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IEEE spectrum

features

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THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC.

departments

the cover

Since the early days of World War II it has become increasingly evident that radar can be useful for studying bird movements. A radar picture of bird activity in Nebraska's Platte Valley is shown on this month's cover. For more information on this fascinating application of radar, turn to the article beginning on page 62.

In January 1967 we described our work on CO_2 lasers. Here we present the first of a two-part discussion on the development of high-sensitivity receivers for infrared systems using CO_2 lasers. Frank Arams, Frank Pace, Bud Peyton, and Gene Sard have all contributed to this work.

High-Sensitivity Infrared (10.6 Micron) Heterodyne Receivers with Gigahertz IF Capability

Part I: Sensitivity and Bandwidth

Military technology has long been interested in the 8 to 13 micron window for passive infrared applications. Now this region is attracting increasing attention because of the CO_2 laser. The CO_2 laser operates in the center of this band at 10.6 microns and provides CW output power at the kilowatt level with an efficiency near 20 percent (reference 1)—substantially better than any other laser. The combination of low-loss atmospheric transmission, a powerful CO_2 laser, and a sensitive 10.6 micron receiver, would provide the key elements for new active infrared systems, opening up frontiers in communications, radar, mapping, and infrared astronomy.

We at AIL are working on several programs to develop 10.6 micron system components in particular a family of 10.6 micron heterodyne receivers that combine very high sensitivity with extremely wide IF bandwidth. Sensitivity and bandwidth factors are discussed here: Part II will present results on the development of a packaged 10.6 micron heterodyne receiver.

Infrared Receiver Sensitivity

For laser systems, heterodyne detectors provide much better receiver sensitivities than infrared envelope detectors. Moreover, heterodyne detectors preserve phase and frequency information, thereby permitting the application of the powerful coherent techniques widely used in radio and microwave systems. In radar, for example, these techniques permit determination of target velocity ("range rate") by measuring doppler frequency. A heterodyne receiver also suppresses background noise and interference by its inherent frequency selectivity and spatial-mode discrimination.

The sensitivity of an infrared coherent receiver is fundamentally limited by noise which has its origin in the quantized nature of the electromagnetic signal. The energy of a quantum (or photon) is given by:

$$E = h\nu$$

where

E = quantum energy

h = Planck's constant

ν = frequency

The sensitivity limit of a coherent receiver operating *in a single mode* can in general be written

$$NEP = \underbrace{\frac{h\nu B}{e^{h\nu/kT}-1}}_{\text{Thermal Noise}} + \underbrace{\frac{h\nu B}{\eta}}_{\text{Quantum Noise}}$$

where

NEP = Noise Equivalent Power ($S/N = 1$), in watts

B = bandwidth

k = Boltzmann's constant

T = temperature

η = quantum efficiency of the infrared mixer (a number less than unity giving the fractional number of carriers generated per incident photon)

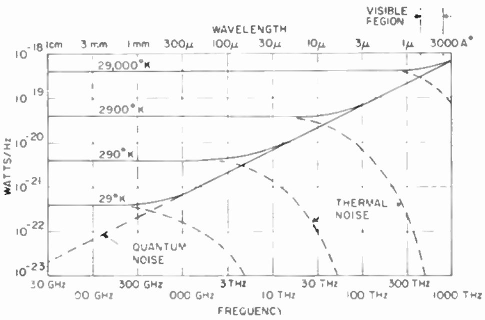

Figure 1. Frequency Dependence of Noise Power.

This expression is plotted in Figure 1 (reference 2). For microwave frequencies and below, $h\nu << kT$, so that thermal noise dominates and the expression reduces to kTB, the familiar expression for available thermal noise power. As Figure 1 shows, thermal noise drops rapidly as the energy $h\nu$ of photons radiated by a blackbody at temperature T approaches thermal energy kT, an intuitively reasonable result. At infrared and optical frequencies, where $h\nu >> kT$, quantum noise dominates, and NEP equals $h\nu B$ for an ideal detector ($\eta = 1$). Thus, at 10.6 microns (the wavelength of the CO_2 laser), the ideal coherent receiver has $NEP = 1.87 \times 10^{-20}$ watt for a 1-Hz bandwidth.

It appears appropriate to define, for optical and infrared coherent receivers, a figure of merit for sensitivity that is analogous to the thermal noise factor at lower frequencies (reference 3). This Quantum Noise Factor (QF) is determined by normalizing receiver noise to $h\nu B$. It is a measure to how closely the actual receiver approaches the ideal receiver. Thus, for an ideal coherent receiver, $QF = 1$, or 0 db.

Since the infrared NEP is proportional to the frequency, ν, an improvement in sensitivity of about 20 times is obtained at 10.6 microns compared with a coherent receiver operating in the visible region. Similar improvements apply to mechanical tolerances since performance of optical components is often specified in fractions of the wavelength. Moreover, the longer the wavelength, the larger the permissible diameter of the receiver telescope and the greater the received energy.

IF Bandwidth

Because the carrier frequency is approximately four orders of magnitude higher at infrared than at microwave frequencies, very substantial doppler frequency shifts can be encountered (see Figure 2). These doppler shifts may be desirable for detecting moving targets and/or measuring their velocity. As Figure 2 indicates, even a relative velocity of only 1 mph results in a two way doppler frequency of 84 kHz. On the other hand, in communications or radar systems where the path length is changing rapidly, the doppler frequency offset is substantial.

For example, a two-way doppler frequency of 840 MHz results for a radial velocity of 10,000 mph. For such applications, the most practical solution is to design the heterodyne receiver with a wideband IF frequency response from near DC to the gigahertz region. This utilizes infrared photodetectors having subnanosecond response times—a requirement quite different than that for passive infrared systems, which normally use slow detectors.

Next month, in Part II, we will describe the successful development of a new 10.6 micron heterodyne receiver which has now been packaged for field operational use and uses an infrared mixer and a circuit arrangement combining sensitivity near the quantum noise limit with gigahertz IF bandwidth.

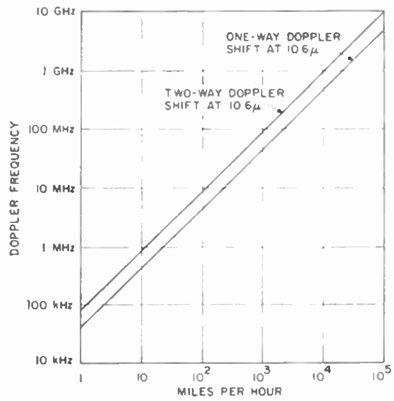

Figure 2. Doppler Frequency Shifts at 10.6 Microns.

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Spectral lines

Time for a change in attitude. Likening the growth of publication to the population explosion is a thoughtless simile. The population explosion has been caused by a dramatic reduction in the death rate without any commensurate reduction in the birth rate. In science and technology, authors have been becoming annually not only more numerous but also more fertile, whereas death has not yet even been recognized; by convention, every contribution to "the archival literature" is deathless.

In 1947, the AIEE published 2896 pages of journal articles (exclusive of advertising), and the IRE published 1636 pages. In 1967, the IEEE published 21 437 pages of its own journals (again exclusive of advertising). If the growth in the next two decades matches that of the previous two, then in 1987 the IEEE journals will run to more than 100 000 pages.

Extrapolation is always an uncertain business. If it were not, the stock market would have made more millionaires than it has. Nevertheless, the forces making for expansion of the literature of electrical engineering have not been spent; unless forces of containment come into play, the literature will continue to expand, though perhaps not at the recent rate.

It seems certain that forces of containment *are* coming into play—not merely from fears about being buried under a future avalanche of literature, but also from dissatisfaction with the situation that exists at present.

There are troubles in living with the literature that we have now. Probably the two chief problems are (1) finding out what one should read, and (2) gaining access to it. The IEEE is taking on aggressively a pioneering role in the search for workable solutions to these problems. Clearly, the answer to the first one is good indexing. Here a number of improvements are already in operation. One is increased attention to the indexing of the Institute's own journals; henceforth, there will be an annual comprehensive index of all articles published in the journals of the IEEE. Another is our collaboration with the IEE in *Electrical and Electronics Abstracts*, an index to several hundreds of journals. It is becoming recognized that an author has an obligation to word his title in such a way as to aid both those who compile the indexes and those who use them.

Although it may not be an exhaustive one, any worker with a little experience and some indexes can readily make a list of articles that seem worth examining. What comes next may not be so easy, unless he has access to the library of a major industrial laboratory or a great university. In principle, microfilming or interlibrary loans give almost any worker a means of seeing almost any document. However, the document ordered may be useful only in leading the worker to another document. If he is in a big library and can read the language of the document, this stage takes a few minutes. If he has to negotiate a new interlibrary loan, the going gets tedious; if in both stages he must also wait for translations, the whole process is so cumbersome that his patience, or his contract, is likely to run out before the document that will help him is in his hands.

Even with perfect indexing, unlimited library, and adequate acquaintance with the needed languages, there would still be trouble. Reading speed is limited, and even the most capacious human mind is just so big. It is not merely that the volume of publication in any one specialty has increased. An additional, and probably worse, difficulty is that the interconnections between specialties have increased so much. A designer of ultrasonic delay lines may encounter a problem that has had the attention of men concerned with thermal stratification in the oceans. People concerned with speech may find, as was pointed out to them in the March issue of the PROCEEDINGS OF THE IEEE, that their fast Fourier transform closely resembles the Butler matrix developed earlier by designers of antennas. A man can find his way in the literature of his own field, but an assault on the literature of somebody else's specialty is something else again. Yet these excursions have become increasingly necessary.

Though it cannot remove these problems, there is a tool, the review paper, that can help with all of them. Editors of the IEEE are convinced of the usefulness of well-executed reviews, and continue to solicit them. Tradition stands in the way. It says that one isn't supposed to take up space in a journal unless one has something new to report, and knows how to be brief about it. Indeed, in theoretical physics journal publication seems almost to have become a game, the object being to say something new that is correct, but maximally terse. The game is won by the author who is intelligible to the smallest nonzero number of readers.

A good review, of course, flies in the face of the old morality. It can contain material that is original with the author, but the purpose of a review is to gather existing material and display it in such a way as to reveal interrelations, so that the mass becomes endowed with order and structure. Writing a good one takes time, energy, and insight, but to win credit with one's R & D colleagues, and with one's supervisor, the often easier task of merely adding to the mass has been a better bet. In the present period, when the need for thoughtful reviews is acute, the old scale of values should change, and I submit that eventually the boss will change his attitude if the colleagues change theirs. The colleagues are you.—*J. J. G. McCue*

Authors

Sonar—a modern technique for ocean exploitation (page 40)

Martin Klein (M) is the president and founder of Klein Associates, Lexington, Mass., where he is engaged in product development and consulting related to undersea search and survey. He was formerly program manager for sonar systems at EG&G International, Inc., in which capacity he was responsible for the design and field testing of several sonar systems including an up-, down-, and side-looking sonar for the bathyscaphe *Trieste II*. He has participated in numerous search and survey operations in the English Channel, in the Bonaparte Gulf in Australia, and Israel. In 1967 he used his side-scan sonar to assist a team of archaeologists in locating an ancient sunken ship. He received the B.S.E.E. degree from the Massachusetts Institute of Technology in 1962 and is a member of the Marine Technology Society and Institute of Navigation.

Harold Edgerton (F) received the B.S. degree from the University of Nebraska in 1925 and the M.S. and D.Sc. degrees from the Massachusetts Institute of Technology in 1927 and 1931, respectively. His pioneering research work in the field of stroboscopic photography was the foundation for the development of the present-day electronic speed flash. He has designed watertight cameras with electronic flash lamps, is a consultant on underwater flash photography and stroboscopy, and has been working with Capt. Jacques Yves Cousteau in explorations of the floor of the Mediterranean Sea. He holds the position of institute professor at M.I.T. and also serves as honorary chairman of the board of EG&G, Inc. Currently Dr. Edgerton is developing sonar devices for positioning equipment in the sea and for the exploration of the subbottom structure.

How engineers can communicate more effectively with managers (page 47)

Joseph A. Robinson (SM) received the B.S. degree in electrical engineering in 1942 and the M.B.A. degree in 1956, both from the University of California, Berkeley. While at Berkeley he worked for two years as principal extension representative for the University's Business Administration Extension, where he has also taught courses in general management and communication. He is now head of Joseph A. Robinson Associates, consultants in management communication. In addition to serving individual and corporate clients, including Standard Oil of California, Pacific Telephone, IBM Corporation, and Lockheed Missiles and Space Division, and banking and CPA firms, Mr. Robinson has conducted meetings and seminars for many professional, academic, and business groups. Before establishing his own firm in 1963, he was manager of staff recruitment and development for McKinsey & Company, Inc., San Francisco, with major responsibility for consulting-staff training programs. His earlier experience includes two years as the vice president and sales manager of the Viber Company, Burbank, Calif.; five years as Western editor of *Electrical World*, McGraw-Hill Publishing Company; and five years with the General Electric Company as field engineer and sales engineer.

Mr. Robinson has been an officer and director in the San Francisco Chapter of the Society for Advancement of Management. He is a member of the American Society for Training and Development, the National Society for Study of Communication, and the Northern California Industrial Relations Council. He is a licensed professional engineer in the State of California.

Monitoring bird movements by radar (page 62)

Warren L. Flock (M) is a professor of electrical engineering at the University of Colorado, Boulder. He received the B.S. degree in electrical engineering from the University of Washington, the M.S. degree in electrical engineering from the University of California, Berkeley, and the Ph.D. in engineering from the University of California, Los Angeles. Prior to joining the faculty at the University of Colorado, he was associated with the University of Alaska's Geophysical Institute from 1960 to 1964. Earlier he was with the Department of Engineering at U.C.L.A.

Dr. Flock's special interests in research and teaching center on studies of the atmospheric effects on electromagnetic waves; the use of electromagnetic waves in investigations of the ionosphere, troposphere, and solid earth; and solar-terrestrial relations. He has been an amateur ornithologist since his early youth. His first experience in the field of radar dates back to his affiliation with the Radiation Laboratory, Massachusetts Institute of Technology, where he was a member of the staff during the period of 1942 to 1945.

He is a member of Tau Beta Pi, Sigma Xi, the American Geophysical Union, the American Association for the Advancement of Science, the Arctic Institute of North America, the National Audubon Society, and the Wilson Ornithological Society.

