# NAVAL RESEARCH

## REVIEWS

JUNE-JULY 1972

# PROFILES IN SCIENCE

*Dr. John H. Van Vleck*

John H. Van Vleck, Hollis Professor of Mathematics and Natural Philosophy, Emeritus, at Harvard University is widely acclaimed as the architect of modern magnetism for his brilliant and comprehensive application of wave mechanics and spectroscopic and crystal field theories to account for the magnetism and the microwave absorption properties of atoms, molecules, and solids. In recognition of his scientific contributions, several which were accomplished under Office of Naval Research sponsorship, Dr. Van Vleck was elected to membership in the National Academy of Sciences, the Royal Academies of Sciences of the Netherlands and Sweden, and is among the very select honorary members of the French Physical Society. On the personal side Dr. Van Vleck is known for a truly remarkable and well-organized memory. Indeed, as a railroad hobbyist in earlier days, he often baffled ticket agents, not only by his detailed memory of obscure time tables, but also by his ability to make connections which according to these time tables were not possible. According to Dr. Van Vleck it was simply a matter of knowing which trains consistently ran late.

# The Role of Time/Frequency in Navy Navigation Satellites

**Roger Easton***
*Naval Research Laboratory*

This paper discusses the role of time and frequency in three areas: (1) The operational Navy Navigation Satellite System, (NNSS); (2) An experimental low-altitude navigation concept termed TIMATION; (3) Proposals for advanced navigation satellites. These operating, experimental, and proposed systems all use concepts which allow the user to remain passive.

The operational NNSS system uses the Doppler technique to establish user positions to ~ 100 m. In this concept, the frequencies received from the satellite are compared to the frequencies generated in the user equipment. One can also compare the time a signal arrives from a satellite clock to a time generated in the user equipment clock for passive ranging. The paper shows that this passive ranging problem is easily transformed to the celestial navigation problem. Extension of these techniques allows one to use satellites as clock transporters and hence to compare clocks located throughout the globe to 0.5 $\mu$s. Experimental results are shown. It has been possible to determine the effects of radiation on quartz crystals and to determine that this effect is due principally to protons. System concepts are described which show this clock/time technique can determine user position, velocity, and time continuously, accurately, and globally.

Time and frequency play an important role in navigation today. The increasing need for reliable and accurate navigation emphasizes this key role. The use of artificial earth satellites in navigation systems offers reliable and accurate navigation, and at the same time, offers the ability of disseminating accurate time and frequency. This ability improves the navigation system and can be applied to other uses as well, for instance communications. Military navigation satellites have been proposed for three altitude ranges as shown in Table 1. The value of navigation satellites is that they provide global coverage with great accuracy. With a sufficient number, continuous coverage is obtained. These objects provide one of the very few accurate means of determining altitude above the center of the earth.

In contrast to the civil proposals, military satellite navigation systems, in use and proposed, employ only passive measurement techniques. One technique, used by the Navy Navigation Satellite System

*Dr. Easton is head of the Space Metrology Branch at the Naval Research Laboratory. His specialty is Satellite Navigation.

(NNSS), measures the Doppler shift (shift in frequency due to satellite motion) of signals emanating from the satellite. The other technique uses synchronized clocks in the satellite and user equipment to find the range from satellite to navigator. If the clocks are not synchronized the technique provides the information needed for synchronization. A common characteristic of all existing or proposed navigation satellites is that the satellite position must be known very accurately. Provided with this accuracy and the means to determine clock synchronization between user and satellite, these satellites can be used to transfer time between two ground stations.

This paper describes the time dissemination aspects of the Navy Navigation Satellite System, and discusses the experimental TIMATION I, II and III satellites. The elementary theory of navigation and time transfer with the TIMATION technique are described and some experimental data presented. Because the time standards in the TIMATION satellites are of particular interest; the two major disturbing influences on them, temperature and radiation, are discussed.

TABLE 1
Characteristics of Satellite Altitude Ranges

| Altitude Range | Altitude (km) | Period |
|---|---|---|
| Low | 900-2700 | 100-150 min |
| Medium | 13,000-20,000 | 8-12 h |
| Synchronous | 22,000-48,000 | 24 h |

### Navy Navigation Satellite System (NNSS)

At present, navigation satellites have been launched only in the low altitude domain. The only operational U.S. system, NNSS, operates with low altitude satellites to gain full use of the doppler technique, *i.e.*, at low altitudes the doppler shift seen by a user is more pronounced due to higher relative velocity between satellite and receiver than at higher altitudes.

NNSS uses five satellites having the characteristics shown in Table 2. This navigation system uses the doppler shift on two carrier frequencies ($\approx 150$ MHz and $\approx 400$ MHz) to determine the position of the receiver. The observed doppler shift is dependent upon the position of the user's receiver relative to the satellite transmitter. Measuring the doppler shift provides the means to calculate the user's position relative to the satellite and subsequently his position on the earth. This system does not use time as a precise parameter—frequency is the stable reference. The

TABLE 2
Characteristics of Operating TRANSIT (NNSS) Satellites

| Scientific Name | Launch Date | Period min | Perigee km | Apogee km | Inclination Degrees | Eccentricity (Ratio) | Right Ascension Degrees |
|---|---|---|---|---|---|---|---|
| 1970 67A | 27 Aug. 1970 | 106.98 | 949.7 | 1218.2 | 90.04 | 0.018 | 238.2 |
| 1968 12A | 2 Mar. 1968 | 106.93 | 1024.7 | 1138.4 | 89.99 | .0076 | 279.0 |
| 1967 92A | 25 Sept. 1967 | 106.75 | 1036.0 | 1110.6 | 89.23 | .0050 | 88.1 |
| 1967 48A | 18 May 1967 | 106.96 | 1066.8 | 1099.0 | 89.63 | .0022 | 12.4 |
| 1967 34A | 14 Apr. 1967 | 106.48 | 1046.9 | 1074.3 | 90.20 | .0018 | 348.8 |

oscillator frequency should be sufficiently stable that it does not cause significant measurement errors during the fifteen minute observation time. This stability ($\approx$ 1 part in $10^9$ for 15 minutes) is easily obtained from a crystal oscillator.

These NNSS satellites can be used for time dissemination by using a portion of its message as a time marker. The best accuracies claimed using this system, are on the order of 10 microseconds. The operational accuracy is about 50 microseconds.

### TIMATION-Time Navigation Satellites

TIMATION, an acronym for Time Navigation, is a time based technique which permits a passive measurement of the range from satellite to navigator. Two low altitude satellites have been launched and a third (medium altitude) unit is being built. Table 3 gives the characteristics of these three satellites.

TABLE 3
Characteristics of TIMATION Satellites

| | TIMATION I | TIMATION II | TIMATION III |
|---|---|---|---|
| Launch Date | 31 May 1967 | 30 Sept. 1969 | Proposed |
| Orbit | Circular | Circular | Circular |
| Inclination, degrees | 70 | 70 | 96 |
| Weight, kg | 39 | 57 | 159 |
| DC power, W | 6 | 18 | 50 |

### *A. Theory of Navigation by Passive Ranging*

In the TIMATION technique of passive ranging, the range to the satellite is computed by measuring the time it takes a radio signal to travel from the satellite to the navigator's receiving equipment. Since the signal travels at the speed of light, measuring the signal time delay permits the range to be directly calculated. The measurement technique will be explained after the use of passive ranging for calculating navigational fix is discussed.

The problem of calculating a navigational fix using satellite ranging techniques is greatly simplified by a direct transformation to the celestial navigation problem. Celestial navigation, well known by all shipboard navigators, permits this new navigation concept to use proven and familiar techniques.

Figure 1 shows the basis of this transformation. The triangle is made up of the radius of the earth ($R_e$) to the navigator's position ($P_n$), the distance from the center of the earth to the satellite ($R_e$ + height), and the distance from the satellite to the navigator (Range). The first side ($R_e$) is known from the navigator's assumed position, and varies due to the change in the radius of the earth with geographical position. The second side ($R_e$ + height) is known from the satellite ephemeris (satellite bodies in an elliptical orbit), and the third side (Range) is measured. From the triangle the angle $\theta$ can be computed. This angle is the complement of the angle that a navigator measures with a sextant to a star having the same geographical position (GP) as the satellite. With this information the navigator could use the techniques of celestial navigation in the computation of his position (1,2). The distance and azimuth (or colatitude and coaltitude) to the geographical position are found from the navigator's assumed position by using one of the many navigational tables available such as H.O. Pub. No. 214, *Tables of Computed Altitude and Azimuth* (3)), and his actual position plotted.

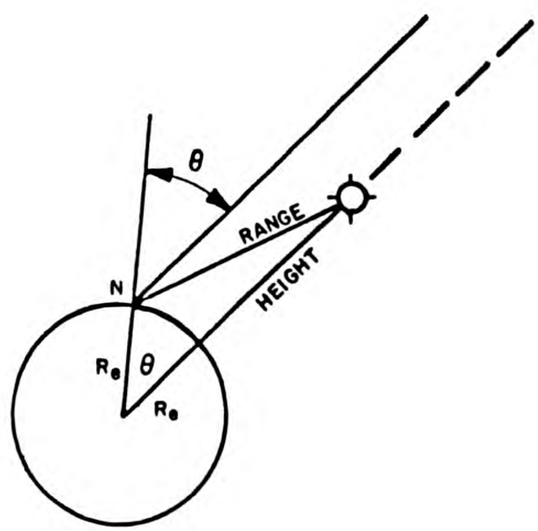



*Figure 1 – Transform to celestial navigation*

### *B. Use of Celestial Techniques*

One advantage of using celestial navigation techniques is that they have been improved over the past two centuries to a point of great convenience. One such convenience is the altitude intercept method or, as it is often called, the Marcq St. Hilaire method (2). In this method an intercept chart (difference between the actual position and the navigator's assumed position) is computed and plotted from an assumed position near the navigator's actual position. Assumed position means that the navigator picks a nearby rather than actual position for his calculations if it is mathematically easier. On this chart the azimuths to the geographical positions, of the stars to be observed, are plotted. The difference between the precomputed value and the actual star sighting determines the navigator's actual distance from the assumed position along the particular azimuth line. The navigator's acutal position can be found by using several stars.

An analogous intercept chart can be drawn for the satellite, as shown in Figure 2. On this chart the center of the diagram is the navigator's assumed position. The radial lines point to the computed azimuth or the satellite's geographical position at the times shown (time is minutes past the hour). The marks on the azimuth lines indicate the signal delay time, in even microseconds, that the signal takes to travel from the satellite to the navigator.

