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RESEARCH REVIEWS

DEPARTMENT OF THE NAVY

WASHINGTON, D. C.

NAVEXOS P-510

Guided by its steering intelligence system, the Talos missile zooms skyward during a recent test at White Sands Proving Ground, New Mexico. See picture set on page 14.

Research in Marine Geology at NEL

Edwin L. Hamilton
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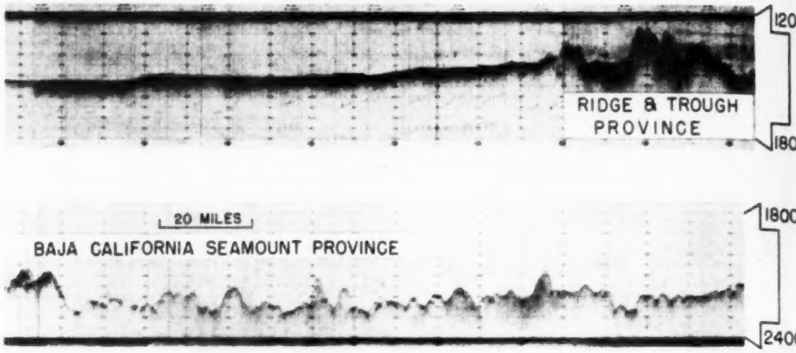
At the present time, the Ocean-Floor Studies Section of the Navy Electronics Laboratory has two functions: (1) to furnish environmental information, such as descriptions of ocean-bottom characteristics (the Section is often called upon to assist other Navy agencies having special problems in this field), and (2) to conduct basic research in marine geology.

Over the past decade, the Section has participated in many expeditions sponsored by the Laboratory or conducted jointly with other institutions. Many of these were with the Scripps Institution of Oceanography, with which the Laboratory has long had a cooperative working arrangement in the fields of oceanography and marine geology. These expeditions have produced much new and basic information on the topography, structure, sediments, and geologic history of the Pacific Basin.

In addition, NEL's marine geologists have concentrated on the study of the mass physical properties of shallow-water sediments, particularly their accoustic properties. To facilitate this and other work, they have utilized the Aqualung; this has led to the establishment of an active program of free diving at the Laboratory. NEL has also developed several deep-sea cameras, and it now conducts the only deep-sea photography program in the Pacific Basin.

In this paper the writer summarizes most of the important unclassified contributions made by Laboratory personnel in the field of marine geology. These studies have been published in NEL reports and in scientific journals.

Until recent years not much was known about the vast bottom of the Pacific Ocean. About the only clues investigators had to go on were a few soundings, most of which had been obtained near the coasts. As the ocean floor is relatively smooth in these areas, the investigators assumed—erroneously—that it was relatively smooth all over and, therefore, that it had not changed much during the millions of years that have passed since the earth was formed.



Reduced echograms showing typical bottom roughness in The Ridge and Trough and Baja California Seamount provinces. Depths are indicated in fathoms. See drawing on next page.

Through ocean-bottom studies carried out by the Navy Electronics Laboratory alone and in conjunction with other institutions, marine geologists have revealed quite a different picture of this huge area of submerged land. These men have shown that only about 10 percent of it is smooth (most of this is on the fringes of the continents and islands and on the surfaces of drowned islands) and that the remaining 90 percent is rough and irregular. They have also shown that instead of "sleeping" these millions of years, the ocean bottom has been very active, undergoing large-scale faulting, mountain building, volcanism, and crustal movement.

THE GREAT FRACTURE ZONES

For a long time, geologists studying the "big picture" of the earth have wondered what the correlation is between the great linear features of the earth's crust. On the continents, unfortunately, these features have been so eroded that little more than "ruins" remain to be studied. Under the sea, however, where the structures have been protected from powerful erosive forces, many more details are revealed. By reference to these, geologists may be able to determine what caused some of the great changes through which the earth has passed.

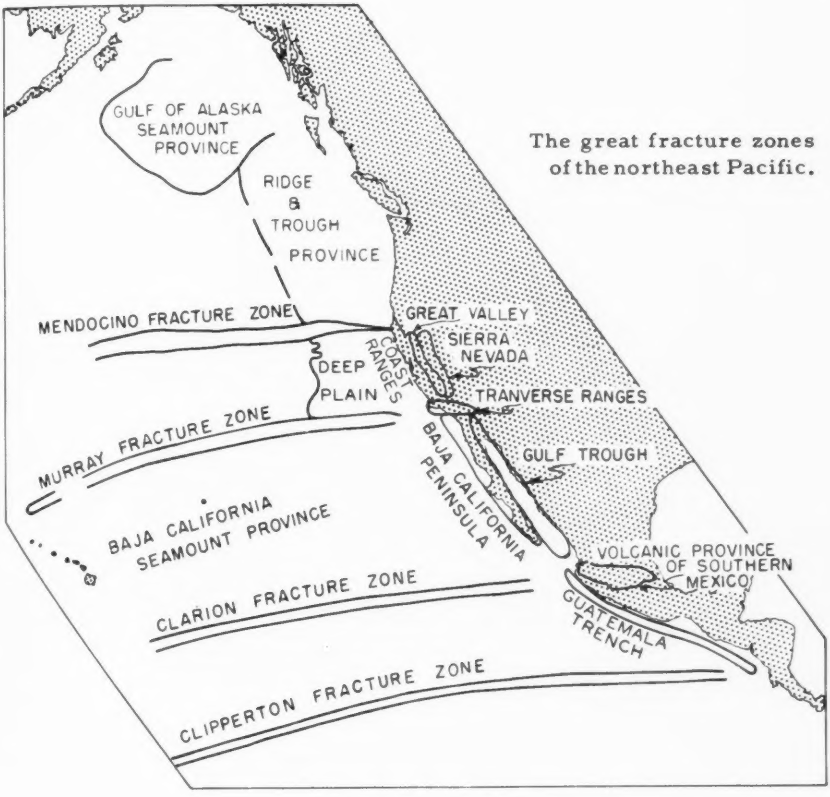
Between 1950 and 1953, Henry W. Menard of NEL discovered four great parallel "cracks," or fracture zones, in the floor of the northeastern Pacific. He found these by studying old soundings and information obtained by half a dozen expeditions dispatched by the Scripps Institution of Oceanography and NEL. The northernmost, called the Mendocino Escarpment, extends westward from Cape Mendocino, California, for more than 1,400 miles. One of its walls is 10,500 feet high. South of this structure lies the Murray Fracture Zone, which can be traced from a point near the Pacific Coast almost to the Hawaiian Islands. This crack may run through the islands and continue into the undersea Mid-Pacific Mountains farther west. Off the coast of Mexico along the

Revilla Gigedo Islands is a third great zone called the Clarion Fracture Zone. It cuts the ocean floor for at least 1,700 miles and is thought to cross the continent along the lines of the volcanoes of southern Mexico. The last zone to be discovered, and the one now being studied most intensively, is the Clipperton Zone, which has been traced for more than 3,300 miles. It lies still farther south.

How are these huge breaks in the earth's crust to be explained? Menard believes that they and the great San Andreas fault of California and possibly the Hawaiian Islands were formed as one great integrated fracture system. We can't be sure when this mighty deformation occurred, but it might have been between 150 and 50 million years ago, during late Mesozoic or early Tertiary time in geologic history. Menard mentions two possible causes of the cracking. The first and most likely is the slow movement of great convection currents in the plastic material of the earth's mantle underneath the harder surface crust. The second is the migration of the north pole from a position in India to its present position.

UNDERSEA MOUNTAINS

Some of the first explorers realized that many of the islands of the oceans are the tops of mountains that rise from the sea's floor.



The great fracture zones of the northeast Pacific.

Most of the islands in the central Atlantic project from the great Mid-Atlantic Ridge. The Hawaiian Islands are peaks along the top of a great submarine ridge more than 1,600 miles long. The Marshall Islands are coral caps on great volcanoes. Thousands of other mountains rise from the bottom of the Pacific, but do not quite reach the surface. And scores of others were islands at one time but have sunk and now lie below the sea's surface.

The sunken islands have posed a fascinating problem.