Spacecraft infrared imaging (page 71)

John J. Horan received the B.S.E.E. degree from the University of Rhode Island in 1949. His experience has been in the fields of television, infrared, and electrooptical development. He joined the RCA Astro-Electronics Division in 1961 and first worked on the electrooptics involved in a classified program. During that period he specialized in infrared space systems, specifically on the complete analysis of the horizon and horizon sensors and their overall transfer function. He prepared the requirements for, and supervised the development and fabrication of, a high-resolution IR system and a medium-resolution thermopile system. Recently he has been engaged in the research and development of a filter wedge spectrometer and an IR imaging radiometer.

From 1957 to 1961 Mr. Horan was employed by Barnes Engineering, where he was concerned with the design and fabrication of infrared thermistor bolometers, radiometers, and cameras. He initiated the original thermography work on nondestructive testing of many varied items for commercial, medical, and industrial applications. He was associated with CBS Laboratories from 1953 to 1957, performing research and development on solid-state electrooptical transducers and demountable vacuum color kinescopes. From 1950 to 1953 he was in the U.S. Army, where he specialized in research and development work on field and remote-control television systems and equipment. He is a member of the Optical Society of America.

The technosphere, the biosphere, the sociosphere (page 76)

J. H. Milsum (SM) is a professor of control engineering at McGill University, Montreal. He received the B.Sc. (Eng.) degree from London University in 1945 and the S.M., M.E., and Sc.D. degrees from Massachusetts Institute of Technology in 1955, 1956, and 1957, respectively. From 1946 to 1948 he served with the Royal Engineers, attaining the rank of lieutenant. From 1950 to 1954 he was employed by the National Research Council, Ottawa, during which time he was a project engineer on the experimental aircraft Rockcliffe "Ice Wagon" for studying anti-icing. Following his postgraduate work at M.I.T., he rejoined the National Research Council in 1957, where he was head of the Analysis Section, Division of Mechanical Engineering, concerned with operating analog, digital, statistical, and hybrid computers, and developing their applications. In 1961 he was appointed Albibi Professor of Control Engineering at McGill University. His activities were centered on research and teaching in optimizing control theory in engineering. As a result of his increasing interest in biological control systems, he was appointed first director of the Biomedical Engineering Unit in 1966. This unit is developing a teaching and research program for graduate engineers and life scientists in this challenging new multidiscipline.

Dr. Milsum has written more than 50 papers for various technical journals. He is the author of *Biological Control Systems Analysis* (McGraw-Hill, 1966) and editor of *Positive Feedback* (Pergamon Press, 1968).

Sonar–
a modern technique for ocean exploitation

In recent years, sonar has emerged as an important commercial and scientific tool for ocean exploration and exploitation. From finding fish to scanning strata, it is providing its users with underwater eyes

Martin Klein *Klein Associates*

Harold Edgerton *Massachusetts Institute of Technology*

Three important parameters are among those governing the application of the many versatile sonar techniques. Penetration and resolution depend upon pulse length and frequency. The angle of the transducer is also important—a perpendicular beam will resolve geological strata, whereas a side-looking beam will provide a "relief map" of the ocean terrain. Finally, several different types of transducers are available, both hull-mounted and towed, to provide the user with the best instrument for a specific application.

Until the past few years sonar was considered mainly as a depth finder or for military applications such as submarine detection. The military sonars were, and still are, generally large, expensive, and unavailable to the general public for geology or archaeology studies. There has been an aura of mystery about the military uses of sonar because of secrecy. Then chart-recording depth sounders became available for small ships, enabling fishermen to "see" their elusive quarry in the sea. This application of sonar has been most successful; it is said that some fishing ships carry two sonars, one for a spare, and will not leave port unless both are in operating condition. Sonar systems have become popular with both commercial fishing fleets and private fishing boats that cater to either a single owner or a charter fishing party. Fishermen have become quite adept in locating schools of fish from sonar traces produced on even the simplest of equipment.

More recently, many other types of sonars have become commercially available, and these sonars are finding, and will continue to find, numerous applications for diversified users who wish to study, explore, or exploit the ocean's resources. Sonar has a great role to play in the sea, with such applications as geological studies, wrecked-ship locations, archaeology, downed-aircraft locations, water flow and pollution study, and harbor mapping.

Geologists of the deep sea and oil prospectors have long used explosives to create the powerful sound pulses that are necessary to penetrate the earth. There is an array of sound sources for this work, such as the boomer, the sparker, the air gun, most of which involve a large ship and equipment; but there is also smaller equipment for special uses in shallow water that is adaptable to smaller craft.

The equipment

All effective sonar systems, we believe, should have a memory system, that is, a chart recorder of some type to put down on paper all of the information that is received back from the echoes in the water. In this way the observer has the entire story of the experiment in front of him for review in graphic form. He can examine visually the information and gain an insight of a complicated situation that is not immediately obvious. The charts then can be filed as permanent records.

Some recorders are more capable than others of displaying information. There are several types in widespread use; each has its disadvantages and advantages. One of the most commonly used is the dry-paper type, in which returned signals are amplified enough to melt a thin layer on the surface of the paper, revealing a dark layer underneath. Vapors are released that can be very objectionable in a confined area, such as a small submarine. Another type of recorder uses the electrochemical effect of current into chemically moist paper. Many problems are encountered if the paper becomes dry under hot operating conditions, so that care must be exercised by the user to keep the paper moist at all times. Hersey discusses these instruments in greater detail in his review article in the book *The Sea.*

The sonars used by the authors utilize a continuous strip chart recorder with moist electrochemical paper. This paper permits high resolution and continuous tone shades for detailing the ocean bottom. A moving helix wire mounted on a revolving drum sweeps a point of electrical contact across the paper. When signals are present the helix is energized, current passes through the paper to a second electrode (a continuous loop blade), and an electrochemical reaction produces a mark on the paper. At the beginning of each sweep a trigger pulse, generated through a photooptic pickup from a reference baseline, energizes the transmitter to emit a sound pulse in the water.

The transmitters use a capacitor-discharge arrangement in which energy is slowly stored in a capacitor and then quickly dumped into the transducer. This technique produces very-high-power (multikilowatt) pulses of very short duration, and thus is ideal for sonar applications. The actual acoustic frequency, pulse length, and transducer-beam pattern depend on a variety of factors that can be controlled to some extent by the design of the transducer. As a general rule, high-frequency pulses give high resolution and low range, whereas lower frequencies give lower resolution but longer range (or penetration of the bottom) due to the properties of sound transmission. Sonars that look into the water or at or along the bottom use frequencies from 10 kHz up to several hundred kHz; sonars that penetrate, or look through, the bottom employ frequencies from 1 Hz to 20 kHz, depending on the resolution and depth of penetration desired. The type of ocean bottom also is important. Some examples are discussed in the following paragraphs.

The Charles River Basin, just in front of the Massachusetts Institute of Technology, has a bottom that cannot be penetrated, owing to large amounts of gas in the surface layer. Sounds of 12 kHz, 5 kHz, and possibly lower, are almost completely reflected from the bottom surface. A similar situation was found in the Sea of Galilee in Israel, except at the shoreline.

Sand on a shoreline is especially difficult to penetrate, unless there is clay with the sand. Clay or fine sediment (mud), if gas-free, is very easily penetrated, and excellent results are obtained.

Limestone layers are usually penetrated with great effectiveness at 2 kHz, and even 5 kHz. The classical area

FIGURE 1. Battery-operated dual-channel portable 200-kHz side-scan system. Robert Henderson of EG&G International, Inc., is holding the towfish. The entire system can be used from the Boston Whaler shown at the M.I.T. sailing pavilion.

of this type is the sediment-free English Channel, where the ocean current keeps the limestone exposed. It must be emphasized that one must experiment with local conditions wherever one wishes to employ a sonar penetration system.

Transmitting and receiving transducers are often attached to the hull of the ship or hung from a vertical pole off the ship's side. However, we prefer to tow the transducer from a cable off the side or stern of the ship, as this makes the transducers relatively independent of the ship motions and allows them to be lowered near the bottom for a closer "look" at details. The transducers are generally mounted in some kind of "fish," which affords protection and towing stability. Figure 1 shows a side-looking sonar with a towfish containing the sonar transducer. The equipment is simple and compact, and can easily be accommodated by a small boat.

Transducers can be made of arrays of piezoelectric crystals, pulsed through a tuned transformer. This is a circuit that rings both electrically and mechanically at the frequency of interest. In some applications the transmitting transducer can be used as a receiver with a transmit–receive gate. In other applications a separate hydrophone (underwater microphone) is towed near the transmitter. The sound pulses go out into the water and echo off objects or geological features. The echoes are received, filtered, amplified, and processed in suitable form for marking on the graphic recorder.

Geological studies

Sonar can be used to observe the characteristics along the surface of the ocean bottom, or to delineate layers of sediments or other materials below the bottom. To look along the bottom, a side-looking or side-scan sonar technique is used. Transducers are aimed sideways in a direction perpendicular to the motion of a ship (see Fig. 1). This technique gives a plan view, which shows the ocean floor directly below the ship as well as the adjacent terrain. A fan-shaped beam, narrow in the horizontal plane and wide in the vertical plane, generally is used. However, a conical beam can also be used, with excellent results, in some circumstances. In order to look through the bottom, the transducers are pointed straight down and a conical beam is generally used.

Figure 2 shows a record made with a dual-channel

FIGURE 2. Dual-channel 200-kHz side-scan record made near Marblehead, Mass. Scale lines are spaced at 50-foot (15.5-meter) intervals. Ripple areas near the center are sand waves, dark areas to the left of the photo are sharp rock outcrops, smaller rock outcrops are seen on the right side. Blank areas represent smooth mud bottom with low acoustic backscatter.

side-scan sonar similar to the type shown in Fig. 1. The transducer is suspended by its electric cable below a small ship. The unit uses 200-kHz pulses in fan beams sent out simultaneously on both sides of the ship. Note that the record resembles a crude aerial photograph, and that several types of terrain can be seen. There are rocky areas, very smooth nonreflecting areas (probably flat sand), and areas of sand dunes or "sand waves." The "continuous tone" quality of the image yields great resolution of detail.

Figure 3 shows a subbottom profile made near Logan Airport in Boston Harbor. This record was obtained with a 5-kHz pulse aimed downward; the result gives an idea of the general pattern one would see if a giant knife cut into the ocean bottom and permitted one to observe a cross-sectional slice. Such profiles can often be observed on land when one is driving along highways that have been cut through geological formations.

Figure 4 shows a subbottom profile made from the research submarine *Alvin* on a dive in the Bahamas about a

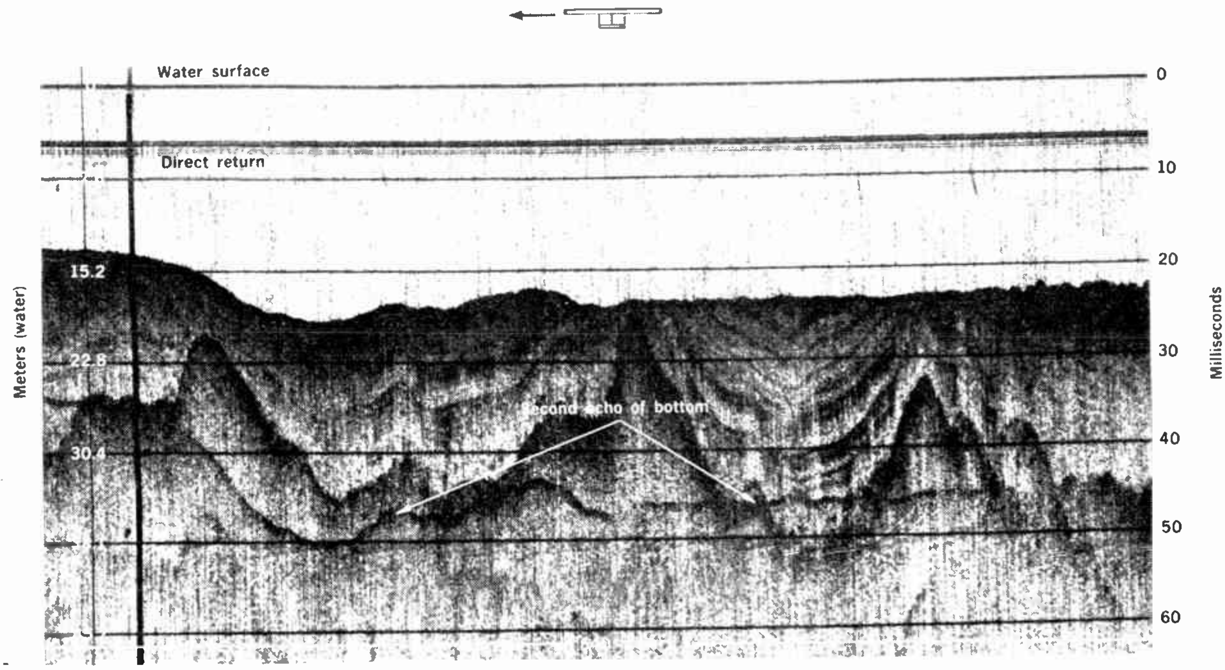


FIGURE 3. A subbottom profile made in Boston Harbor with a 5-kHz transducer. Note second echo and the profile of the subbottom layers.

FIGURE 4. Subbottom profile made from the submarine *Alvin* at a depth of about a mile (1.6 km) in the Bahamas showing sand layers.

