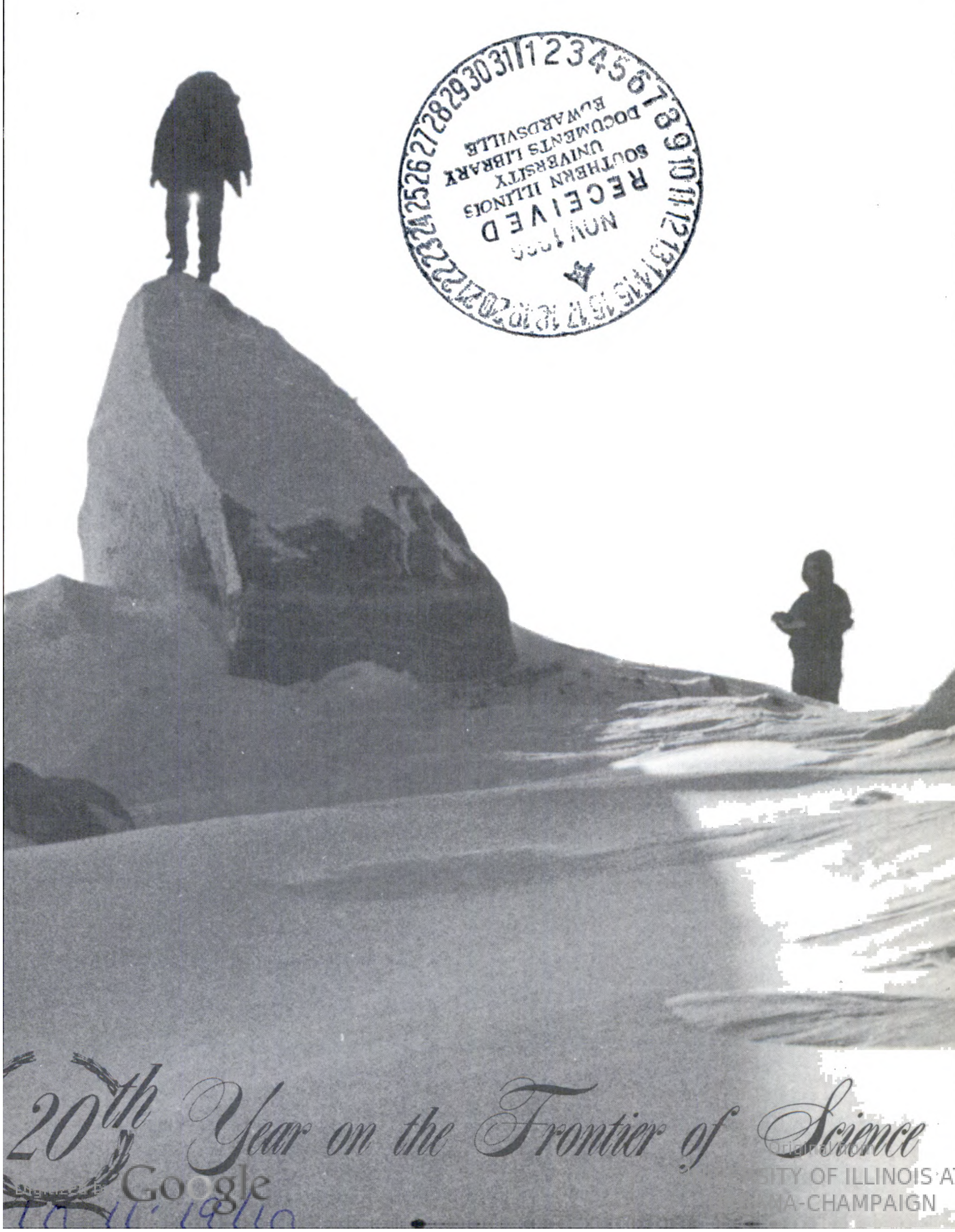
NAVAL RESEARCH

REVIEWS

OCTOBER 1966



20th Year on the Frontier of Science

Ultrareliability Achieved in Communications Equipment

A pioneering research effort directed towards achieving ultrareliability in communications equipment through the use of microelectronics coupled with redundancy and adaptive switching techniques has been successfully completed by the Office of Naval Research. Two experimental all-solid-state ultrahigh frequency transceivers manufactured by two different companies have been operated continuously for ten months for a total of nearly 7000 hours without any significant failures or changes in operation. The two transceivers were chosen as the result of competition among 11 companies in the field.

The exploratory program was generated by the great need by all three Services for ultrareliable tactical communications equipment with a range of ten miles. The Navy research program was designed to determine what are the problems in achieving such hardware and also to advance the state of the art in microminiaturization.

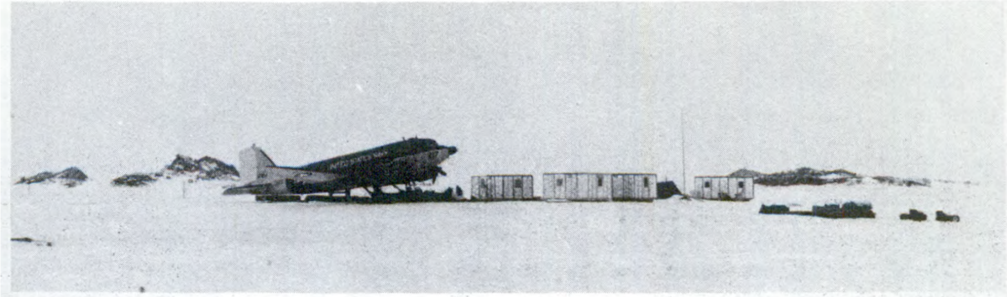
Originally, it was planned to test the two experimental UHF transceivers for two years, or a total of 18,000 hours, with the hope of achieving 98 percent reliability. Although lack of funds made it necessary to terminate the testing program at the end of ten months, there is every indication that this goal would have come close to achievement if the testing has been continued. The success of the program has justified the development of operational hardware utilizing this new approach. Ultimately, it is hoped that a sealed unit can be developed which never will need to be repaired or receive maintenance care.

The Gemini XI Cosmic-Ray Experiment

A cosmic-ray experiment designed by scientists of the Naval Research Laboratory and NASA's Goddard Space Flight Center was carried out successfully on the recent Gemini XI flight. For the first time, a photographic cosmic-ray detector was exposed directly to the energetic cosmic rays in the earth's equatorial regions. Analysis of the results will provide information on the composition and origin of the heavy atomic nuclei that bombard the earth from outer space.

Carried into orbit was a package of sensitive photographic "nuclear emulsion" to record the tracks of nuclear particles. The package was located in the retro-adapter section of the spacecraft. Shortly after launch, a "guillotine" automatically cut a cable that allowed a covering hatch to spring open to expose the detector to the sky. Astronaut Gordon then depressed a switch to start the experiment. Every minute for the next 22 hours, or 15 orbits, a photographic sub-stack moved with respect to a stack above it. This motion provided a time history of the arrival of the cosmic particles.

While passing over the South Atlantic Ocean, Command Pilot Conrad oriented the spacecraft so that interference from the background of Van Allen particles in that area was minimized as the particles entered the stack. When CDR. Gordon opened the hatch for his "space walk," he retrieved the cosmic-ray package and stowed it inside the spacecraft.



ARLIS II's rocky hills, support aircraft, and station huts contrast bleakly with the white clouds and snow of the Arctic Ocean.

Arctic Basin Research

Vicennial Article

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The Office of Naval Research has supported contract research on a year-round basis at Point Barrow, Alaska, since 1947. That year a group of five scientists from Swarthmore College and two from Cornell University began a program of physiological investigation in a 20- by 40-foot quonset hut provided by the Office of Naval Petroleum Reserves, which was exploring the potential of the Naval Petroleum Reserve No. 4. In February 1948, the Arctic Research Laboratory was officially established "to provide facilities at Point Barrow for fundamental research in all appropriate scientific fields related to the arctic environment and to afford facilities as a base for field studies in arctic Alaska." From its beginning, ARL was conceived as a national facility. The charter states, "It is expected that the program will be largely initiated by competent groups in and out of Government and that some will be supported by ONR and some by others." (Shelesnyak, 1948.)

It is difficult to determine exactly the magnitude of the impact of the laboratory in the expansion of knowledge of the Arctic Basin and its environment since scientific groups from many Naval and other government activities have used ARL as a base of operations. ARL assisted all of these groups as well as scientists working under ONR contracts.

If one compares what was known about the Arctic Ocean in 1950 (Figure 1) with the map of current knowledge (Figure 2), he appreciates how substantial have been the accomplishments of the program. Although ARL cannot claim exclusive credit for these accomplishments, it has been associated to some extent in nearly every scientific activity conducted from northern Alaska during two decades.

Figure 1 – Bathymetry and currents of the Arctic Ocean (Sverdrup, 1950, after Wust), as known in 1950.

Sverdrup (1950) who summarized the status of knowledge concerning arctic oceanography in 1950, concludes his article, which theorizes about the circulation, ice drift, and water masses, as follows: "...it should be emphasized that our information about the character of the waters is available only from the Siberian-European side of the North Polar Basin. The larger region north of the American Continent is still unknown."

Early Efforts

To close this gap in knowledge, several imaginative projects were launched by the Navy from ARL and by the Air Force from Fairbanks and Barter Island. The Navy scientists sought two important benefits from research on the Arctic Ocean: (1) to develop a method for

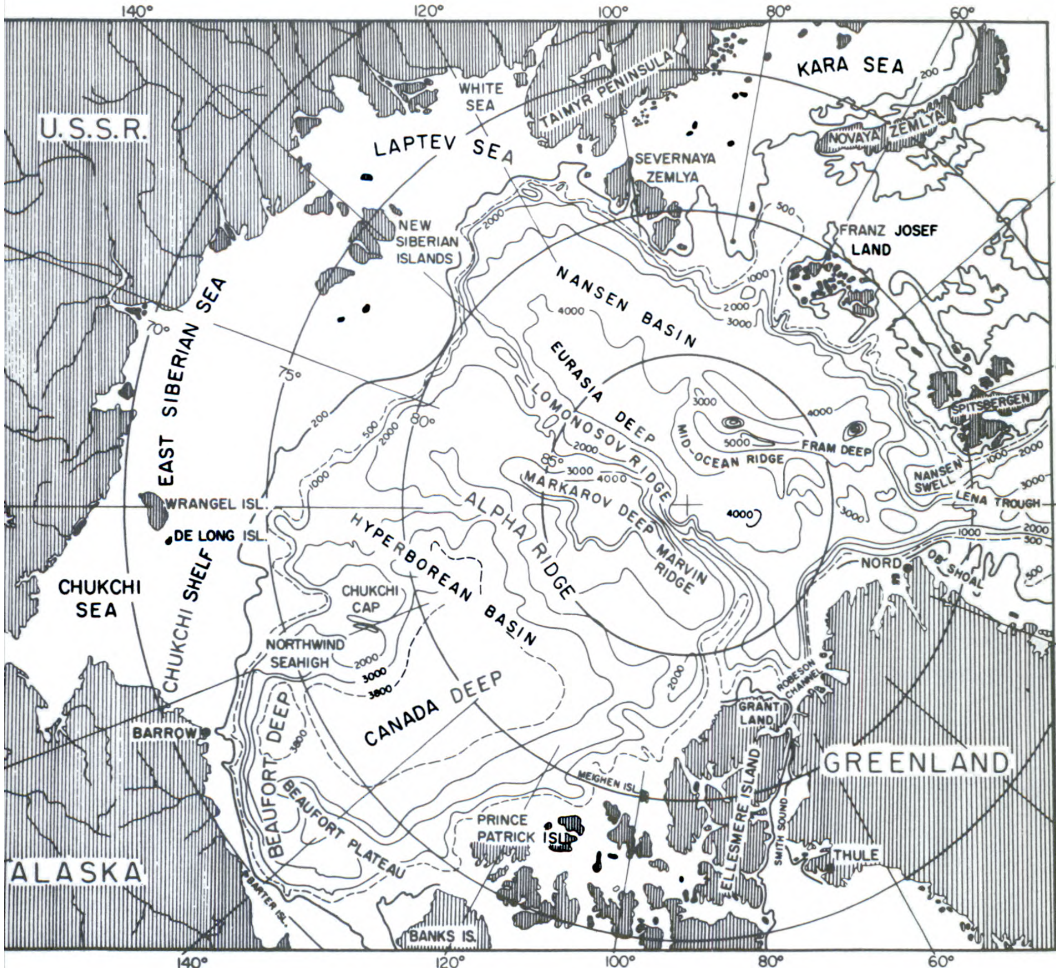

Figure 2 — Bathymetry and physiographic features of the Arctic Ocean Basin (Ostenso, 1962), as known in 1962.