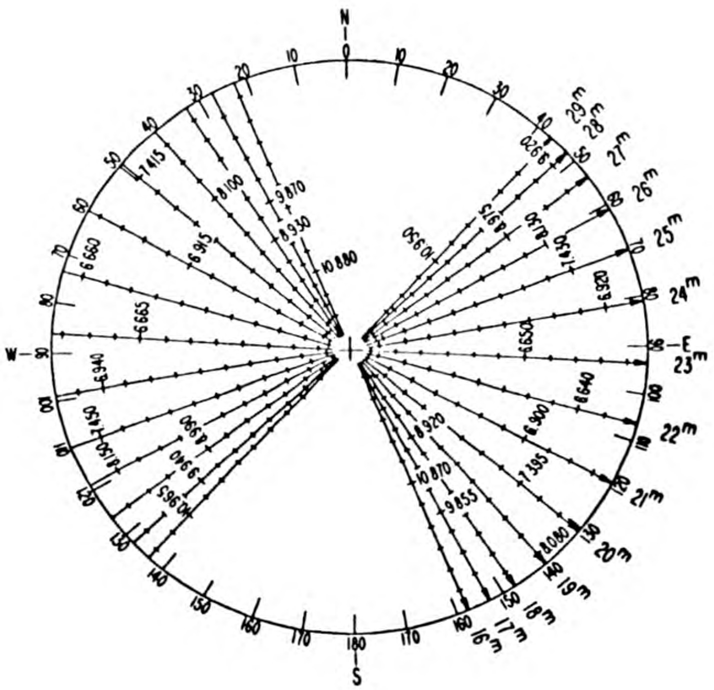



*Figure 2 — Precomputed intercept chart*

To use the chart, the navigator measures, at a given time, the time delay from the satellite. A perpendicular to the azimuth line at the time-delay mark corresponding to the measured value becomes a Line of Position (LOP). Since the navigator measures only range to the satellite he could be anywhere on a circle of equal range around the geographical position of the satellite. The azimuth line gives direction to the center of this circle of equal range and the perpendicular line approximates an arc of this circle. The navigator then takes as many measurements as are desired and a navigational fix results. Figure 3 shows such a fix with the intersection of the LOP's being a sharply defined point. If the clocks in the satellite and the user equipment are not synchronized

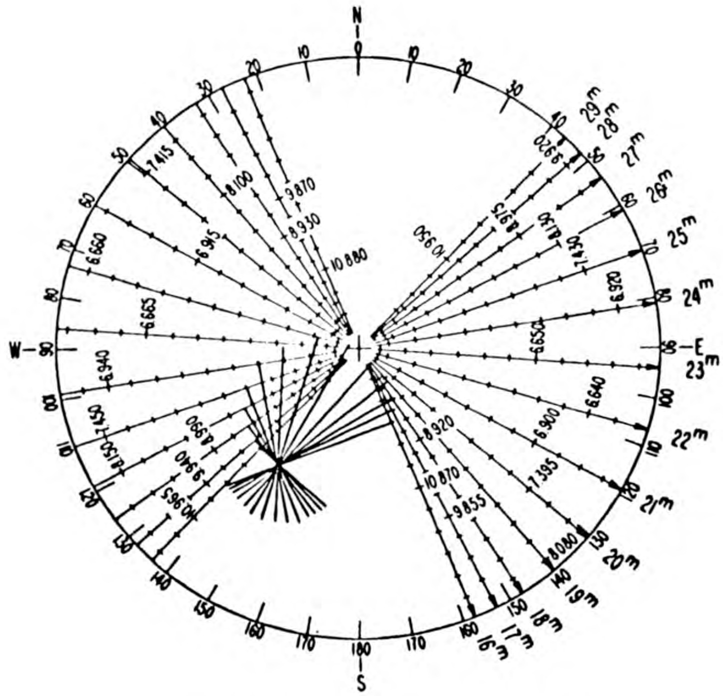



*Figure 3 — Fix determined on intercept chart*

the LOP's will not intersect at a single point. This is analogous to an instrument error in a sextant. Figure 4 shows such a condition. In this case the LOP's will form an arc of a circle as shown. The navigator lies at the center of the circle with the radius being the time difference between the two clocks. The time difference introduces a bias into each signal-delay measurement which becomes a constant difference in the spacing of the LOP's. The navigator can then introduce estimated corrections into his data and draw new LOP's to obtain the single point intersection. The amount that he corrects the data for a fix provides the difference between his clock and the satellite's.

### *C. Reading the Satellite-Navigator Time Delay*

So far we have described all the techniques needed to give a fix except that of reading the time-delay measurement from the satellite signal. The TIMATION I satellite transmitted the following modulations in sequence on its 400 MHz carrier: 100 Hz, 300 Hz, 1 kHz, 3 kHz, 10 kHz, and 30 kHz; and a 100 kHz signal continuously. Figure 5 shows an example of these signals after comparison with the ground receiver generated signals produced from the navigator's clock. To illustrate how the data is read a clock analogy is used. The uppermost clock faces shown in Figure 5 correspond to the modulations on the carrier. One full turn of the clocks is one wavelength of the modulation frequency, *i.e.*, for

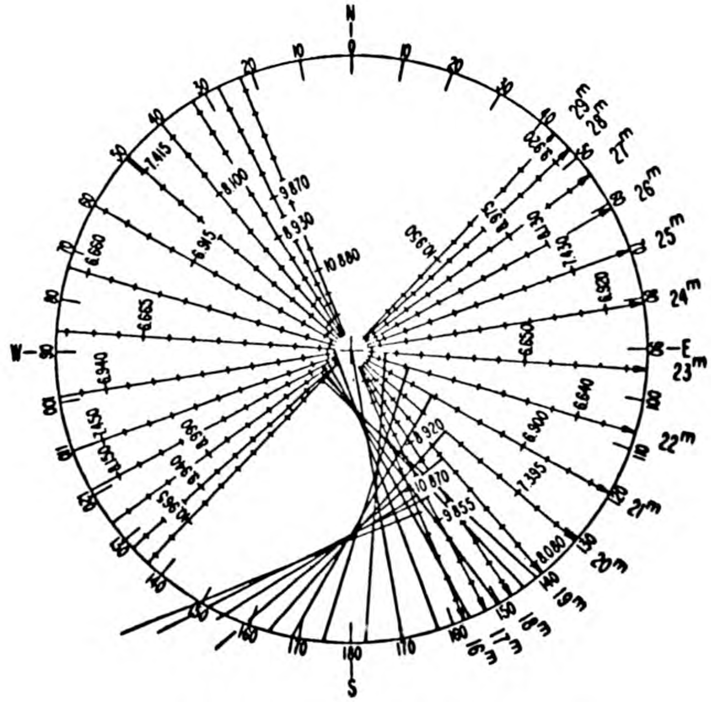


*Figure 4 — Intercept chart showing effect of synchronization error on plot*

the 100-Hz signal it requires 10,000 microseconds for the signal to travel one wavelength; for the 300-Hz signal, 3333.3 microseconds; and so on. The second row of clock faces correspond to the navigator's clock signals which are assumed to be synchronized to the satellite's clock. The third row shows the satellite signals received by the navigator. At the bottom is shown the data as it comes from the receiver. The sawtooth line is the 100-Hz phase comparison, and the other is the sequenced phase comparison placed beneath their respective clocks. For example consider the 10,000-microsecond clock, which shows a time (or actually phase difference between the two signals) difference of 0.68 between the navigator's clock and the satellite signal. The actual recording shows 0.68 of a full scale of 1.0. This reading implies that the signal traveled 0.68ths of one wavelength of 10,000 microseconds. We know then that the time delay between the satellite and navigator's receiver is approximately 6,800 microseconds.

Since the signals shown are clear, that is, there is no jitter in the recording, it is possible to proceed to the 1000-microsecond clock which registers 0.92. This is 920 microseconds which when combined with the 6,800 microseconds previously determined gives 6,920 microsecond time-delay. This figure is not the result of addition but successive approximations where the navigator chooses the figure indicating less error. From the 10,000 microsecond clock reading a 6,800 microsecond time delay is indicated. From the 1000 microsecond clock a 920 microsecond

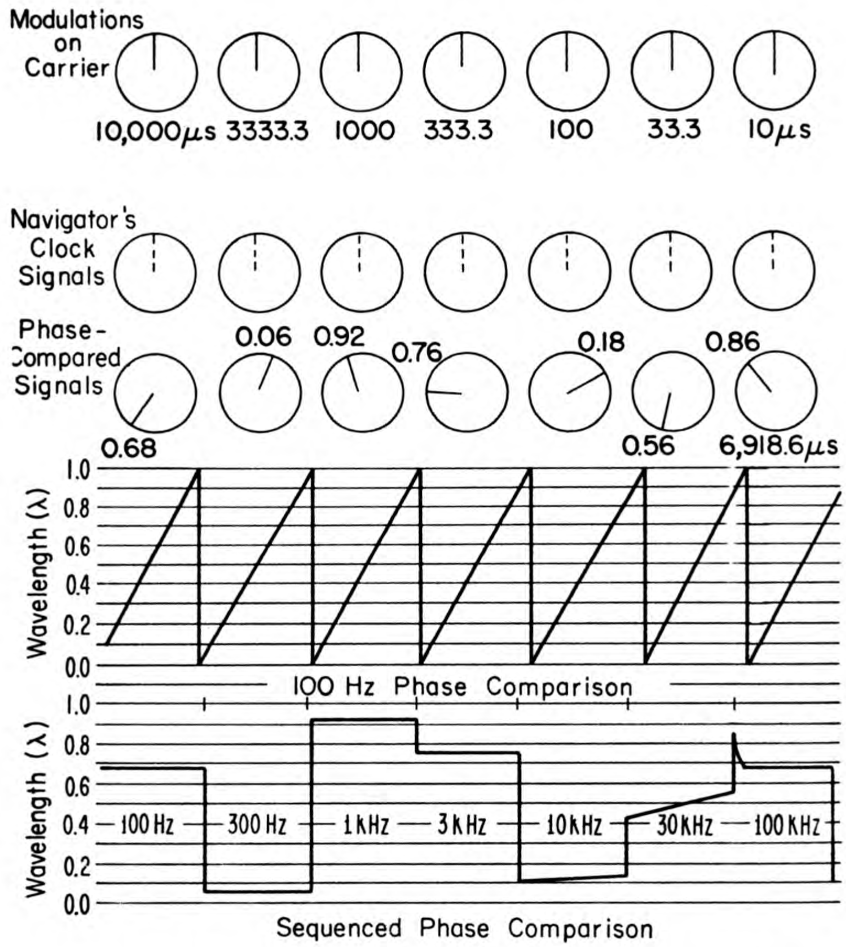



*Figure 5 — Method of reducing phase measurements to range delay*

time delay is indicated. Since 920 is better than the 800 in 6,800 we change the error to be corrected to 6,920. It is apparent then that the progressively finer measurement of the delay improves the precision of measurement. Proceeding then to the 100-microsecond clock, it reads 0.18 or 18 microseconds giving a total delay of 6,918. The 10-microsecond clock reads 0.86 or 8.6 microseconds giving a total delay of 6,918.6 microseconds as the signal time delay from the satellite to the navigator. The intermediate clocks not used here were not used for the sake of simplicity. They are shown for information.

***D. Navigation Satellite Technique***

Now we have prepared the intercept chart and can read the time delay to the satellite. In order to navigate we now take a time delay reading at each minute of the satellite pass corresponding to the azimuth lines on the intercept chart. We can then transfer the time-delay measurements to the intercept chart and draw the LOP's. If there are no synchronization errors a clearly defined fix will result. If the fix is not clearly



473-642 O - 72 - 2

defined correction can be made for clock errors. Many fixes have been made with this technique in many different locations. Figure 6 shows a fix made from a truck moving along Route 66 outside Washington, D.C. The fix involved advancing the LOP's according to the truck's velocity, as in a celestial running fix, and correcting for a clock error. Similar experiments have been made from aircraft and boats. The results obtained from the truck fixes are among the best obtained from all the experiments. The difference in the others is thought to be due to the lack of exact knowledge of the airborne or seaborne vehicle's velocity.