While the transport USS CAPE Johnson made its long voyages across the central and western Pacific during World War II, Dr. Harry Hess of Princeton University—her navigator and later her commanding officer—studied the records of the ship's echo sounder. One day the soundings revealed the presence of a large symmetrical submarine mountain whose top was too flat and too big to have been the crater of a submerged volcano. Later, Hess crossed 19 more of these features and discovered others in the records of the Navy Hydrographic Office. Believing that the flat tops could have been formed only by ocean waves, he identified them as ancient drowned islands. Hess and other scientists who were interested in these features realized immediately that some of the flat-topped seamounts known to occur in the Gulf of Alaska probably were former islands, too.

In 1950, the Mid-Pacific Expedition of the Scripps Institution of Oceanography and the Navy Electronics Laboratory embarked at San Diego in the Scripps' vessel HORIZON for Bikini. On the way, scientists aboard the ship studied the ocean bottom, particularly in an area about 1,000 miles west of Hawaii where, according to Navy charts and Hess' studies, several of these flat-topped seamounts occurred at depths of about a mile.

This voyage resulted in the discovery of the Mid-Pacific Mountains, a mighty submarine range extending from the vicinity of Necker Island in the Hawaiian group to the vicinity of Wake Island. Many of the peaks of the range, the highest of which towers more than 13,000 feet above the sea floor to the north and south, have the peculiar flat tops noted by Hess.

Material obtained by dredging and coring along the tops and upper sides of five of these seamounts provided convincing clues as to the origin of the flat tops. This material consisted of pebbles, cobbles, and boulders of basalt, many of which appeared to have been rounded by the action of rivers or beach waves; and of phosphatized limestone containing an integrated shallow-water reef-coral fauna of Late Cretaceous time (about 100 million years ago); from one dredge haul, both reef coral and sandstone were collected. As a result of these discoveries, an important conclusion was drawn: during the time when dinosaurs still roamed the continents this undersea range formed a chain of islands.

Here's the sequence of events that may have led to their formation and disappearance: During Cretaceous time the sea eroded the projecting peaks of the chain to flat surfaces. Reef coral larva drifted to the islands, probably from the east, and lodged on and among the erosional debris. In the warm tropical surface waters enough of the corals grew and accumulated to form banks, but not enough to conceal the rocks and finer sediment and to form atolls. Probably as a result of adjustments of the earth's crust, the great range sank, at first fast enough to kill the reef coral, then more slowly, until the present depth was reached. There it remains—the oldest uneroded group of mountains known on earth—disturbed only by weak currents and the slow rain of tiny organisms from the waters above.

Studies made on six of the expeditions sent into the Pacific by NEL and Scripps since 1950 have shown that the ocean bottom has also sagged around the Hawaiian Islands. These islands, like the peaks on the Mid-Pacific Mountains, lie along the top of a great ridge. The southern part of this ridge is flanked on both sides by great deeps, beyond which the ocean floor is bent into two great arches. Soundings made across the arch on the east side of the ridge indicate that it has been faulted, that it slopes more steeply to the west than to the east, and that it is about 200 nautical miles wide and as much as 3,000 feet high. NEL geologists believe that these deeps and arches were formed as the result of the elastic down bowing of the earth's crust which occurred in response to the great weight imposed on it by the Hawaiian Ridge.

Other impressive groups of submarine mountains rise from the floor of the Gulf of Alaska. As the result of several NEL and Scripps expeditions to the Gulf it was learned that at least 35 major seamounts, some as high as 12,400 feet, rise above the smooth, gently sloping floor of the ocean in that area. These have been divided into two groups. Those of one group are volcanoes, many of which have flat tops indicating that they, like the flat-topped seamounts farther south, were eroded at the sea's surface when the seamounts were islands. The other group consists of peaks on low ridges. Dredge hauls and cores indicate that the entire floor of the Gulf, including the tops and sides of the seamounts, is covered by glacial debris. This material was rafted by ice over a widespread area of the northeastern Pacific during the ice age.

CORAL ATOLLS

Much has been learned about the formation of atolls in the Pacific Basin since World War II. Most of this new knowledge was obtained in 1952 during a large-scale survey that was made of the atolls and flat-topped seamounts in the northern Marshall Islands to determine their suitability as a proving ground for atomic bombs. As a part of this work, holes were drilled to depths of 2,556 feet on Bikini Island and to 4,222 feet on Eniwetok Island. (Research Reviews, June 1955.) Rock and fossils obtained from these holes and from Sylvania Guyot, a flat-topped seamount near Bikini Island, as well as data obtained from geophysical work done in the Marshalls, give definite proof that the coral atolls of this area are calcareous caps on great volcanic mountains—mountains whose tops were once at or near the sea's surface.

Studies of the fossil material collected indicate that corals began to grow on the tops of these islands during late Cretaceous and early Tertiary time. Coral growth kept pace with the slow sinking of the islands, which occurred later, thereby forming the atolls we see today. If submergence of the flat-topped seamounts of the Mid-Pacific Mountains

Ripple marks at a depth of 4,500 feet on Sylvania Seamount, Marshall Islands, as photographed by a deep-sea camera. The sediment is globigerina ooze; the rocks are volcanics. Bottom edge of photograph represents a width of about 6 feet; top edge, about 7-1/2 feet.

Deep-Sea Photography

The history of deep-sea photography began in about 1938 when Dr. Maurice Ewing and his associates at Columbia University and other investigators at Woods Hole Oceanographic Institution began to experiment with cameras which could photograph the ocean bottom at depths divers were unable to reach. The first experiments were with free-floating cameras. After being dropped overboard, these cameras sank to the bottom, took pictures, released ballast, and finally floated to the surface. The "Ewing camera" and modifications thereof were successfully lowered thousands of times by Columbia University, Woods Hole, Scripps, and NEL.

Since World War II, new cameras have been developed by the Lamont Geological Observatory, Woods Hole, the University of Southern California, and NEL. Most of these models are designed to be lowered on wire lines.

NEL has developed several cameras. One of these—a Robot 35-millimeter camera designed by Carl J. Shipek—was built to be operated at depths as great as 20,000 feet. As this camera weighs only 125 pounds in water, it can be lowered on the 3/16-inch wire carried by most research ships. The camera and its electronic flash tube are housed in forged aluminum cases attached to a light steel frame. Hanging from this assembly is a free-swinging lead weight, which, upon touching bottom, activates an electrical tripping switch. The camera can take as many as 24 pictures during a single lowering if it is alternately raised and lowered at 30-second intervals. A special electrical system lets the camera operators know the instant the camera touches bottom. The greatest depth at which a picture has been taken with the camera so far is 13,062 feet; this picture was taken off the Pacific Coast near San Diego. Many excellent shots have been taken, particularly around the seamounts in the northern Marshall Islands and off Clipperton Island in the east-central Pacific.

had been more gradual, coral growth would have kept pace with it, too, and would probably have formed atolls similar to those at Bikini and Eniwetok.

An important problem in connection with the formation of atolls is whether the sea floor sank or the ocean level went up. Most marine geologists now think that the sea floor has subsided, but a small number believe the ocean volume may have increased enough to explain most of the relative sinking of the seamounts. If the latter theory is correct, a 30-percent increase in volume of the oceans must have occurred during the last 100 million years. Assuming that subsidence did occur, there remains the question of whether the entire floor of the central Pacific or only the individual seamounts, groups of seamounts, or mountain ranges sank. Most evidence points to local and regional sinking.

SUBMARINE CANYONS

Beneath the shallow waters at the edges of North America and other continents are numerous great canyons, many of which are aligned with the courses of streams that pour into the oceans from the continents. As some of these features are as large as the Grand Canyon, geologists have been hard pressed to account for their origin. For one reason or another, none of the explanations put forth is entirely acceptable. It has been suggested, for example, that they were eroded by streams, But for this to have happened, the sea level would have to have been many thousands of feet lower than it is now, a condition most geologists do not

Scientific Diving

The most important new tool being used to facilitate studies of the shallow-water fringes of the seas is a self-contained underwater breathing device called the Aqualung. Although the device was developed primarily for use by sportsmen—for underwater hunting, for example—scientists soon discovered that it could serve some of their purposes, too. Consequently, these men—biologists, ecologists, and marine geologists for the most part—began adapting the new technique to their own ends. So successful were they that today programs of scientific diving are being undertaken by many government and academic institutions.