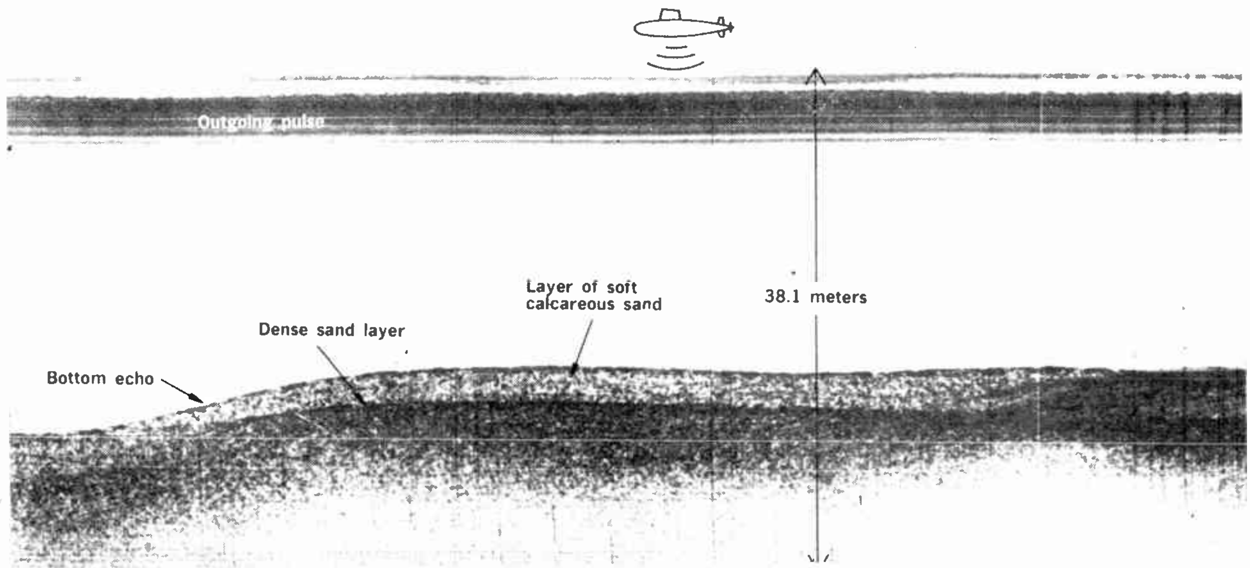
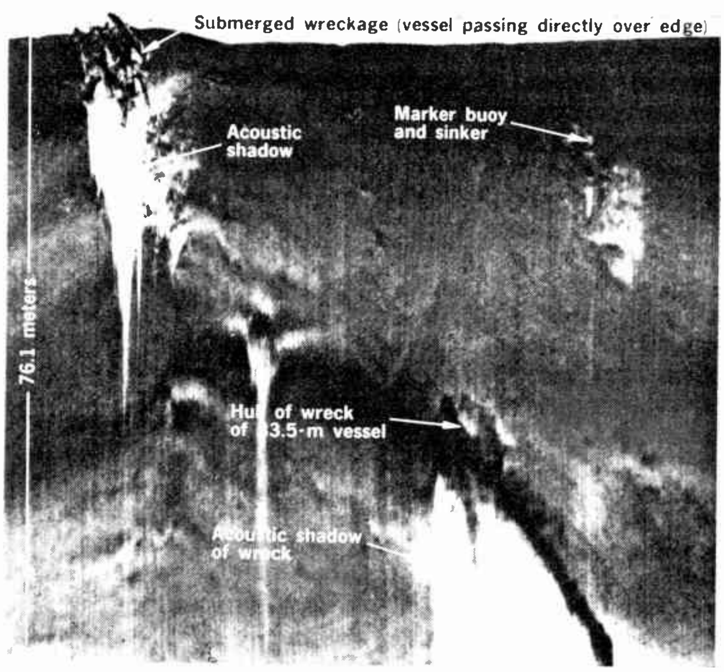


FIGURE 5. This record was made with a 12-kHz down-looking sonar in Boston Harbor. The chart clearly shows the outline of the Sumner and Callahan vehicular tunnels, which run below the harbor. Note that the Callahan Tunnel is slightly deeper than Sumner Tunnel.

FIGURE 6. A 260-kHz side-scan record made on the Potomac River. The record shows a shipwreck and its marker. [Note that the marker is nearly 100 feet (30.48 meters) from the wreck. The record also shows submerged wreckage and a tall, sharp object, possibly the cause of the wreck.]



mile (1.6 km) deep. The record was made using a miniaturized battery-operated recorder and a 12-kHz pulse aimed downward. Note that two distinct layers of the same general type of sand can be observed. Figure 5 shows an interesting down-looking sonar record made over the Sumner and Callahan Tunnels in Boston Harbor. The scan was made with a 12-kHz sonar.

The geologist using a down-looking or side-scanning sonar, or both, can thus make a rapid qualitative observation of the surface and subbottom terrain in an area of interest. If core samples reveal a certain layer of one type of material that can be identified on the sonar records, he can then follow the layer of that material with a sonar easily over large areas instead of taking hundreds of core samples.

Locating wrecked ships

Sonar has proved very successful in the location of sunken ships. If the wreck is recent and not buried, a side-looking sonar is used, although an ordinary depth sounder is often useful if the position of sinking is well known (a rare circumstance). Navigation at sea is rarely accurate, and currents are often strong, particularly in conditions that cause ships to sink, so that wrecks are often far from where the ships were supposed to have gone down.

In 1964 the *Vineyard Lightship* was found by Harold E. Edgerton, Edward P. Curley, and John Yules, far from its reported location on the navigation charts. The ship had been lost in a hurricane in 1944. This search was made with a 12-kHz transducer with a conical beam in side-scan mode. After the wreck was located, some 1000 feet (305 meters) from the indicated location on the chart, the transducer was pointed downward and the ship passed directly over the wreck, revealing the exact location.

Some time ago the authors had a call from a Boston tugboat owner who had lost his tug in one of the frequent harbor storms. The search was unusually fortuitous. A 12-kHz sonar was used and the wreck was spotted very quickly. Then the ship's depth sounder was positioned directly over the wreck and the owner was told to throw over a buoy. The buoy knocked loose a gas bottle on the tug that floated to the surface and began to puff in circles as if to announce that the right target had been found. The astonished owner was told that the operators usually aim for the nameplate of the ship!

Figure 6 shows an interesting record in which a wreck can be seen, as well as a sharp underwater structure that probably caused the wreck. This record was made using a 260-kHz side-scan sonar with a one-degree-wide horizontal beam on the Potomac River.

Archaeology

When a wrecked ship is ancient, it becomes of extreme interest to archaeologists because it represents a small chunk of history ended by sudden disaster rather than by slow decay. Figure 7 shows a sonar record, made by Martin Klein near the coast of Turkey on the Aegean Sea, of a wreck that was the object of a search by a team from the Museum of the University of Pennsylvania. The team, lead by Dr. George Bass, was interested in the ship because a sponge fisherman had dragged up an interesting bronze statue in the area. This record seems to show a large net that the sponge fishermen snagged on the ancient ship and lost. Individual floats of the net can be seen. The ship was 280 feet (77.5 meters) deep—too deep for scuba divers, so the little submarine *Asherah* dived to confirm the find. The sonar was used to position two buoys on the wreck. Then the submarine, piloted by Yuksel Egdimir and Donald Rosencrantz, followed the buoy lines and landed directly on top of the ancient shipwreck. Plans are now in progress to make further sonar and underwater television studies, and possibly to excavate the wreck for its archaeological value.

Late in 1967 the authors participated in an archaeological study in the Mediterranean near Ashdod, Israel. This area was the sight of an ancient Philistine shipping port, and the object of the mission was to use sonar to try to locate the ancient harbor, and, if possible, a Canaanite shipwreck. A 12-kHz sonar was used both for side-looking and for bottom penetration. For deeper penetration, a 5-kHz sonar was used, as well as the "boomer," an electromechanical sound source with a very clean, high-intensity pulse having a frequency of about 2 kHz. Although neither the port nor a ship was located, some items were found that bear further investigation. First an interesting chain of underwater rock projections was found about 3 km from the coast. Then the expedition divers, Hayim Stav and Shuka Shapiro, found three ancient Canaanite stone anchors, as well as some old pottery. It is suspected that the rocks may once have been the ancient shoreline when the level of the Mediterranean was lower; and the anchors may indicate the presence of shipwrecks below the sand. Further studies with bottom-penetrating sonar may reveal the presence of buried wrecks of archaeological importance that are capable of being recovered for additional investigation.

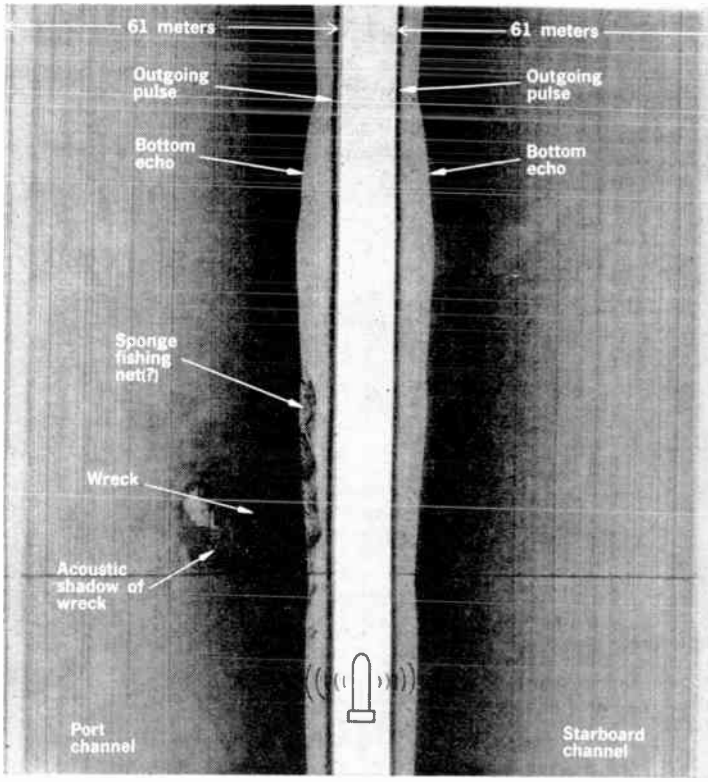


FIGURE 7. This record was made with a dual-channel 200-kHz side-scan sonar. The record was made near Bodrum, Turkey, in the Aegean Sea and shows an ancient shipwreck that may have been carrying bronze statues.

Locating downed aircraft

Side-looking sonar has proved very successful in the location of downed aircraft. Whenever possible, an attempt is made to recover aircraft wreckage so that the cause of the accident may be investigated.

Side-scan sonar was used to locate a radar picket plane, a DC-121-H, that went down off Nantucket in 1967. Figure 8 illustrates the traces made with a 260-kHz sonar. This record was made by Frederick Anderson, Lee Furse, and Donald Krotser of EG&G International, Inc. In this search the sonar was used in conjunction with underwater television equipment made by Ocean Engineering Corporation. After the wreck was picked up on sonar, a bearing was taken and the ship headed toward the wreck to get a look with the television. Video tapes were made of the wreckage for detailed analysis by the Air Force investigators.

FIGURE 8. A side-scan record showing aircraft wreckage.

Water flow and pollution

Just as air pollution has become a serious urban problem, river and harbor pollution is increasing. Figure 9 shows a sonar cross section made near a sewer outlet near Deer Island Light in Boston Harbor. The record, made by Harold Edgerton and Hartley Hoskins, shows the actual outlet, the flow of warm fresh water into cold salt water, and the many fish who come to feed on the sewer garbage. Note that there is sufficient difference in the acoustic character of fresh and salt water to create an echo-producing interface.

This phenomenon is shown more clearly in an interesting record made in the lagoon across from M.I.T., on the

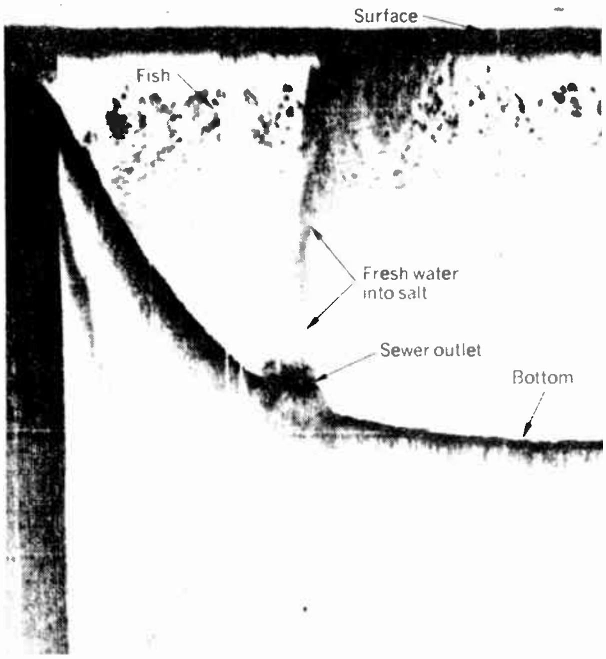


FIGURE 9. Record made with a 12-kHz down-looking sonar, over a sewer outlet near Deer Island Light, Boston Harbor. Note that the escaping fresh water can be seen, as well as the fish. There is sufficient acoustical difference between fresh and salt water to create a delineative echo.

FIGURE 10. Record made with down-looking 12-kHz sonar in the still lagoon near the Community Boat Club on the Charles River in Boston. The record reveals a sharp acoustic echo from the interface between a dense, stagnant pool of salt water and the fresh water above and toward the surface. The salt water apparently flows under the fresh water; the interface appears as a line on the record.

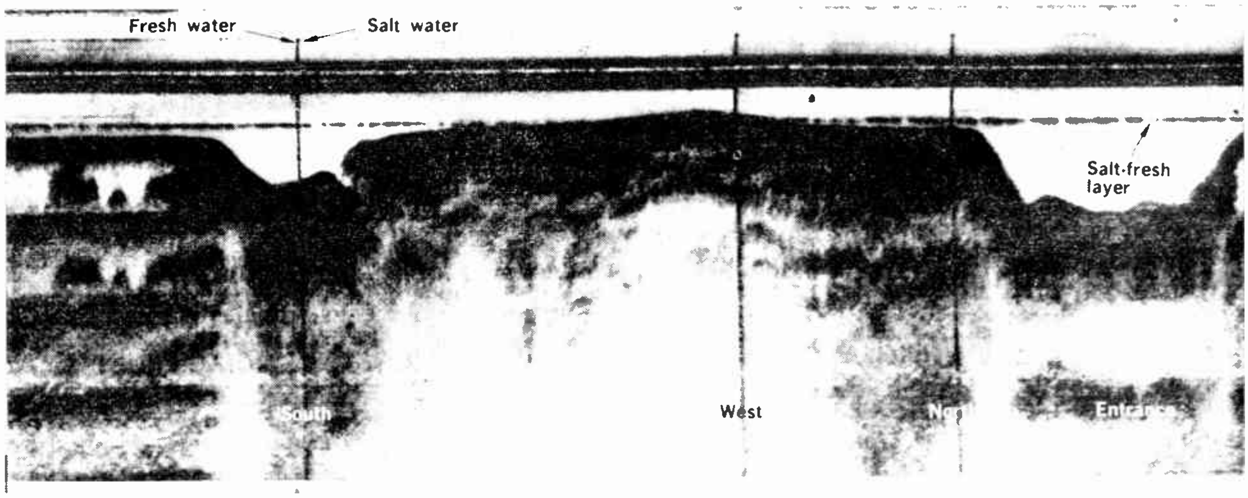
Charles River in Boston. The depth of the Charles River basin is controlled by a lock connecting the basin to Boston Harbor. When the tide is high, the lock introduces a considerable quantity of salt water each time it opens. The cold salt water apparently flows under the fresh water. Figure 10 shows that, in the relatively stagnant lagoon area, the layer is undisturbed; and the fresh-water–saltwater interface appears as a discernible line of demarcation on the sonar record.