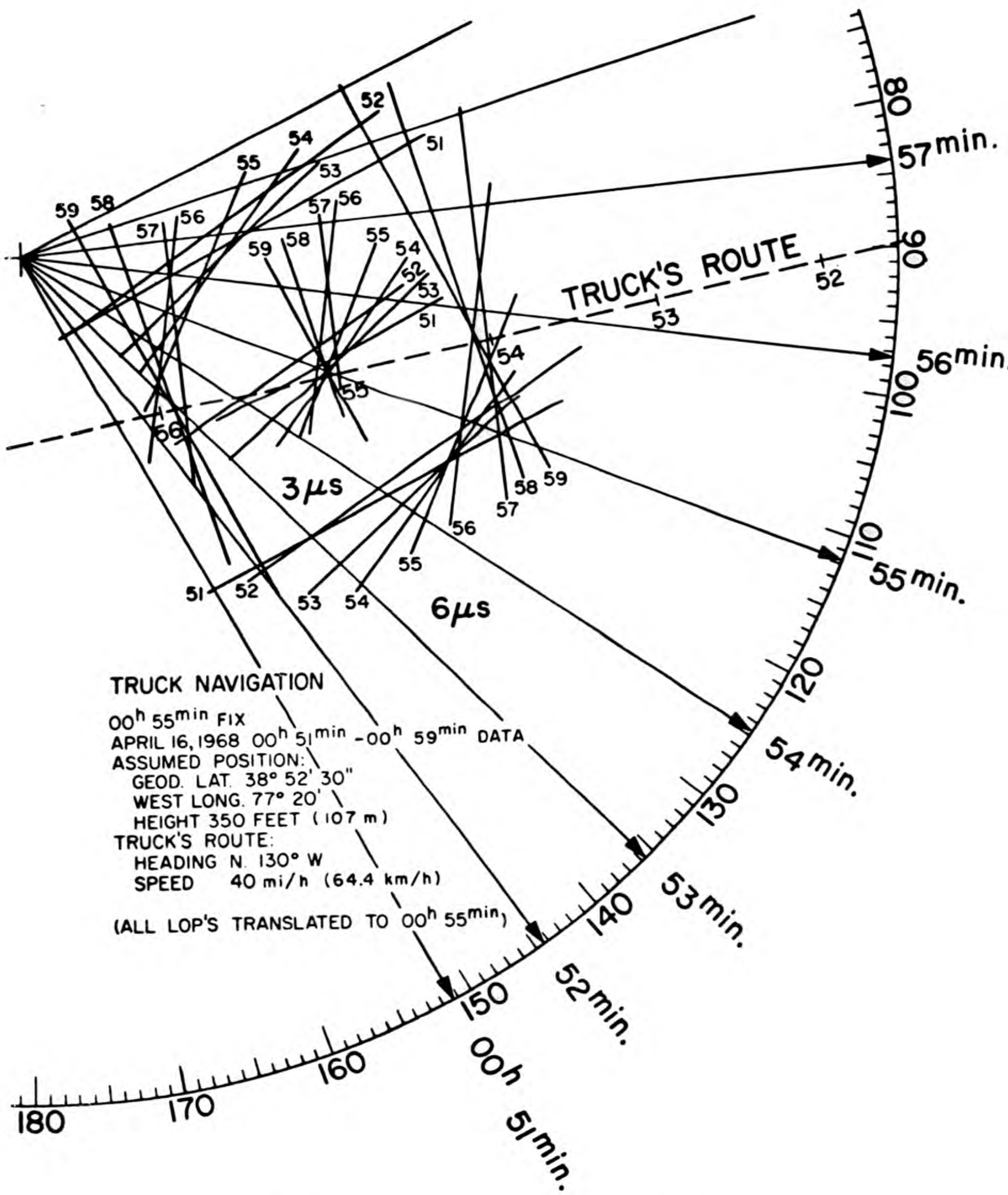



*Figure 6 — Fix made on a moving truck*

### *E. Time Transfer via Satellite*

As shown previously, it is possible to use this satellite to determine a navigation fix and to determine the time difference between the satellite and the navigator's clock. It is then only a short procedure to make the measurement at two different sites and thereby use the satellite clock as a means of comparing the clocks at the two sites. If the measurements are made simultaneously, the stability of the satellite clock is unimportant; if the measurements are made at different times, the accuracy will depend on how well the satellite clock rate is known. However, since this satellite's clock rate is known to be better than 1 part in $10^{11}$ and since the satellite travels rapidly between distance stations, it is a very good instrument for the exchange of time.

Experimental time transfers have been performed between NRL and the established stations with the TIMATION satellites. The results of some of these experiments are shown in Figure 7. There the error in microseconds is plotted against time in days. The experiments resulted in comparison between the cesium-bean resonators in the outlying stations and the cesium-beam resonator at NRL. The overall rms error of all the initial time transfers if 0.55 microsecond.

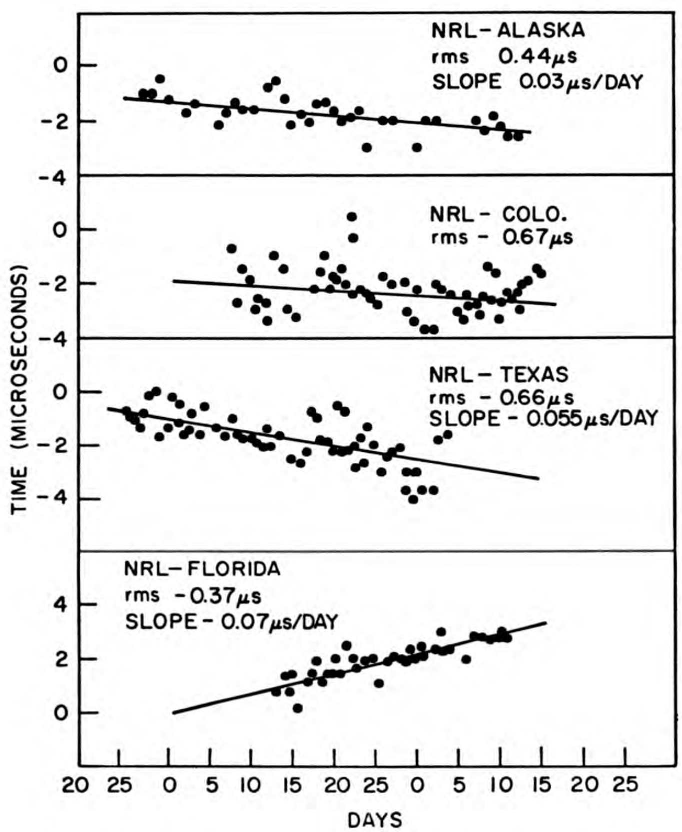



*Figure 7 — Comparison of a cesium beam resonator at a central station to the resonators at the stations shown as determined by satellite time transfer.*

The TIMATION satellites, 1967-53F (TIMATION I) and 1969-82B (TIMATION II), which were used in the time transfer experiments, both utilize high-stability crystal oscillators. The first satellite contains an oscillator which uses a selected commercial 5-MHz crystal. The second contains a special metal-enclosed 5-MHz unit (4), protected from radiation by 2 mm of lead.

The aging effect demonstrated by most crystal oscillators acts in such a way as to increase frequency with time. In recent years (5), considerable effort has been expended in methods to reduce this aging effect. This effort has involved the use of better polishing techniques, higher vacuums, and longer bakeouts at higher temperatures. The crystals used in these two oscillators exemplify these two crystal types.

In a space environment a crystal oscillator experiences a frequency decrease with time. This decrease results from the natural radiation background present around the earth. The composition of the radiation is principally electrons and protons, in a range of energies. The apparent effect on the crystal is that its size is increased, consequently lowering its resonant frequency. Investigations into the effect have revealed that a more likely mechanism is that the particle bombardment dissociates the molecules in the crystal. The dissociation would lower the resonant frequency of the crystal.

## Crystal Oscillators in TIMATION I and II

The crystal oscillators in the TIMATION satellites are both enclosed in proportionally controlled ovens and use fifth overtone, 5-MHz, AT-cut crystals. They are controlled in frequency by ground station command. The two differ, however, in detail such as temperature control, crystal preparation, crystal shielding, and crystal stability.

### *A. Temperature Control*

The TIMATION I oscillator uses a double proportional oven control. This control gave the oscillator a frequency change of approximately 2 parts in $10^{11}$ per degree C. While this change is large enough to make short term drift measurements unreliable, the frequency can still be measured at those times when the oscillator temperatures are equal, thereby obtaining the long term drift.

The TIMATION II oscillator uses a triple proportional oven within the crystal case, and the case itself is kept within $\pm 0.05°C$ by means of Thermo-Electric Devices (TED's). Figure 8 shows the variation in frequency of this oscillator with time. It can be seen in this figure that the frequency is not affected by the satellite structure temperature, as was the TIMATION I frequency.

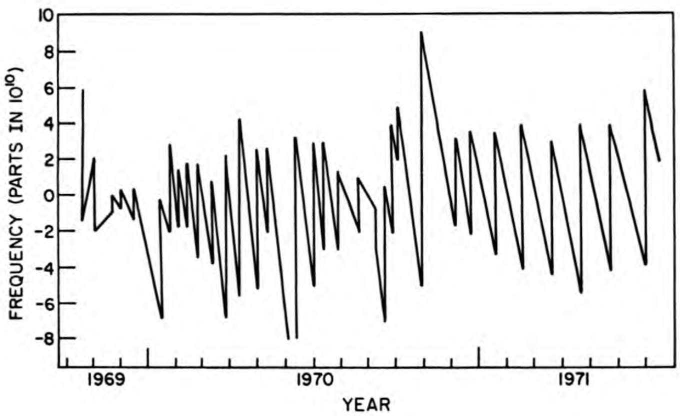



*Figure 8 — The measured frequency of the TIMATION II oscillator*

### B. Radiation Effects

It is seen that, for the first year the aging rate of TIMATION I varied about 1 part in $10^{11}$/day while the rate of the TIMATION II oscillator varied 6 times as much. Part of the explanation of this difference lies in the differences between the two crystal units. TIMATION I used a commercial quartz unit sealed in a commercial glass envelope. When launched it had an appreciable positive rate which was almost exactly balanced by the radiation effects.

The TIMATION II oscillator has a metal-enclosed crystal that is ground to a better surface, and evacuated to a better vacuum at a higher temperature. The metal-enclosed crystal has a much lower initial aging rate than the glass enclosed unit and so its positive aging rate was quickly overcome by the radiation effect and quickly became stabilized at a high negative aging rate. The TIMATION II oscillator crystal is protected by 2 mm of lead. This shield eliminates any effect from electrons and halves any proton effects. The pronounced radiation effect remaining is thought to result from two causes: (1) protons which penetrate shielding and (2) a more radiation sensitive quartz used in the second unit.

## Time Transfer *Via* TIMATION II and Loran-C

An interesting time-transfer experiment involved comparing the Loran-C oscillator on the Pribilof Islands to U.S. Naval Observatory time. This experiment involved using the Loran-C signal from the Pribilofs to the TIMATION station in Fairbanks, Alaska; transferring the time *via* satellite to NRL and from NRL to the U.S. Naval Observatory *via* microwave link. The significance of this experiment is that it empirically demonstrated the capability of this technique to provide accurate time transfers to stations requiring time synchronization to the Naval Observatory.

An experimental receiver, Figure 9, has been built by a commercial concern for using the experimental TIMATION II satellite as a time-dissemination device. This receiver has been used to synchronize clocks with good results. It must be remembered that this is an experimental device and cannot be expected to be used for general time dissemination for any length of time or in an operational sense.

## TIMATION III Satellite

The TIMATION III experimental satellite, the next one planned for launch, is scheduled to operate at a 14,000 km (7500 nmi) altitude. The ranging signals will be broadcast at approximately 400 and 1600 MHz to reduce the ionospheric refraction of the signals. It is of interest to consider the radiation environment this satellite is expected to endure.