forecasting the extent, character, and movement of the pack ice, which severely hampered passage of the ships that resupplied the Naval Petroleum Reserve camp and (2) to explore the possibility of utilizing submarines in the deep Arctic Basin.

The latter program was sponsored by the Navy Electronics Laboratory under the direction of Dr. Waldo Lyon. In August 1947, BOARFISH maneuvered under the ice in Chukchi Sea northwest of Point Barrow for ten hours in three dives, and in 1948, CARP, which was equipped with a topside fathometer, successfully made vertical dives and ascents in large leads or polynyas in Chukchi Sea and penetrated 50 miles into the pack ice.

In 1949, scientists from the Navy Electronics Laboratory, the Hydrographic Office, and two ONR contractors (Woods Hole Oceanographic Institution and Scripps Institution of Oceanography), began a joint systematic investigation of arctic oceanography, surface meteorology, and sea-ice mechanics. This program of research and instrument development was responsive to the problems of both sea-ice forecasting and under-ice submarine operation. Research was conducted offshore from ARL and from ships and icebreakers.

In the meantime, the Air Force Air Weather Service had inaugurated the Ptarmigan Flights from Fairbanks to the North Pole, recording weather and sea-ice conditions. These surveys were significant to Arctic oceanography because they led to the discovery, by radar observers aboard the planes, of ice islands—large, tabular icebergs afloat in the pack—and to the perfection, by the Hydrographic Office, of the nomenclature and recording and reporting codes for sea-ice observers (Bates and Lill, 1950).

In 1950, a new approach to Arctic Ocean research was initiated. In a joint Air Force-Navy program utilizing a ski-equipped C-47 aircraft of the 10th Air Rescue Service, landings were made on sea-ice and geophysical and oceanographic observations were attempted. The work was, however, frustrated, first by a landing-gear accident and then by the recall of the aircraft to search for a lost plane with an ARL scientist aboard.* Accordingly, the next year ONR acquired a Navy R4-D aircraft from Patuxtent Naval Air Station to operate from Point Barrow, while the Air Force Geophysical Research Directorate continued its operation from Barter Island.

Under the Air Force project, A. P. Crary from GRD and R. D. Cotell and Jack Oliver from Lamont Geological Observatory made six landings on the Beaufort Sea ice pack (Crary and others, 1952). The C-47 aircraft remained on the ice from four to six hours at each landing while sonic soundings, seismic profiles, ice-movement studies, and gravity observations were accomplished.

The ONR project, called "Ski Jump I," under the direction of Woods Hole Oceanographic Institution scientists F. Holmes, William Metcalf, and L. V. Worthington, operated from ARL and established three oceanographic stations north of Point Barrow. In 1952, Ski Jump II was organized on a more elaborate basis. The R4-D was equipped with a lightweight winch that could operate through the floor of the plane. Also, since the area of operation during Ski Jump I was limited by the range of the R4-D, two P2-V aircraft on skis were provided to fly cover and refuel the R4-d laboratory plane. The laboratory plane thus could remain on the ice overnight while the personnel were flown to ARL by a P2-V. In this manner it was planned to establish stations throughout the Arctic Ocean and concentrate observations wherever interesting features were discovered. Unfortunately, the project came to a sudden termination on March 27, 1952, when the R4-D's port landing gear collapsed on take-off from station 8 at 82°22′N, 145°20′W, making necessary the abandonment of the plane and equipment.

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*A chartered aircraft on a flight from Barter Island to Barrow disappeared. No clue as to its fate has been found.

From the meager data obtained from these eight stations, L. V. Worthington (1953) concluded that the circulation pattern of the Arctic Basin is complicated by a clockwise eddy around the Beaufort Sea. He further found that the temperature minimum in the Beaufort Sea (−0.45°C at 2300 meters) is about 0.5°C warmer than that observed on the Siberain-European side. This difference suggested to him a possible separation of the North American basin from the Siberian-European basin by a submarine ridge running roughly from Ellesmere to the New Siberian Islands. Subsequent release of information by the USSR and further research by U.S. scientists have corroborated both of these conclusions.

Russian scientists and aviators carried out observations at more than 200 sites in 1948-49 and discovered and mapped a great submarine ridge extending from the New Siberian Islands toward Ellesmere Island. It has been named after Lomonosov, whom the Russians regard as the founder of arctic oceanography (Webster, 1954).

While Ski Jump II was underway, the Air Force, under the leadership of LTCOL J. O. Fletcher, installed a scientific station on ice island T-3, which then was located near the North Pole (87°54′N, 156°30′W). At this station, A. P. Crary carried out geophysical investigations, and the Air Weather Service operated a weather and upper atmosphere program (Crary and Goldstein, 1957). This first U.S. drifting station was continuously occupied until May 1954, it was briefly reoccupied from April to September 1955 and again reoccupied as part of the International Geophysical Year (IGY) program from March 1957 to May 14, 1960. During this period, T-3 drifted around the periphery of the Beaufort eddy and ran aground north of Point Barrow at 71°51′N, 159°45′W. The results obtained corroborated Worthington's hypothesis regarding both the Beaufort Sea circulation and the presence of a submarine ridge. The ridge discovered from T-3 was later determined to be the Marvin Ridge, which parallels the Lomonosov Ridge.

Perhaps the greatest pay-off from the early work of U.S. scientists in the arctic was the fact that the publication of the findings in the open literature apparently encouraged the Russians to release information on their own activities. The following translated excerpt (USAF Air Intelligence Information Report IR-361-5b, Unclassified, Nov. 15, 1954) is typical of several releases made by the Russians in 1954 that end with the statement "the reports of the American press have no basis in fact":

> *The achievements of Soviet polar flyers, working in cooperation with scientists, are considerable. A major accomplishment of the post-war years was the discovery of "ice islands"; this term was used because of their similarity to real arctic islands. The ice islands consist of ice and drift together with ice movements.*
>
> *The new important research of Soviet polar workers was discussed in a number of foreign newspapers. In this connection, the reports of the American press are quite surprising.*

U.S. newspapers have recently published many stories that the U.S. Air Force allegedly discovered three ice islands in the Central Polar Basin and named them T-1, T-2, and T-3. One of these was said to have been discovered by U.S. flyers in August, 1946, and the remaining two in the summer of 1950. In the spring of 1952, the U.S. Air Force established an air strip and a meteorological station on the T-3 ice island.

In all fairness, it must be stated here that these islands, among a number of others, were discovered and investigated from the air by Soviet polar flyers and hydrologists long before the Americans.

In March 1946, the Soviet pilot, I. Kotov, discovered a large ice island northwest of Wrangel Island; the ice island was located at 76N-165W and was at first assumed to be land. Its dimensions reached 25km. in width and 30km. in length. Subsequently this island was observed by another Soviet pilot, L. Kruze. This was the island later "discovered" by the strategic intelligence of the U.S. Air Force and named T-1.

In April 1948, a Soviet pilot, I. Mazuruk, in the course of navigational patrol, discovered an ice island with the characteristic wavy surface located at 82N-155E. The dimensions of the island were 28 by 32 km. The appearance of the island resembled land. In 1950, this island was observed by Soviet pilots at 87N-155E. The same land, discovered by Mazuruk, was named T-2 by the Americans.

During the March inspection of ice in 1950, a Soviet pilot, V. Perov, discovered a 100 sq. km. ice island northeast of Ostrov Ceralda. Much later, American pilots investigated this island, naming it T-3. Thus, the reports of the American press have no basis in fact.

The loss of the Ski Jump R4-D was a severe blow to ONR's research program in the arctic. Funds were not available in the research program to purchase a new plane, and attempts to acquire one from the Chief of Naval Operations were unsuccessful. Accordingly, for the next four years, oceanographic and marine biological work was confined to the margin of the ice pack, conducted from small craft from ARL and, as opportunity afforded, from icebreakers. A tide station was established at Eluitkak Pass near Point Barrow, and detailed bathymetry of the Barrow Sea Valley as well as analysis of the coastal waters were accomplished by M. Allan Beal of the Scripps Institution of Oceanography in 1955-60. Programs of thermal radiation and drift of sea ice were carried out jointly with the Navy Hydrographic Office and Navy Electronics Laboratory at instrumented sites along the coast and by automatic weather stations on the pack ice.

Alpha, Bravo, and Charlie

Arctic research was immensely stimulated in 1957 by the advent of the IGY. The Alaskan Air Command established two drifting-ice stations for the U.S. IGY program, Station Alpha on April 13, 1957, on a floe at 79°40′N and 159°W, and Station Bravo on March 7, 1957, on Ice Island T-3, then located at 82°46′N and 99°33′W. This support activity was called "Project Ice Skate." Station Alpha was occupied for 17 months before breakage of the floe necessitated an emergency evacuation on November 6, 1958, at 86°12′N, 113°08′W. Station Bravo was manned until October 1961, although the ice island grounded at

71°52′N, 160°20′W, in July 1960. As a replacement for Station Alpha, the Office of Naval Research and the Alaskan Air Command of the Air Force established Station Charlie (sometimes referred to as "Alpha II") at 75°02′N, 158°30′W, on April 29, 1959. This station was also evacuated because of hazardous ice conditions on January 7, 1960, at 76°55′N, 169°04′W.