Sonar is also proving useful in other areas of pollution control. Recently there has been a serious problem on the East Coast of the United States as a result of old ships releasing trapped oil as they decompose, thereby fouling the water and beaches along the coast. Side-scan sonars are being used to track down these ships systematically for inspection so that precautionary action can be taken. It might be possible to salvage the oil from wrecked tankers.

Conclusion

Anyone who plans to work in the ocean needs a means to see his environment. Since light and radio are severely attenuated under water, sound is used to recreate a graphic display that the eye and brain can interpret. We have shown a few areas in which sonar is just beginning to be used. As more sonar becomes commonly available we feel that it will become an increasingly useful tool.

The systems used by the authors have only been briefly outlined. We recommend that the interested reader consult other articles in the bibliography for further details of the equipment, techniques, and applications of sonar systems.



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For an idea to be truly effective, it must be effectively communicated. To achieve this, one must first determine two things: the objective to be accomplished and the audience to be reached

How engineers can communicate more effectively with managers

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Joseph A. Robinson Associates

By improving his communication with management, particularly his boss, the engineer can gain recognition, a better feeling for how he stands, more interesting assignments, and increased pay and advancement. He can tackle the physical, intellectual, experience, and psychological barriers to communication by applying three basic principles for effective communication: it requires thinking, involves both sending and receiving, and includes verbal and nonverbal devices. To apply these principles he should first think carefully about his objective and audience, and then select, simplify, and specify.

Today's engineer must communicate, or perish by inches. And of all his communications, none more directly affect his fame, fortune, and general well-being than his communications with managers, particularly his boss. This article summarizes some of the reasons why good communication with the boss and other managers can pay off, some of the communication barriers the engineer encounters, and what he can do to overcome these barriers.

Why bother?

The engineer has several good reasons to care about how effectively he communicates with managers.

First, the way he organizes and expresses his ideas directly affects how much he can accomplish and how easily others can recognize and properly evaluate his accomplishments. For example, he may need to have management approve a project. A well-presented project may go through without a hitch, but if it is poorly presented it may die aborning. Even the best problem analysis, investigation, and solution benefit from a clear, crisp presentation, and anything less invites a cursory turndown if management simply doesn't understand. What managers cannot understand they usually will not approve—and what they do not approve the engineer cannot accomplish.

Once an engineer has obtained approval of a project, he may need the cooperation of others. Clear, logical coordination can make a project; misunderstanding can break it. Moreover, even the finest completed project cannot tell the entire story of an achievement, no matter how eloquently it speaks for the engineering genius who conceived, designed, and completed it. If the results of the work are presented to management haphazardly, with jumbled documentation and disorganized recommendations, one cannot expect the recognition he thinks he deserves. Thus, better communication can help pave the way for solid accomplishments that management can recognize and appreciate.

Second, because communication includes receiving as well as sending, it can help the engineer judge how management feels about his performance and potential. As he improves his ability to listen to and understand managers, he can begin to recognize what they consider most important on his job and how they evaluate his performance. This allows the engineer to concentrate on his most important improvement opportunities and so earn further recognition of his efforts.

Third, as better communication allows one to accomplish more and to concentrate on better performance, it also can lead to more interesting assignments.

Management often does not have—or will not take—time to explain a problem over and over. The engineer who demonstrates an ability to grasp a problem quickly from management's viewpoint and to propose an approach that management can understand has an appreciable advantage in the assignments sweepstakes. The way a man communicates says much about the way he thinks, and the interesting assignments go to the thinking engineer.

Finally, the ability to communicate effectively can directly affect one's pay and advancement. It influences the kinds of assignments the engineer receives, how well he can accomplish them, and the recogniton he is accorded. When management assesses what he contributes to the organization, they consider what they know of his accomplishments. If he has failed to communicate effectively, they may be aware of only a fraction of what he has done—and reward him accordingly.

Despite all the various reasons why he should want to communicate effectively, the engineer still sometimes falls short. By examining some of the barriers he faces we can identify ways in which he can overcome them and thus improve his effectiveness.

Barriers to effective communication

The engineer faces some common barriers—and some special ones—in communicating with managers, particularly with his boss. These include obvious physical barriers, some less-obvious intellectual and experience barriers, and many (often-ignored) psychological barriers. To surmount these barriers, he must first recognize and understand them.

Engineers, and others, easily identify two obvious physical barriers to effective communication with management—time pressures and separate, remote locations.

Many managers consider time their most limited resource, and leave little of it uncommitted on their schedules. As a result, they may require advance appointments and set time limits for oral communications, or demand condensed extracts of written ones.

Separate, remote locations can compound the effect that limited time availability has on the manager's accessibility. Although modern communication hardware does much to minimize distance as a barrier, it still cannot substitute for the opportunity to step next door or across the hall.

In communicating with managers the engineer also faces formidable barriers resulting from his different intellectual development and life experience. His education, background, and job experience often differ significantly from those of a manager, particularly as management becomes more and more a separate profession with its own academic discipline and professional body of knowledge. Once upon a time, organizations that depended on engineering for their existence—electrical manufacturing, for example—largely used engineers to fill their management ranks. This no longer holds true to the same degree, and the engineer cannot count on management to have comparable, if dimly remembered, education and experience to draw on to interpret what he has to say.

This trend contributes to a second important barrier: the language barrier. As each branch of engineering becomes more specialized it develops its own jargon, which becomes less intelligible to the uninitiated. To communicate successfully with management, the engineer must translate what he has to say into management's language, unless unusual circumstances force management to learn the language of the engineer.

As a third barrier growing out of his different background and experience, the engineer often finds some important differences between his and management's formal objectives, both job and personal. Management wants to get the job done; the engineer cares more about how he does it. He may strain for perfection, set unrealistic or uneconomic standards, or choose to ignore subjective considerations important to management in the overall picture. As a person, he may wrestle with dual loyalty to his professional standards and his career, as opposed to management's pragmatic demands for the pressing present.

Better communication alone cannot remove these intellectual and experience barriers, but it can help to highlight them and bring them out into the open.

Perhaps the most devastating barriers to communication with management exist within the conscious and subconscious mind of the engineer himself.

Some barriers grow out of long-established status relationships within the organization. Traditionally, to continue to advance and gain status in a company the engineer eventually had to enter management ranks. Thus management retained for itself the marks of higher status—larger offices, company cars, executive dining rooms—as well as the top salaries. Only recently have more progressive companies tried to recognize and award equal status to the man who prefers to remain an engineer-contributor rather than move into management.

Generally speaking, however, the engineer continues to feel some important differences (real or imagined) in status between himself and management. You have only to sit in an office larger than your own, be ushered in and seated by a secretary when you have none, and engage in a conversation interrupted by two or three long-distance calls to understand why.

A second and more obvious psychological barrier relates to personalities. Granted many exceptions on both sides, the engineer often feels himself less skilled in using words, and displays less self-confidence than the manager in conversational give and take. Where we feel bested we often withdraw with some kind of rationalization, and many an engineer has deprecated "smooth talk" when he might better have tried some himself. Solid thought need not always be clothed in dense language.

Different personal value systems and attitudes provide a third psychological barrier to effective communication with management. This relates to, but goes deeper than, the different job and personal objectives mentioned earlier.

We communicate most effectively with those who share our personal values, and instinctively distrust those who do not. The engineer who values precision and objectivity will have difficulty understanding or making himself understood by the manager who simply wants the job done and sees no point in any "unnecessary" niceties.

The traditional struggle to get the engineer to release a design for production as long as he sees any possible refinements illustrates the point.

If the engineer feels it "right" to rely only on facts, figures, and statistics as he sees them, he cannot help but resent management's feeling something different. When we start debating "right" and "wrong" on subjective matters we build barriers, and communication soon breaks down.

By far the most inhibiting psychological barrier to communication with management comes from the boss's influence on the engineer's pay, promotion, and even continued employment. Although in our present economy engineers move relatively easily from job to job, this barrier still exists in many minds, consciously or subconsciously.

When a man influences one's income or determines what kind and how much work he can do, communications with him assume special importance. This can present a double-edged dilemma. As an example, we hesitate to bring bad news to the boss because, justifiably or not, he may react against us personally. However, if we do not keep him well informed, he may make bad decisions based on incomplete data, which he then holds against us.

Understanding the boss's interest in having the bad news with the good can help minimize that one part of the psychological barrier. But we might as well recognize that this and all other communication with the boss take place against a backdrop of job security and pay. They therefore demand careful thought and attention to sound principles if we want to communicate most effectively.

In the remainder of this article three basic principles for effective communication are developed and ways are suggested in which one can begin to use them immediately, not only to overcome the barriers listed above but in all communications.

Overcoming the barriers

Select—simplify—specify. The engineer who understands and uses this three-part prescription can improve almost overnight his ability to communicate with others. As an engineer you have utilized much the same approach in problem solving. To transfer it to the allegedly frustrating art of communication requires only that you recognize a new set of variables. With practice you can then begin to break through the communication barriers and use your technical knowledge and ability more effectively in all situations.

How can you do this? By understanding and using every day the three basic principles of effective communication that stand behind this deceptively simple prescription. These principles, along with two key questions, can help you take the first big step toward becoming a more effective communicator.

First, you must think. Clear communication starts with clear thinking. Too many communications fail because the sender fails to think them through before he starts to try to communicate.

No competent engineer would consider driving a pile or winding a coil until he had thought through at least the first phase of his project, and yet many communications show little or no planning; they wander and meander, start too soon, and go on too long. We can think of communication as the process of exchanging ideas and information. But until the sender has the idea or information clear in his own mind, he cannot hope to make it clear in the mind of the receiver, any more than a blurred photographic negative can produce a sharp print.

As we will see later, the communicator must think about many things that influence the complex process of recreating his idea accurately in the mind of another; but think he must, if he wants to have any control over what happens at the other end of the communication channel.

A two-part, two-way process. As a second principle, the communication process includes two parts, sending and receiving, and to be most effective we should try to make it a two-way process as well. When we think of exchanging ideas we immediately recognize that we must have a receiver as well as a sender. We have not communicated until we have to some degree affected our receiver—hopefully, in the way we desire.

This sending–receiving, two-part nature of the communication process may remind some engineers of Newton's elementary law of action–reaction. Unfortunately, unless we design and deliver our message with careful regard for what happens at the other end, our action may create as a reaction nothing more than a yawn.

Although we can never know positively and completely what happened at the other end of our communication channel, if we want to make the best possible estimate of how we were received we must add one more element to our sender–receiver model—a "feedback" channel. Otherwise, we have no way of sensing and measuring our receiver's reaction and therefore our effectiveness in accomplishing our communication objective.

Feedback serves other useful purposes for both sender and receiver, but none more important than this one of testing understanding. To use it most effectively, we must realize we can test understanding at several levels of effectiveness.

At the negative or neutral level we can pause only when interrupted, or pause momentarily and wait the briefest moment for a question. For a minimum test we can ask the familiar "do you understand?" and accept a nod of the head. Too often this means only that the receiver prefers not to admit he doesn't understand. For a deeper probe we might ask the receiver to repeat our message. Here we do well to remember that a tape recorder can give back our words more faithfully than any human receiver—with absolutely no understanding.

As a more effective approach, and probably the least we should try, we can require the receiver to translate and give back the message in his own words. Beyond this, testing understanding becomes more complicated. If we try to transmit knowledge we can ask him to outline how our message relates to or contrasts with what he has known before. If we instruct, we can ask how he will carry out our instructions, or what action he will take. And if we try to persuade—often the goal in communicating with managers—we can count any observable change in attitude or behavior as a sure sign of success.

When we receive feedback that raises a question in our minds about how well the receiver understood our message we have an advantage over the sender who neglects to build in a feedback channel, or who ignores what he does receive. As a result of feedback we can consider ways to reinforce our message and we often can take advantage of several opportunities to accomplish our objective.

To emphasize another value of an open feedback channel, we can recall a classic demonstration that contrasts one-way and two-way communication. In one version, a sender stands before a group, separated visually from them by a portable blackboard or easel on which only he can see a random pattern of four to eight identical touching rectangles. He describes this pattern orally to the group, who individually reproduce it as best they can. During this one-way communication they may not communicate with the sender.

When the sender feels satisfied that he has described the first pattern so all can reproduce it, he turns to a second, different pattern of the same number of rectangles. This time the group has two-way communication, and can feed back to the sender. They can stop him any time, ask him to clarify, repeat, or even start over. He continues until they agree they have reproduced the pattern to their own satisfaction.

The results of the demonstration are predictable. When you open the feedback channel the group takes more time than was used without it, but they have a higher score of correctly completed patterns. More sophisticated research generally confirms that one-way communication takes less time than two-way, but sacrifices some accuracy. And if we look at communication efficiency—information accurately received and interpreted per unit of time—we will often find the two-way mode more efficient.

One other point shows up on this demonstration. When you ask the sender how he felt about the two modes he will often say that he felt fine the first time, but uncomfortable, criticized, and challenged by the group the second time (when they could talk back). The group, on the other hand, will use words such as "frustrated" and "confused" in describing the one-way mode, and "confident," "satisfied," or "at ease" for the other.

Thus, in communicating messages where your audience's attitude may influence what they hear, understand, and accept, you can almost certainly improve your effectiveness by building in a channel that allows and encourages feedback. Any engineer who has listened to an author read a technical paper to a restless audience without once looking up knows what happens when the meeting finally opens for discussion. Although two-way communication may take more time, it generally improves efficiency and almost always improves receiver attitude toward the message.