Marine geologists at NEL began using free-diving techniques in 1951. Since then they have expanded their applications of the technique and now use it in a variety of research programs that require them to descend to depths as great as 100 feet. (See photograph on front cover.) In the summer of 1953, NEL's marine geologists completed the first underwater geologic mapping job to be undertaken in the United States. This work was done off San Nicholas Island, California, for the Naval Ordnance Testing Station. Another study carried out recently by means of free-diving techniques was of the correlation of the physical properties of marine sediments with the velocities of sound waves passing through them. Other work done by NEL divers on the sea floor includes studies of minor structures, such as ripple marks, and studies of underwater weapons and other equipment. The divers have also taken many fine underwater photographs, both with still and motion-picture cameras.

believe existed. Another theory holds that the submarine canyons were eroded by turbidity currents—layers of moving water that contains suspended sediment; the sediment gives the water a higher density than surrounding waters and causes it to flow down ocean-bottom slopes.

Marine geologists at NEL have shown that deposition by turbidity currents explains the existence of many natural levees off the West Coast of North America. They have also shown that the type and distribution of much of the minor topography in the northeastern Pacific Basin can be correlated with turbidity currents. Those areas connected to the continent by gradual slopes have smooth plains formed by sediments deposited by turbidity currents while those beyond basins and troughs remain rough and irregular, presumably due to the fact that turbidity currents are trapped by them before they have a chance to smooth the terrain. In addition, NEL geologists believe the currents may have formed smooth deep-sea fans and delta-like slopes at the mouths of many submarine canyons.

As we do not yet know how important a role turbidity currents play in submarine-canyon formation, and as no other entirely acceptable explanations have been given, the canyons remain an enigma. It may be that some process not yet known to geologists is responsible for them.

CONTINENTAL SHELF AND SLOPE

Extending many miles seaward from the shores of the continents are gradually sloping plains called continental shelves. At varying distances from the shores these shelves end abruptly in steep slopes that descend to about 12,000 feet to the floors of the oceans. Until recently, the shelves were thought to consist of sediments poured into the sea by streams.

Using recently obtained echo-sounder profiles, Robert S. Dietz and Henry W. Menard of NEL made a study of the abrupt change in slope at the outer margin of the continental shelf. As a result of this work they were able to show that the old concept of "wave base" is erroneous. During the ice age, they believe, the ocean bottom in the vicinity of the shelf break was within 30 feet of sea level because of lowered sea level during that time. Thus the ocean bottom in the vicinity of the shelf break was put in a position to be cut by ocean waves. According to the NEL geologists this bottom consists of solid rock instead of sediments, as was formerly believed. As the solid-rock shelf was cut, the resulting debris was deposited at the foot of the slope. Dietz believes that sediments have been accumulating here since the ice age, causing some down-bowing of the earth's crust in those areas. Eventually, he thinks, the apron of sediments will cover the entire slope.

The great floor of the Pacific Ocean is probably the largest "unknown" piece of land remaining on earth. It is so vast and sounding lines are so few, no thoroughly accurate and complete charts have been made of it, except in local areas, particularly along the coasts. Thus almost all investigations that are being undertaken now and that will be undertaken for many years to come will be of a pioneering type and, therefore, likely to yield much new information.

We have really only just begun our work here.

Foundations of 'Exotic' Fuels

Research Staff
College of Engineering
New York University

The motorist driving up to some gas stations these days finds three, instead of two, types of fuel on sale. The third, "super" gas, is intended for use in engines with higher horsepower and torque. But "super" gas for the road is as nothing compared with what E. V. Murphree, former czar of the nation's guided missile effort, recently called "exotic types of fuels or propellants."

"Exotic" fuels are made up of materials that give a higher thrust or specific impulse per unit weight than those of conventional fuels, such as gasoline and kerosene. As high specific impulse depends both on a high heating value per pound of fuel and a low molecular weight of exhaust products, only light elements such as hydrogen, beryllium, and boron meet the specifications. For several reasons, boron appears to be the most promising element of the group, and a good deal of work has been done both in this country and abroad on the boron hydrides, which are compounds of boron and hydrogen. Despite the fact that such compounds are expensive and hard to handle, the Navy feels that their

Referring to a model of the first jet-assisted take-off unit, Dr. Paul F. Winternitz points out rocket-motor components. A, nozzle; B, expansion tube for temperature differential; C, cooling area; D, injectors for fuel and oxidizer. Rocket motors of today have the same basic design as this product of the 1940's.

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superior performance will justify their use. New York University has played an active role in synthesizing and evaluating these high energy fuels, much of it on Navy sponsored projects. The work is being done in a new specially designed building near the University Heights Engineering campus, and also at a field station in Carlstadt, New Jersey.

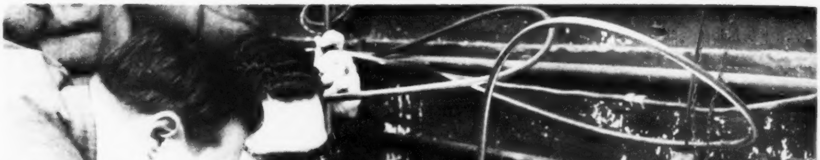
Researchers are concentrating on three areas:

- Combustion properties of jet fuels.
- Improved liquid and solid propellants for missiles and rockets.
- Evaluation of monopropellant fuels.

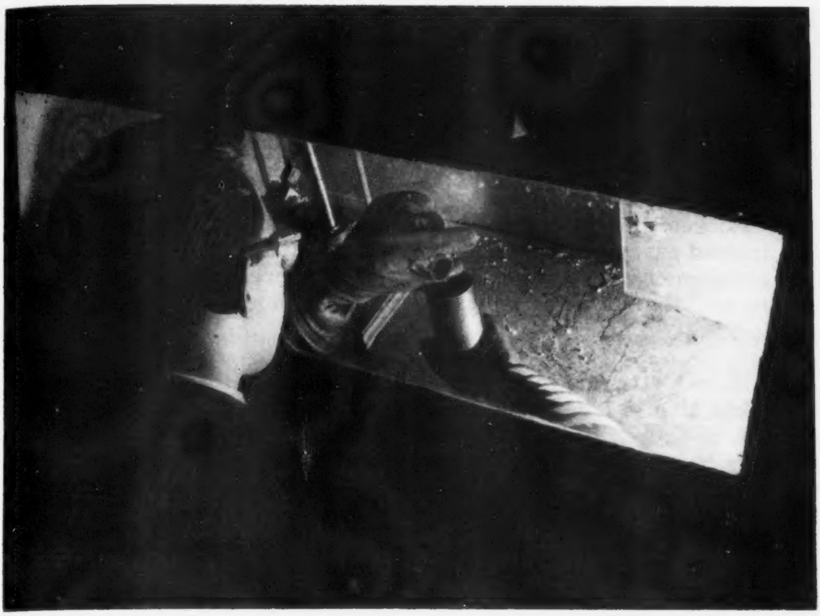
COMBUSTION

We are now getting about all we can out of conventional fuels—they are about 90 to 95 percent efficient. But we are not yet getting all we can out of "exotic" fuels, despite the fact that they have excellent properties. Their efficiency must still be raised considerably.

Because of the high speeds of new jet aircraft and rockets, the rate and pattern of fuel burning are major problems. Space requirements



Ignition and combustion studies include the removal by scrubbing of solid particles from an aerosol gas stream. Left, Dr. Charles J. Marsel; right, assistant engineering scientist Norman Plotsky.



"Dry box" is used by research assistant to transfer an air-sensitive fuel to a pressure bomb, where it is tested for impact sensitivity. The safety chamber has an inert (nitrogen) atmosphere.

dictate that the fuel combustion area be as small as possible. At the same time, considering air-breathing engines like the ramjet, the air flow must be distributed evenly. Under such conditions as turbulent flow, thin air, uneven flight path, and pitching, the air flow is apt to be erratic. Therefore, fundamental studies of combustion by Engineering Research Division investigators aim at finding clues to more even flame patterns, which will give more efficient combustion.