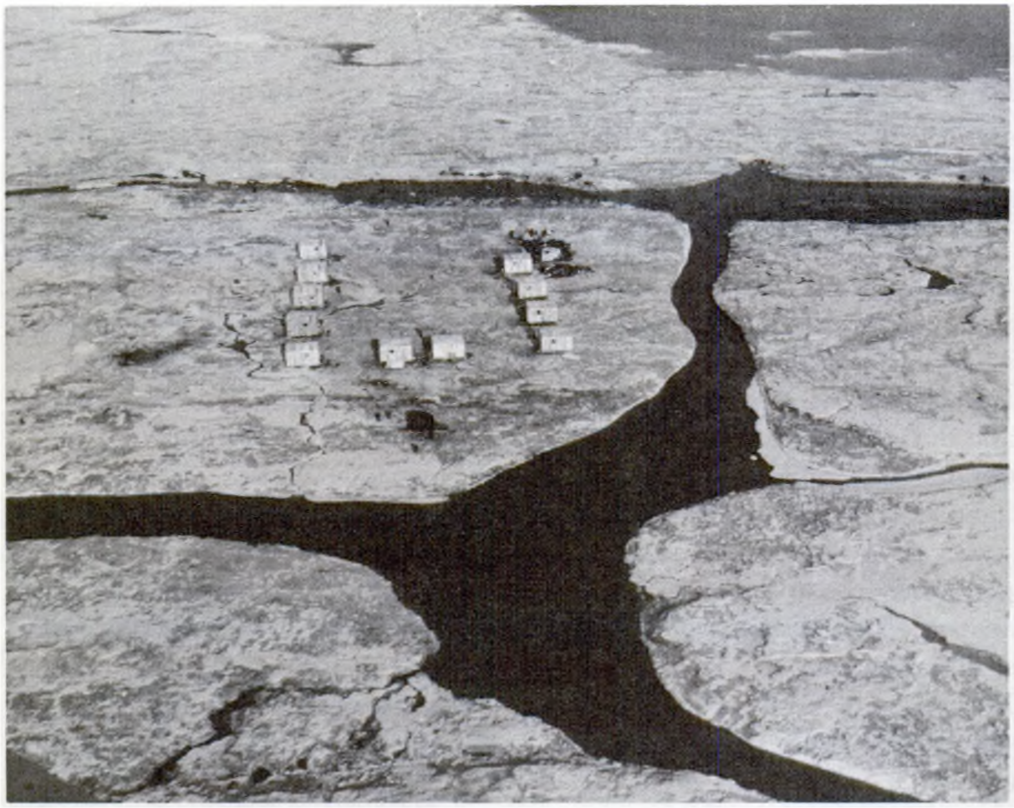
The abandonment of Station Charlie after so brief a period of operation occasioned serious stocktaking on the part of the supporting agencies of the Navy and Air Force. It was concluded that the drifting-ice station was a highly suitable platform for oceanographic, geophysical, and biological research and that much new and significant information about the structure and environment of the Arctic Ocean had been obtained. However, it was clear that either the cost of operation would have to be greatly reduced or some means of prolonging the life of the stations would have to be devised. Obviously, ice islands could provide platforms suitable for long-term occupation, but ice islands are seldom available in the area selected for study. The Office of Naval Research stimulated activity directed to three separate solutions of this problem. It requested the Bureau of Yards and Docks to reactivate a program of sea-ice thickening to examine the feasibility of reinforcing the runway of a floe station; it requested the Bureau of Ships to consider the feasibility of strengthening a ship or designing a barge suitable for freezing in and drifting with the pack ice; and it encouraged ARL to present a plan for operating less complex drifting stations.

The Air Force assisted with the ice-thickening experiments, and thickened air strips were successfully developed, but the high salt content of the artificial ice and fracturing of the ice adjacent to a thickened strip limit their useful life to one season.

The Bureau of Ships' study concluded that the construction of a specially designed barge was preferable to strengthening a surplus ship. Funds for the construction of such a barge were requested in the 1964 budget but were not appropriated. This project was accordingly shelved and is now under consideration by the National Science Foundation.

ARLIS I and ARLIS II

ARL developed a plan of support for drifting stations by civilian-manned aircraft based at ARL, Point Barrow. Thus began the ARLIS (Arctic Research Laboratory Ice Station) series of platforms, the basic concept of which was to keep the logistics as simple and inexpensive as possible. Whereas Alpha, Bravo, and Charlie were supplied by large aircraft based at Fairbanks and Anchorage, the ARLIS stations were supplied by R4-D and Cessna-180 aircraft flown from Barrow, augmented when possible by icebreakers. Also, whereas the so-called "ABC



Jamesway huts
Station Charlie.

"Main Street"
Fletcher's Ice Isla
(T-3), Septemb
1961.

RLIS II in July 1961,
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prefabricated building
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LIS II.

ARLIS I.

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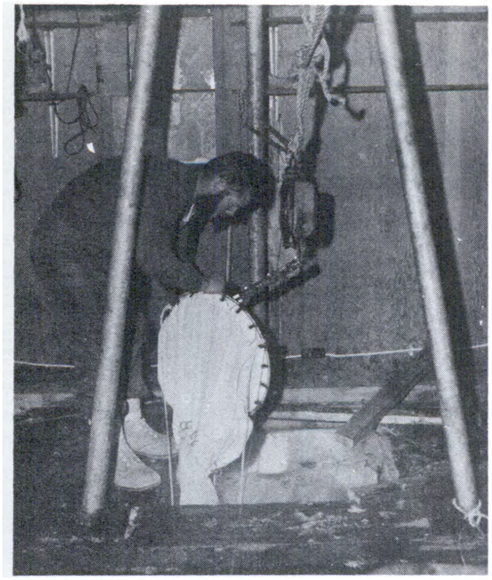
stations" utilized airmen as supporting personnel, the ARLIS stations employed civilian helpers and operated with about one third the number. The ratio of scientists to support personnel on the ABC stations was 1 to 1 or 2 to 1, whereas ARLIS had 3 or 4 scientists per support person. The cost of establishing and supporting the ARLIS stations was an order of magnitude cheaper than it had been formerly.

ARLIS I was established on September 10, 1960, by the icebreaker USS BURTON ISLAND (AGB-1) on an 8-foot-thick ice floe at 74°40′N, 141°06′W. The personnel consisted of six scientists, one cook, and one Eskimo maintenance man. ARLIS I, which drifted almost due west, following closely the 75th parallel, was evacuated on March 18, 1961, at 74°59′N, 169°50′W. Although ARLIS I was occupied for only six months, it was evacuated according to plan, not because of the break-up of the floe. This is not to say that the floe remained intact during its occupancy, but rather, owing to the support by ski-equipped R4-D aircraft, an extensive, prepared landing strip was not required, hence moderate fracturing of the floe could be tolerated. The station was evacuated because it had drifted too far west and apparently would not be caught in the Beaufort Sea Gyral, as had been hoped. Accordingly, it was decided to evacuate this island and establish an ARLIS II in a more favorable location.

ARLIS II was established on an ice island sighted at 73°10′N, 156° 05′W, on May 23, 1961, as ARL aircraft were on route to erect the station on an ice floe selected on the previous day. Although its location was farther south than desired, the relative stability of a thick ice island greatly outweighed all other considerations. The ice island measured 3.25 by 2 miles and was 70 feet thick. Erection of the research station on this stable platform resulted in a modification of the original ARLIS concept of austere stations to be abandoned when beyond the range of R4-D aircraft operating from ARL. In fact, ARLIS II was occupied for four years and drifted more than 4300 nautical miles before it was evacuated by the icebreaker USS EDISTO on May 9, 1965, at 66°43′N, 27°01′W, in Denmark Strait between Iceland and Greenland. During its drift it crossed the international dateline, reaching a farthest-west position of 82°21.8′N, 160°27′E, on September 17, 1962; its farthest-east position was 79°50′N, 5°20′W, reached on December 13, 1965. A total of 101 scientists conducted research at this station during its four-year lifetime. The subjects investigated and the organizations represented by the investigators are summarized in the following list:

- *Airborne sensing of pack ice—Naval Oceanographic Office*
- *Drift of arctic pack ice—University of Washington and Naval Oceanographic Office*
- *Geology of sea floor—University of Wisconsin*
- *Geomagnetism—University of Wisconsin*



Richard Davidson, of the University of Southern California, lowers a plankton net through the ice on ARLIS II.

A hydrophone is lowered into a hole in the ice of ARLIS II to record echoes produced by explosions.

- *Geophysics of Arctic Basin—University of Washington and University of Wisconsin*
- *Geothermal (heat flow)—U.S. Geological Survey*
- *Glaciology and geology of ice island—Louisiana State University*
- *Gravity—University of Wisconsin*
- *Marine biology—University of Southern California*
- *Micrometeorology—University of Washington*
- *Oceanography—University of Washington and Hokkaido University*
- *Physics of sea ice—University of Washington*
- *Seismology—Lamont Geological Observatory and University of Wisconsin*
- *Underwater acoustics—General Motors Corporation and Lamont Geological Observatory*
- *VLF radio navigation—University of Wisconsin*
- *VLF radio propagation—Navy Underwater Sound Laboratory and Lamont Geological Observatory*

ARLIS III and ARLIS IV

Despite the fact that support of ARLIS II was severely straining the logistic capability of ARL and the budget of ONR's Arctic Program, ARLIS III and ARLIS IV were established on ice floes near Barrow. ARLIS III was set up at 73°N, 151°W, on February 7, 1964, and evacuated on May 16 that same year at about 72°50′N, 154°W. ARLIS IV was established on February 25, 1965, at 73°5′N, 151°12′W, and evacuated on May 16, 1965. The R4-D's were used to establish these stations, but thereafter Cessna-180's provided all air support.

These stations were planned for temporary occupancy for specific objectives, generally by two or three scientists and one support person. According to plan, the buildings were abandoned at the time of evacuation of all equipment and personnel, which was performed on schedule by the Cessna-180's.

ARLIS III was established for Dr. Victor Hessler, of the University of Alaska, who conducted a study of telluric currents, geomagnetism, and aurorae. The station was also used by the University of Wisconsin for gravity measurements and by the University of Washington for micrometeorology. ARLIS IV was also set up for Dr. Hessler (see *Naval Research Reviews,* May 1966), but again other programs took advantage of its presence to conduct special studies. No ARLIS station was established in 1966, but ARL is prepared to set up such stations whenever required to do so.

Fletcher's Ice Island (T-3)

As indicated before, the occupation of an ice island required a modification of the "austere station" concept, because such stable platforms are too valuable and rare to abandon. It was only because of the fortuitous location of Fletcher's Ice Island (T-3), however, that ARL, with its short-range aircraft, was able to continue the occupation of ARLIS II until it entered the North Atlantic. T-3 had grounded north of Point Barrow (71°51′W, 160°00′W) and was abandoned by the Air Force in October 1961. On February 16, 1962, the ARL aircraft returning from ARLIS II discovered a major portion of T-3, with camp and air strip intact, adrift at about 74°24′N, 161°18′W. The next day, a three-man occupation crew was flown in by three Cessna aircraft to set up a homer beacon and clear the runway for the R4-D. On February 19th, the R4-D landed with additional supplies, and on April 12, the Alaskan Air Command officially transferred the station to ARL.