Verbal and nonverbal communication. The many different ways we exchange information and ideas make communication both verbal and nonverbal. "Verbal," in the strict sense, includes all the ways we use words and related symbols, whether spoken or written, as contrasted with "oral," which means spoken only.

The words we use convey only part of the meaning our receiver finds in our message. We have all heard that "actions speak louder than words," perhaps without realizing how much nonverbal communication influences our total message. But tone of voice, emphasis, facial expression, posture, even silence, convey meaning, sometimes more than we intend.

Our written communications convey meaning nonverbally also. We observe and interpret almost automatically such obvious physical cues as the paper and ink used, neatness, size and style of type (or handwriting), and layout on the page. Nonverbal cues can also take even more subtle form. Some managers, for example, refuse to read any form letter that comes across their desks. Many companies, aware of this, spend literally tens of thousands of dollars to have form letters individually typed by machine so that when the reader runs his finger suspiciously over the letter's surface the slight indentations made by the typewriter will reassure him that he has an original letter. This, they think, improves the chances that he will read at least the first paragraph before consigning the letter to the wastebasket.

Nonverbal signals can effectively block or contradict the meaning we want to convey. Perhaps you have had the experience of walking into the boss's office to ask a question just after his secretary left his correspondence for him to sign. With a wave of his pen he beckons you to a chair, saying, "Go right ahead—I'll listen while I sign these few letters." If you have an exceptional relationship with your boss you may know from experience that he can indeed give you full attention under these circumstances. But in most cases you cannot help feeling that he might have said more accurately something like, "Go ahead and talk, but what you have to say can't matter enough for me to delay signing these letters."

Thus you can communicate at your full effectiveness only if you watch carefully to see that your actions reinforce—or at least do not contradict—your words.

As a receiver you can also improve your effectiveness by recognizing these verbal and nonverbal aspects of the messages you receive. Knowing that the nonverbal cues may have slipped in without the sender's realizing it, you can allow for any seeming contradictions, concen-

I. Checklist: communicating with managers

1. Objective

(a) To inform?
- What value to him—help him decide or act, now or later?
- How much background must I include?
- How much detail does he need?
- What precision does he require?
- Can I condense the past, highlight only changes?
- How important to stress trends versus absolutes?

(b) To persuade?
- What value to him—save him time, effort, uncertainty, resources?
- What possible objections, and how can we meet them?
- What specific steps to start desired action?

(c) To present myself, my accomplishments, my potential?
- What value to him—how can he use me better, now or later?
- What have I accomplished, specifically?
- How did I do it? (briefly)
- Possible future contributions?

2. Audience

(a) The man
- Education
- Background
- Experience
- Language, other capabilities
- Personal characteristics—prejudices, commitments, values

(b) His job
- Primary job interests, responsibilities?
- What does he need from me?
- What previous knowledge, relationship to my job or project?
- How do others measure his performance?
- His formal and informal role in the organization?

(c) Circumstances surrounding the communication
- Our personal, professional relationships
- Best medium, format
- Best time, place

trate on the words he uses, and try to interpret the meaning he intends to convey. In the final analysis you will add in the nonverbals also and judge the entire message, but unless you deliberately put aside some possibly misleading nonverbal cues you may find you have "turned off" the sender before you have given him a fair hearing, and you may have missed an important message.

Here, then, you have three basic principles for effective communication: it starts with clear thinking, requires both sending and receiving (with feedback where possible), and includes verbal and nonverbal message elements. Now let us apply these principles to develop two key questions with which you can tackle any communication situation.

Two key questions. In a world in which machines print thousands of lines per minute and the very air we breathe vibrates with hundreds of simultaneous never-ending messages, communication threatens to drown us all. As we think about how we can convey meaning amid all this noise, we conclude that we must select and concentrate on a few key ideas if we want them to stand out by contrast.

When we feel we have something important to communicate we usually have much we could say. For example, let us take a report on a meeting we attended. We could describe at great length how we traveled and arrived; the weather outside, the facilities inside; what the speaker wore, and how he sat while waiting for the chairman to introduce him; and even whether the pattern of the carpet on the floor ran parallel or diagonal to the walls of the room. Or we could ignore such items and explore exhaustively every nuance of the text and footnotes on every page of all published papers.

Which communication better serves our purpose? We cannot know until we have thought about our purpose, but in the majority of cases neither of these two extremes serves us well. Why? Because we measure communication effectiveness not by how much we present, but by how much our receiver absorbs and takes away.

In most instances we increase the probability that he will understand and retain our message if we limit drastically the total number of key ideas we present at any one time. Those who study the process feel we should set the maximum at about three to five key ideas; beyond that we reach diminishing returns. This demands discipline. When you have invested time, effort, and thought in accumulating information and ideas you naturally want to use them. But if you really care about how well you communicate you will ruthlessly test each item, as well as your entire communication, against two key questions.

What objective do I have? As your first task you must determine your objective. You may want to inform, you may want to persuade, you may want simply to demonstrate your accomplishments and potential, or you may want to do a dozen other things. However, until you can answer this question clearly and succinctly, you cannot begin to select intelligently from the material you have available.

Only when you have determined your objective can you begin to sift and sort by using the related question, "How does this help me accomplish my objective?" Many communications founder on the shoals of shallow thinking about the communicator's objective, one of the twin guides essential to success.

What audience do I have? As your other equally important guide, you need to know as much as possible about your audience (one person or more) and the circumstances that will surround your communication. No communication takes place until the audience receives and understands the message, so ignoring or incorrectly evaluating the audience and its characteristics can stop the process cold.

The checklist given in Table I indicates some of the kinds of questions with which you can start to analyze your audience. Obviously, you will not find, nor need, answers for all questions for every audience, but investment of a few minutes or hours (depending on your communication's importance) in analyzing your audience will repay you many times over.

Even when you repeatedly communicate with the same man you need to take stock from time to time. Men change, circumstances change, and your objectives may change enough to dictate a different weighting of his characteristics, which will in turn influence the content of your message.

Becoming a more effective communicator

You can begin to communicate more effectively with managers and others by starting to use these principles immediately in many different communication situations. Get into the habit of using a checklist, which will start you thinking about your objective and your audience. As soon as you have them well in mind, start reviewing material you have and getting additional material you think you might need; you can always discard anything you decide not to use. Now apply the three-part prescription mentioned earlier.

Select. Remember, your receiver will understand and retain most if you concentrate on no more than three to five major points. Rank your points in the order in which they contribute to accomplishing your objective and chop them off from the bottom. Incidentally, you need not use them in your communication in their order of importance.

Simplify. Here you apply the second principle, and simplify to suit your receiver's language and other capabilities, always bearing in mind his interests, his attitudes, his needs. Watch technical jargon, and don't overwhelm him. Most managers care more about conclusions and recommendations than about details of how you solved the problem, so give him only what he needs.

Specify. This means using relevant, concrete evidence and examples that your receiver can understand and relate to his own experience. It does not mean loading your communication with raw or processed data you needed for your problem solving. Give him what he needs to evaluate your message, nothing more.

In conclusion, once you have launched your communication, solicit, accept, and use constructive feedback so you can learn from your experience. Try not to take it as a personal criticism and don't argue or you will shut it off.

Above all, observe constantly the many communication processes going on around you, and learn by observing others as they apply (or violate) these basic principles. The way we communicate probably reveals us more intimately than any other act; and as you improve your ability to express and share your ideas with others you will find you have much more of value to reveal.

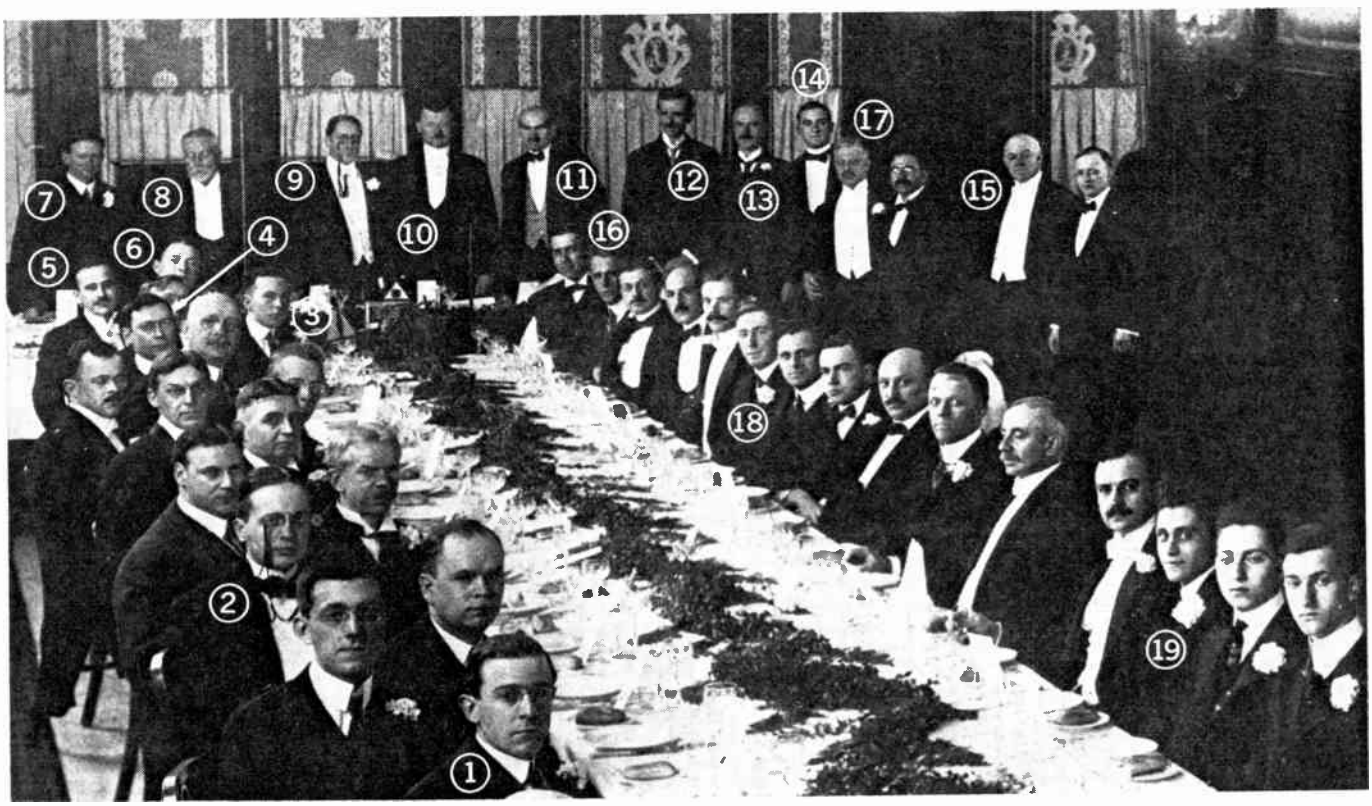
Radio ancestors—an autobiography by Robert H. Marriott

A condensation by Haraden Pratt

Modern electronics has evolved from the static of wireless, with its bigger and better spark coils, patent infringement suits, fraudulent stock schemes, and a mass of hasty legislation to bring order out of chaos

Robert H. Marriott, IRE Founder (1879–1951)

SECOND BANQUET of the IRE, held on April 24, 1915, at Luchow's in New York City. Many prominent "radio ancestors" attended, including: (1) G. W. Hayes; (2) J. A. White; (3) J. V. L. Hogan; (4) G. S. DeSousa; (5) E. J. Simon; (6) D. Sarnoff; (7) G. W. Pierce; (8) F. Braun; (9) J. Stone Stone; (10) J. Zenneck; (11) L. de Forest; (12) N. Tesla; (13) F. Lowenstein; (14) A. N. Goldsmith; (15) E. J. Nally; (16) R. A. Weagant; (17) E. F. W. Alexanderson; (18) G. W. Clark; and (19) L. Jones.



Robert H. Marriott (1879–1951) was one of the fathers of radio, and the founder of The Wireless Institute, one of the earliest engineering societies devoted to the advancement of communications. On May 13, 1912, the Institute of Radio Engineers was formed, through the merging of The Wireless Institute, headquartered in New York, and the Society of Wireless Telegraph Engineers, located in Boston. At the time of its foundation, the Institute of Radio Engineers had fewer than 50 members. The consolidation of the two societies and the initial work of organizing the IRE were done by Alfred N. Goldsmith, J. V. L. Hogan, and R. H. Marriott. The following article, completed about 1950, gives an insider's intimate view of the dawn of radio and the birth of the IRE.

Born in Richmond, Ohio, February 19, 1879, I was graduated from Ohio State University in 1901, having majored in physics, specializing in "wireless." A newspaper account of Tesla[1] sending electrical messages between mountains without the use of wires, and reports in 1897 about Marconi's[2] experiments, stimulated me to believe that sending messages without wires had great possibilities. Before I left high school, the university invited students to visit and arrange for courses. I wanted one in wireless, and was referred to Prof. B. F. Thomas, who told me to take a general science course, there being none in wireless.

"Daddy" Thomas, whom I came to think was nearly human, and who sometimes could be practical and should not be regarded with awe, knew that wireless, at that time, was fairly old although no scheme had been developed to use it. The university's physics laboratory had apparatus like that used ten years before by Hertz[3] for his famous demonstration of "radiation wireless." Three other kinds of wireless could be demonstrated in 1897. The Spaniard Salva proposed in 1795 that the ocean could be spanned using only two short wires, each on the opposite beach. An area of land on one side could be positively charged with a telegraph key in that wire. The other side was expected to become negatively charged and a small spark gap in that wire should flash when the key was closed. This idea may have stimulated subsequent thinking. In 1882 Professor Dolbear[4] of Tufts College patented such a wireless scheme.

The methods capable of demonstration could be designated as: selenium, conduction,[5] induction, and radiation[6] wireless. Light-sensitive selenium could detect beams of light flashed from transmitters. Signals could be conducted short distances with electric currents through water and earth, and many experimenters, including Morse in 1842, tried this method. Induction wireless could also be made to work for short distances by using two separated coils, the transmitting coil being energized by alternating currents. Radiation wireless was demonstrated by Hertz and, during my college days, was said to act like light beams. However, before 1901 it became apparent that this kind of wireless was different from light since it would carry through fog and could extend beyond the horizon, which worried the staid and correct Professor Thomas.