In a jet engine, burning can be affected in several ways. It is affected by the system for injecting the fuel and by the design and geometry of flame holders—mechanical devices inserted in a combustion flow zone to anchor the flame and stabilize combustion. It is also affected by the placement, design, and number of nozzles. While it is not necessarily desirable that injectors act as a perfect atomizer, they must spray the fuel into the air in a very complex manner if burning is to be efficient.

Among the experimental facilities used by NYU researchers is a special pyrex glass combustion wind tunnel in which a vacuum and air flow are created by an Allison engine. By changing the arrangement of nozzles each time conventional and new experimental fuels are injected into the tunnel, the burning characteristics of the fuels can be closely scrutinized. High-speed cameras (2,000 frames per second) permit detailed examination of flame velocity and ignition.

OXIDIZERS

Ramjets and turbojets are air-breathing engines. They are used for some manned aircraft and such long range missiles as the Snark and the Navaho. Most missiles, however, and the most advanced aircraft are rocket powered. Rocket power plants give the highest concentration of energy. For example, the best jet engine, which provides 10 horsepower per pound of engine, would be inadequate for such aircraft as the Bell X-3. Before that experimental rocket plane crashed last September it probably reached a record speed of 2,200 miles per hour. Rockets must provide about 500 horsepower per pound of engine.

Rockets do not use the air as the oxidizer for burning their fuel, but instead carry along their own oxidizer. This not only complicates the problem of weight conservation, but also presents obvious handling problems, the conventional oxidizers being liquid oxygen and fuming nitric acid.

When NYU a few years ago took on the task of improving oxidizers, it looked like a "seemingly hopeless" task simply because most compounds of oxygen had already been made. So observes Dr. Paul F. Winternitz, who, with Dr. John Happel and Dr. Charles J. Marsel, heads the Engineering Research Division program. But he says that important chinks have now been made in the wall of hopelessness.

LIQUID PROPELLANTS

Some time during the IGY a spectacular demonstration of "exotic" liquid rocket propellants in action will be made—the flight of the three stage Vanguard vehicle for the artificial earth satellite. The enormous fuel requirements for the Vanguard may be glimpsed by the fact that it will need a thrust of about 27,000 to 28,000 pounds and an orbital velocity of 25,000 feet per second. Writing on the chemical fundamentals of satellite flight in the September 1956 issue of the "Journal of the American Astronautical Society," Dr. Winternitz notes that the propellant system should, in addition to having high chemical energy per pound, have "satisfactory ignition and combustion properties, good stability, and high density, be compatible with materials of construction, and be safe in handling.

"We like to avoid premature starts which take rockets and operators on an unscheduled trip to heaven or somewhere else."

To avoid such "starts," NYU has devoted one phase of its program to the evaluation of compounds prepared here and elsewhere. Among the ways investigators test the compounds is to drop weights on tiny samples; this enables them to determine the impact sensitivity of the materials. They also subject the fuels to a wide range of temperatures to measure their thermal stability.

SOLID PROPELLANTS

Solid propellants, which provide power for both missiles and rockets, but not for manned aircraft except as "bumbers" on jet-assisted take-offs, present considerably less handling and stability hazard than do liquid propellants. There are two types—double base and composite. Double-base propellants are homogeneous mixtures of nitrocellulose and nitro-glycerine, with oxygen supplied by the nitro group. They are mixed with materials that plasticize the combustible components and make burning faster and smoother. In composite propellants the oxidizer is not an integral part of the molecule. Composite propellants consist of organic materials usually mixed with such oxidizers as potassium nitrate, potassium perchlorate, and ammonium perchlorate. Some of these deteriorate rapidly; therefore, research at NYU is directed toward more stable high-energy compounds, principally in the perchlorate family.

Solid fuel oxidizers were originally mixed with asphalt. Currently, research is turning to rubberlike hydrocarbon polymers that not only serve as fuel but also as binders between the fuel and the oxidizer. Organic binder systems with high energy per pound and with elastic properties capable of resisting cracking at low temperatures are now being developed at NYU.

MONOPROPELLANTS

Some jet fuels (propylnitrate, hydrogen peroxide, and hydrazine, for example) are premixed and, therefore, called monopropellants. Their advantage lies not so much in greater energy per pound but in their requirement for only one pumping, metering, and control system. These fuels are particularly appropriate for use in compact rockets and missiles and in units produced in great numbers. NYU's work in this field consists of the evaluation of all research that has been and is being done on these fuels in the United States and of published research done on them in other countries.

Besides low weight and good burning properties, fuels developed for new systems must be suitable for large-scale manufacture, they must not be corrosive to the metals with which they come in contact, and they must utilize economically available materials. To date, most of the work done toward developing such fuels has only military application. However, one can clearly forsee that the military developments of today will have civilian applications tomorrow. Fuels of the type described may very well aid in powering the new fast civilian jets which we will be flying in the near future.

Comprehensive Report on Titanium

The Carnegie Institute of Technology, under contract with ONR, has issued a report on a four-year study of the chemical and thermal properties of titanium compounds. The exhaustive survey is entitled "Properties of Titanium Compounds and Related Substances." It was compiled by Frederic D. Rossini, Phyllis A. Cowie, Frank O. Ellison, and Clarence C. Browne, and contains an appendix prepared by Dr. William C. Arsem of ONR.

The report is for sale for $2.00 by the Superintendent of Documents, U.S. Government Printing Office.

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The Navy Strengthens Its Air Arm

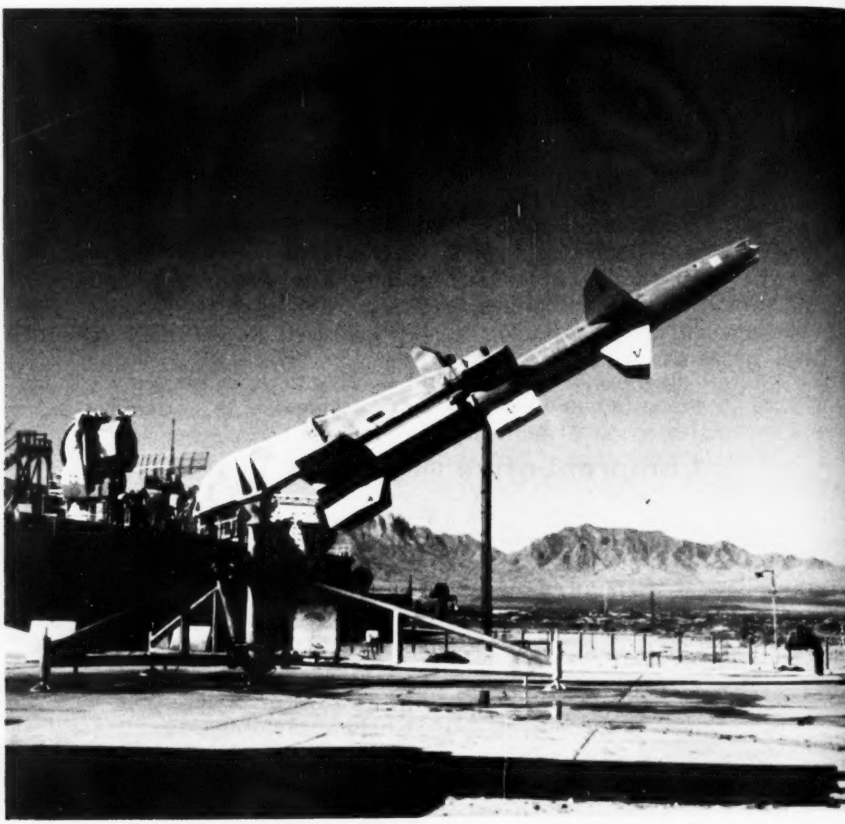
Last month the Navy unveiled the new version of the Talos, a surface-to-air guided missile that can wield destruction on enemy aircraft up to 25 miles from its launching point. Only a few weeks earlier, it unveiled a model of the Bullpup, the air-to-surface missile it is now evaluating. Outside the field of missiles, the Navy has recently disclosed a number of other developments of its air power. These include an inflatable rubber aircraft, a short take-off and landing craft, and new radar equipment for plane and blimp.

