work at lesser depths had indicated two physiological problems whose mechanisms are unexplained. One of these is the "hyperexcitability" phenomenon where

monkeys have exhibited twitching, tremors, and convulsions starting at about 1500 feet depths and continuing downward. The other, is the considerable slowing of heart rate which ended in complete cardiac arrest. Dr. Langley was able to bring his monkeys down to 5500 feet equivalent depth by increasing the partial pressure of oxygen to a level (pO_2 1.0 atm) well above the level usually used (pO_2 at about 0.25 atm).

The benefits of this high level of oxygen, however, were transient and the animal died. Unfortunately, increasing the partial pressure of oxygen was limited because of the convulsive dangers of oxygen toxicity.

In 1968, a team of divers breathing a helium/oxygen mixture descended to the equivalent depth of 1190 feet in the high pressure chambers of the Compagnie Maritime d'Expertise (COMEX) at Marseille, France. By the time this depth was reached, the EEG records (*i.e.*, recordings of the electrical activity of the brain) plus obvious mental and physical deterioration in the divers indicated that the pressure where useful mental and physical work could be accomplished had been exceeded. Since then however, other chamber dives in the U.S. and the U.K. to approximately the same simulated depths were found to be well tolerated by man.

In March 1970, a team of British workers at the Royal Naval Physiological Laboratory, conducted a successful dive to a simulated depth of 1500 feet for 10 hours without showing any evident deterioration in performance by the divers. As a matter of fact, the divers actually spent about 3-1/2 days at depths of 1200 feet or greater during the compression, bottom time and decompression phases without apparent adverse effects.

It seems as if the "helium barrier" (for humans) will be deeper than the 1200 feet proposed in 1968.

New Research Instrument Alerts to Onset of the Bends

A new research instrument is being tested that holds promise for alerting Navy scientists to the onset of decompression sickness in divers before symptoms are seen. The new tool along with other research studies is helping the Navy gain a better understanding of the cause and prevention of what is known as the bends.

The bends can affect divers who decompress too rapidly upon their return to the surface after a prolonged dive. The effects of the sickness range from pain in the joints to paralysis and death. The leading theory of the causes of decompressing sickness is that bubbles which are produced in the blood stream block blood flow in the capillaries. The new device is an ultrasonic sensor that can detect the formation of the first bubbles before there are any ill effects.

Called a doppler ultrasonic flowmeter (DUF), it is being tested and modified by the Virginia Mason Research Center, Seattle, Washington, under an Office of Naval Research contract with funds provided by the Naval Bureau of Medicine and Surgery.

The instrument consists of a system of transducers which send sound waves of known frequencies through predetermined places in the blood stream. When a bubble flows past the transducer, it causes a change in the frequency of the sound waves known as a doppler shift. Properly amplified, the change can be heard as a "chirp." The bubbles can also be detected visually as a change in the wave amplitude on the oscillograph screen.

Experiments have been conducted with sheep made susceptible to decompression sickness. Results indicate that the surgically implanted DUF sensor can detect the formation of microscopic bubbles long before the animals show clinical manifestation of the bends. Recent experiments make use of a newly developed external hand-held transcutaneous DUF that can monitor human subjects during decompression.

By understanding the physiological mechanisms related to the origin of the bends, the Navy can develop much more accurate decompression tables for divers returning from various depths. Present schedules are largely based on experiences and the subjective observation of divers. Such schedules are not completely reliable since the decompression

rate can vary depending on an individual's age, physical condition, weight and diving history.

A long-range possibility is that the DUF instrument can be the basis of an early warning device that will tell the diver undergoing decompression or the medical technicians monitoring him that he is about to get the bends and permit preventive action to be initiated before bends symptoms actually occur.

Superconducting Technology

Recent progress at Stanford University under ONR contract in large-scale superconducting technology included completion and successful tests of a cryogenic system consisting of a 300 watt refrigerator, phase separator, dewar, a superconducting niobium cavity section in the dewar, and two 300-foot cryogenic pipelines. The cryogenic system was filled with approximately 800 liters of liquid helium at 1.8 degree Kelvin. The system was operated at various power levels up to 250 watts for about a week, and the delivery of 200 watts of refrigeration to the dewar was accomplished without difficulty.

The stability of the system was such that 120 watts switched off and on in the dewar resulted in a vapor pressure change of less than 0.05 torr and a frequency change in the niobium cavity section of only a few parts in 10^9. The heat leak into the cold parts of this system was about 6 watts.