Academic wireless to professional wireless

Sir William Crookes,[7] in 1892, predicted in some detail how radiation wireless could be used for telegraphing messages, and also suggested the concept of tuning. At least two types of detectors were known before the Hertz spark gap: one, the Branly[8] coherer, dating back to the Varley cohesion experiments of 1866[9]; the second was the microphone used by the Englishman Hughes, who created and received electromagnetic wave signals in 1879. The sensitive Hughes[10] refused to write a paper or continue his experiments because the Secretary of the Royal Society would not believe in his theories; only on the urging of friends did he reveal in 1899 what he had accomplished in 1879.

Among other early experimenters was Tesla, who proposed elevated conductors and ground connections for wireless working in 1893, but conducted no demonstrations. Professor Popoff[11] in Russia detected wireless waves produced by lightning in 1895, using a vertical wire and ground connection. But it was left to Marconi to achieve the Crookes' prophesy by communicating over several hundred yards in 1895, and nearly two miles (3 km) the following year in England, using only the instruments available to previous workers.

Upon my entry into college most men who had been recorded as prominent in wireless had been professors or scientists with reputations, but about this time youth began taking a hand. The new generation had no reputations to protect, and their wishful thinking was not influenced by any profound knowledge of established theories or facts. They borrowed credit for what others had done, and enjoyed laudatory publicity. In other words, up to the mid-gay nineties, professors and scientists developed wireless step by step, in dignified waltz time, with soft music. Then the boys cut in to take wireless out for two-stepping with plenty of brass. In addition came promoters and stock salesmen who used substitutes for, and stretched, the truth, with the result that some of them did stretches in penitentiaries. They tried in several ways to monopolize wireless, usually by claiming they had invented it or some necessary part. But since wireless had been developed before they took a hand, they could not patent it; and rival wireless companies were successful in dodging or countering each others' allegedly necessary patents. When a would-be monopolist sued a rival, the rival could usually find enough wireless history to defend his case successfully. No company was able to obtain a wireless monopoly in the United States.

No other boy at college was interested in my subject; and I had to experiment alone. Repeating the Hertz experiment was easy for one person, but transmitting over longer distances was more difficult. I used an automatic, electrically driven grandfather's clock in the laboratory basement as a transmitter, the pendulum of which touched a small pool of mercury on each swing. By means of a relay in the clock-energizing circuit, a spark coil could be driven, the spark gap being connected to antenna and ground connections. The receiver used was that cantankerous coherer,[12] with metal filings loosely packed between two electrodes. This involved, in effect, a lot of very, very minute spark gaps that closed up when a surge of electricity went through to operate a relay, which recorded the signal and started a mechanical tapper to knock the filings apart. This device was publicized as wonderful, and it was wonderfully erratic and bad. It would not work when it should, and it worked overtime when it shouldn't have. I became determined to avoid its use and, after leaving college, bought telephone receivers like those the "hello" girls wore, and rewound them with the finest wire I could buy. I obtained fair results with several kinds of microphone contacts.

Stock certificates, static, and messageless wireless

Just before graduation, newspaper publicity announced the formation, in 1900, of the American Wireless Telegraph and Telephone Company (AWT&T) and the wonderful wireless stations they were going to build. I applied for, and got, a ten-dollar-a-week job, reporting to Dr. Gehring, the president, in Philadelphia. Dr. Gehring had become interested in the field through a brother. He learned that wireless was old before Marconi experimented with it, and that United States patents on wireless had been issued to Professor Dolbear[4] in 1882 and 1886. Rights to these patents were purchased and the new company was organized. I was assigned to clerical work.

Soon AWT&T became a parent company, having babies born in 1901 with such names as New England, Atlantic, Federal, Southern, Gulf Central, Middle Western, Great Lakes, Northwestern, Southwestern, Continental, and Pacific.

The company's prospectus was flamboyant. Among other statements, it said: "Plans are being perfected for the transmission of messages across the ocean in the near future." It also announced that: "Taking a stretch of, say, 50 miles, we find the cost by the old system, per mile $3000, to be $150 000, whereas the cost by the wireless system, per mile $150, to be $7500, a saving in first cost of $142 500."

In July 1901 I was transferred to Brielle, N.J., where the company had a station equipped with a spark coil. The spark gap was connected to a 100-foot (30.5-meter) wire on a mast and to a piece of copper in the dry sand. A receiving station was located at Galilee, where there was a coherer and tape recorder. Most of the signals on the tape came from static electricity. Among them many Morse code characters could be identified, such as the letters e, i, s, h, and p, which are made up of dots. I could not find anyone to talk engineering with. Promoters, as a class, seemed to feel that technical people might be too frank and expose weaknesses in their company. That was one of the difficulties I had later in organizing an institute; technical men were afraid to talk.

But at Galilee I found the later-well-known Greenleaf Whittier Pickard,[13] grandnephew of the poet; he could lecture on almost any scientific subject.

Galilee was to be our receiving station for the reporting of the yacht races between the *Columbia* and the *Shamrock*. The English Marconi people had done it for the 1899[14] races, using a receiver at the Heights of Navesink, and were to do the same in 1901. Newspapers announced that de Forest[15] was also going to report them by wireless. Shoemaker, our chief engineer, asked me to look over the Marconi and de Forest receiving stations. At the latter, the little house was empty, and no antenna hung from the gibbet. I was told that de Forest was his own promoter then, and had not been able to acquire a workable transmitter. The Marconi setup at Navesink had both a transmitter and a receiver, but was next door to a hotel where a small portable spark coil easily could be used to interfere with reception. I reported these facts to Shoemaker.

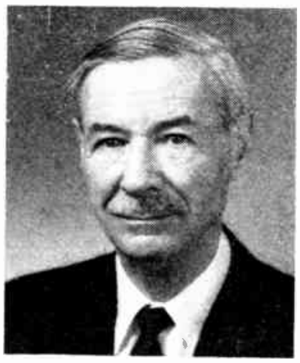
The boat *Maid-of-the-Mist* bore the AWT&T transmitter. Pickard contrived a code, based on the "putting-a-brick-on-the-key" method of creating interference, made up of very long dashes. One dash meant *Columbia* ahead, two dashes *Shamrock* ahead. These dashes were identified and the messages got through. The Marconi effort failed because these long dashes on their tape recorder obliterated their own signals, so they demanded a division of time for the rest of the races.

The subsidiary Continental and Pacific Companies in the west offered me a position as chief engineer at a salary of $50 a week. I accepted and reported, in Denver, in October 1901.

Avalon needed it and wireless disbelievers

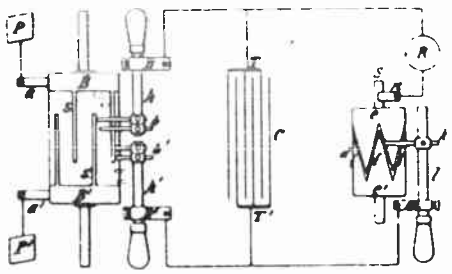
We organized the Carstarphen Electric Company in Denver to make our apparatus. At my suggestion that wireless stations be built only where there was no existing telegraph service, Avalon, Catalina Island, in California was chosen as a place where its owners, Banning Brothers, wanted service.

I developed the idea of using two rewound Stromberg telephone receivers, with a common head band, to get the most out of both ears and to exclude outside noise. A microphonic detector was made, which had a steel needle with a slightly rounded point held against an iron oxide surface by a very fine-threaded adjustment screw, fitted with a large knurled knob. The most satisfactory



Haraden Pratt (F), Director Emeritus IEEE

A radio and communications pioneer in his own right, Haraden Pratt has frequently served as an historian of the IEEE and one predecessor, the IRE. He received the B.S. degree from the College of Mechanical and Electrical Engineering, University of California, in 1914. In 1928 he was appointed chief engineer of the Mackay Radio and Telegraph Company. Shortly thereafter he became the company's vice president, and remained in this capacity until his retirement in 1951. He was President of the IRE in 1938, and Secretary from 1943 to 1962; in 1963 he became Secretary of the IEEE, a position retained by him until 1965. He was director of the American Standards Association from 1939 to 1942, and Telecommunications Advisor to the President of the United States from 1951 to 1953.



REPEATER — TESLA, 1899

oxidized iron was obtained by burning the tin off a Prince Albert tobacco can. A small drop of oil protected the area of contact. This design was selected after innumerable trials with a large variety of metals, both clean and corroded. With this receiver the operator could discriminate between the desired signals and the undesired static, which coherer receivers could not do.

The equipment for the two stations was ready in March 1902, and I left with assistant Gustave T. Swenson for Los Angeles on April 15.

White's Point, on the mainland off Catalina Island, and a site 270 feet (82 meters) high on the island were the locations, about 25 miles (40 km) apart. They were equipped with gasoline engine generating plants, and had soundproof rooms with concrete piers on bedrock to mount the microphonic-type detectors. The gas engines had to be stopped in order to receive signals. Neither Swenson nor I were telegraph operators, so we handled our first messages by slowly transmitting the dots and dashes from a printed copy of the Morse code, and received by making long and short pencil marks as the dots and dashes came in. Later, regular telegraph operators were employed who had been trained to interpret the buzzing sounds of the wireless in place of the accustomed telegraph sounder clicks.

I received the first message at Avalon on July 9, 1902.[16] It read: "Do you get me?" A few days later the returns of the Jeffries and Fitzsimmons[17] fight in San Francisco were laboriously received by me around midnight and posted on the town bulletin board. Even after verification by the newspapers that came on the next boat, the feeling that my information must have come by carrier pigeon, a small night boat, flashing lights, or otherwise was epidemic. Then a wireless message got a specialist sent over for a sick woman. And all doubts vanished when two men robbed the Metropole Hotel bar and left on the 5 A.M. boat. This type of getaway had been safe for years, but a wireless message arranged an official reception for the robbers when they reached the pier in San Pedro.

The *Los Angeles Times* started a daily paper at Avalon called *The Wireless.*[18] A worldwide service was available by connecting with the wire companies, and continued without interruption for 21 years, although with changes of ownership and systems. Two of the important successors were the United Wireless Telegraph Company[19] and the Marconi Company of America.[20]

As the fog produced by promoters was clearing it became apparent that the apparatus we were using was not patented or covered by valid claims of other companies. Fundamentally, everything we used had been appropriated from the professors who had employed them for years in their academic pursuits. Our apparatus was simple and did not contain the erratic coherer or induction coil vibrator; any parts could be bought in the open market and repairs could be made by any studious electrician. We used a dependable motor-driven interrupter. These are the main reasons for the success of this everyday public service.

In 1901, a wireless system using English Marconi apparatus was established in the Sandwich (Hawaiian) Islands[21] but it failed to operate successfully.

When Marconi claimed the reception in Newfoundland of the letter "S" signals from England in December 1901, the inexperienced thought he used the classic coherer. With a coherer he could have received these three-dot signals just from static electromagnetic disturbances without the help of a wireless transmitter. Years later it was revealed that he gave up the coherer attempts and used a carbon–mercury microphone contact with an old-model telephone receiver his helpers found in their gear. With this they could recognize the sound made by the spark at the Poldhu transmitter.

Wireless operators often made their own receivers or purchased them from stores that supplied amateurs in preference to the receivers supplied by the Marconi companies in their installations. The domineering efforts of these companies retarded wireless development for at least 20 years. However, we must not lose sight of the fact that the boyish enthusiasm and influence of Marconi was probably the important force that took wireless from the academic side issues or extras of professors to public service.

Organizing a new company, more wireless and less money

I returned to Denver, September 1902. To promote new business I went east to confer with patent lawyers and to interview the Navy Department. Admiral Bradford told me that all the apparatus they had tried gave better results than that of the Marconi Company. Bradford sent me to Annapolis where tests were under way, one of which included a successful transmission from the *U.S.S. Prairie*, 80 miles (128 km) away, using German apparatus made by Slaby-Arco and Braun. Both of these had been making instruments since 1898 and years later combined into the important Telefunken Company.[22] Braun, a Nobel Prize recipient, had developed the cathode ray tube prior to 1897, which is now used for radar and television. Professor Fessenden,[23] formerly a teacher who had established his own wireless company, had offered to submit instruments but had not done so. They did not like de Forest's system because he used coherers. I felt that I could not offer them anything better than the German apparatus they were testing.

Visiting the AWT&T Company, Shoemaker told me that their Atlantic stations along the New Jersey coast, particularly the one at Atlantic City, were working fine and doing business. Thinking that November was a poor business month for a resort area, I went to Atlantic City and photographed the station. It had no antenna, boards were nailed over the windows, and the door was closed and locked.

Returning to Denver, I found the office nearly vacant and the treasury nearly bare. I was paid $100 and then no more. The California stations had been sold for $5000. Armstrong had interested other capital and had formed the Pacific Wireless Telegraph Company. About

1904 this company built stations in San Francisco and at Friday Harbor, Wash. I took employment with the Carstarphen Electric Company for less money.

The attempt of the Fessenden Company to establish a wireless service between New York and Philadelphia was abandoned. The AWT&T Company was succeeded by the Consolidated Wireless Telegraph Company, then by the International Wireless Telegraph Company, and then finally by the American de Forest Wireless Telegraph Company, without being able to revive stock selling.

A promoter named Abraham Schwartz met Lee de Forest and became head of his American de Forest Wireless Telegraph Company after changing his name to Abraham White. I suspect that this colorful man made the change because black is the absence of color and white is all colors. Abe did not hide his "White" light under anything. He and de Forest put on a big show at the 1904 St. Louis Exposition, including having de Forest's name shown from a high tower and having electric automobiles, called Abe White's Showcases, fitted with wireless equipment running around the grounds; these were also shown in New York and Denver. Abe publicized de Forest's inventive ability and recommended stock as an investment. After the Exposition they took in a financial dealer named Col. Christopher Columbus Wilson and put him in charge in Denver. Two stations in Denver and one in Boulder were built under the direction of Charley Cooper, a telegraph operator.

Because they had big plans, including a chain of stations from Wyoming to Texas, I was hired as superintendent of construction and maintenance. White liked the idea of stations in the Rocky Mountains, because the people there were accustomed to buying mining shares and might take flyers in wireless stock.