### *A. Time Transfer with the TIMATION III Satellite*

While the low-altitude satellites can be useful for time transfer, satellites at higher altitudes offer a number of advantages. These satellites can be seen from a much larger area of the earth and stay within view for a much longer time. The present TRANSIT and TIMATION satellites have useful pass intervals of 1/4-hour. Objects at 14,000 kilometers

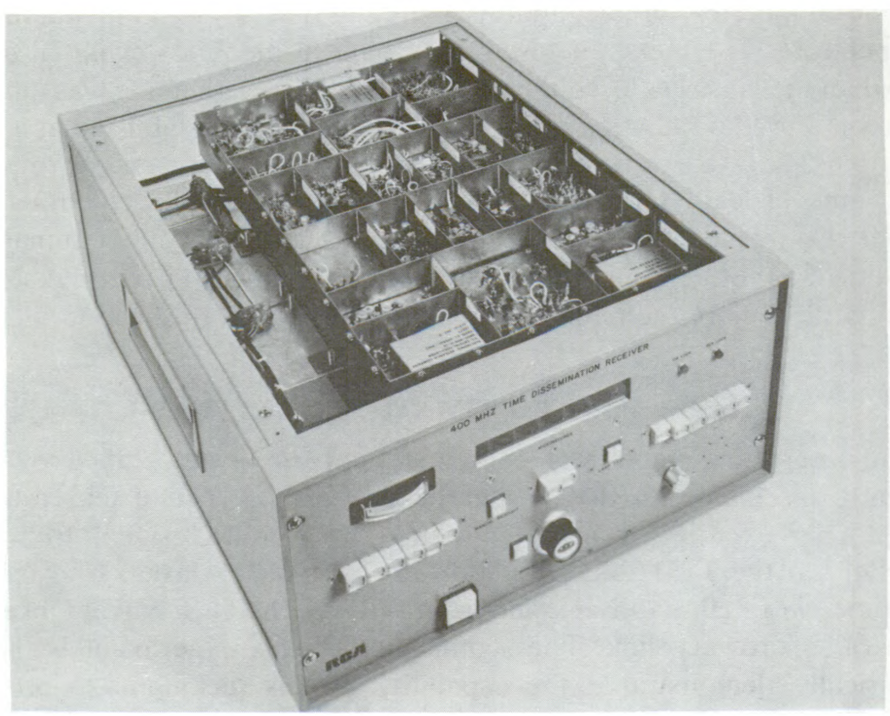



*Figure 9 — Commercially built time dissemination receiver*

(TIMATION III) will be in view for intervals varying from 2 to 4-1/2 hours. During this interval one will have an opportunity to make several leisurely measurements.

An advantage of this type of satellite is that its position will be well known (drag will be negligible; geodetic effects greatly reduced). Knowledge of satellite position will be so well defined that the possibility exists of using the satellite to determine the fine structure of the earth rotation rate.

## Conclusions

The trend in U.S. military navigation satellites is toward the use of onboard clocks to allow time-delay to be measured directly and passively by the user. This trend would permit the accurate dissemination of time by navigation satellite to users in the field. Operational and experimental navigation satellites are now located in low-altitude (1000 km) orbits which can be used for time transfer.

This paper has shown the following major points:

1. Operational military satellites can now be used to transfer time operationally to 50 microseconds;
2. Experimental low-altitude satellites, used as a means of transporting clocks at high velocities, have demonstrated time transfer accuracies of 0.5 microseconds;
3. The ranging navigation satellite problem is easily transformed to the celestial navigation problem; and
4. Electron and proton bombardment affects the aging rate of quartz crystals in low-altitude satellites. At higher altitudes the electron flux increases and the proton flux decreases. With shielding, the effects attributable to electrons can be made small so a properly shielded crystal oscillator should show negligible radiation effects when used in a higher-altitude satellite.

Navigation satellite systems are foreseen that will provide users with data for continuous clock updating.

## References

1. J. C. Hill, T. F. Utegaard, and G. Riordan, *Dutton's Navigation and Piloting*, U.S. Naval Institute, Annapolis, Maryland, 1958.
2. Nathaniel Bowditch, *American Practical Navigator*, H.O. Pub. No. 8, U.S. Navy Hydrographic Office, United States Government Printing Office, Washington, D.C., 1958.
3. U.S. Navy Hydrographic Office, H.O. Pub. No. 214, *Tables of Computed Altitude and Azimuth*, United States Government Printing Office, Washington, D.C., 1952.

4. M. Bloch, J. Ho, J. Denman, and D. LaGlasso, "Kold-Seal Thermal Compression Bonded Crystals," *Proc. of the 22nd Annual Symposium on Frequency Control,* pp. 118-135, April 1968.
5. A. W. Warner, D. B. Fraser, and C. D. Stockbridge, "Fundamental Studies of Aging in Quartz Resonators," *IEEE Trans. Sonics and Ultrasonics,* Vol. SU-12, pp. 52-59, June 1969.

## Oceanographic Expedition

Recently scientists from Scripps Institution of Oceanography, University of California, San Diego, began an eight-month expedition around the continent of South America. Work in both the Atlantic and Pacific Oceans will cover physical, biological, and geological oceanography.

Funds for research come from the National Science Foundation and the Office of Naval Research.

The 2,075-ton, 245-foot-long research vessel *George Melville* will travel a total of 29,720 miles. During the first half of CATO Expedition (Cycloidal Activities in Two Oceans), she was scheduled to go west to the Hawaiian Islanda and Tahiti and then down through the Strait of Magellan into the Atlantic Ocean.

Remaining research will be conducted in waters off the eastern coast of South America and in the Caribbean Sea. R/V *Melville* steams through the Panama Canal back into the Pacific in mid-January and returns to San Diego in mid-February.

Captain for the entire cruise is Noel L. Ferris.

Thomas E. Chase, associate specialist for the Geological Research Division at Scripps, is scientific leader in charge of coordinating research.

While in the South Pacific during the beginning of the cruise, scientists will continue a study of the structure of communities of plankton in the center of large gyres (spiraling systems of ocean circulation). Because these communities are thought to be at ecological "climax," they should be constant in relative abundances of species.

Work in the Atlantic involves collecting copepods, tiny shrimp-like marine organisms. Specimens are needed to complete studies on the biogeographic and evolutionary relationships among copepods of the genus *Labidocera*, found only in the western hemisphere.

Overall objective of another segment of investigations is the determination of wave growth rates in winds of 15 to 30 knots off the coast of Argentina. Similar studies will also be conducted in the Gulf of Tehuantepec, part of the Pacific near Central America where winter winds call "tehuantepecers" cause particularly rough seas.

# Biodegradation of Polluting Oil

**Richard Bartha and Ronald M. Atlas***
*Rutgers University*
*New Brunswick, New Jersey*

It has been estimated that 2.5 percent of the current annual production, *i.e.* approximately 5 million metric tons of petroleum and petroleum products, wind up polluting the oceans of the world (1). While estimates of this type are necessarily vague, calculations based on the abundance of floating tar lumps in the North Atlantic and in the Mediterranean seem to give support to this or an even higher figure (2). A breakdown of this oil pollution load according to its sources reveals the startling fact that the much publicized spills that are due to accidents in off-shore production or loss of tankers at sea account for only 4 percent of the above yearly total. A much larger share (21 percent) results from the routine operation of ships and tankers, and the rest is brought about mainly by the inappropriate disposal of spent lubricating oils and refinery residues (3). While concern is mounting over the ultimate effect on marine life of this large oil pollution load, at present only the massive and localized spills are tractable with cleanup procedures. Even in those cases, current treatment methods leave much to be desired with respect to their effectiveness, absence of side effects on marine life, and economics (4).

Operating on "beans, bullets, and black oil," the U.S. Navy shares in the current concern over environmental pollution and, among other countermeasures, supports numerous research projects aimed at the prevention or cleanup of oil spills (5). The aims of one of these ONR projects "Biodegradation of Oil Slicks in the Marine Environment" were outlined in *Naval Research Reviews* two years ago (6). Progress during the elapsed period concentrating on the practical aspects of our work will now be summarized.

## Limiting Factors

Since microbial degradation is known to play a crucial role in the eventual dissipation of otherwise untreated oil slicks (7), it seems logical to harness this natural force in the fight against oil pollution. Unfortunately, the natural rate of oil biodegradation in sea water is too slow to provide effective relief against massive oil spills. A number of possible causes were cited to explain the low rate of oil biodegradation in the sea (8). The absence or the low density of oil degrading microorganisms,

*Dr. Bartha is Associate Research Professor of Microbiology at Rutgers University. Soil microbiology and microbial ecology are his fields of interest. Mr. Atlas is a Ph.D. candidate at Rutgers.

unfavorable temperature conditions, inhibitory substances in crude oil, and insufficiency of mineral nutrients in sea water seemed to us the most significant reasons. Considering the importance of the subject, it is surprising that these parameters had not been sufficiently evaluated in a quantitative and environmentally oriented manner. Since the several hundred components of crude oil have been only partially characterized (9), the analytical problems of working with such a complex mixture were quite formidable. Modern instruments have rendered this problem somewhat more tractable. Relaying on analysis by gas-liquid chromatography, occasionally in combination with mass spectrometry and other techniques (see Figure 1), the goal was to assess these limiting conditions with the ultimate aim to alleviate them.

The abundance and distribution of marine microorganisms that are capable of growing on sea water agar plates containing 1 percent crude oil was measured in the Raritan Bay area on repeated cruises. One hundred ml sea samples were passed through millipore filters and the filters were incubated on the surface of the described agar plates. Microbial colonies that developed on these plates but not on those without added crude oil were counted as petroleum degraders. Their numbers reached 300/100 ml close to the mouth of the oil-polluted Arthur Kill, but decreased to 25-30/100 ml at the seaward fringes of the Bay. Seasonal variations were evident, the numbers of petroleum degraders being higher during the summer than in the winter. All aseptically collected 100 ml sea water samples were able eventually to cause an extensive biodegradation of petroleum when incubated under favorable conditions. However, the time required for multiplication of the oil degraders to sufficient density delayed the onset of significant biodegradation for several days; a delay that we could ill afford in the case of an actual oil spill.

Biological activity is greatly dependent on temperature. Up to a certain optimum, the rate of biochemical processes roughly doubles with every 10°C increase in temperature. Optimum temperatures are not likely to be exceeded in marine environments, but in arctic areas, cold currents, and during the cold season in the temperate zone suboptimal water temperature can severely limit biodegradation. When petroleum in freshly collected sea water samples at various controlled temperatures was incubated, predictable decreases in the rate of petroleum biodegradation were observed. Unexpected was, however, a dramatically increased lag period that preceded the onset of measurable biodegradation at low incubation temperatures. While at 27°C biodegradation became measurable 2-3 days after the start of the experiment, at 20, 10, and 5°C, 10, 20, and 40 days elapsed, respectively, before biodegradation could be observed. These long delays could be explained only partially by the lower rate of microbial multiplication at low temperatures. Indeed, when instead of fresh crude oil a "weathered" sample was used (crude oil subjected to losses by evaporation, but not by biodegradation) the previously described delays at 20, 10, and 5°C were shortened to 4, 12, and 20 days, respectively. The highly volatile components of crude oil have appreciable microbial toxicity. At high water temperatures, these components are quickly eliminated from the crude oil by evaporation, allowing the microbial degradation of the residual material. At low temperatures, these ingredients are retained longer and inhibit the degradation of the rest of the crude oil components.