A recent ONR review presented the main advantages of superconducting machinery as follows:

- Superconducting electrical machinery offers enormous savings in weight volume, and cost for such naval applications as (1) power generators, (2) ship propulsion systems and (3) electrical generators for aerospace use. Further significant gains in weight and volume are expected from a broad research and development program. The present-day feasibility of large superconducting homopolar and synchronous machines has been firmly established. Some 10 superconducting machines with ratings in excess of 1000 HP will be operating by 1972.
- Using existing superconducting machinery technology, the significant advantages of electric ship propulsion may now be utilized in destroyers and submarines. A gas turbine driven electric propulsion system with small lightweight motors is optimum for such new high speed vessels as: (1) semisubmerged ships, (2) hydrofoils and (3) catamarans. By separating power generation equipment from the motor and propeller, these components may be placed in optimum locations. High power superconducting propulsion systems installed in submarines will allow for greater speed.
- The availability of very lightweight high speed generators in the 1-10MVA class will be of great advantage in such military aviation applications as: (1) electrical propulsion machinery systems and (2) electrical generators for very high power airborne surveillance systems.

X-Rays from the Coma Cluster—Is the Universe Closed? Are Clusters of Galaxies Gravitationally Bound?

Cosmology is the science of the organization of the universe as a whole. It is undoubtedly the oldest of all the sciences, but only recently has it become subject to discriminating observational tests. The questions that are being put to test concent the problems of whether the universe is open or closed, whether it originated in a "Big Band" creation, whether it oscillates from one Big Bang to another, or whether it exists in the steady state. X-ray astronomy is perhaps unique in its potential to answer some of these questions.

The question of an open or closed universe is particularly intriguing to cosmologists. In the "Big Band" model, which is the presently favored theory, the universe was originally condensed in a primordial fireball which explosed and expanded into space. As the expansion continues, gas condenses into galaxies of stars which continue to separate from each other, filling an ever expanding universe. Whether the expansion continues forever while stars die out and all the cosmos grows dark and infinite, or whether the expansion slows down and eventually reverses until all the masses return to a new fireball, depends critically on the total mass of the universe. All the stars and all the galaxies add up to only three percent of the required mass for a closed universe. Cosmologists suspect that the missing mass is contained in very dilute gas that fills the vast spaces between the galaxies. X-ray astronomy may be the only means of detecting this invisible 97 percent of the universe.

Three years ago, the Naval Research Laboratory rocket astronomers detected a diffuse background of low energy x-rays (about 1/4 keV) which they interpreted as evidence of hot intergalactic gas at a density of about 3 atoms per 100 cubic feet of space (10^{-5} atoms/cm^3) at a temperature of about a million degrees. This amount of gas thinly spread through all the reaches of the universe would barely suffice to bind the universe by gravitation. On a time scale of about 80-billion years the universe would expand from the explosion of the primordial fireball to a maximum size and then collapse to the original fireball configuration. The present epoch is estimated to be about 10-billion years into the expansion phase.

It is estimated that, perhaps, 90 percent of all the galaxies are grouped in clusters. Although the NRL astronomers attributed the very soft x-ray background to hot intergalactic gas, they recognized the possibility that the gas may be condensed in clusters of galaxies. If that were the case, the total amount of gas required would be only one-tenth the critical mass for a closed universe. To probe this question x-ray instruments aboard two Aerobee rockets were pointed at the large and distant clusters of galaxies in Coma and Virgo. Each cluster contains thousands of galaxies which presumably radiate x-rays like our own Milky Way. The observations revealed x-ray fluxes about 20 times as great as would be expected from the individual galaxies, and the NRL astronomers suggest that this excess is produced by hot gas within the clusters. The mass of gas within each cluster appears to be no greater than that in intergalactic space, but its temperature is much higher—greater than 8-million degrees. As a result of this high temperature, the x-radiation of higher energy, about 2 keV, and is distinct from the very low energy x-rays which have been attributed to intergalactic gas.

The new x-ray evidence for the Coma and Virgo clusters raises some intriguing questions about the nature of clusters of galaxies. It has generally been assumed that clusters of galaxies are gravitationally bound—that they are condensing—yet the total mass of stars involved is only a few percent of the required gravitational mass. As in the case of the universe at large, astrophysicists have attributed the binding to gas which fills the volume of a cluster.

The x-ray observations suggest that the amount of gas is about 50 times less than required to bind the Coma cluster. If the required mass is not present in visible stars or in gas, it has been proposed that it may take the form of black holes. This hypothesis would require that the earliest generation stars were very massive and that they evolved to black holes in the first eon of the universe.