The new equipment is illustrated on this and following pages.

● TAL

Talos, the Navy's increased ra
surface-to-air guided miss
has been undergoing exten
flight tests at White Sands Prov
Ground, New Mexico. Thro
the tests, the missile has dem
strated its ability to deliver
high-explosive or nuclear w
head to any altitude an airplan
now capable of flying. The mis
is powered by a ramjet eng
which, although less than 30
ches in diameter, gives the m
sile a velocity of several ti
that of sound.

The Talos poised in launcher at White Sands Proving Ground, N. M.



Trailed by a great stream of fire,
Talos takes off.

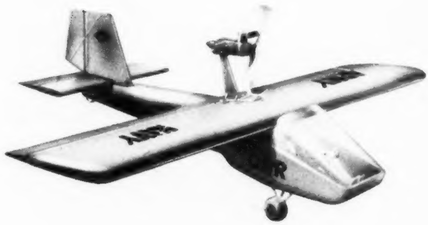
The Talos closes in for "kill" on QB-17 drone.

Model of the Navy's new air-to-surface missile.

● BULLPUP

An 11-foot 600-pound missile to be carried by attack aircraft and fired at small targets on the ground is now being evaluated by the Navy. The Bullpup, as the missile is called, is designed to be launched from positions outside the effective range of enemy high-volume ground fire. The basic idea for the missile was conceived during the fighting in Korea, where pilots flying at low altitudes were often harassed by enemy small arms and automatic ground fire.

The Navy's Inflatoplane, powered by a 44-horsepower engine, flies over Akron, Ohio, during recent tests.

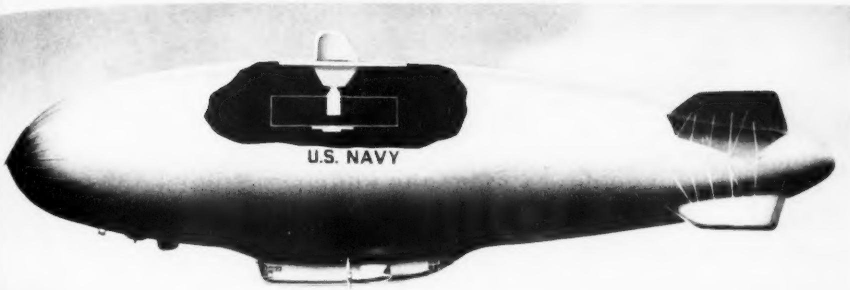


Drawing of two-place Inflatoplane now being developed for the Navy and Army. It will have more power than the model pictured above.

INFLATOPLANE

The wing, tail, and cockpit of the Navy's new inflatable rubber aircraft are made of two walls of rubberized fabric joined by nylon thread. Rigidity is achieved with less air pressure than is required to inflate an automobile tire. The model shown above has already been built and tested. The one shown at right is now in the process of development.

The Navy's new "look of tomorrow" radar plane.



Cutaway view of the radar antenna being installed in the Navy's largest non-rigid airships.

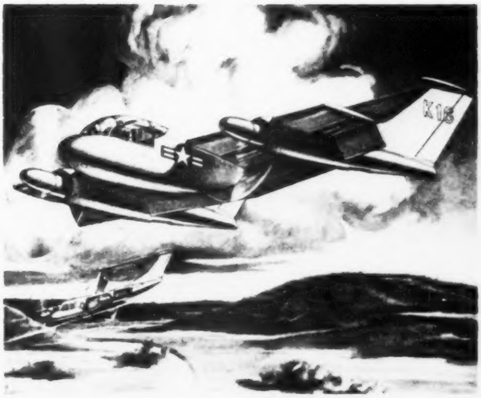
● RADAR BLIMP

Navy airships of the type that recently set new airship endurance and distance records (see Research Reviews, June 1957) are now being equipped with the largest radar antennas ever believed to have been installed on any aircraft. The airship's envelope serves as a radome for the antenna, but does not interfere with its functions.

● STOL

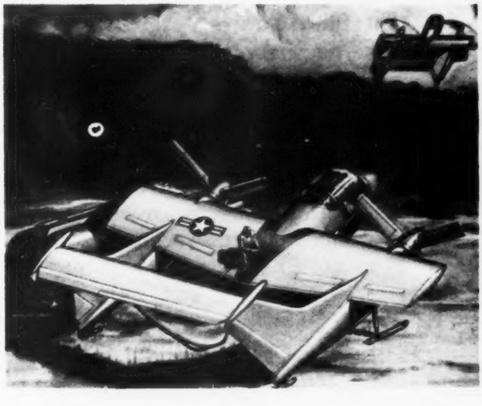
STOL (short take-off and landing) is the name given to a Navy aircraft that will utilize two propellers having small controllable flaps buried in their trailing edges. By means of the flaps the lift characteristics of the blades can be changed so as to give the pilot full control of the plane at air speeds under 50 miles per hour.

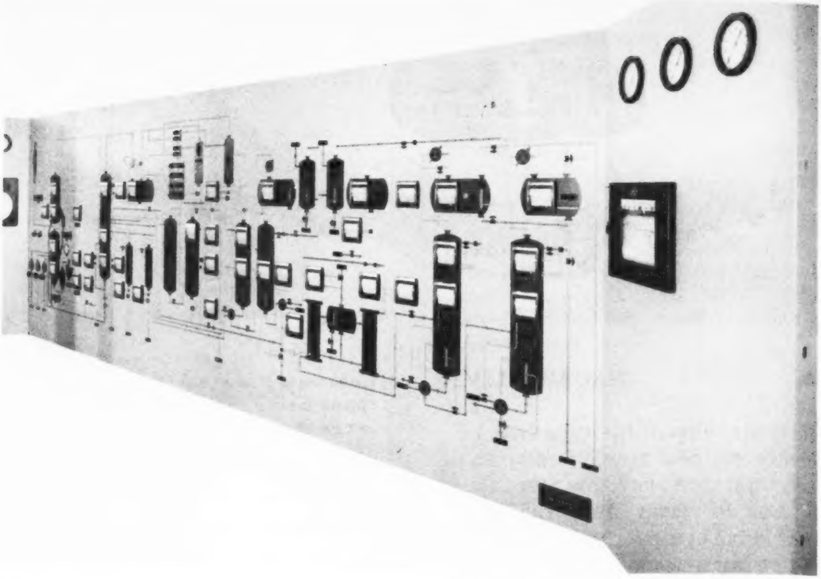
Artist's concept of the new and different STOL.



● RADAR PLANE

This huge new sky sentry, now in pre-production planning, has a "flying saucer parasol," actually a radar antenna. The plane is equipped with four Allison T-56 pro-jet engines and with Westinghouse J-34 Turbojets, attached in wing-tip pods.





The graphic panel—an elaborate scheme for integrating human operation with system requirements. This particular panel depicts the activities of a catalytic cracking unit. Courtesy of the Foxboro Co., Foxboro, Mass.

System Design and Human Tasks*

John H. Hill
Applications Research Division
Naval Research Laboratory

Many types of military equipment have failed to live up to their potentialities simply because their human operators have been unable to carry out the jobs assigned to them. These failures do not necessarily mean that the operators were inefficient. More often than not, they mean that the operators' tasks were poorly formulated or that the operators were not given the tools they needed to do their work effectively.

To get around this problem, human engineers were asked to help build complex military equipment—the idea being that they would give full consideration to the man in the system. But to do this they had to get into the design process at an early stage. Getting in early did not mean simply just before the control panels were designed. It meant before most of the system's components were firmed up—even those that were not to be operated by man, such as the unattended computer. The

*Based on a speech given at the last national convention of the Instrument Society of America.

reason for including the unattended computer in the human engineering analysis was that it might, as a by-product of its primary computation, produce information the operator could use. As this information could not be displayed unless provision was made for tapping the computer, the tapping had to be planned for in advance.

There was one drawback to "getting in early." At that stage the system was only an idea; there was no operation to observe, no hardware to experiment with. With apparently nothing to go on, the human engineer had to find out what tasks the operator would have to perform and what information he would need to perform them.