During the first two years of occupation of T-3 by ARL only a limited scientific program was conducted there; the ice island served primarily as a staging station for supplying ARLIS II. Figure 3 shows how fortuitous was the drift pattern of T-3 in relation to that of ARLIS II. During 1962, ARLIS II drifted northwestward, crossed into the Eastern Hemisphere, and reached its farthest point northwest of Barrow (82°22′N, 160°27′E) on September 17, 1962. During the same period, T-3 was also drifting northwestward, maintaining a position intermediate between ARLIS II and ARL. T-3 was at 78°45′N and 166°W on September 11, 1962, when the USS BURTON ISLAND made a record-breaking penetration in the western arctic to deliver about 1200 barrels

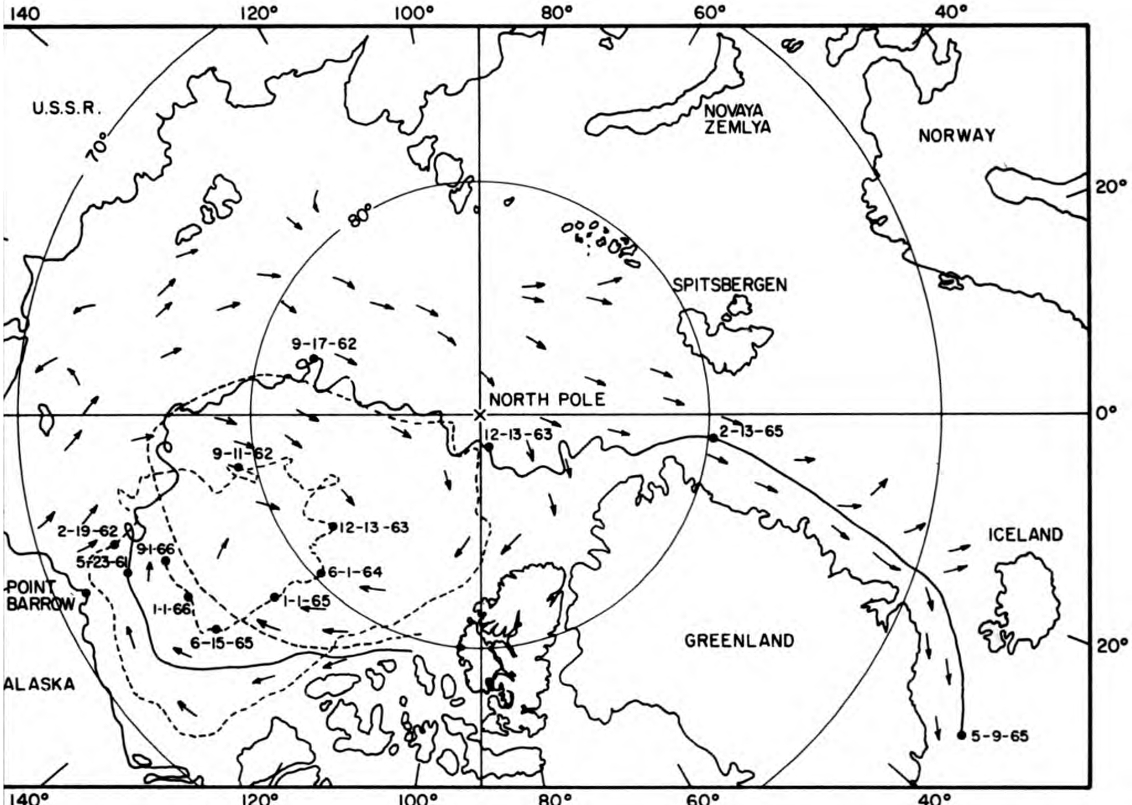


Figure 3 — Generalized tracks of ice-islands T-3 (dotted line) and ARLIS II (solid line) and directions of currents (arrows) in the Arctic Ocean.

of petroleum products to the station. Then, as ARLIS II moved northward toward the North Pole, T-3 turned northwestward. On December 13, 1963, ARLIS II reached its northernmost position, 88°39.7′N, 97°00′W, and T-3 was at 81°50′N, 142°44′W. As if anticipating the drift of ARLIS II eastward into the Atlantic Ocean, T-3 moved in tight circles in the vicinity of 80°N and 135°W during all of 1964. In the fall of 1964, arctic oceanographers were afforded two rare opportunities for research. ARLIS II entered the Greenland Current, and T-3 was apparently still caught in the center of the Beaufort Sea Gyral (or one of a series of eddys associated with this center). Despite shortages of funds, personnel, and support facilities, the research programs on both drifting stations were expanded.

Some of the most difficult flying in the history of ARL was accomplished during the winter of 1964. Not only were the distances extreme, but as ARLIS II entered the McKinley and Greenland Seas, heavy snowfall and drifts complicated the logistics effort. The weather station, Alert, was added as a staging station for the supply flights. Because of limited fuel capacity and range, the R4-D had to be refueled at each staging station. For example, on the flight of January 9, 1964, the aircraft flew from Barrow to T-3 (then at 77°50′N, 138°13′W), pumped aboard 9 drums of Avgas, then went on to Alert, where 16 drums were added. Eight drums of fuel had to be pumped aboard at ARLIS II, and 4 more were taken on at Alert on the homeward leg. The last R4-D to carry supplies from Barrow departed on March 26. A flight of 17 hours and 57 minutes was required to reach ARLIS II (72°50′N, 16°44′W), with stops at T-3 and Alert. The plane continued to Keflavik Naval Station, Iceland, the following day, reaching that point in 3 hours and 50 minutes. All flights for the remaining support of ARLIS II were made from Iceland, and T-3 no longer was called upon to serve as a staging station.

After abandonment of ARLIS II, ONR decided to concentrate its drifting-station efforts on T-3 and such auxiliary, temporary stations as might be needed. In the summer of 1966, nine research programs were in progress on T-3. For the first time since the evacuation of Station Charlie, a full-scale weather and upper-air observation program was in operation. This program, which was carried out by the U.S. Weather Service with ONR financial support, augments the other scientific efforts and also provides reports to the World Meteorological Network. The University of Washington continues to carry out micrometeorological and heat-budget investigations of the sea ice and ocean under Dr. Phil Church and associates. It also conducts research in physical oceanography, under the direction of Dr. Lawrence Coachman, and in marine biology, under Dr. Thomas English. Dr. Kenneth Hunkins of Lamont Geological Observatory, Columbia University, continues his investigations of hydro-acoustics, and a new program, under Dr. Max Dunbar of McGill University, has been initiated to determine the relation of the acoustic scattering layer to the marine biota. A systematic investigation of arctic underwater acoustics is being carried out under the direction of Beaumont Buck of the General Motors Defense Research Laboratory. A systematic study is being made also of the marine biology of the Arctic Ocean under the direction of Dr. John Mohr of the University of Southern California. In addition, Dr. Thomas English of the University of Washington is investigating the role of sea ice in marine ecology and productivity.

The end. Inhabitants of ARLIS II gather for ceremony marking the evacuation of the ice island.

Ice Island T-3 has remained in the center (or centers) of the Beaufort Gyral for the past three years. At the time of this writing—August 27, 1966—it is at 75°38′N, 155°37′W, and appears to be headed westward. Water depth is decreasing rapidly as the ice island drifts up the Chukchi Rise (1202 meters on August 29). It is expected that T-3 will drift around the periphery of the Beaufort Sea Gyral or follow the general path of ARLIS II into the North Atlantic. In either case, it should provide a platform for research in the Arctic Ocean for several more years.

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Training Program Established for Aquanauts

A permanent home port and training program for Navy aquanauts assigned to the Man-in-the-Sea program were established in San Diego, California, on September 1. The Deep Submergence Systems Project Technical Office, which will direct the program, will provide curricula, schedules, and equipment for training present and future Navy aquanauts. In addition, the Office will offer engineering, research, testing, and technical services required to meet specific Navy operational requirements and will give assistance during the implementation of ocean-engineering experiments. Among the tasks undertaken will be the performance evaluation of ocean-engineering hardware, such as diving suits and air-breathing equipment for divers.

It is estimated that complete training in all aspects of advanced diving techniques will be available at the new Office within 16 months. Initially, the Office staff included ten officers and 33 enlisted men, but the final complement will number 15 officers and 43 enlisted men. Captain Walter F. Mazzone, MSC, USN, has been named Officer-in-Charge. Capt. Mazzone served as physiological control officer during both of the Navy's previous SeaLab experiments.

The Friction-Reducing Effects of High Polymers

J. W. Hoyt
Naval Ordnance Test Station
Pasadena, California

Few recent discoveries in hydrodynamics have created such intense interest among scientists as the finding that relatively small amounts of a high-polymer substance dissolved in a fluid will drastically reduce the fluid's friction during turbulent flow. Still more remarkable is the fact that even after several years of study by some of the world's leading fluid dynamicists, no theory exists to explain the effect.

The Navy's interest in the possibilities of adding certain chemicals to fluids to reduce their friction during turbulent flow was first aroused in 1961 by an oil-field equipment concern, Westco Research, whose workers found that less power was required to pump high-pressure water through pipelines when a gum, Guar, was added to suspend sand particles in the water. Although the initial reaction—among Naval Ordnance Test Station staff members, at least—was one of disbelief, a few simple experiments in our laboratory quickly confirmed the fact that very small quantities of Guar gum had a remarkable friction-lowering effect. Other high-polymer substances, mostly plant gums, were also found to reduce friction during the turbulent flow of fluids.

According to the literature, the friction-reducing property of chemical additives had been noticed at least twice before—once by B. A. Toms, in England, who measured the turbulent flow of polymethylmethacrylate in chlorobenzene; and even earlier by K. J. Mysels and co-workers during World War II, in connection with the flow of gasoline thickened with napalm.

By early 1963, after an extensive screening program to survey likely substances for their friction-reducing properties, A. G. Fabula of NOTS had identified the remarkable efficacy in this regard of polyethylene oxide, a water-soluble, high-molecular-weight material, of completely linear construction, sold under the commercial name, "Polyox." Polyethylene oxide is still the most effective known friction-reducing agent. However, many other industrial chemicals, such as the polyacrylamides, polysulfonates, and hydroxyethyl cellulose were quickly found by experimenters in Navy, industrial, and university laboratories to be almost as good. The choice of chemical to be used in a given situation will probably be made on the basis of cost, ease of solubility, time available for mixing, and other factors, in addition to drag-reduction ability.

Friction Measurements and Friction Reduction

The reason the drag-reducing effect of polymers escaped notice for so long probably lies in the characteristics of the instrument used traditionally to measure the friction created by the flow of fluids—the viscometer. Since all viscometers operate in laminar flow, measurements of polymer-solution viscosity, as shown in Fig. 1, indicate only that these solutions have a somewhat higher viscosity than the solvent. On the basis of these data only, one would logically predict that a slight friction *increase,* not a remarkable decrease, would occur during the turbulent flow of fluids containing polymers.

However, when a solution of polyethylene oxide is pumped in turbulent flow through a pipe (*i.e.,* at a Reynolds number above 2,000-3,000, where $R = VD/\nu$, V = flow velocity, D = pipe diameter, and ν = kinematic viscosity of water), friction reductions such as those shown in Figure 2 are obtained. Thus the addition to a fluid of a few parts per million of this completely linear polymer (molecular weight: 4 million) is all that is required to substantially reduce friction of the fluid during turbulent flow. Further work has shown that the friction reduction is a function of Reynolds number: The larger the Reynolds number, the greater the drag reduction. Friction-reductions of 80 percent or more have been recorded in pipes.