Alternatively, one may take the x-ray evidence to indicate that the Coma cluster of galaxies is not bound, and that the member galaxies are separating. Each cluster may be the remnant of a little bang, duplicating on a small scale the original Big Bang. The argument for this situation proposes that large irregularities in the form of dense regions are imbedded in the primordial fireball. Theorists call these regions "lagging cores" and endow them with rotation and magnetic fields. When the Big Bang occurs, they are expelled intact as embryonic galaxies, ready to explode at a later time to full scale spirals, ellipticals, quasars, or clusters of galaxies.

The x-ray observations of the Coma cluster are reported by J. F. Meekins, G. Fritz, the May 14 issue of *Nature*. The Aerobee rocket observations were made from White Sands Missile Range on March 14, 1969.

Anti-Germ Disinfectant System

A general purpose disinfectant system developed by Naval Research Laboratory scientists originally for use as an anti-germ agent appears to have numerous applications.

Scientists at NRL report that the materials used in the dual decontamination systems, dubbed ASH and SLASH, are plentiful, safe, effective and inexpensive.

George H. Fielding of NRL's Chemistry Division, who played a major role in the development, said the solution can be readily used to disinfect hospital floors, wards or operating rooms without interruption of normal activities. It can also be used to sterilize food processing machinery and for disinfection of facilities or land areas after contamination associated with natural disasters.

Although the system was designed specifically to kill the most resistant disease-causing spores in a matter of seconds, it is equally effective against a wide range of less resistant microorganisms. In spite of its powerful germicidal effects, the ASH/SLASH System is usable on most areas of the human body, including open wounds.

ASH is an ancronym for activated solution of hypochlorite while SLASH is an acronym for self-limiting activated solution of hypochlorite. ASH, which can be produced at a cost of less than ten cents per gallon, has been successfully used to disinfect at least two dozen different construction materials without evidence or corrosion or other deleterious effects.

SLASH is produced by the addition of an internal neutralizer or self-destructing chemical to ASH, which reduces the hypochlorite to a harmless salt at a controllable rate; SLASH disinfection experiments have been conducted on fully clothed men without irritation to the skin or damage to wool, nylon, cotton clothing or shoes. It has been tested on electrical devices, such as small drills and radios without affecting their normal operations.

Heart Rate Seen as Measure of Mental Alertness

An ONR sponsored research study shows that heart rate variability—an increase or decrease in the interval between heart beats—can be used to measure the state of mental alertness in an individual. The finding stems from an ONR research program conducted by Human Factors Research, Inc. aimed at determining the relationship between the level of mental alertness or vigilance and certain body chemical changes in personnel engaged in vital but monotonous tasks such as radar or sonar display monitoring. It is known that personnel undergo progressive deterioration of alertness while standing such watches, and the ONR investigation is concerned with identifying the causes of such vigilance decrement and ways to prevent such vigilance failure.

The study has determined that vigilance is related to the variability of heart rate, variations that can only be detected by instruments. A constant heart rate variability—that is, a steady lengthening or shortening of the heart beat interval—indicates a high rate of alertness. An erratic change in the time between heart beats, however, such as long intervals followed by short intervals, indicates a decrease in vigilance. The results of this research have been adopted by the Department of Transportation in experiments aimed at utilizing the heart rate variability as an indicator of alertness in motorists and their ability to drive safely.

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A Versatile and Comprehensive Data Description Language

The Moore School of Electrical Engineering, University of Pennsylvania, in an ONR sponsored program, recently accomplished a major goal—the development of a data description language (a new type of computer program) that will serve as a "utility" in computer systems to process data bases or data files of existing formats and organizations, and to produce these data in new desired forms. This work is being carried out in two phases. In the first phase, which is now completed, a data description language (DDL) has been developed which is sufficiently rich and expressive so that it could be readily used to describe the organization format of an existing data base and the structure of a desired data base. The second phase, which is presently starting, consists of the development of a processor (a collection of computer programs) that can accept a file with its description in DDL and produce a new desired file in accordance with the DDL description of the desired file.

The intended use and capabilities are very broad. Some of these are:

1. Integration of files—
2. Extraction of data from files—
3. Creation of new data bases—
4. Reorganizing files—
5. Interfacing of files with new programs and new programming languages—
6. Interfacing files with new computers—
7. Interfacing files to use new devices—
8. Interfacing files with new operating systems and new file management systems—

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Model of two, two-legged modules linked together to form one stable floating platform shows how FLIP-like legs would extend vertically to stabilize platform in open-ocean operations. Two of the two-legged full-scale modules would be towed to an ocean station with legs horizontal. When flooded with seawater the concrete legs pivot downward to a vertical position. The upper ballast tanks are pumped dry and the platform rises above the ocean surface.

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