PROCEDURAL ANALYSIS

The situation was not as hopeless as it appeared, however, and before long, human engineers at the Naval Research Laboratory had developed a technique that could be applied to it. Called procedural analysis, or the operating procedure approach, it can be considered as the operation of a proposed system in imagination. It is based on the assumption that if one goes to the right sources and asks the right questions, he can get enough information about the system to predict much of its operation and indicate problems requiring specific research. In making the analysis the human engineer and design engineer must work together. Teamwork is important here, because each man is dependent upon the other's specialized knowledge.

Briefly, the technique is this:

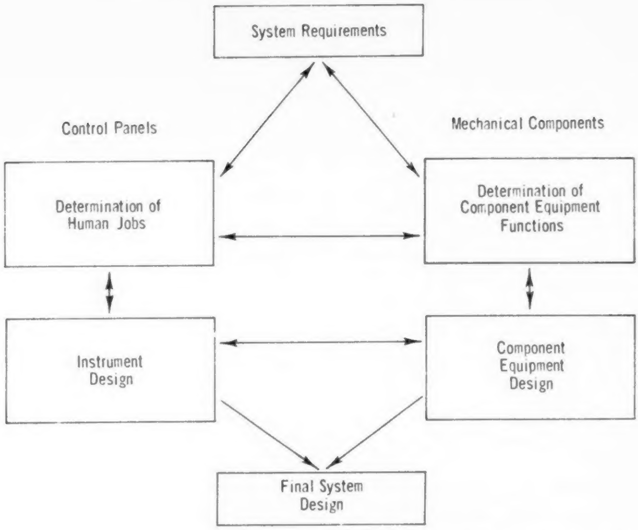
First, the human engineer thoroughly familiarizes himself with the system; he must do this because of the many relationships that exist between equipment design and engineering design (see chart on page 20). Next, he and the design engineer consider the system in terms of the preliminary definition of human tasks and facilities made by the system planners. Having so oriented themselves, they attempt to answer the following question: What step-by-step procedures must the operator perform? If the system requires several operators, the step-by-step procedures of each is written up and indication given of how the activities are coordinated at each stage and how the required information flows from one station to another. Also, the effects of each human operation on the component equipment are noted.

The next step is to examine these procedures in the light of several questions that arise as the procedures are written up. For example:

- What information does the man need from the machine to perform his job? Does the prospective equipment design give him that information?

- Are incompatible activities required simultaneously of the operator? If so, will the system permit a different timing of the operator's activities, or will an additional man be needed?

- In general, is the man being utilized so as to contribute most effectively to the achievement of the system's mission?



Generalized representation of the progression of the design of a system from the original concept to the final plan. Relationships between human operation and system design are indicated by arrows.

Through procedural analysis, the human engineer and design engineer are able to pinpoint problems and get ideas that will help solve them through equipment design. Many of their considerations concern such questions as "is this design feasible?" and "if it is not feasible, what compromise must be made?" Just as an ideal engineering design may be unachievable because of such factors as weight, space, cost, and development time, so an equipment design that is ideal for human operation may be unattainable. For example, there may be equally strong requirements for placing both the most important and the most frequently used instruments in the small central area of a panel. But as both cannot occupy the same space, the human engineer must be ready with second-best solutions. In applying these, he can rely to some extent on the inherent ability of the human to adjust. He should be careful, however, not to try to stretch this adaptability too far.

The chart above, a generalized representation of the progression of the design of a system from the original concept to the final plan, shows some of the relationships the human engineer and the design engineer have to consider. The boxes on the right side of the chart show the stages of design of "mechanical" equipment—that is, equipment that is not included on the control panel. The boxes on the left show stages of design of the control panels. The arrows linking the boxes indicate the effects of one stage of development upon another. That most of the vertically oriented arrows point in two directions is to be expected. They point downward because the progression represented is toward the final design of the system, shown at the bottom; and they point in the other direction because backward steps often have to be taken—for example, if the job proposed for an operator is found to be more than he can handle, certain modifications of the system have to be made.

One conclusion that is easily drawn from this chart is that the design of human-operated equipment affects the design of all the rest of the system. Thus the human engineer must be concerned not only with the control panels themselves, but also with what is behind them; he must consider not only such questions as "Is this the right shape for the knob?" but also, "Is the man who turns the knob really required?" To make such judgements, he must be aware of ways the mechanical equipment can economically do portions of the operator's job or otherwise make his job easier, and, conversely, what tasks the operator can do that will eliminate complex equipment.

Here are some of the problems that arise in considering these relationships. Each is expressed in terms of interactions indicated in the chart.

WHAT IS THE HUMAN OPERATOR'S ROLE IN TERMS OF SYSTEM REQUIREMENTS?

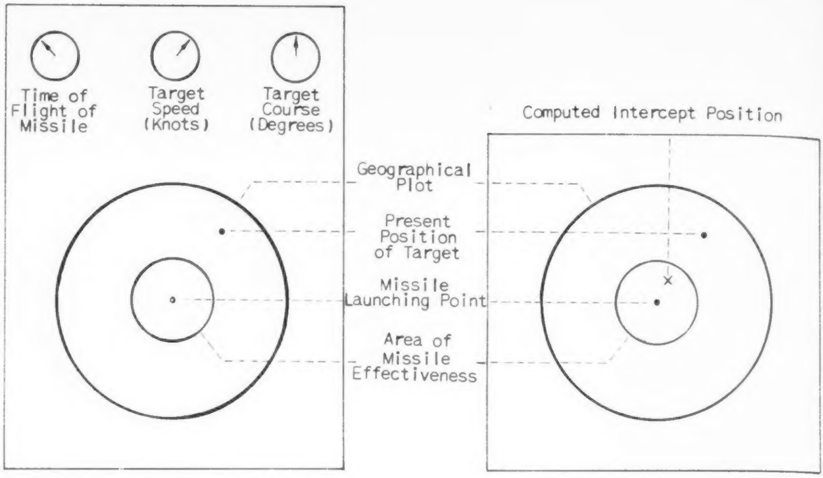
The relationship between system requirements and human jobs raises the question of whether or not the job set up for the operator is humanly possible to achieve. If the job is beyond human capabilities, modern technology can probably find a way to aid or replace the operator. Or, possibly additional personnel can be included in the system to assist him. If these approaches do not succeed, the system requirements will have to be reduced to a level attainable by man. An illustration would be the earliest horn-type anti-aircraft sound detector systems, which were limited by human capabilities. At that time, it would have been foolish to require an accuracy exceeding that of which the operator was capable.

IS THE OPERATOR REALLY NEEDED?

The relationship between mechanical equipment and human jobs raises the question of whether the man or the machine will do the job. Often it is found that very simple mechanical devices can be used in place of an operator. Consider, for example, an instrument panel that was designed to serve as a relay point between a station that commanded operations and the stations that executed them. The panel consisted of lights and switches. When a light flashed, indicating a particular command, the operator turned the switch underneath it, thus sending the command on to the appropriate action station. But as the operator and the panel served only to relay the commands, they were not really needed, and could have been replaced by electrical relays or perhaps by short pieces of wire, permitting the commands to be sent directly. The short cut is both inexpensive to effect and entirely reliable.

HOW HARD DO THE INSTRUMENTS MAKE THE OPERATOR WORK?

A number of principles or guides have been evolved concerning the relationship between human jobs and instrument design. One of them is that information should be displayed in the form in which the operator is required to use it. In other words, the operator should not have to make mental conversions. An example of the neglect of this principle



Two types of panels for displaying target intercept position relative to missile capabilities. In "A", intercept position is inferred from the information presented at the top of the panel. In "B", it is indicated directly.

is the now outmoded practice of graduating optical target-designation equipment in mils instead of in degrees, the latter being the unit used by the spotter to report the target's bearing and elevation. Thus the designation-equipment operator had to convert degrees to mils before he could learn the exact position of the target. By simply regraduating the dials on the equipment, this limitation was removed.