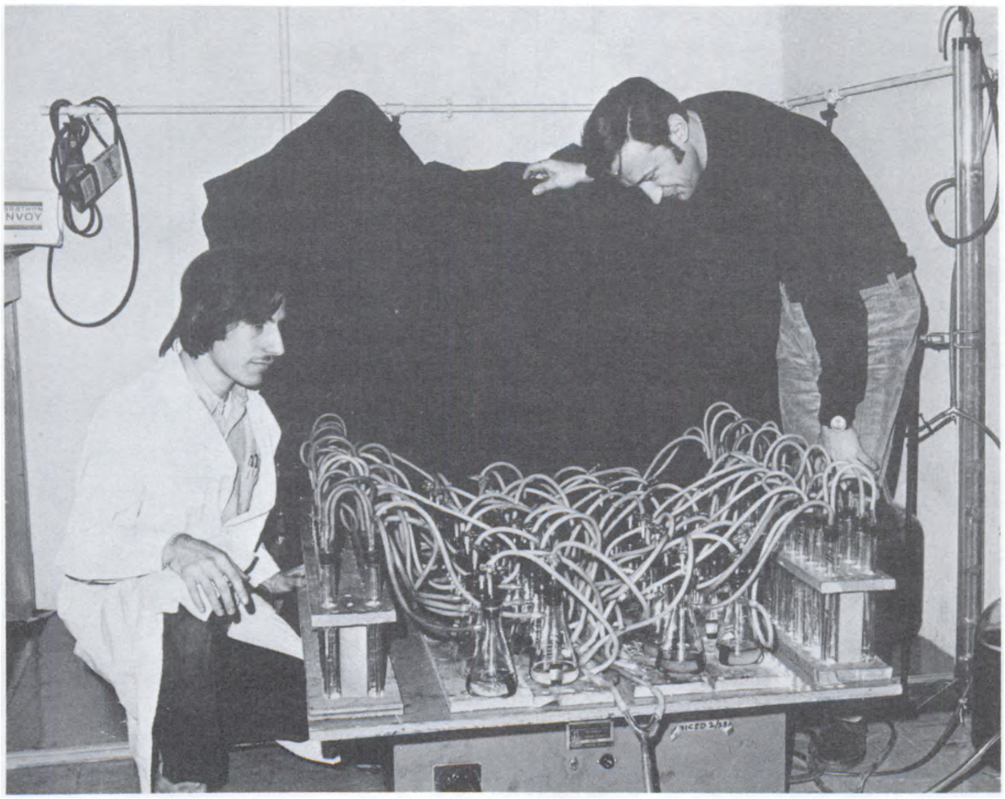


*Figure 1 — Apparatus used in the monitoring of petroleum biodegradation. Flasks containing sea water and petroleum are incubated on a rotary shaker under controlled environmental conditions. Carbon dioxide liberated in the course of petroleum biodegradation is trapped and measured.*

The described experiments were all conducted in sea water that had been fortified with suitable concentrations of nitrate and phosphate. Natural sea water, as well as crude petroleum, contain insufficient amounts of nitrogen and phosphorus to support extensive microbial growth. When the supply of these elements becomes exhausted, petroleum biodegradation slows down or comes to a complete standstill. Only 3 percent of 1 ml petroleum, added to 100 ml natural sea water and incubated for 18 days under otherwise favorable conditions, was degraded, but in samples amended with small amounts of nitrate and phosphate ($10^{-2}$ M and $3.5 \times 10^{-4}$ M, respectively) biodegradation increased to 70 percent (see Figure 2). A similar limitation of petroleum biodegradation by lack of nitrogen and phosphorus may well occur in an actual spill situation, especially when vertical circulation in the underlaying water column is low and photosynthetic organisms (algae) compete for the same elements.

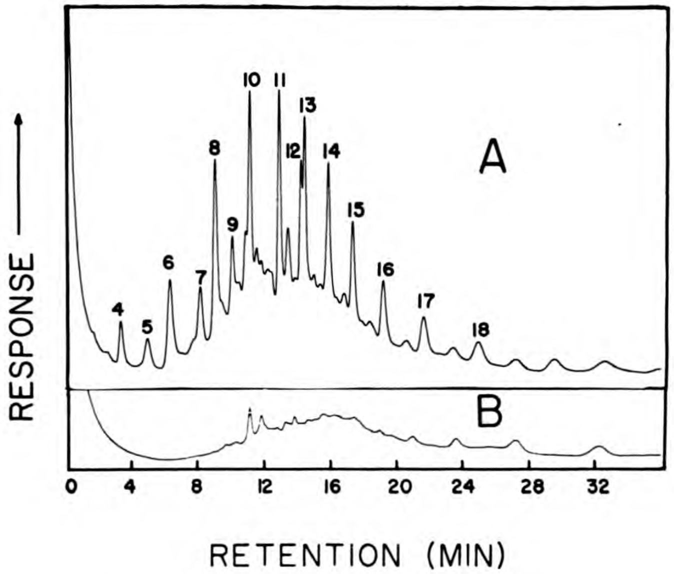



*Figure 2 — Gas chromatograms of "weathered" petroleum after incubation for 18 days in sea water samples. The area under each chromatogram corresponds to the amount of residual oil. The numbered peaks indicate major identified components of the petroleum. Sample A did not receive supplements; phosphate and nitrate were added to Sample B.*

## Artificial Stimulation

Having defined the major factors that delay oil degradation in the sea, the feasibility of remedial actions can be considered. Since petroleum degraders were found to be present in sea water at low initial concentrations and required time to multiply to effective densities, it was concluded that in most situations the seeding of an oil slick with appropriate microbial cultures (see Figure 3) may be helpful in speeding the degradation process. Such cultures should have high metabolic rates and an ability to degrade a broad range of hydrocarbons. They should have the ability to grow and multiply in sea water and remain viable during long periods of storage. Last but not least, they should not damage or taint marine organisms. No single culture is likely to serve satisfactorily alone and an effective microbial inoculum will contain several different and complementing microbial strains. Such seed materials are being developed and tested in our as well as in other laboratories (10).


*Figure 3 — An oil-degrading marine* Brevibacterium. *Lipid inclusions (arrow) are typical after growth on petroleum. Electron micrograph courtesy of Dr. C. E. Heintz.*

There seems to be no practical way to raise the temperature of sea water in cold areas in order to increase the rate of oil biodegradation. However, in certain situations it may be feasible to ignite a fresh spill and thus rapidly remove the more volatile fractions of the crude oil. According to research data this procedure should render the remaining oil more susceptible to biodegradation.

Perhaps the most important conclusion is the finding that inoculation of an oil slick with suitable microorganisms will do little or no good unless the oil slick is properly "fertilized" with nitrogen and phosphorus. This is easily accomplished in the laboratory flask, but poses a difficult technological problem in the field. Nitrate and phosphate salts or conventional agricultural fertilizer formulations would be rapidly diluted in sea water. They would be consequently of little benefit to the oil degrading microorganisms that adhere to the slick, but would most likely cause severe eutrophication (algal bloom) problems. In searching for a fertilizer that would selectively adhere to the oil slick we attempted to render phosphate and nitrate salts hydrophobic (water-repellent) by encapsulation in paraffin or by adsorption on fired colloidal silica. The best results, however, were obtained with alkylphosphate and alkylurea compounds. Here the phosphorus and the nitrogen are chemically bound to hydrocarbons that dissolve in and behave like oil, but their phosphorus and nitrogen content supports the degradation of crude oil 50 to 100 times their own weight. Their cost is reasonable, and they are degraded simultaneously with the oil slick. In laboratory experiments they gave as good results as the free nitrate and phosphate salts, but their final evaluation will be accomplished in a tank with circulating sea water under simulated field conditions. If the biodegradation of miniature oil slicks can be stimulated under these conditions without significant release of phosphate and nitrate into the sea water effluent, then these compounds hold indeed a great promise as selective "oil slick fertilizers."

Efforts to clean up oil spills by biological methods should be seen in perspective, and their potential should neither be over- nor underestimated. Even if the fullest potential of stimulated oil biodegradation in sea water can be attained, this will not obviate the need for containment and physical removal of the bulk of a massive oil spill. There is no conceivable way to render harmless by biodegradation 50,000 tons of crude oil that is spilled within a few miles from shore and is being driven shoreward by wind and current. Stimulated biodegradation will, however, find its proper place in an integrated oil spill control program by helping to eliminate oil that has escaped containment and collection, and has spread out too thinly to be eliminated by these methods.

## References


1. Blumer, M., Sanders, H.L., Grassle, J.F., and Hampson, G.R., "A Small Oil Spill," *Environment* **13,** (2) 2-12, 1971.
2. Morris, B.F., "Petroleum: Tar Quantities Floating in the Northwestern Atlantic Taken with a New Quantitative Neuston Net." *Science* **173,** 430-432, 1971.
3. Zeldin, M., "Oil Pollution." *Audubon* **73,** 99-119, 1971.
4. Swift, W.H., Touhill, C.J., Templeton, W.L., and Roseman, D.P., "Oil Spillage Prevention, Control and Restoration—State of the Art and Research Needs." In: *Oil Pollution: Problems and Policies*. S.E. Degler, Ed., B.N.A. Inc., Washington, D.C., pp. 31-61, 1969.
5. Nelson, S.B. In: *Proceedings, Offshore Drilling Conference,* Sept. 13, 1971. New York Ocean Science Laboratory, Technical Report No. 0011, 1971.
6. Bartha, R., "Controlling Oil Pollution of Harbors Through Biological Means." *Naval Research Reviews* **23,** (5) 24-26, 1970.
7. ZoBell, C.E., "The Occurrence Effects and Fate of Oil Polluting the Sea." In: *International Conference on Water Pollution,* London. Pergamon Press, Oxford, pp. 85-118, 1972.
8. ZoBell, C.E., "Microbial Modification of Crude Oil in the Sea." In: *Proceedings, Joint Conference on Prevention and Control of Oil Spills,* A.P.I.-FWPCA, New York, A.P.I. Publication, New York, pp. 317-326, 1969.
9. Whitehead, W.L., and Berger, I.A., "Geochemistry of Petroleum." In: *Organic Geochemistry* (E. Ingerson, Ed.). Pergamon Press, Oxford, pp. 249-332, 1963.
10. Anonymous, "Microorganisms Consume Oil in Test Spills." *Chem. Eng. News,* 48, (38) 48-49, 1970.

# Dolphins Communicate—But They Don't Talk

**David K. Caldwell and Melba C. Caldwell***

*Communication Sciences Laboratory*
*University of Florida*

The communication systems of dolphins, and especially the Atlantic bottlenosed dolphin, *Tursiops truncatus,* have received much public attention and publicity over the past decade or so. While we have been examining many likely communicative systems, the major focus of our work has centered around the underwater sounds made by these dolphins. There are three primary classes of these sounds: (1) the echolocation clicks now well documented as serving as an underwater sonar system used for environmental exploration, (2) the typically mammalian "squawks," "squeaks" and "barks" that should be familiar to all from somewhat analagous dog vocalizations, and (3) a type of sound most atypical of non-human mammals, a "whistle."

This whistle-like sound is the one to which we have directed much of our effort, and we have been attempting, under sponsorship of the Office of Naval Research's Oceanic Biology Program, to resolve some of the problems and controversy in this particular area.

The methods by which marine mammals utilize sound for communications and information acquisition is of interest to the Navy. An understanding of the methods by which these animals localize themselves within a school and seemingly analyze their environment by acoustic signals may be of benefit to swimmer/diver operations.

The Navy's effective use of underwater acoustics for surveillance, communications and guidance systems is impaired by the contributions of soniferous marine mammals to the ambient sea noise with the result that a high ambient noise level will distort or entirely mask the desired acoustic target or communication signal. An analysis of sounds from dolphins will provide the basis for a capability of distinguishing such ambient noise from militarily useful targets or signals.