Experiments have shown that the polymers effectively reduce the friction of fluids in other turbulent-flow situations, as when rotating disks and other moving objects are immersed in polymer solutions. Whether the solution consists primarily of salt water or fresh water seems to have little influence on the action of most of the drag-reducing materials.

Characteristics of Friction-Reducing Chemicals

"But how do they work?" is the question most frequently asked by persons hearing about high-polymer additives for the first time. As yet, no good answer has been found. Many scientists believe that the hair-like structure of the polymers interferes somehow with the production of turbulence, but the details of the mechanism of interference have not been worked out. Finding the explanation will involve fundamental studies in turbulence—which, in itself, is an incompletely understood area—and studies of the properties of dilute polymer solutions, such as the molecular size, shape, and stiffness, when dispersed in the solvent.

We do know a great deal, however, about the characteristics of effective chemicals, so we can formulate a few general rules:

- The friction reduction occurs only in turbulent flow. As Figure 3 shows, it is only in the region of higher velocities for a given pipe

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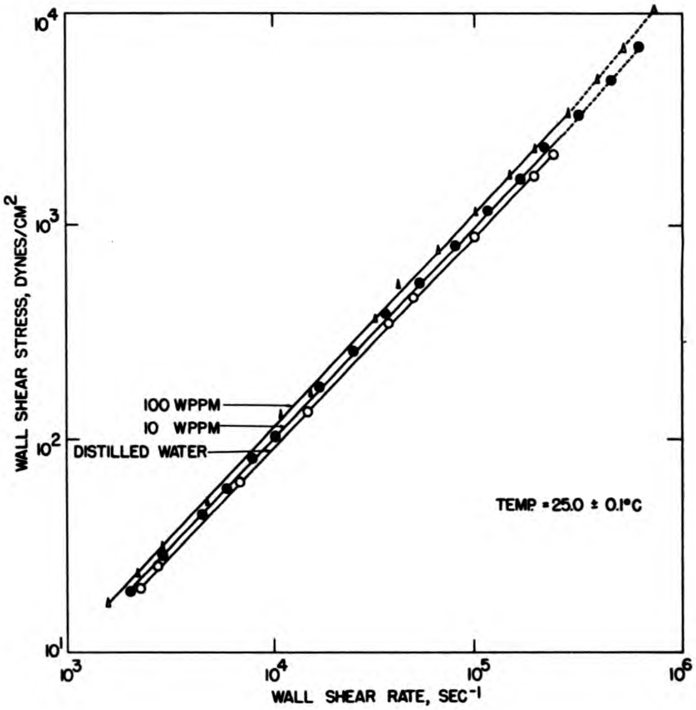


Figure 1 — Rheogram for 10 and 100 weight parts per million (WPPM) of polyethylene oxide of 4-million molecular weight.

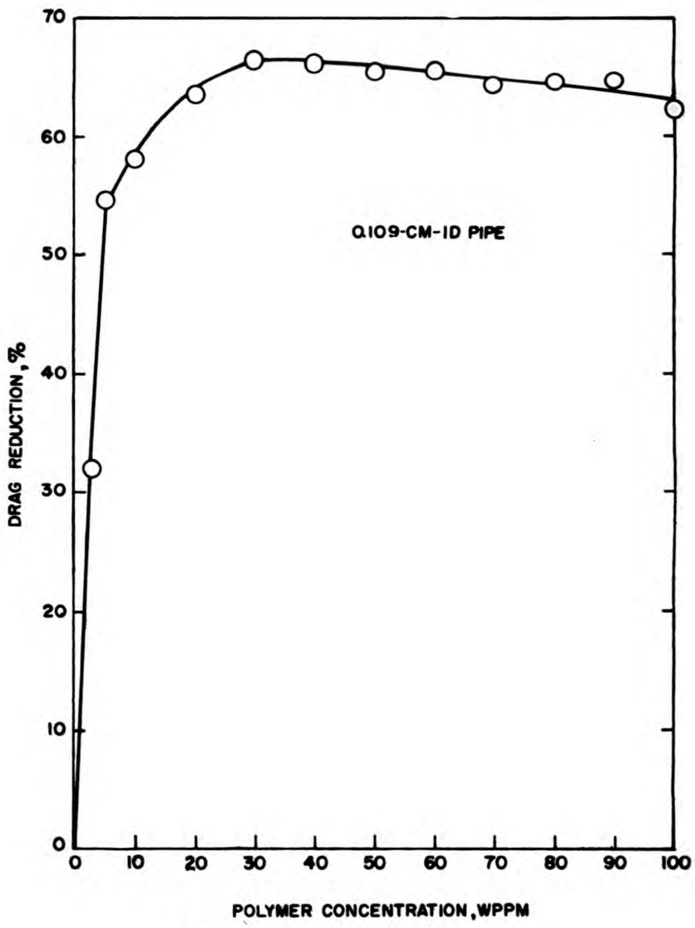


Figure 2 — Drag reduction produced in a small pipe by solutions containing various amounts of polyethylene oxide. (Reynolds number: 14,000.)

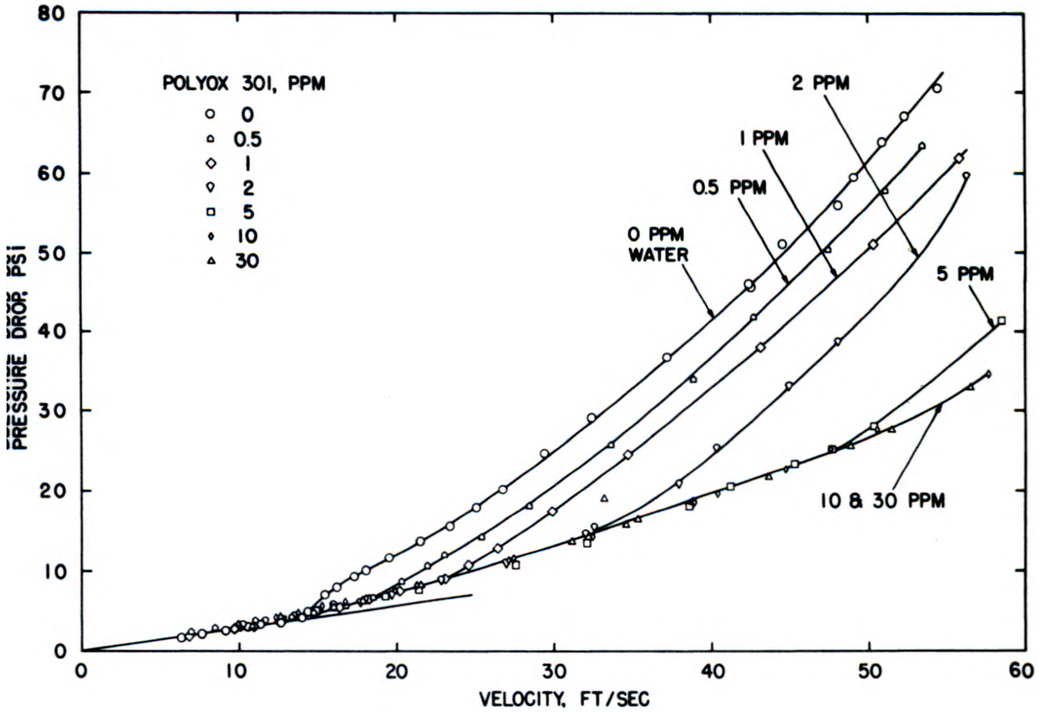
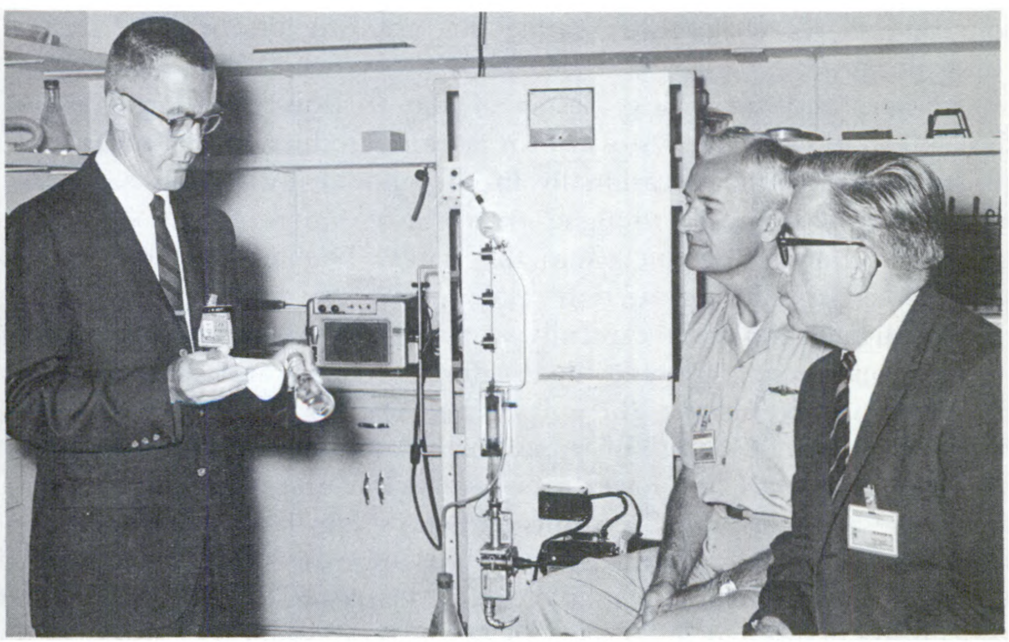


Figure 3 – Effect of Polyox on pressure drop in a small pipe.
Pressure drop is related to friction resistance.



Dr. Hoyt demonstrates friction-reducing polymers to VADM I. J. Galantin, Chief of Naval Material, and Dr. G. W. Johnson, Director of Naval Laboratories, during a recent visit to NOTS, Pasadena.

size—beyond the point where the pure solvent undergoes transition from laminar to turbulent flow—that the polymers become effective.

- The polymers must be of a generally linear molecular structure and have a high molecular weight, at least above 50,000. For most polymers, the higher the molecular weight, the more effective the resistance to friction.

- For the greatest effectiveness, the polymer must be soluble.

As yet, we have encountered no polymer which, upon meeting these three conditions, did not reduce friction.

Applications

So far, the major industrial application of friction-reducing polymers has been made in oil-field and other drilling and pumping operations, but many other flow situations are under study. Among the latter are those of special-purpose Navy vehicles designed to provide sudden bursts in speed or to conduct short-duration missions.

In the scientific and technical world, however, the recognition of the amazing properties of friction-reducing chemicals has already brought important advances. By means of polymers, it may be possible to test ship models in towing tanks at prototype friction as well as wave-making resistance coefficients, thus avoiding correction factors, which have proved a source of difficulty. Furthermore, the thickness of the wake entering the propellers of a ship model operating in a polymer solution will more closely resemble that entering the propellers of a full-scale ship.