A less obvious example of the relationship between human jobs and instrument design concerns the prediction of an event that is to occur in the future from information presented in terms of the present. In the system in question, a ship's guided-missile officer had to decide whether or not to fire on a specific enemy aircraft. As his decision depended upon whether or not the missile would hit if fired, he needed to know the position at which the plane would be intercepted by the missile, then determine if the missile could reach that point. The diagram above illustrates two types of panels that were proposed to display information the officer needed. "A" shows the instruments used to display information received on the plane's present position, course, and speed. By reference to this information, the operator can calculate the intercept point. But this task consumes time when time is at a premium and, further, it allows chances for error. If, however, the intercept position is computed automatically, as it has been in "B", the officer can determine immediately whether the intercept point is inside or outside the area of missile capability. As the officer is able to make his decision more quickly and accurately by means of the "B" panel, that panel was chosen for the system.

DO THE INSTRUMENTS TELL ALL?

Human engineering that concerns the relationship between instrument design and component equipment design might be considered a checking procedure. It is the determination that all the items of information that the man needs from the machine are actually represented on his instrument panel, and that all the control required by the machine is actually furnished it by appropriate levers or switches on the panel. When considering the controls required, one should be on the alert for redundancy, cases in which the design provides for the human to insert information into the system when the information is already available there. In such cases, the information should be gotten from one source or the other, depending on engineering feasibility and on the need to lighten the man's task.

It may be that the machine produces very important information as a by-product. For example, the display shown in "B" of the diagram on page 22 would not have been feasible if voltages representing the target intercept position did not occur in one of the components of the system. As it turned out, the voltages were found to occur as by-products of certain mechanical computations performed to satisfy system needs irrespective of display considerations. There is always the possibility that the system contains quantities which can enhance the human operation. But to be utilized, they have to be discovered early. The system designer has to be constantly on the lookout for them.

INDUSTRIAL INSTRUMENTATION

Discussions the author has had with people working in the field of industrial instrumentation reveal that industry pays considerable attention to problems revolving around the man in its systems. Recognizing, for example, that men are poor monitors and must be alerted to sources of trouble, it has installed automatic indicators on many of its panels to call the operators' attention to activities that run outside of specifications. It also solicits the viewpoints of experienced operators on proposed panels. This procedure is of some value, but it is limited as a source of new ideas. An experienced operator is experienced because he has been successful with the present design. Consequently, he often feels that the present design is adequate and cannot conceive of any improvements. An analysis of required operations by the design engineer is usually a better means of generating new ideas.

Of course all of the relationships shown in the chart on page 20 exist in industrial systems. However, the one that is receiving the most emphasis is that between human jobs and instrument design. This is indicated by the interest being shown in graphic panels, one of the most elaborate types of control systems.

A graphic panel (see photograph on page 18) is an assemblage of meters, gauges, and controls so placed on a large board as to resemble the flow chart of the process involved. Some graphic panels include miniature instruments and recorders. These are placed within the flow diagrams at the points representing the stages of the flow where the measurements are actually taken. The temperature within a tank, for instance, might be indicated on a meter placed inside the miniature tank appearing on the flow chart.

Graphic panels can be useful or not depending on the extent to which they provide information that will help the operator do his job.

They have the advantage of presenting a good picture of a flow-type process. By reference to this picture, the operator can—if he has the ability—diagnose the cause of an unwanted condition and take remedial action. For some personnel, however, it would be necessary literally to spell out the required action—that is, to place legends beside the indicators telling the operators exactly what steps to take in the event of an off-tolerance reading. If the abilities of the available operators are limited to this extent, the graphic panel would be an unnecessary expense for it would not contribute to effective operation. Another disadvantage of this panel is that it does not permit the display of the controls in terms of frequency of use or relative importance. And still another objection to them is that they require excessive eye travel, particularly the larger ones, which may spread over three walls of a big room.

The question of whether a graphic panel or some other type of display best meets the needs of the system could be answered through procedural analysis. The human operations required by the system would be listed, step by step, then analyzed in terms of panel form. Of course, the study would take into account the difficulties of operation of various panels and the level of skill of operators who could be hired from the local labor market.

AUTOMATION

As more and more technological advances are made, more and more ways are being found to substitute mechanical devices for human operators in complex modern equipment. Thus the question arises, how near are we to complete automation? In talks the author has had with many people working in the field of instrumentation, both inside and outside of government, the general opinion expressed is that complete automation is coming, but that for several years the human will remain in the control loop. It appears, therefore, that the human engineer will be concerning himself more and more with the redetermination of the role the man will play in system functions.

Let it be understood that human engineers do not oppose automation, but, on the contrary, are interested in working realistically toward it. Human engineering analysis of some systems has led to the virtual elimination of human activity. In fact, the principle has been established that a closed-loop man-machine control system should be so designed that the human operator can respond as a simple amplifier. The application of this principle to several military systems has resulted in big improvements in system output.

If a man's task can be reduced to that of a simple amplifier, why not dispense with the man and substitute an actual amplifier? While there are often good reasons for retaining the man in the system, questions such as this are being taken seriously. As a result, the human engineer may eventually put the man out of the system and, thus, put himself out of a job. But the human engineer identifies himself with the advance of technology and, like all technologists, follows this advance and contributes to it with the faith that the ultimate consequences will be good for everybody, including himself.

On the Naval Research Reserve
Seminar in Aviation Medicine

Naval Reserve officers attending Seminar in Aviation Medicine.

The Second Annual Reserve Research Seminar in Aviation Medicine was held at the U. S. Naval School of Aviation Medicine, U. S. Naval Air Station, Pensacola, Florida, from 12 to 26 May 1957. Of the 63 Reservists who attended, 43 belonged to the Navy, 17 to the Air Force, and 3 to the Army. These Reservists represented more than 30 different scientific fields, including the basic medical sciences, biological sciences, physical sciences, social sciences, as well as the clinical sciences of internal medicine, ophthalmology, dentistry, and optometry. In addition, industrial engineering, mechanical engineering, civil engineering, aeronautical engineering, electrical engineering, business administration, law, and architecture were represented.

The Seminar had been planned for such a broad range of scientific and applied interests in order to give non-aviation specialists information on the scientific and operational problems related to human factors in naval aviation.

The presentations covered such subjects as the selection and training of naval aviators, and the physical and physiological stresses experienced by these men in flying high-performance, high-speed, and high-altitude aircraft under all-weather, operational, and combat conditions. Tours were conducted to outlying bases to observe training in basic flight, navigation, communications, escape and rescue, helicopters, and jet operations. A special event was the trip to Eglin Air Force Base for demonstrations of fire power; long-range, high-altitude aircraft; and escape and rescue. A visit was made, also, to the Air Proving Ground Command where planes and ordnance are put to a variety of tests; for example, they are subjected to climatic conditions ranging from those of the tropics and deserts to those of the arctic regions.

One of the most interesting portions of the program was a demonstration of activities of the Navy's Flying Physiological Laboratory by CAPT Norman L. Barr (MC) USN, Deputy Director, Research Division, Bureau of Medicine and Surgery. (The National Geographic Magazine, February 1957, published a complete story on this facility.) Remote recording and transmission to ground stations of the pulse, heartbeat, respiration, and several other physiological functions of a subject were observed both while in flight and while on the ground. Groups of 16 were taken on flights in the Navy's four-engine R5D.

The Seminar was conducted, as last year, by CDR Henry A. Imus (MSC), a member of NRRC 5-10, Naval Medical Research Institute, Bethesda, Maryland.

"Your Golden Opportunity"

"Your Golden Opportunity" was the theme of a float produced through the efforts of Naval Reserve companies of Bartlesville, Oklahoma, in preparation for the 1957 Armed Forces Day. The groups were NRRC 8-8, Petroleum Co. 8-7, and Supply Company 8-10, commanded by CDR Charles G. Cruzan, USNR, LCDR Robert V. Gerner, USNR, and LT Don A. Hartmen, USNR, respectively.

Unfortunately, the float, as pictured, does not include several of the attractions that were planned for it—namely, two beautiful Waves, several sailors, and a bearded prospector. The prospector was to "lead" the donkey and look for gold. The results of his strike (rocks painted gold) are stacked in back of the round sign reading "Join the Naval Reserve."