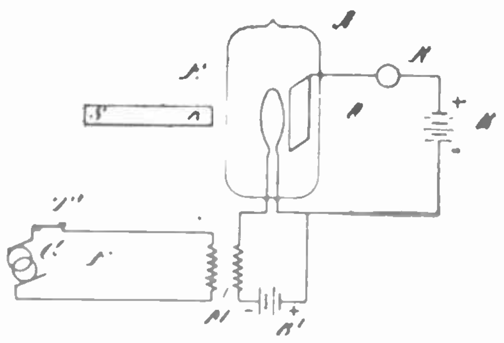
Detectorless de Forest

Wireless men did not know much about wireless; promoters and officers knew even less. Two of the latter were looking at the new electrolytic detector in the Denver station when one asked what the liquid in it was. The answer: "It is a secret fluid only de Forest can produce." To this I remarked that any acid or alkaline solution would work. This shocking answer was passed on to Colonel Wilson. Later, when a court ruled that de Forest had not invented it, Wilson often consulted me on technical matters.

The de Forest equipment was rugged, simple, standardized, and easy to install and maintain by nonskilled operators. Cloyd Marshall, an electrical engineer of Scottish descent who joined the company at the St. Louis Exposition, contributed to this.

Early in 1905, de Forest came out from New York to see us. He looked at the stations and seemed to think everything was all right. I never found out why he came.

About 1906 the American de Forest Wireless Telegraph Company became the United Wireless Telegraph Company, with C. C. Wilson as president. The Fessenden people sued on the use of their electrolytic detector and won and de Forest and White were dropped from the company. But the United Company had the Dunwoody[24] carborundum detector at its disposal. These were manufactured at its Jersey City factory in tubes sealed in wax. To make them operative I unsealed them, fitted adjustable contacts, and mounted them in sets of four so that the operator would usually have at least one that was



AMPLIFIER – DE FOREST, 1906

good. They worked better than the electrolytic detector, which was very vulnerable, the point burning off with strong signals and static, not to mention the effects of spilled acid. The attempt of Fessenden to rule wireless through the electrolytic detector prevented that device from being brought to a more practical state, and accelerated the use of crystals. Fessenden's superior mistakes helped wireless a lot.

By early 1907, it became evident that ground could be gained by building up a ship-to-shore business. I was sent to the Pacific Coast with Cooper and others. Our first installation was at Astoria, Oreg. About this time *Success* magazine, of New York City, published articles by Frank Fayant on wireless companies and their stock-selling methods. For $1.10 *Success* would sell a page about a company signed "The Investor's Department." Our building contractor at Astoria became so disturbed by these articles that work was delayed while he demanded money be put in escrow for him. At this point the *Success* articles suddenly stopped.

From Astoria to the Waldorf-Astoria, and DF

C. C. Wilson moved to New York and I was sent back to Denver to dismantle the Colorado stations, after which I also went to New York, arriving in December 1907. Cooper remained on the West Coast with the company.

My work took me to the famous Manhattan Beach station, which was used as a laboratory in the daytime and for telegraph service at night. Its call, DF, was taken from de Forest. President Wilson lived at the Waldorf-Astoria Hotel, and a station in its penthouse, operated by Elmo Neal Pickerell, was his pet.

Now that I was in New York where there were a number of wireless people, I set out to organize a wireless scientific society. A member of the American Institute of Electrical Engineers, I talked to their Secretary, Ralph W. Pope, and others. Pickard and Shoemaker were sympathetic. Others in United Wireless felt that, although they could not understand the technical aspects, such a society might help wireless development, and therefore they would join as financial contributors.

I thought the organization should not be limited to the United States as wireless was not limited by national boundaries. Secretary Pope and others of the AIEE wanted to take us in, but it seemed better that we try to be international and not a minor part of a national organization. Mr. Pope gave us good advice on how to proceed, which was one of the main reasons we succeeded. We called it "The Wireless Institute."[25]

The first meeting of the WI was in Farnsworth's office, Room 1909, at 42 Broadway, on January 23, 1909. Most of us had to get the consent of our employers, as some officials thought engineers should mind their own jobs and not fraternize with others.

At the house I rented in Brooklyn, I used one room for a subreceiving station. When working with wireless telephony, the instruments in that room talked or played tunes. Sadie, our maid, always ran by the door of that room, believing there were ghosts in it. Our little arc-type telephone transmitter at DF could be heard by ships as far south as Atlantic City.

The Manhattan Beach station could cover great distances. I had often heard its 2-kW transmitter when listening in Colorado. Vessels equipped with United apparatus operated to Bermuda, the West Indies, and southern Brazil. While I was at DF we got better operators, with improved equipment; and the volume of paid words handled increased some 16 times. On the other hand, the Marconi station on Coney Island had a very short range.

Doc asked Bab to stick in the third electrode

In late 1907, C. D. Babcock was in charge of the United Wireless factory. He was the best all-around mechanic and shop superintendent in United States wireless at that time. When de Forest lost his position, Babcock took the title of "scientific manager." I became assistant scientific manager.

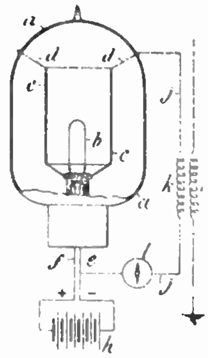
Babcock told me that de Forest had all wireless inventions he heard of copied. This was done with the Fleming valve, a two-element rectifying tube made by Dr. J. A. Fleming[26] of England, based on Edison's discovery many years earlier of electric current flow from the filament of the electric lamp to an extra electrode he put in it.[27] Edison was trying to find out why lamps collected a dark coating on the inside of the glass. Bab said he was working on a drawing when de Forest rushed up and said: "Bab, if two electrodes in a bulb make a detector, maybe more of them will make a better one." He illustrated by making little sketches on the margin of a patent; and asked Bab to have some vacuum tubes made with three or four electrodes—a "flock" of electrodes. Bab had them made. Eventually it was found that three electrodes suitably positioned gave better results than two, but more than three did not do any better. In later years de Forest told me it was Babcock who gave the "audion" its Latin–Greek name. After the audion became useful, Babcock would refer to the "flock" as the amusing part of de Forest's order.

Dr. Poulsen[28] of Denmark patented a hydrogen electric arc transmitter in 1905 that produced continuous waves reliably and powerfully. The desirability of such waves had become obvious as providing more efficiency and sharper tuning, and as being adaptable for telephony. De Forest's next company was named the De Forest Radio Telephone Company, and it made some small arc telephones with which Teddy Roosevelt's "round-the-world" navy fleet was equipped. With one of these, Chief Electrician H. J. Minerratti on the battleship *Ohio* provided daily broadcasts for the fleet from phonograph records. Radio had been frequently suggested as a name for the brand of wireless that we used. Fessenden, the son of a preacher, had, with a platinum point and acid, forced de Forest, also the son of a preacher, to substitute radio for wireless and telephone for telegraph.

The show "Via Wireless" and contacts

Frederick Thompson, a showman who put on "The Pike" at the St. Louis Exposition and had built the New York Hippodrome and Coney Island's Luna Park, staged "Via Wireless" at the Liberty Theater in 1908 and 1909. This play involved a romance where people were rescued by wireless. Part of the scene was a wireless room on a ship, which was equipped with a regular United Wireless spark transmitter fitted on a steel ball so that it could be rocked back and forth. Thompson got the company to help him, and I was assigned the job, including making sparks outside the Liberty Theater before show time.

While "Via Wireless" was running, the *S.S. Florida* rammed and sank the *S.S. Republic* in January 1909, on the same day of the first meeting of the Wireless Institute. Jack Binns, the *Republic*'s operator, sent out the distress call CQD (later changed to SOS) that enabled passengers to be rescued by other ships. Binns became a well-publicized hero, and Thompson got him for the show. When his turn came, Marconi equipment, as used on the *Republic*, was put on the rocking ball. Binns wrote a paper for us, which was read at the Institute meeting in June. This, with its discussion, was instrumental in getting our first law enacted, requiring the licensing of radio operators on ships.



RECTIFIER — FLEMING, 1905

Pickard started working for the Weather Bureau in 1898, studying voltage gradients of atmospheric electricity, and later chaperoning a coherer, trying to make it tell the truth about weather. He was best known for later developments of the audibility meter, a tuner, and his crystal detectors. These became popular in the Navy. He, with Colonel Firth, the salesman, and Farnsworth, the patent attorney, established the Wireless Specialty Apparatus Company and had their instruments made by Foote, Pierson and Company, of which Morris Liebmann was the shop foreman.

The tuner became the favorite of the Navy. It was the famous 1P76, later called the IP76. The crystal detectors used galena, silicon, fool's gold, bornite, zincite, and other minerals. They called them the "perfect contact" detectors, from which they derived the name "Perikon." Although he was a great reader, Pickard did not discover for many years that this word had been invented previously by Giovanni Boccaccio, and, what is more, that the very early "Pericon" detected a vessel in distress and rescued passengers. (To get all the details, read Boccaccio's *Novel VII, the Second Day of the Decameron.*)

Amateur clubs started quickly and died as quickly, as a rule. One did not. The Junior Aero Club of the U.S. changed its name to the Junior Wireless Club, Limited, in 1909; and then, in 1911, to the Radio Club of America. This club still meets.

Wireless was lawless

How laws did, could, or should apply to wireless was a subject coming to recognition between 1909 and 1912.[29] Patents had shown their lack of much value, and old methods used in stock selling were judged illegal; it was maintained that steamship companies should be compelled to protect lives and property by using wireless, that wireless commercial companies should be regulated, and that the amateur wireless stations that were increasing should be regulated or prohibited.

The Marconi Company had failed to get control of wireless in the United States on the strength of Marconi inventions, but when United Wireless was almost a dead cripple, the parent Marconi Company in England bought its assets with the sanction of the court for $750 000 and sold them to the American Marconi Company, together with some Lodge[30] patents and high-powered equipment for future transocean working, for $1 400 000 in shares. This required financing, and so, on April 18, 1912, the authorized capital stock was increased from $1 662 500 to $10 000 000. This stock jumped from about $12 a share to fantastic prices, with sales netting the company some $6 000 000.

But of all the lawless, I guess you could say the amateurs were the worst, at least as far as numbers were concerned. Many of them did not care how much they interfered with commercial or Navy wireless. There was no law to prevent them from interfering. Very cheap equipment was on the market for amateurs to buy. For example, a static machine could be had for $3.75 to be used as a wireless transmitter.

Insofar as making proper use of wireless and contributing to its cost, steamship companies were lawless too. There was no law to make them use wireless; and captains of vessels were generally against it because, when out of communication with their bosses, they were virtually kings. Captain Maxon, of the Southern Steamship Company, was an outstanding exception. When he changed ships he took his wireless with him and reinstalled it. He did a lot to get wireless introduced on ships.

The liner *Titanic* hit an iceberg in 1912, and about 1500 persons were lost. The *New York World* wanted a wireless-equipped tug to meet the rescue ship *Carpathia*. On behalf of the Marconi Company (now successor to the United) I fitted out a tug, but when we met the *Carpathia* at sea (a ship I had previously fitted with United apparatus) we saw only rails lined with silent, white faces. The reporter for the *World* got no news, the *Carpathia* having been ordered to give out none.

The Institute acquired continuous workers

I was experimenting at the Manhattan Beach station when ex-amateur Frank Hart, operator, told me about a physics instructor at the College of the City of New York to whom he had mentioned my experiments and who wanted to see what I was doing. I consented, and the next day Frank brought the young professor out. I got him to join the Institute, and we converted him from specializing in color photography to wireless. His name was Alfred N. Goldsmith[25,31] and he has been a continuous worker for the Institute ever since. Through Goldsmith we got Pupin, an inventor and professor at Columbia University, who provided a lecture room and gave us a paper. It was Pupin who put student Howard Armstrong[32] on the way to making money out of a self-tickling audion.

Although Institute attendance increased, the number who could pay dues decreased; the difficulties of the United Wireless Company contributed to this condition. We had trouble financing the printing of papers.

John Stone Stone [33] of Boston, bachelor gentleman and member of exclusive clubs and producer of many wireless patents, established a company to make wireless apparatus of quality. In 1907 he began inviting employees to meet at his home to read and discuss papers. In 1908, Stone had the group incorporated as the Society of Wireless Telegraph Engineers (SWTE).[25] When Stone later gave up his business, he and some of his employees moved to New York City. The society became less exclusive and added some members who lived in New York, for example, Hogan,[25,31] de Forest, and Lowenstein. But SWTE had trouble collecting dues.

Changes occurred in Fessenden's company, the National Electric Signalling Company (NESCO). S. M. Kintner was replacing Fessenden, and most of them moved to Brooklyn. This brought some active members to the WI, for example, Roy Weagant. One day Jack Hogan, who had been continuously helpful, remarked to me that he thought Stone and his people would come with us if we could make combine the SWTE and the WI, under a new name. I had never thought of that. We of the WI talked it over, and then made a proposal to the SWTE. Goldsmith typed it. The name was to be "Institute of Wireless Engineers"; at the last minute, this was changed to "The Institute of Radio Engineers" (IRE).[25] The members were to consist of those who had paid their dues in the WI and in the SWTE. Stone personally paid for some in the SWTE to make them eligible.

On May 13, 1912, a meeting of the IRE was held in a Columbia University room and officers were elected.

Servicing ship wireless, and Isaacs to Lloyd George

The equipping of ships by United Wireless was increasing. More shore stations were built to serve them. I was put in charge of ship installations. On September 21, 1911, Seldon Bacon, the 26th court-appointed receiver of the United Wireless bankruptcy, discharged me because I was the highest-paid employee. In May 1911, six of the company officials had received sentences in the mail fraud case. I had been called on by the defense to supply much information about stock selling. One of the brokerage firms gave me a list of 17 wireless companies said to have sold stocks. I do not recall having heard that any of them rendered any service.[34]

Mr. Sammis, chief engineer of the Marconi Company, gave me a job as his assistant. But this did not get me away from a stock selling enterprise.

Then came the wireless scandals[34] in England, where Sir Godfrey Isaacs, managing director of the parent Marconi Company, was promoting a contract to provide the government with an Imperial wireless system extending throughout the Dominions. He gave some shares to his brother Rufus, Attorney General, who, in turn, sold shares very cheaply to the Master of Elibank and to Lloyd George, Chancellor of the Exchequer, who later testified that he made a comfortable profit on the deal. The resulting investigation by a Select Committee of Parliament rocked the empire, but in the end no action was taken against anyone.