The whistle is made by both sexes and by all age groups including newborn infants. So many theories had evolved concerning its function, including the highly speculative one of a true language, that we were initially surprised to find that each animal only repeats much the same

* Dr. and Mrs. Caldwell are both associated with the Marineland Research Laboratory, St. Augustine, Florida. Dr. Caldwell is oriented toward the general biology and systematics of odontocete Cetaceans. Mrs. Caldwell is more oriented toward animal behavior and has done much work on underwater communication methods in odontocete Cetaceans.

type of whistle, although there are differences between individuals. There is also much complex interplay between the two basic central nervous system controls of excitation *versus* inhibition. These do affect the whistle in much the same way as they do the human voice as to whether the animal is excited at the moment or inhibited by fear or when its attention is suddenly directed toward a change in its environment and it sharply terminates all whistling. As we see it, the social functions of the whistle are (1) alerting other animals to another animal's presence, (2) the identification of that particular individual, (3) the localization of that individual, and (4) some indication of the emotional state of the animal doing the whistling. For instance, very excited animals do usually whistle a lot unless afraid. Whereas these are important functions, they are a long way removed from being true language as humans know it and we do not believe that the dolphins are "talking" as we humans understand the term (Figure 1).

Behaviorally, through our own observations and those of others in many tank and some wild situations, the first function is obvious. Along with our students, we have investigated experimentally the second and third of the proposed functions in our theoretical evaluation of the dolphin whistle. The first set of experiments was conducted to determine whether a bottlenosed dolphin was capable of telling the differences

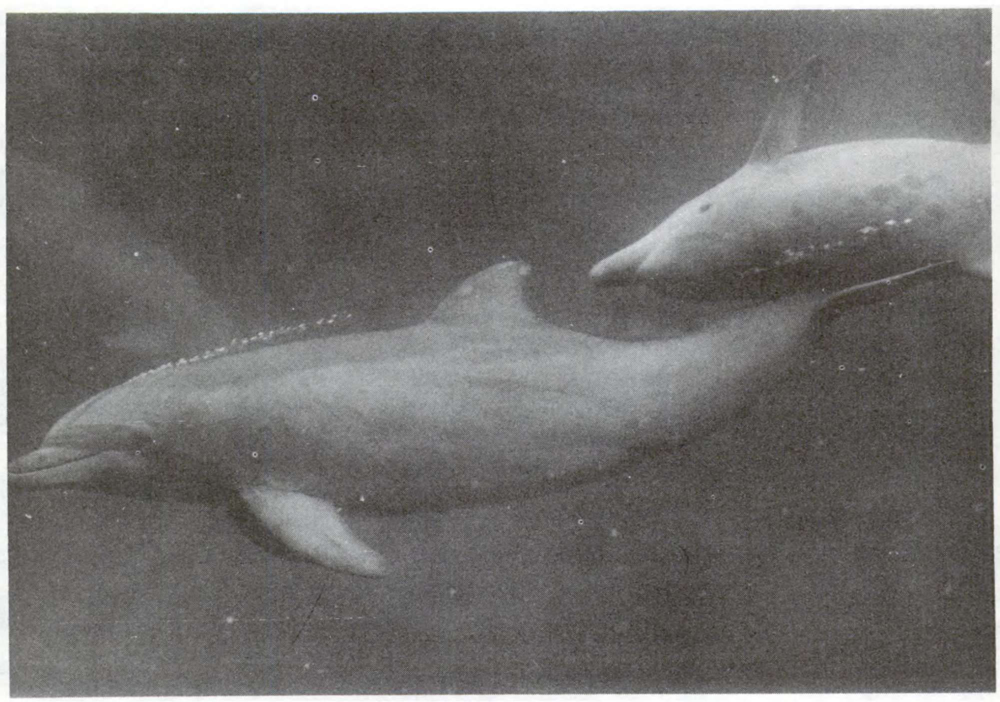


*Figure 1 — Frequently, but by no means always, dolphins emit air bubbles from the blowhole while whistling. Here a juvenile male calf playfully chases his mother and the streams of bubbles issuing from their blowholes show that both are whistling—probably out of the excitement of the chase.*

between whistles of other individuals of its own species. Dolphins of this species are apparently able to do this with considerable ease for the dolphin used in these experiments could flawlessly pick out all of the whistles of one animal from a continuously running tape containing many assorted whistles of nine other animals. He also learned to respond differentally to assorted whistles of eight other individuals of his own species. He proved his ability to tell the differences between the whistles of individual members of other dolphin genera as well (including the short-finned pilot whale, *Globicephala macrorhyncha,* the eastern Pacific common dolphin, *Delphinus delphia bairdi,* and the spotted dolphin, *Stenella plagiodon*).

The next factor needing resolution was the dolphins' postulated ability to localize the source of underwater sounds. Dolphins have lost the external pinnae that are so important to terrestrial mammals in their localization of airborne sounds, but even so, preliminary investigations in this field indicate that dolphins are capable of precise performances in difficult underwater sound localization tasks.

One unresolved factor in our work is the determination of a dolphin's capability of picking up cues concerning the emotional state of other dolphins from the minor shifts in quality and quantity of whistles. We are just beginning to study, on a systematic and experimental basis, the correlations between the assumed emotional state of a dolphin and the quality of the whistles it is then producing (or not producing). Via the tool of biotelemetry, already being developed and adapted for our specific needs, we hope also to have a more quantitative evaluation of the emotional state of the animal as well as of its whistles.

There is some evidence that dolphins may occasionally mimic an alien sound, but this is a well-known phenomenon in other non-human animals (especially dogs and birds). Whereas both interesting and worthy of biological study in itself, too much importance should not be attached to it as it is by no means a phenomenon peculiar to dolphins and men alone.

The surprise that we felt in finding that individual dolphin whistles are largely stereotyped has been nothing compared to the surprise felt at the unbridled anger that we evoke when forced to state this conclusion. It is an unpleasant experience, for we too want to be loved by our fellow man, to evoke social approval rather than anger. To have been cast into the role of destroyers of one of the few myths remaining to our own benighted species was forced upon us, not sought. We had rather hoped initially that dolphin whistles would at least prove to have songs like birds, but find no evidence of this either in the Atlantic bottlenosed dolphin, or in other kinds of dolphins as well. In addition to *Tursiops truncatus,* we have strong evidence for a lack of song patterning in the eastern Pacific common dolphin, good but not as strong evidence in the spotted dolphin, and such evidence to a much lesser degree (due only to small samples) for the gray grampus or Risso's dolphin (*Grampus griseus*). the eastern Pacific striped dolphin (*Lagenorhynchus obliquidens*) and the short-finned pilot whale. Similarly, we have found no "song patterning" in our studies of the non-echolocation-type pulsed sounds (which we call burst-pulse sounds on the advice of other workers) produced by the Atlantic bottlenosed dolphin, the eastern Pacific striped dolphin, the spotted dolphin and the Amazon freshwater dolphin (*Inia geoffrensis*). Recent evidence has evolved that indicates that such patterning does occur in some of the large and less social (and vocal) baleen whales—namely the humpback whale (*Megaptera novaeangliae*) and the right whale (*Balaena glacialis*). In the dolphins we have studied it appears that these burst-pulse sounds (or "complex sounds" of some authors) tend to be behavior specific on an individual moment to moment basis rather than as portions of a repetitious song pattern. On the basis of present evidence, and in conflict with some earlier writers, we do not believe that either whistles or burst-pulse sounds in dolphins are used for anything other than communication on a very general basis. The "echolocation" clicking sounds, usually broadband and emitted in regular pulsed sequences, while perhaps providing some communicative value in that they may signal that other dolphins are seeking food nearby or investigating potential danger or something of interest, in our experience serve chiefly, if not exclusively, for environmental exploration and are the only sounds emitted by dolphins for this purpose (Figure 2).

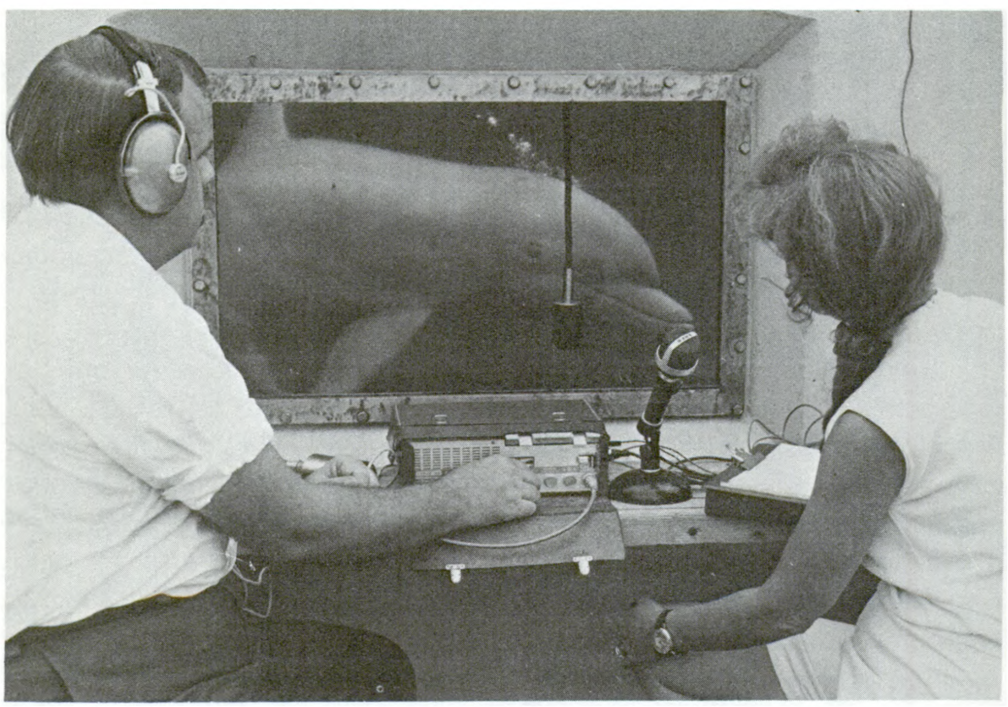


*Figure 2 — Here the Caldwells record and observe a juvenile bottlenosed dolphin. (Photo courtesy Marineland of Florida)*

While we and others have made good progress in our studies of dolphin acoustics, there are still many problems remaining in this field. However, at this point we can already state unequivocably that the Atlantic bottlenosed dolphin, and many of its cousins of other genera, has an excellent and compact acoustic computer, encased in a watertight container which in turn is totally unaffected by salt water. This computer is fully respresentative of a naval engineer's dream but a biologist's nighmare for we cannot open the particular black box without destroying it.

Other communicative systems clearly exist between dolphins, but studies of these are in an even more embryonic state and have been limited for the most part to subjective observational studies. Such systems include body positions and postures, mouth gestures, swimming attitudes and speeds, slapping the surface with the tail (lobtailing), explosive releases of air both above and below the water surface, and even genetically fixed pigmentation patterns. Most of these systems are difficult to quantify, but breakthroughs are slowly emerging and it is hoped that these factors, along with the better known and more easily quantifiable acoustic systems, will give us a relatively good overview of dolphin intercommunication. Whether we can ever have man—dolphin communication on more than a very superficial man—dog kind of conditioned response level is an entirely different matter and a subject that we presently consider improbable (Figure 3).