Another, and surprising, result of the friction-reduction work is the explanation of the "storms" or sudden reductions of measured resistance that occur occasionally in ship-model towing tanks. These effects have been traced to algae—many species of which exude high-polymer metabolic products into the water. The high-polymer polysaccharides are effective friction reducers. Hence, to obtain consistent results, algae should be carefully excluded from towing-tank water.

Many microscopic marine algae (dinoflagellates and diatoms) also exude high-molecular-weight polysaccharides, for some reason as yet not understood. "Blooms" of some phytoplankton may afford areas of reduced turbulence and lower the resistance of the water to ships entering the area; historical accounts and ships' logs have mentioned the remarkable and sudden steadyness of ships upon entering a sea in which high concentrations of plankton exist. Plankton blooms may even explain the occasional differences in power requirements of sister ships on the measured mile.

A host of other scientific applications, such as the measurement of molecular weight in terms of friction reduction and the study of the

DNA molecular configuration in terms of its drag-reducing effect now are under investigation in the laboratory.

To date, the story of the friction reduction of fluids to which dissolved high polymers have been introduced is one of discovery, empirical research, and laboratory testing. However, through the large research program currently sponsored by the Office of Naval Research, National Aeronautics and Space Administration, National Science Foundation, and the Material Commands of the Navy, enough data are certain to be accumulated to enable scientists eventually to present a theory to explain the effect. When this is done, not only will we know how to apply more effectively the high-polymers as friction reducers, but we will know a great deal more about the fundamentals of turbulent flow.

Navy Satellite Navigation System Installed Aboard Research Ship

A Navy-supported oceanographic research ship has become the first civilian vessel aboard which the Navy satellite navigation system has been operated on a permanent basis. The ship, the schooner VEMA, which is now operating in the North Atlantic, has reported the successful operation of the system after making 20 extremely accurate fixes of the ship's position each day on its present voyage. The VEMA is operated by Columbia University's Lamont Geological Observatory with support from the Office of Naval Research.

Experimental models of the navigation system were tested successfully last year aboard Lamont's ROBERT D. CONRAD and the research vessel ATLANTIS II, which is operated by the Woods Hole Oceanographic Institution. The system measures the doppler frequency shift of the satellite signals. By reference to data on the satellite's position in orbit, which is already known, a small commercial digital computer aboard the VEMA calculates the ship's position rapidly and accurately. Where conventional navigation techniques allow errors to occur that are measurable in miles, the satellite-computer system limits the errors to distances that are measurable in yards. The system also will operate in all kinds of weather.

Celestial navigation has never enabled oceanographers to determine their positions at sea with the precision required to make many of their scientific measurements fully meaningful. Moreover, much of the work conducted by Lamont and other oceanographic institutions is in regions in which bad weather and poor visibility limit the number of celestial observations that can be made to one or two per week (as compared with the 20 daily fixes obtained recently by the VEMA). Dr. Maurice Ewing, Director of Lamont, has stated that the advent of the Navy system "marks the beginning of a new era in oceanography and marine geophysics."

Plans are under consideration by ONR to provide satellite systems for other oceanographic research ships supported in its programs.

Over the past few years, the United States has poured ever increasing amounts of money into the exploration of the oceans. While expenditures on oceanography were less than $4 billion ten years ago, they are now well over the $12 billion mark. Presently, there are approximately 95 oceanographic vessels roaming and studying the world's oceans. Fifty-seven of these vessels have been constructed since 1960.

The Omega Navigation System

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Electronics Branch
Office of Naval Research

Origin

During the last two years of the second World War, members of the MIT Radiation Laboratory who had developed Loran, the first "long range" hyperbolic radio aid to navigation, were trying hard to achieve a low-frequency version. Their obvious reason was to take advantage of the transmission over longer distances that obtains at the lower radio frequencies. Although the experiments were moderately successful and led to the highly accurate Loran-C in use today, the hope of a dramatic increase in coverage area was not realized. Fortunately, the war in the Pacific developed in such a way that the standard Loran System, now called "Loran-A," could provide satisfactory coverage.

At the end of the war, a number of members of the Loran team formed a research group at Cruft Laboratory, Harvard University, under the leadership of J. A. Pierce. This group, which was supported under one of the first university research contracts of the Office of Naval Research, proposed to apply some of the new wartime techniques to the study of radio-wave propagation. Interest in radio navigation was still keen, and a part of the research effort was applied in this area.

At the low radio frequencies, one cannot transmit pulses of the kind generated in Loran. A survey was made, therefore, of other ways of encoding the necessary information. The key to the problem seemed to lie in the exploitation of the phase characteristic of a demodulated signal when two modes of propagation interfere, as they frequently do in radio transmission. Supported by this theoretical justification, a proposal was made in 1947 for a navigation aid called "Radux" that was intended to operate in the 40-50 kilocycles-per-second (kc) region, with the primary information residing in the phase of a low-frequency modulation. Average errors of 3-5 miles were expected over ranges as great as 3000 miles.

In 1950, the Navy decided to conduct an experimental investigation of the Radux concept, and projects were established for this purpose at the Navy Electronics Laboratory (San Diego) and Naval Research Laboratory. The groups founded then are still conducting the Omega program. Experimental transmissions were made from San Diego, Haiku (Hawaii), and Bainbridge Island (Washington), and for a number of years data were collected from many fixed points and from moving vehicles. These studies showed that the system would, in fact, do about what had been expected. Unfortunately, the need for greater navigational precision was increasing during the years of the development program, and it gradually became clear that the Radux implementation was not sufficiently advantageous for operational use.

In the meantime, research at Harvard in the transmission time of radio waves was being extended to lower frequencies. This work was supported jointly by the Office of Naval Research, Army Electronics Command, the Bureau of Ships, and the Air Force. In 1954, transatlantic signals at 16 kc were shown to have a day-to-day repeatability within a very few millionths of a second. This surprising result was extended in the subsequent decade, leading to the very-low-frequency (vlf) transmission of today, which is the primary mechanism for accurate comparison of frequencies between widely separated points. The frequencies of most of the powerful communication stations now are controlled with a precision of a few parts in a trillion, thus serving a secondary purpose as standard frequency sources.

The utility of this stable vlf transmission for navigation was apparent from the first. Unfortunately, however, the carrier-frequency phase measurement is highly ambiguous; even at the lowest practical frequency, phase readings repeat about every eight miles. A navigator making measurements continuously could track his position with accuracy, but if a failure in transmission or reception occurred, he would be lost, unless he could make some other measurement that would establish his position within ±4 miles.

In 1955, the group at Harvard proposed to the Office of Naval Research that a hybrid system, called "Radux-Omega," might be useful. In this implementation, Radux would resolve ambiguities, and Omega, a vlf hyperbolic carrier-phase measuring system, would provide high accuracy and would permit rapid position determinations to be made during maneuvers. The Haiku-San Diego pair of stations began transmitting the Omega-type format in 1958. From then until 1962, the primary efforts were devoted to studies bearing on the selection of optimum frequencies and measurements of the phase velocity of propagation, which had to be known accurately so that phase measurements could be translated into navigational positions. In addition, much effort was directed to ionospheric propagation characteristics which influence the phase of arrival of vlf radio signals. A solution to the problem was found at Harvard in 1960, and values have been improved continuously in subsequent years.

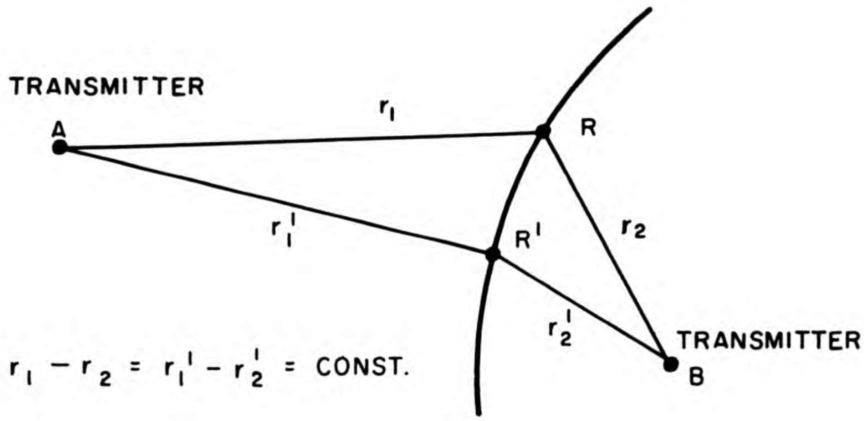
In this same four-year interval, the Radux part of the hybrid system was gradually abandoned. The fundamental reason was simply that the range of Radux was limited to about 3000 miles, while Omega could be useful over ranges as great as *8000 miles* and, therefore, would require fewer transmitting stations. At the same time, it was recognized that two current developments were reducing the importance of the problem of identifying the lane of position of the receiving points in Omega. One was a general increase in the accuracy of dead reckoning that would make the loss of lane count less likely if an interruption of the vlf tracking occurred. The second was a large increase in the reliability of electronic systems. This factor made it much less probable that a lane count would ever be lost.

The result of these considerations was that the Omega concept replaced Radux as the primary low-frequency navigational proposal. At about this time, the Omega team at the Bureau of Ships and the Navy Electronics Laboratory succeeded in obtaining use of suitable antennas from the Air Force (at Forestport, New York), from Naval Communications (at Summit, Panama Canal Zone), and from the British Post Office, through the help of the Admiralty (at Criggion, Wales). While these antennas were not located at sites chosen with the navigational requirements in mind, and although their power outputs were rather limited, they and the antenna in Hawaii provided Omega signals useful over much of the Pacific and most of the Atlantic. Data have been taken aboard ships and aircraft and at many fixed points from the Arctic to southern South America and from Norway and Africa to the Philippines and Australia. All of these data have been used to formulate rules for the calculation of the velocity of transmission and to determine the errors of the system. In an operational system having properly located stations, the errors certainly will average less than a mile, and they may well ultimately average as little as a half mile, anywhere in the world.

Principles of Operation

As presently envisaged, the Omega system, when completely implemented, will include eight transmitting stations to provide complete global coverage with an effective error of less than one-half nautical mile during the day and one nautical mile at night. This long-range, phase-comparison, vlf electronic navigation system will function in any kind of weather. At the present time, only four stations are in actual operation, and they are transmitting on a research and development basis. These stations are located at Haiku, Hawaii; Forestport, New York; Trinidad, West Indies; and Aldra, Norway.

The four stations operate on 10.2 and 13.6 kc. The phases of all 10.2-kc transmissions are maintained coherent at the source by means of cesium atomic frequency standards, whose long-term stability is about one part in 10^{10}. At a receiving point, the phase difference of signals received from any two stations gives information on the line (actually lane) of position of receiving points. This line of position is really an hyperbola, since the points on the line follow the rule that the difference in the distances from a particular receiving point to the transmitting stations is a constant, as shown below:



Inasmuch as the phase of a signal from transmitter A is changed (relative to the signal's phase at A) as a function of the distance traveled by that signal, it may be seen that phase-difference and path-length distances are directly related. (It must be added that ionospheric path influences also must be considered in phase changes, but these influences are much less at very low frequencies than they are at intermediate frequencies).