The City Service Oil Companies financed the venture and members of the Naval Reserve companies (many of whom are employed by Phillips Petroleum Company) supplied the labor to complete the project. While there was much cooperation on the part of the participating groups, there was none from the weatherman, a heavy rainfall cancelling the parade.

Dr. W. F. Pickering, center, discusses a model of the earth satellite with LCDR M. S. Allen, USNR, Commanding Officer, NRRC 11-4, left, and LT D. L. Fitzgerald, Commanding Officer, Naval Reserve Training Center, Compton, California.

Seminar Features Earth Satellite

The scientific program to be carried out by means of the IGY earth satellite was the subject of the final session of a highly successful seminar presented by NRRC 11-4, Compton, California. The meeting was held on 28 May 1957 at the Naval Reserve Training Center in Compton.

Dr. W. F. Pickering, a member of the United States National Committee Technical Panel on the earth satellite program and chairman of the Working Group on Tracking and Computation, discussed the experiments to be performed. With the aid of a complete full-scale model of the satellite, Dr. Pickering described the data to be obtained both from an analysis of the satellite's orbit and from instruments carried by the satellite. Dr. Pickering is the director of the Jet Propulsion Laboratory at the California Institute of Technology.

A second IGY seminar is now being planned by NRRC 11-4. It will consist of two meetings per quarter between October 1957 and June 1958. The exact dates of the sessions may be determined by writing to the Commanding Officer, NRRC 11-4, care of the Naval Reserve Training Center, Compton, California.

Reservists Promoted to Lieutenant Commander

On 24 May 1957 the Chief of Naval Personnel released the list of Naval Reserve officers selected for promotion to the grade of lieutenant commander in the line and chaplain corps by the fiscal 1957 Inactive Reserve Selection Board. The 55 Research Reserve officers who are on the selection list and their respective companies are as follows:

BAILY, David Z.	1-1	DRUMMOND, Kenneth H.	8-3
EPPLING, Frederic J.	1-1	EIDEMILLER, Donald I.	8-3
LICHT, Truman S.	1-1	FRENCH, Richard A.	8-3
ROHSENOW, Warren M.	1-1	HUNTER, Parks C., Jr.	8-3
YOUNGBLOOD, W. A.	1-1	BEST, Frank L.	8-4
ESAU, John W.	3-2	BROOKS, Clyde S., Jr.	8-4
BENZING, Walter C.	4-1	RIDER, John A., Jr.	8-4
BELZ, Lawrence H.	4-2	HUNTER, Robert L.	8-5
VAUGHAN, Robert T.	4-2	FAVRE, John A.	8-8
STECKER, Freeland F.	4-3	GITTINGS, Homer T., Jr.	8-9
COLSON, Henry D.	4-9	JOHNSON, William S.	8-9
HART, John B.	4-11	FITE, Robert C.	8-13
POMEROY, George W.	4-11	WADSWORTH, Dallas F.	8-13
JACOBSON, Keith H.	5-4	NELSON, Eric L.	9-1
CLARK, John F.	5-8	LEAVITT, William G.	9-22
GRISWOLD, Victoria S.	5-8	HAYES, Joy D.	9-24
STEVENSON, John M.	5-8	NEWTON, Floyd C.	11-4
ABRAHAM, George	5-9	LAUCK, Eugene A., Jr.	11-7
AWRAMIK, Joseph, Jr.	5-9	STARRH, Gerald L.	11-9
BIRKS, Laverne S., Jr.	5-9	DAVY, Louis H.	12-1
BRYANT, Robert W.	5-9	AXELSON, John A.	12-3
KEYSER, Russell H.	5-9	FOLLANSBEE, Lewis A.	12-4
SMITH, Herschel L., Jr.	5-9	CALDWELL, Ralph R.	13-1
TOMS, Marian E.	5-9	KNOTT, Donald M.	13-2
HARTMANN, Frederic H.	6-4	SCOTT, Raymond H.	13-3
LINDSEY, Quentin W.	6-6	REIN, James E.	13-6
YARBRO, Claude L., Jr.	6-6	VANHOOMISSEN, John E.	13-6
ROBERTS, Bayard, Jr.	6-15		

"Man of the Year"

CDR John H. Carter, USNR, former commanding officer and now an active member of NRRC 9-8, St. Louis, Missouri, was named Man of the Year for 1957 by the chamber of commerce of Webster Groves, a large suburb of St. Louis.

Mr. Carter, a consulting engineer, is a member of the City Council of Webster Groves and was formerly vice-chairman of the Webster Groves City Plan Commission. He is also an active member of the Board of Directors and the Executive Committee of the city's chapter of the American Red Cross. An active man, Mr. Carter has just completed a survival plan for Greater St. Louis. He did this under the auspices of the Federal Civil Defense Administration.

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LAST MONTH WITH VANGUARD

● A prototype of the U. S. earth-satellite launching vehicle has been delivered to the Navy's Project VANGUARD Unit at the Air Force Missile Test Center, Cape Canaveral, Florida. It will be the first VANGUARD rocket to be test fired (two previous satellite vehicle tests have utilized Viking rockets to simulate the first of the rocket's three stages). It will also be the first rocket to carry the new General Electric 27,000 pound thrust first-stage engine, built specially for the first-stage vehicle.

Before being sent aloft for testing, the rocket will receive a series of ground trials. These usually take from 6 to 8 weeks.

Although the flight test will be intended primarily to examine first-stage flight characteristics, dummy second- and third-stage rockets will be flown also. The dummy rockets will carry enough instruments and ballast to allow realistic performance, thus permitting a study of overall aerodynamic qualities.

The rocket was transported to Florida from the Baltimore, Maryland, plant of The Martin Company, its designer and builder. Laboratory technicians of this company and of the Naval Research Laboratory will conduct both the ground and flight tests.

● The machine that will produce a 'celestial timetable' for the earth satellite as it swings around the earth has been delivered to the VANGUARD computing Center in Washington, D. C. The machine—an electronic processing unit—will require about 1,700 square feet of space in a specially built air-conditioned and humidity-controlled room. The Center will be staffed by mathematicians and other scientists from both IBM and NRL.

Many of the calculations for the satellite could not be made without the high-speed magnetic-core memory of the computer. More than 147,000 tiny doughnut-shaped cores are woven along a complex screen of wires so that electrical impulses can alter their magnetic state. These altered cores will stand for figures or words, much as do the dots and dashes in Morse code.

Dr. John P. Hagen, Director of Project VANGUARD, said "The satellite's orbit will not be a true circle, but will be elliptical; due to the earth's atmosphere and shape, the orbit will change. The services of a high-speed computing center are necessary to sense these changes and to keep track of the satellite so that data can be supplied to observers all over the world to aid them in locating the satellite."

● On 20 June at Blossom Point, Maryland, NRL engineers gave visiting scientists and newsmen a preview of how the VANGUARD satellite will be tracked. An airplane carrying the little 13-ounce MINITRACK transmitter passed over the huge ground antenna system. In simple, graphical form, the visitors were shown how the signals are picked up and recorded.

In This Issue

Research in Marine Geology at NEL .... Edwin L. Hamilton 1

During recent years, marine geologists of the Navy Electronics Laboratory have made some fascinating discoveries of what has been going on, geologically, at the bottom of the Pacific Ocean.

Foundations of 'Exotic' Fuels .... Research Staff, NYU 9

The tremendous speeds achieved by present-day rockets are accounted for by the high heating value of the fuels they burn. 'Exotic'—the name given these fuels—is well chosen, for it means "out of this world."

The Navy Strengthens its Air Arm 14

Recently, the Navy has disclosed a number of developments of its air power. Some of these—the Talos and Bullpup missiles, the Inflatoplane, the STOL, and new radar equipment for plane and blimp—are illustrated here.

System Design and Human Tasks .... John H. Hill 18

In order to assure that the tasks given the operators of complex modern equipment are within the operator's capabilities and also serve system needs to best advantage, the human engineer must get into the design process at an early stage and work closely with system planners.

On the Naval Research Reserve 25

COVER PHOTO: NEL diving geologists, equipped with Aqualungs, investigate a rocky ledge on the sea floor. See insert on page 7 for an account of the work these men are doing.

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