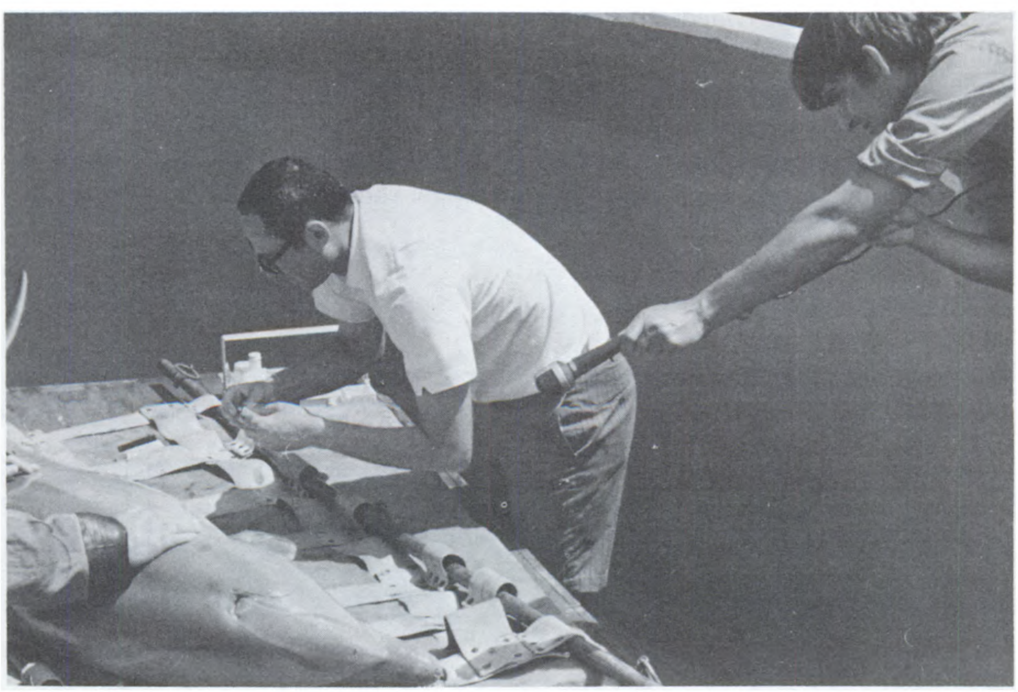


*Figure 3 — In order to study their vocalizations, dolphins are recorded under a variety of circumstances. Here one is recorded in air during a routine medical examination.*

## Patent of the Month

The Chief of Naval Research is responsible, for the Navy, for patents and related matters, such as inventions, copyrights, and associated royalty payments. Ideas for patents emerge from military or civilian individuals within the Naval establishment, from Naval laboratories, Commands, or offices, or from universities or contractors receiving finanicial support from the Navy.

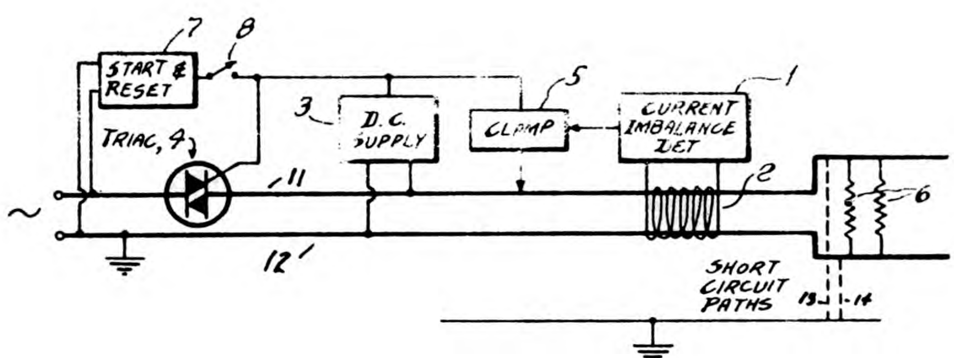
The following example of a recent patent stemmed from an idea of Mr. Max Yoder, of the Office of Naval Research. The invention is registered as United States Patent 3,617,808.

### Electrocution Prevention Circuit

This invention relates to electrocution prevention and more particularly, to a system whose response time is fast enough to prevent fibrillation of the human heart due to electric shock induced when a human accidentally provides a ground path for electric current.

Many Navy personnel aboard ships or aircraft, or working at shore installations, are constantly exposed to the possibility of electrical shock. The probability that these shocks may be fatal is increased by the omnipresent metal grounding situation common aboard ships or associated with military equipment. An almost equal need extends to the civilian situation, where electrical shock from 120 volt, 60 cycle, household current kills many victims needlessly each year.

Devices have been developed which interrupt the line voltage when there is a ground path provided by accidental contact by some exposed part of the human body to a current carrying switching device, called the "Triac." There devices utilized relays whose response times were too slow to prevent fibrillation, the major cause of death from electrical systems. The development of the Triac, whose response time is in the order of 0.001 second, has led to a means for interrupting the flow of current within a time short enough to prevent cardiac fibrillation.




*Ground current (implying a shock) is sensed by a current imbalance detector (1). A signal is then sent through clamp (5) which shorts the DC supply (3) and thus quenches triace (4) thereby interrupting the circuit.*

The present invention utilizes the short response time of Triac along with special activation circuitry to interrupt the current path. The Triac is solid-state semiconductor, five-layer NPNPN junction device having a gating electrode which is capable of switching high power flow through the device. It may be used as an integral part of the electrical service entrance panel or in individual branch circuits.

---

# On the Naval Research Reserve

*The Research Reserve program is composed of 66 companies throughout the United States. The Naval Reserve Officers are qualified in the conduct and/or administration of scientific research, or in patent, trade mark, and copyright matters. These officers are available in the event of national emergency to meet the needs of the Office of Naval Research and the Naval Establishment. Through the year the companies report on their activities and training programs.*

### Promotion Selections

There were two thousand seven hundred and forty-two (2,742) officers selected for promotion to Lieutenant by the Fiscal Year 1972 Reserve Selection Board. Congratulations go to two members of the Research Reserve:

| | |
|---|---|
| SCHAPPER, Robert P. | NRRC 13-5 |
| TAGGART, Richard J. | NRRC 9-3 |

Five officers were selected from the Staff Corps by the Fiscal Year 1972 Reserve Selection Boards.

Three Research Reserve officers were selected for promotion to Lieutenant Commander:

| | |
|---|---|
| BALLBACH, John D., SC | NRRC 6-6 |
| FORREY, Arden W., Jr., MSC | NRRC 13-1 |
| MOORE, Charles E., MC | NRRC 1-7 |

Two Research Reserve officers were selected for promotion to Lieutenant:

| | |
|---|---|
| EHLER, David G., CEC | NRRC 9-21 |
| SARGENT, Howard H., III, CEC | NRRC 9-21 |

# Research Notes

## Mid-Ocean Dynamics Experiment

Research vessel KNORR of the Woods Hole Oceanographic Institution recently made a three-week buoy cruise, primarily to implant instruments on moorings for the Mid-Ocean Dynamics Experiment.

Known generally as *Mode*, the project involved 15 universities and oceanographic institutions engaged in a study of motions in the central ocean. According to participating scientists, information on low-frequency motions is imperative for understanding the physics of general ocean circulation. This, coupled with present knowledge about the atmosphere, could lead ultimately to a greater appreciation of other aspects of the environment—such as weather and climate.

Under the direction of Chief Scientists James Gifford, KNORR this trip was planned to check, launch, and retrieve a number of buoys at sites in the North Atlantic, where moored instruments are providing temperature and current measurements.

At the *Mode* site, two surface and five intermediate depth moorings were retrieved, and in addition both surface and intermediate depth moorings of five months' were deployed.

Other experiments conducted during the ship's single-leg cruise include routine hydrographic station lowerings, the collection of water samples, and recovery of paint and corrosion samples from the *Mode* site moorings.

*Mode* was launched officially in 1971, and the present program of preliminary field exercises will continue through 1972, culminating in more intensive studies during March through June of 1973. *Mode* is underwritten by the Office of Naval Research and the National Science Foundation as part of the International Decade of Ocean Exploration.

R/V KNORR, provided to Woods Hole by the Office of Naval Research is one of five ocean-going vessels operated by the Institution for scientific investigations around the world.

## NRL Acquires New Aircraft

The Naval Research Laboratory (NRL) has recently acquired a Lockeed P-3A Orion patrol aircraft, which has been modified to serve as an oceanographic research platform for NRL's Ocean Sciences Division, as well as a general test bed for other NRL users.

The Ocean Sciences Division will equip the four-engine plane with research instrumentation to be operated by NRL scientists in an oceanographic study program at sea, sponsored by the Naval Air Systems Command. The aircraft will carry upward and downward-looking radiometric sensors to monitor the energy transfer between the sea and sky and its effect on the air-sea interface.

Other equipment on board include temperature, pressure and humidity sensors; multi-directional cameras; an instrument for measuring radiation from the atmosphere (pyranometer); a radio altimeter; and a radio transceiver for measuring the distance to oceanographic ships with which the Orion will be working.

These test data will be recorded continuously in digital form on magnetic tape by a special multi-channel recorder, and processed at the NRL Computer Center.

The Orion is the first research aircraft in NRL's history to be configured at the outset for general laboratory use rather than just for a specific project.

## Mathematical Model Assists Biomedical Study

A mathematical model developed in an ONR-supported program at New York University's Institute of Mathematical Sciences is assisting an ONR-supported biomedical study on Schistosomiasis, a debilitating disease that affects more than 200 million people throughout the world, including areas encountered by naval personnel. The disease, which is particularly prevalent in areas just north and south of the equator, is caused by a parasite that goes through an involved life cycle, including an intermediate host, before reaching the infectious stage.

Starting off as a flatworm, male and female mating produces eggs that are generally deposited in watery areas, such as rivers and irrigation ditches where they search for and infest certain types of snails. After undergoing some changes of life forms, the parasite leaves the snail in spherical form (cercariae) that can penetrate the skin of humans or animals who enter or work in watery areas inhabited by the snail. Settling in a man's or animal's system, particularly in the liver, the parasite becomes a flatworm again. Male and female mating again produces eggs which are discharged with human waste. If the eggs reach watery areas, the cycle begins once more. Meanwhile the human host suffers sluggishness of this blood, causing him to tire easily and preventing him from working to his full capacity. This infested condition can continue for many years.

The mathematical model can incorporate various bits of information on the biological characteristics of the parasite and provide a test of various candidate procedures for the control and or eradication of the disease. It can predict, for example, what might be the best point in the cycle to attack the disease. The model has indicated that the most effective approach is to kill off the spherical form when it leaves the snail, and ONR-supported research on a substance that appears to be capable of destroying the spherical form is underway. It is believed that the model can also be used to study other diseases that go through cycles involving an intermediate host.

## IR&D Data Bank

An Independent Research and Development (IR&D) Data Bank has been established at the Defense Documentation Center at Cameron Station, Alexandria, Virginia in coordination with the Office of the Director of Defense Research and Engineering. This IR&D Data Bank, now operating on a full scale test basis, will provide a centralized body of limited technical and management information that will enable DoD scientists, engineers and R&D program managers to identify related independent technical projects being conducted in the defense industry.

The Data Bank was developed with the cooperation of industry personnel through the industrial associations and with special assistance from several companies who agreed to test the developed system and help "debug" (perfect) it.

IR&D is that research and development performed by industry and partially reimbursed by the Government without a specific contractual arrangement or grant. It is an indirect or overhead cost shared in by all of a company's customers as described in the Armed Services Regulations (ASPR 15-205.35).

The overall DoD objective in supporting IR&D is to encourage the evalution and maintenance of a strong, up to date and creative technology based industry, one from which the DoD can draw as needed both new concepts and rapid responses on a competitive basis to satisfy specific operational needs.

Although the companies conduct independent research and development to maintain their market position, a continuous dialogue between the DoD and the industry research and engineering organizations can be made invaluable in maintaining an adequate technology base—one capable of supplying our military needs.

For additional information, please contact Mr. Ancel Cook, code 400A1, Office of Naval Research, 800 N. Quincy St., Arlington, Va. 22217.

## ONR Sponsored Meeting

The Third International Congress on Marine Corrosion and Fouling will be held October 2-6, 1972 at the National Bureau of Standards, Gaithersburg, Maryland, U.S.A.