Having established one line of position by observing signals from two stations (such as A and B), the receiver then learns that he is also on some other hyperbolic line by observing signals from another pair of stations (one of which might be A or B). The position of the receiving site is then determined as the crossing point of the two hyperbolic lines.

Each station transmits with an average power of about 2 kilowatts for about one second. Distinction among the stations is made by the exact duration and sequence of the transmitted signals. For example, station A transmits for 0.9 seconds; whereupon station B transmits for 1.0 second; then station C, for 1.1 seconds; and station D, for 1.2 seconds. The receiver knows which station is which simply by measuring (synchronizing) the varying time intervals. The entire sequence pattern is found on 10.6 kc and, thereafter, on 13.6 kc. Use of these two carrier frequencies permits precise determination of the particular lane in which the receiver is located; that is to say, a 360° ambiguity in phase difference, which gives rise to a lane with a width of about 8 miles at 10.2 kc, is somewhat resolvable by observing phase differences at 13.6 kc. In addition, use is made of the 3.4 kc frequency difference in resolving lane ambiguity. Ambiguities which come about from uncertainties in phases of 720°, 1080°, and higher are so great that they are more appropriately resolved by dead reckoning, celestial navigation, or radio-direction-finding triangulation information.

Variations in system characteristics to accomplish particular ends are being studied. One of these involves phase modulation of the carrier signals to deliberately widen lanes of the system in order to give high-speed aircraft which enter these lanes an opportunity to make position readings. Another variation involves updating of phase information in a particular sector which Omega may be serving by transmitting the latest information on vagaries in the system created by ionospheric changes.

Program

In 1962, the Bureau of Ships designated a small group of scientists and engineers from outside the Navy to help plan the details of the proposed improved system, to be called Omega. This group, named the "Omega Implementation Committee," consists of J. A. Pierce (Harvard University), W. Palmer (Sperry Gyroscope Co.), A. D. Watt (DECO Electronics Co.), and R. H. Woodward (Pickard and Burns, Inc.). With the exception of Mr. Watt, who is an expert in radio-wave propagation, these consultants have worked on radio-navigation systems that have evolved from the early Loran developments. The Committee is supported under contract with the Office of Naval Research and by the Office of the Chief of Naval Material.

After study and conferences with representatives of the Federal Aviation Agency and the Royal Aircraft Establishment, the Committee issued a report in 1964 which gives details of its work. The report is a comprehensive survey of the geometrical and propagational background aspects of Omega and of the various methods which might be used in implementing an operational system. Its suggestions go far beyond those made previously, for they include the recommendation that a complex spectrum be radiated by the stations of the system. This spectrum would contain elements that might be required for the simultaneous solution of many different navigational problems, although it is recognized that usually circumstances would require the use of only a part of the transmitted information. The broad plan for Omega includes elements that permit operation of the system in the manner of Radux (tone modulation) or Draco (vlf communications station radio-frequency phase comparison), as well as for measuring changes in distances from the transmitting stations and for operation in the hyperbolic mode described in "Principles of Operation." A navigator could completely resolve any ambiguity that might occur if he wished to carry the requisite instrumentation and make enough measurements, or he could decide that he would not be concerned with ambiguities beyond any of several levels, thus permitting simplification of the navigational apparatus.

In 1964 and 1965, the first experimental steps were taken to confirm the validity of the plans for lane identification. Although circumstances have prevented the accumulation of a large amount of data on this subject, it is already clear that lane ambiguity problems can be adequately solved.

An interesting current development is a joint effort by the Federal Aviation Agency and the Navy to produce a coordinate-converting computer for use with an airborne Omega receiver. This computer will be able to accept data from Omega and from a doppler or inertial system at the same time and make available navigational operational information, such as position in latitude and longitude, distance and time remaining to travel, course, wind velocity, and ground speed, if desired.

In July 1965, the management of the Omega program was transferred to the Office of the Chief of Naval Material. This Office coordinates the efforts of the many Naval agencies and contractors that must contribute to a successful program, and it arranges cooperation with other departments and governments. The first efforts of this Office are being directed to the development of new and improved receivers and other apparatus and techniques.

At the same time, continued research, testing, and development of instrumentation is being pursued by the Naval Research Laboratory and the Office of Naval Research. Any man-made instrument or system must consider the influences of its environment. In the case of Omega, research is continuing on the influence of solar flares and other natural phenomena on the height and electron density profile of the ionosphere and the relationship of these variations to the phase and amplitude of received signals. Research is going forward also on the world-wide, time-varying distribution of atmospheric noise in the vlf radio band. The ONR program includes sustained support of Pierce's group, in the Division of Engineering and Applied Physics at Harvard, and support of industrial laboratory groups, such as Pickard and Burns, Inc. It is oriented primarily toward obtaining propagation data for Omega, but is of such broad basic character that its products will be useful in any long-range communications, detection, or navigation systems which may require phase and noise-background information in the vlf portion of the electromagnetic spectrum.

Red Tide Identified. Samples of sawdust-like particles on the sea surface, sent in from ocean waters off the northeast coast of the United States, have been identified as plankton *Trichodesmium*. Large concentrations of these organisms are known to produce red and brown discoloration of the sea surface. They are the same plankton which gave the Red Sea its name. The identification was made by the Naval Oceanographic Office.

Concrete Data-Collection Station to be Erected in Deep Ocean

Until last year, many engineers had thought that concrete, the most widely used construction material on the earth's surface, was too weak and porous to serve as a building material for underwater structures. Because of the cost factor, however (concrete is the most economical of all construction materials), the Naval Civil Engineering Laboratory, Port Hueneme, California, conducted experiments to find out how serviceable this material really is under the tremendous pressures of the deep ocean. The initial results were promising. Tests conducted in laboratory pressure vessels indicated that concrete structures can withstand the pressures which exist at depths as great as 5000 feet.

After establishing the feasibility of using concrete as an underwater building material, a model for an unmanned oceanographic data-collection station was built. The concrete station, which will stand on a tripod and have plexiglass windows and a beacon light for illumination, will be used for such purposes as to determine the direction and rate of the current and to photograph sea life inhabiting the depths.

The next step is to build the full-scale station, which will be ten feet in diameter, and to determine if Navy divers can assemble the concrete structure from precast panels on the ocean floor near the Laboratory. A concrete foundation has been placed on and removed from the bottom already, and an aluminum frame and the concrete portions of the sphere have been designed.

High-Resolution Radar Developed for Helicopters

The first successful helicopter radar system designed to be installed in the rotor blade of a helicopter has been flight tested as part of the Joint Army-Navy Instrumentation Research (JANAIR) program. The objective of the long-range JANAIR program, which is managed by the Office of Naval Research, is to improve and greatly simplify cockpit instrumentation systems in fixed-wing aircraft and helicopters.

By means of the new high-resolution system, flights can be made under conditions of poor visibility, such as those which occur at night and in fog—conditions which in the past have prevented helicopters from taking to the air except at great risk. The radar operates on any one of four antennas, each 15 feet long, mounted in the rotor blade. The receiver and sweep generator are all-transistorized units. The system does not require a computer, mechanical components, or servo systems, thereby providing reliability, maintainability, and the ruggedness necessary to survive in a combat environment.

The radar display serves both as an adequate navigation and landing-approach aid. Flight tests have demonstrated that contrast between objects and different types of terrain is such that almost pictorial ground mapping results. Large and extended objects, such as airport runways and highways, are unmistakable. Pilots aided by photos or charts or by previous knowledge of the terrain can readily identify clusters of trees, buildings, or oil tanks. Although the experimental system operates at a minimum altitude of 200 feet, the system can be modified to reduce this altitude to 50 feet.

The new radar was developed by Bell Helicopter of Fort Worth and the Texas Instrument Company of Dallas, Texas.

The Office of Naval Research has recommended further development of the system for installation in Army and Marine Corps helicopters, particularly those slated for operation in Viet Nam.

The Magnetics Division of the Naval Oceanographic Office has moved from the Washington Navy Yard to the Naval Research Laboratory's Chesapeake Bay Division, Chesapeake Beach, Maryland. Approximately 30 scientists are involved in the change of location. The Magnetics Division currently is conducting a geomagnetic survey, called "Project Magnet," of all accessible ocean areas of the world.

On The Naval Research Reserve

Albuquerque's Third Research Seminar

"A unique opportunity." Thus did CAPT Clayton Tidyman, a Naval Reserve officer from Fresno, California, summarize the third annual Research Reserve Seminar in Applied Research, held in Albuquerque, New Mexico, from July 31 through August 12. "The seminar," CAPT Tidyman said, "provides a unique opportunity for Naval Reservists to learn about the latest developments in nuclear research and related research. The many research agencies in and near Albuquerque enabled the attendees to participate in sessions on biology, weapons, space medicine, nuclear reactors, and delivery systems."

The seminar, which was sponsored by Naval Reserve Research Company 8-7 of Albuquerque in conjunction with the Office of Naval Research, drew 65 Reserve officers from throughout the United States. Because the seminar covers a broad spectrum in applied research, it is the only one for which the Office of Naval Research authorizes quotas from every Naval district.

A sampling of the sessions follows: fission/fusion principles, blast and thermal effects, nuclear safety, subsurface and amphibious weapons, radiation and dosimetry measurements aboard Gemini 4, aerospace isotopic power supplies, extreme physics, lightning research, radiochemical research, and blast and shock biology.

Sessions were held at Sandia Laboratory, Defense Atomic Support Agency at Sandia Base, Naval Weapons Evaluation Facility, Air Force Special Weapons Laboratory at Kirtland Air Force Base, Los Alamos Scientific Laboratory, Holloman Air Force Base, Lovelace Foundation, the University of New Mexico, and New Mexico Institute of Mining and Technology.

The seminar was opened with a welcoming address by RADM Pierre Charbonnett, USN, Commandant of the Eighth Naval District. Speaking also on opening day were two Naval officers from ONR, Washington, D.C. CAPT Lewis Melson, USN, who represented the Chief of Naval Research, told about the recovery of the atomic weapon from the Mediterranean off the coast of Spain; and CAPT D. J. Marker, USNR, Special Assistant to the Chief of Naval Research for the Research Reserve, discussed the status and goals of the Research Reserve program. Dr. Clayton White of Lovelace Foundation, which does research in space medicine, was the principal speaker at the banquet closing the seminar.

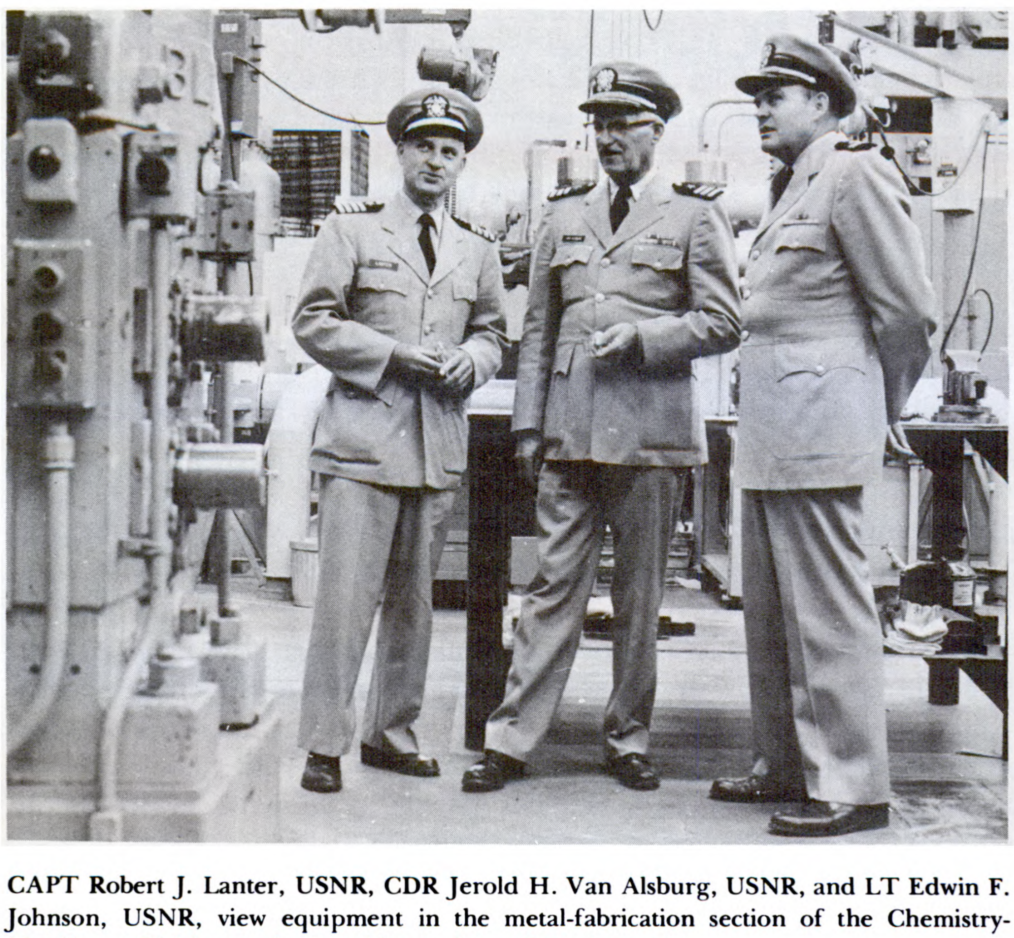
CAPT Tidyman also remarked on the outstanding job of organization done for the seminar. He said that when the seminar was first proposed three years ago, it was felt that it could not be accomplished because of security problems and the number of government, military, and private agencies involved. But the cooperation of these agencies was secured, and, in all respects, the seminar was successful. The general chairman was LT Edwin F. Johnson, USNR, a member of the Space Isotope Power Department at Sandia Corporation. CDR J. H. Van Alsburg, USNR, of Santa Fe, was manager of the seminar.

Some of the comments made about the seminar are as follows:

LCDR Clifford Comfort, Forest Service representative on the Department of Agriculture's Rural Defense Committees: "I feel that the seminar will give me additional knowledge to serve the committees better should atomic attack occur."

CDR P. P. Holz: "I chose the nuclear weapons seminar to broaden my perspective in nuclear science and to fill in a gap between my civilian (primarily reactor) experience and my previous billet in nuclear mine warfare training."

CDR W. L. L. Schwesinger: "I requested orders to this seminar because I felt that information received would help in understanding the effects of atomic radiation on electronic equipment. This information



CAPT Robert J. Lanter, USNR, CDR Jerold H. Van Alsburg, USNR, and LT Edwin F. Johnson, USNR, view equipment in the metal-fabrication section of the Chemistry-Metallurgy Division at the Los Alamos Scientific Laboratory.

would be particularly useful in successfully filling my mobilization billet as training officer at the Naval Electronics School at M.I.T."

LCDR Jack Taig: "The Third Research Reserve Seminar in Applied Research has been the most enriching two weeks of active duty for training that I have ever experienced."

CDR Harry D. Felsenthal, Jr.: "My mobilization billet is at the Naval Ordnance Laboratory, Corona, in a technical capacity. The developments in warheads and the methods of testing ordnance items that have been presented at this seminar will be positive aids in accomplishing my function should I be recalled to active duty. Much of the information presented will also be applicable in my civilian occupation as an electronic engineer at the Naval Missile Center, Point Mugu."

Electronic Computers Seminar

The Fourth Annual Research Reserve Seminar on Electronic Computers was held at Texas A & M University, College Station, Texas, from August 29 to September 9. The seminar was sponsored by the Office of Naval Research in conjunction with the University and Naval Reserve Research Company 8-3, College Station.

The seminar was attended by 47 officers and 3 enlisted men of the Navy, Army, and Coast Guard Reserves. Forty-two attendees were Naval reservists, five were Army reservists, and three were Coast Guard reservists. Twenty-one states were represented. The administrative and teaching staff for the seminar was composed of three officers, including one Army reservist, and two enlisted men.

At the luncheon session on the opening day, participants were welcomed to the Eighth Naval District by CAPT R. H. Ballinger, USNR, who served as Commandant's Representative and seminar administrator. Mr. Dorsey McCrory, Director of University Development, welcomed participants to the University. The keynote address was given by Dr. Robert J. Lundegard, Head, Logistics and Mathematical Statistics Branch, Mathematical Sciences Division, Office of Naval Research. He discussed an advanced, fully computerized logistics information system for the Navy.

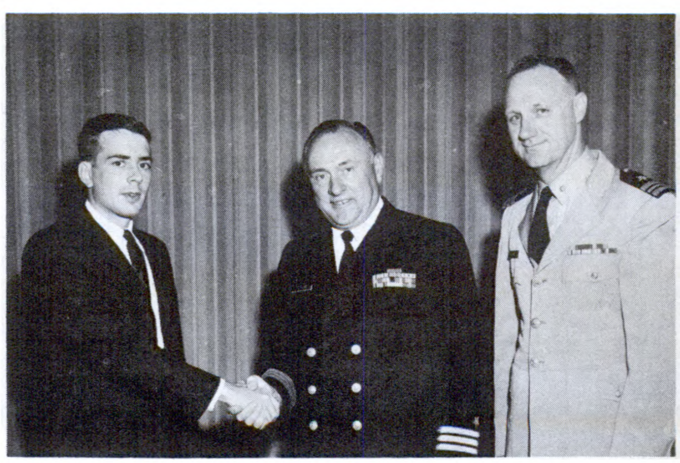
CDR B. C. Moore, USNR, served as seminar chairman and chief instructor. He was assisted by 1st LT Robert Bower, Jr., USAR, Assistant to the Director of the Data Processing Center, Texas A & M University. The participants were given instruction in FORTRAN programming and were assigned problems for which they wrote programs, which were compiled and run on the IBM 7094 of the University's Data Processing Center. In addition to the instruction and workshops on programming, a variety of special topics and computer applications, with emphasis on military problems, was presented. Special topics included random number generation, simulation, game theory, linear programming, PERT, and impact of computers on statistics. Applications of computers to management information, activation analysis, industrial operations, scientific research, and space travel were presented by authoritative speakers from the faculty of Texas A & M, industry, and the Manned Spacecraft Center, NASA. Participants were encouraged to write programs on their own subjects of interest, and some of them did so. These programs were also compiled and run. Prior to coming to the seminar, participants had been encouraged to bring problems with them. The University's Data Processing Center provided both facilities and personnel for the support of the seminar.

On the last day of the seminar, CAPT D. J. Marker, USNR, Special Assistant to the Chief of Naval Research for the Research Reserve, discussed the Naval Research Reserve Program. CDR J. W. Tilford, USNR, Assistant for Research Reserve, ONR Branch Office, Chicago, and CAPT J. E. Peek, USNR, Assistant Chief of Staff for Naval Reserve and Training, Eighth Naval District, discussed the program from the standpoint of an ONR Branch Office and the Commandant.

A critique of the seminar was held on the last day. Participants had previously written programs compiling statistics on the group and the group's evaluation of the seminar. The latter showed enthusiasm for the seminar and a strong recommendation that this training session be continued in the future.

NRRC 8-13 Recruits Through Direct Commissioning

Three new Naval Reserve officers have been directly commissioned through efforts initiated recently by Naval Reserve Research Company 8-13, Stillwater, Oklahoma. Commissioned recently were ENS Larry Joe Peery, USNR, ENS Kenneth C. Keudell, USNR, and LTJG Eldon C. Nelson, USNR, Oklahoma State University biochemistry professor. ENS Peery and ENS Keudell are Oklahoma State graduate students who work in physics and microbiology, respectively.



ENS Larry Joe Peery, USNR, left, is congratulated by CDR Joseph W. Tilford, USNR, after the former was commissioned. Looking on is LCDR Franklin R. Crow, USNR, Commanding Officer of NRRC 8-13.

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Promotion Selections

Selections for promotion to lieutenant commander and lieutenant have been announced for officers in the Staff Corps by the fiscal year 1966 Reserve Selection Boards. The following officers were selected from the Research Reserve:

LIEUTENANT COMMANDER, MEDICAL SERVICE CORPS

	NRRC		*NRRC*
Askren, William B., Jr.	4-9	Neill, Viola M.	12-8
Boyle, Robert E.	5-3	Remsberg, Arthur R., Jr.	5-3
Grier, Charles P.	8-12	Ribble, David W.	9-22
Morton, Anton S.	1-1	Shoenberger, Richard W.	4-9

LIEUTENANT COMMANDER, MEDICAL CORPS

Thoen, Dennis D.	1-1	Veggeberg, Kermit R.	8-4

LIEUTENANT COMMANDER, SUPPLY CORPS

Aaron, Harvey C.	9-6

LIEUTENANT COMMANDER, NURSE CORPS

Wheeler, Clara V.	1-1

LIEUTENANT COMMANDER, DENTAL CORPS

Moffitt, Richard E.	13-5	Smith, Lloyd L.	9-26
Novak, George E.	13-5		

LIEUTENANT, MEDICAL SERVICE CORPS

Scott, Walter L., Jr.	8-1

LIEUTENANT, SUPPLY CORPS

Bunker, Steven J.	6-9	Purrington, John W.	6-6

A new office headed by RADM Odale D. Waters, Oceanographer of the Navy, has been established to plan and control the Navy's oceanographic effort. In an address delivered to a technical audience on August 29, Dr. Robert A. Frosch, Assistant Secretary of the Navy (Research and Development), said that RADM Waters would act as Naval Oceanographic Program Director on the Staff of the Chief of Naval Operations. In this capacity, Admiral Waters will exercise centralized authority, direction, and control, including control of resources, in order to make certain that an integrated and effective Naval oceanographic program is carried out.

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Editor: RICHARD D. OLSON

NAVSO P-510

Two scientists explore a 15-foot-tall rock, called "Obelisk," on arctic ice-island ARLIS II. The ice island, which was "home" for a Navy scientific party for four years while it drifted through the Arctic and North Atlantic Oceans, disintegrated off the southeastern coast of Greenland last year. A discussion of research conducted on ARLIS II and at other sites in the Arctic Basin begins on page 1.