Co-sponsored by the Office of Naval Research, Maritime Administration, National Bureau of Standards and the Oceanographic Office, the forum will include all phases of design, development, applied engineering and economics which may influence the construction and operation of ships and underwater installations.

For additional information, please contact Mr. A. C. Jewett code (443) of the Office of Naval Research, Arlington, Virginia.

## New Source of Heavy Ions Discovered by ONR Satellite

The ONR-001 Ionospheric Research Satellite Experiment designed and built for ONR by Lockheed Palo Alto Research Laboratories, was launched 17 October 1971. An important new discovery has been made with the data from the low-energy energetic ion spectrometer. During the 17 December 1971 magnetic storm, intense fluxes of heavy ions of mass-per-unit-charge of approximately 16 were observed precipitating into the atmosphere at the low-latitude edge of the auroral zone. They were observed over the entire energy rate of the spectrometer (700 eV to 12 keV) on 24 satellite passes over a two-day period. The peak energy flux of these oxygen ions was greater than 0.25 ergs/cm$^2$-sec-steradian. This represents a considerable energy source in terms of magnetospheric processes and has been up to this time completely unknown.

This new energy source could have great importance in understanding the processes by which the Van Allen radiation belts are populated. More importantly for the Navy, this discovery should aid in understanding ionospheric processes which affect radio and radar propagation.

## Book on Ocean Floor Based on ONR Research

In a new book entitled *The Face of the Deep* two ONR contractors, Dr. Bruce C. Heezen, (Lamont-Doherty Geological Observatory) and Dr. Charles D. Hollister, (Woods Hole Oceanographic Institution) have shown the oceanographic community, through their ONR-supported research work, the value of bottom photography as a serious contributor to our knowledge of sea floor processes. The authors approach the subject of sea floor terrain in a very unusual manner. First of all, they present the best, the most clearly defined bottom photographs, seismic reflection records, and photographs of core samples taken over the major sea floor features of the world's oceans. Second, the latest scientific knowledge of the origins of these features and of the sea floor processes that created them are presented in clear, uncluttered jargon-free English. Complex bottom processes such as turbidity flows are described in the form of about a thousand diagrams illustrated by about two thousand bottom photographs. The currents are followed from their near shore origin through their catastrophic and destructive paths in the submarine canyons to their final resting places on the abyssal plains. The effects of bottom organisms on the sediments of the sea floor are illustrated side by side with the effects of man's impact on the sea floor—flow marks on the abyssal floor from cable grapnels, whales dead from being ensnared in sea floor cables. The startling effects of the little known abyssal currents are illustrated by the bottom photographs of a rippled, eroded 5000 meter deep sea floor. The paths of these currents are carefully traced along the Atlantic, Antarctic, Pacific and Indian Ocean floors by a series of photographs and diagrams. The processes of sea floor generation at the mid-ocean ridges and sea floor destruction in the trenches are vividly illustrated. The 660-page book published by the Oxford Press is the only successful effort to date in providing the scientist and layman alike with a real feeling and visual understanding of the processes active on the floors of the oceans.

## ALVIN on Deep Drilling Project

The deep-diving research submarine ALVIN and its mother ship the catamaran R/V LULU left Woods Hole recently for research in the Gulf of Maine.

The two vessels are operated by the Woods Hole Oceanographic Institution. Acting as escort was the A. E. VERRILL, operated by the Marine Biological Laboratory.

The purpose of the cruise primarily centers around a 1500-pound deep-sea drilling device. The rig was tested in 70 feet of water in Woods Hole's Great Harbor by the submarine and then, attached to ALVIN, was loaded aboard LULU for further testing at depths of about 600 feet in the Gulf of Maine. The equipment is planned for use in drilling through basalt, a hard volcanic rock, in studies next year of the Mid-Atlantic Ridge at depths of thousands of feet.

Primarily constructed of aluminum, the coring rig weighs only 550 pounds in water due to buoyancy material, the neutral weight of oil in water, and the fact that aluminum weighs only two-thirds as much in water as it does in air. After diving to the sea floor with the coring rig, ALVIN separates from it. The action activates a magnetic switch and a timing device, which sets the mechanism drilling for a specified length of time, after which the drill automatically retracts from the sea-floor. ALVIN then retrieves the equipment and rises to the surface with it for recovery by LULU.

The Gulf of Maine research will focus on further testing of the rig, and if possible, cores will be obtained. The project is concerned with the geologic mapping of the sea floor, and the study of rock samples from the Gulf of Maine area to learn more of the possible transplant of material from Africa to North America when the two continents separated from each other some 180 million years ago. The Oceanographic Institution's R/V GOSNOLD will place buoys above specific areas of the sea floor to be used as indicators for ALVIN in obtaining the rock samples.

The Gulf of Maine operation is the first planned for ALVIN since its certification dive to 6,000 feet after a winter's overhaul. It is also the year's first research cruise for ALVIN and LULU as a team. During the submarine's overhaul, the mother ship was operating in the same capacity for the undersea habitat, EDALHAB, in the three-month FLARE (Florida Aquanaut Research Expedition) project earlier this year, funded by the National Oceanic and Atmospheric Administration (NOAA). In LULU's most extensive operation without ALVIN since she was built in 1964, teams of scientist-divers studied coral reefs, fish behavior, and the chemical composition of sea water from the habitat in depths of up to 45 feet.

Chief investigator on the drilling project, funded by the Advanced Research Projects Agency (ARPA), will be Dr. Richard von Ierzen of the Geology and Geophysics Department, while David Williams, a graduate student in Geology and Geophysics, will be chief scientist on the Gulf of Maine cruise. Besides ALVIN and LULU, which are owned by the Office of Naval Research, the Woods Hole Oceanographic Institution operates four ocean-going research vessels, including GOSNOLD, for scientific investigation of waters around the world. With a resident staff of more than 650 scientists and support personnel, the Oceanographic Institution conducts a wide range of studies in biology, chemistry, geology and geophysics, ocean engineering and physical oceanography at the Woods Hole facilities on Cape Cod.

# Lasky Receives DOD Distinguished Civilian Service Award

The Department of Defense Distinguished Civilian Service Award has been presented to Mr. Marvin Lasky (center), Director, Acoustic Programs, Office of Naval Research, for his outstanding contributions to both the pro- and anti-submarine warfare efforts of the United States Navy. In particular, he developed the concept of a new type of sonar that operates with significant capabilities not possible in current operational equipment.

Mr. Lasky was presented the award by Secretary of Defense Melvin R. Laird (left) in a ceremony at the Pentagon accompanied by the Secretary of Navy John W. Warner (right). The award is given annually to a small number of civilian employees whose careers reflect exceptional devotion to duty and extremely significant contributions of broad scope.

His overall contribution was the development of acoustic measurement technology that has spin-off applications to areas of submarine silencing, submarine noise measurements, sonar system development, oceanography and ocean science. He shared in an earlier award for the creation and design of the Atlantic Undersea Test and Evaluation Center (AUTEC) that now provides the major testing of underwater acoustic equipment. He has also received the Navy Distinguished Civilian Service Award. He has been elected a Fellow of the Acoustical Society of America for his role in increasing and diffusing knowledge of acoustics and promoting its practical application.

## Navy Selects Winners at ISEF


Rear Admiral David Carmichael, MC, USNR, representing the Chief of Naval Research, Rear Admiral Carl O. Holmquist, announces that Cindy Lindsay, of Los Alamos, New Mexico, has been selected by the Navy for its top science prize at the 23rd International Science and Engineering Fair (ISEF) held in New Orleans, Louisiana. She was one of three ISEF finalists selected by the Navy, Army and Air Force for a new grand award consisting of a trip to Stockholm, Sweden, next December where they will be special guests at the Nobel Prize Ceremony. The Navy, through the Office of Naval Research, will serve as executive agency for the visit and provide the escort. Cindy, a high school junior, won with her exhibit (seen below) entitled, "Voluntary Heartrate Variation and its Correlation to Alpha Waves." She obtained her major piece of equipment by salvaging it from a junk pile and restoring it. Selected as alternate for the Stockholm visit was Terrance Ward, of El Paso, Texas, for his exhibit entitled, "Excitons and the NQR Spectra of $MaC10_3$."

The two students were also chosen as Navy Science Cruisers along with eight other ISEF finalists and will visit Navy laboratory facilities and go out to sea in a Navy ship this summer in San Diego. The remaining eight are: Janice Gwin, of Palacios, Texas; Steven Johnson, of Westerville, Ohio; Gary MacKay, of Hamilton, Ontario, Canada; Christopher Nicholson, of New Castle, Indiana; Maria Porcaro, of Reading Pennsylvania; Bill Smith, of Muskogee, Oklahoma; Victor Talmadge, of Poughkeepsie, New York; and David White, of Columbus, Georgia.



U. S. GOVERNMENT PRINTING OFFICE : 1972 O - 473-642

## New Radar System Penetrates Sea Ice, Permafrost in Navy Arctic Tests

Navy experiments conducted with a newly developed radar system that "sees" beneath the ground have demonstrated that the radar can penetrate sea ice and determine its thickness as well as detect subsurface ice wedges present in permafrost (permanently frozen ground). This is believed to be the first successful penetration of sea ice by radar.

The tests, sponsored by the Office of Naval Research, were performed in the vicinity of ONR's Naval Arctic Research Laboratory at Barrow, the northernmost tip of Alaska. The portable pulse radar system, developed by Geophysical Survey Systems, Inc., North Billerica, Massachusetts, was previously shown to be able to locate objects and different materials below ground. Its display is in the form of a graphic map called an Electromagnetic Subsurface Profile (ESP).

Material probed by the system produces a unique pulse shape that results from the material's dielectric constant and conductivity, which are affected by the physical and chemical properties of the material. When the pulse passes through different materials, it is partially reflected and partially transmitted at each interface. An oscilloscope samples the reflected pulse signal, which is stored in a tape recorder that drives the graphic recorder to produce the ESP printout.

The ice thickness in the area of the experiments was determined to be about five feet, with the system capable of penetrating and measuring much greater thicknesses. Permafrost was penetrated to nearly ten feet, a limitation believed to be the result of the high-salt content of permafrost near coastal areas.

Locating masses of ground ice beneath the surface of permafrost is important to construction or land use in the Arctic. If the presence of ice is not carefully ascertained, significant ground subsidence can take place, leading to costly repairs or abandonment of the structures. Borings can give an incomplete and even misleading picture of subsurface conditions.

Further experimentation is planned to determine the limits of penetration and resolution in different types of materials.

---

**NAVAL RESEARCH REVIEWS** publishes highlights of research conducted by Navy laboratories and contractors and describes important naval experimental facilities. Manuscripts submitted for publication, correspondence concerning prospective articles, and changes of address, should be directed to Code 109, Office of Naval Research, Arlington, Va. 22217. Requests for subscriptions should be directed to the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. Subscription price: $1.75 per year in the U.S. and Canada; $2.25 per year, foreign; $0.20 per individual copy. The issuance of this periodical approved in accordance with Dept. of the Navy publications and printing regulations.

*Editor:* WILLIAM J. LESCURE — NAVSO P-510

*Associate Editors:*

A. R. LAUFER, ONR PASADENA

A. R. DAWE, ONR CHICAGO

A. L. POWELL, ONR BOSTON

D. A. PATTERSON, NAVAL RESEARCH LABORATORY

# IN THIS ISSUE

VOL. XXV, NO'S. 6 AND 7



*A high jumping Dolphin playing games. See page 23.*

DEPARTMENT OF THE NAVY
OFFICE OF NAVAL RESEARCH
ARLINGTON, VA. 22217

OFFICIAL BUSINESS
Penalty for Private Use, $300

POSTAGE AND FEES PAID
DEPARTMENT OF THE NAVY

U.S.MAIL
DoD-316