29 Cliff Street and regulating wireless

The Marconi Company of America increased its staff. J. Albert Proctor, an engineer who left later to join Pickard in Boston in the Wireless Specialty Company that now belonged to the United Fruit Company, had an ex-office boy named David Sarnoff[35] who had become an operator and wanted to learn wireless engineering. Weagant, Hallborg, and Chadbourne were taken over from the National Electric Signalling Company.[36]

I became interested in the regulation of wireless and its further use to protect life and property at sea.[29] The first wireless law was quite limited; W. D. Terrel and R. Y. Cadmus, wireline telegraph men in government positions, were assigned to New York and San Francisco to enforce the law. When the new and more drastic law was to go into effect in 1912, competitive examinations were held. I took one, passed with the highest grade, and on October 19, 1912, submitted my resignation to the Marconi Company. I was going into a job where none of my associates sold stock. The other men who came into the U.S. Radio Inspection Service were John Dillon, Henry C. Gawler, V. Ford Greaves, Charles C. Kolster, Arthur R. Rice, Roy E. Thompson, Benjamin E. Wolf, R. B. Wolverton, and Louis R. Krumm.

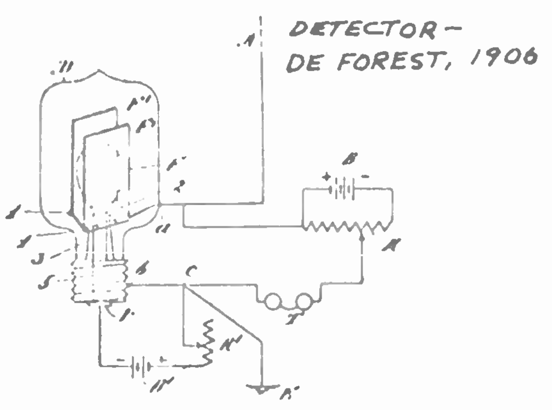
Fred Kolster,[37] elder brother of Charles, had a Civil Service job at the Bureau of Standards, where he developed a Decremeter and in later years designed radio compasses that were destined to be introduced as standard navigation equipment for ships.

After being sworn in we spent some time at the Bureau of Standards making measurements, and we visited the Arlington[38] Navy Radio Station where a large arc transmitter[39] was being installed alongside the big Fessenden rotary spark gap transmitter. Here was to be the office of Captain Bullard, Director of Naval Communications, who, after the war, promoted an American organization to get rid of the Marconi British ownership of radio in the United States. Here also, in 1915, under the direction of R. A. Heising, was to be installed by the American Telephone and Telegraph Company a flock of improved audions to telephone to San Francisco, Hawaii, and Paris.[40]

Terrel and I were assigned to New York with offices in the Custom House. At first the work was challenging, but it soon became routine. The Radio Club joined us to enforce the laws pertaining to amateurs. One of their members was a du Pont research man named Hudson who had wrapped an audion filament with wire so it could produce more electrons without burning out, thereby introducing the "Hudson filament" audion bulb.

Extracurricular radio activities and the amateurs

Being in New York, I was able to give much time to the new Institute of Radio Engineers.[25] In 1913, we got out the first work on standardization. Our committee included, in addition to myself, Goldsmith, Hogan, Kennelly, Weagant, and Pickard (President in 1913). The committee's final product then went to famous Professor Kennelly[41] at Harvard, who could not attend meetings.



He was probably more familiar with the making of standards than any other person. He had run away to sea as a boy, and was a practical electrician long before he became a college professor.

Expanding radio affairs in 1913 helped the Institute. Installations on ships increased greatly. Growth took place in the Marconi and other companies, and the Navy. The Federal Telegraph Company, introducing Poulsen arc systems, had arranged convincing demonstrations, causing the Navy to adopt this as their standard operational method.[42] Two large German transatlantic stations were coming into use.[43]

Amateurs did not turn out to be preventers of etheric communications as was prophesied. They ignored simple mathematics. So far as doing a neat job of wiring was concerned, they did this in the same way that they left their clothes scattered around. Because of these tendencies, several amateurs and at least one professional wireless operator, by connecting audions in the wrong way, obtained better results than by doing it in the "right" way.

Whether or not amateur Armstrong was the first to use the regenerative audion, he did the things most important from the standpoint of belonging to a radio club. He interested others, particularly Professors Pupin and Morecroft,[44] and gave a paper before the IRE.

Amateurs grew to be potential engineers and operators and, after the first World War, the available audience for the beginners of the era of broadcasting. In time they formed the American Radio Relay League, which spread to other nations.

Amateurs were generally at school when radio inspectors came; some of their mothers became frightened at these visits. I remember that Walter Lemmon's mother did, and I had to explain that nothing would be done to him if he made an inexpensive change in his set before using it again. To catch an amateur purposely creating interference was not easy. In running some of these down, we would go to their homes. An inquisitive Federal Inspector with a badge, accompanied by a cop with a badge, uniform, nightstick, handcuffs, and gun, plus two unidentified intent men (members of the Radio Club), was a disquieting combination for any who felt no more than even a suspicion of family guilt.

Keeping an ancestor out of the pen

De Forest had been indicted for fraudulent stock-selling practices, and his case came up in late 1913. Emil J. Simon was trying to help him, but did not develop much enthusiasm from others because most felt de Forest might not be innocent. Furthermore, they were not sure that the audion was a practical device or that de Forest had invented it.

Finally, on November 5, 1913, I got a petition prepared by Simon and Goldsmith, signed by 49 IRE members, asking Assistant District Attorney Stevenson to give de Forest a separate trial so as to set him apart from other, nontechnical, defendants. I conferred with Stevenson for 2½ hours. De Forest was not given a separate trial, but he was not attacked as severely as the others; and the jury found him not guilty on three counts and disagreed on the fourth count.

De Forest later tried to get advanced to the Fellow grade of membership in the IRE, but because I had been so criticized for helping him, I would not agree to this.

Variety in inspections and an ancestor dies

Some of the events during this period promoted the passage of radio laws. For example, the *S.S. Titanic* was notified by wireless that icebergs were in the vicinity. Before the ship struck an iceberg the wireless operator on the *S.S. Californian*, which ship was nearby and could have rescued everybody, went off duty and therefore could not respond to the subsequent calls for help. No other ship was nearby.

To facilitate testing a ship's transmitters without creating interference I made a dummy antenna, or artificial load. Members of the Radio Club assisted carrying this heavy gear around the waterfront. More selective receivers replacing the United Wireless type "D" tuner (usually called the detuner) became available and made sharper tuning feasible.

It was necessary to cite many ships for failure of their wireless equipment to work. Two outstanding examples were the *S.S. Majestic* and the *S.S. Cedric*, whose sailings were delayed, resulting in considerable press publicity. An *Electrical World* editorial of February 7, 1914, said: "The sublime confidence of the seagoing public in wireless as an all-patent saviour would appear to be misplaced. It is high time that all passenger steamers were equipped with emergency or auxiliary transmitters which are really worthy of the name." Thirty-four years later I learned that J. V. L. Hogan wrote that editorial.

The plain aerial type of transmitter was retired in 1914. Marconi had used it for some 18 years. It was such an objectionable arrangement that others had abandoned it a dozen years earlier. The new rules concerning this were unanimously agreed to at a meeting of 17 government and company people held on April 4, 1914.

Early in 1915 I was borrowed by the Navy Department to serve as expert in a patent case; and later I transferred there with the title of "expert radio aide."

Peaceful-preparation-for-war wireless; and Mars was a radio ancestor

David Sarnoff telephoned one morning in 1914 asking me to lunch at which he told me he had decided not to be an engineer. I asked him why. His answer was that he did not think he could be as good a one as "you fellows" are; and additionally, that an engineer is at the place where money is going out. The place to make money is where it is coming in. People who control money are hurt when they see it disappearing, but are continuously pleased by the man who brings it in. So Sarnoff said that he was going to solicit the sale of contracts and service. Later, after he became an executive, some of the "you fellows" he referred to worked for him. In his new job he was assigned a space right by the door of E. J. Nally, the head of the Marconi Company; and this opportunity put him in touch with executive matters by helping Nally.

These were the days when various people were trying hard to produce better waves of constant amplitude. The Federal Telegraph Company of California had introduced the Poulsen arc system. E. F. W. Alexanderson,[45] in earlier years at the General Electric Company, had made a high-frequency alternator for Fessenden, and then went on to make still larger ones. The German installations at Sayville, N.Y., and at Tuckerton, N.J., were putting in still different kinds of high-frequency alternators.

Emil Simon was a major radio ancestor. When his friend Morris Liebmann lost his life in the armed services, Simon gave IRE $10 000 to provide an annual prize.

While the war was on in Europe, I inspected the *S.S. Lusitania*. I was told that she carried guns and that therefore the Germans would sink her. I saw the gun emplacements forward on the deck, but my official duties only concerned the wireless. That was her last voyage.

The war effort stimulated the development of the vacuum tube. The de Forest audions would have been better if McCandless, the New York glass blower who made them, had been able to use a better vacuum pump. In 1911 Sammis sent me to McCandless to get some tubes pumped out to a higher vacuum, but he was irritable because de Forest had been after him to do the same. "Since some vacuum is good, more may be better." High-vacuum tubes produced by others ushered in the tremendous developments based on the triode.

Seattle, 1915, and I was borrowed and reloaned

I was transferred to Seattle; but before I left, IRE had its first banquet, on December 23, 1914. In Seattle I started an Institute Section.

At this time Roy Thompson, formerly a radio inspector, Charlie Cooper, and the Alaska Steamship Company, with the Kilbourne and Clark Company, a Seattle manufacturer of ship wireless equipments, organized the Ship Owners' Radio Service.

Because the Navy Department had acquired a lot of German apparatus, I was ordered to attend patent trials in New York, the German "Atlantic Communication Company" that had the Sayville radio station on Long Island, having been sued for patent infringement by the Marconi Company and the National Electric Signalling Company. Ferdinand Braun (of cathode-ray fame) and Jonathan Zenneck[46] were sent from Germany. Nicola Tesla, John Stone Stone, and several other pioneers were brought into the case. The German company won both cases.

On April 24, 1915, IRE held its second banquet, in honor of Braun and Zenneck. Stone was president and toastmaster. Judge Julius M. Mayer, who was presiding over the patent cases, was also present.

The IRE gets a medal, and the public's radio date

On my way to the Navy job in Seattle in July 1915, I stopped at the Panama Pacific Exposition in San Francisco. This was the year that the American Telephone and Telegraph Company opened transcontinental telephone service, which was made possible by using modified audions as amplifiers. In San Francisco I visited a station on the roof of the Fairmount Hotel, where phonograph records and local-talent music programs were being broadcast with an arc in alcohol vapor.

Later, I delivered a paper at a joint meeting of the IRE and the AIEE in San Francisco and was presented with a medal for the IRE by a Fair official in the Court of Abundance.

An infringement suit by the Marconi Company against the Kilbourne and Clark Company brought some old-time wireless people to Seattle in 1916. I was appointed a patent suit assessor (court expert paid by both sides).

In 1918 the Navy Department prevented the selling of Poulsen arc rights and radio stations to the Marconi Company of England. Then, in 1919, the Navy discovered that the Marconi interests were about to acquire rights to the new Alexanderson alternator. The government sponsored the organization of the Radio Corporation of America, which took over the Marconi Company of America, eliminating English stockholders.[47]

With the war over, none of the naval radio work seemed to be very important. Broadcasting, made possible by the advent of the vacuum-tube transmitter, became introduced generally. I found, traveling around the country, that John Q. Public seemed to think that radio began in about 1925. That year I resigned from the Navy and moved to Brooklyn to become a consulting engineer.

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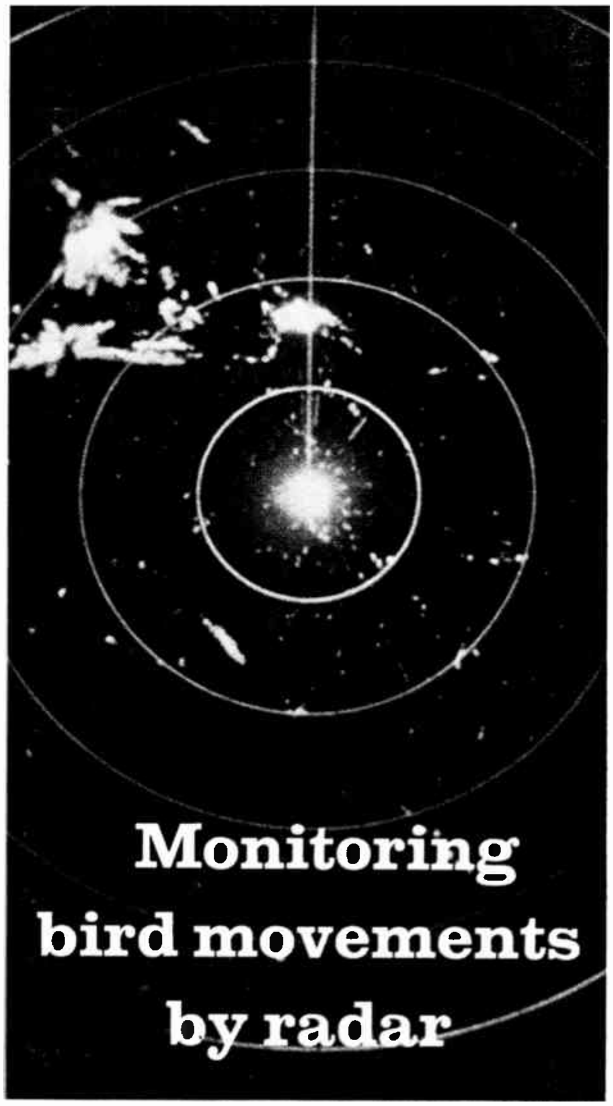

Monitoring bird movements by radar

Studies of bird movements by radar techniques are useful not only from an ornithological point of view but also in connection with research involving the problem of hazards to aircraft

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Shortly after the development of radar some 25 years ago, it became apparent that bird movements were often discernible on radar screens. These "radar angels" in some cases are looked upon as clutter to be eliminated from the radar screen. However, they should be regarded as signals conveying valuable information, since birds can provide a real threat to aircraft, particularly in certain areas and at certain times of the year.

Radar angels (radar echoes from the apparently clear atmosphere) first came into prominence during World War II; at approximately the same time, the ability of radar to detect birds was also reported.[1] These reports, however, referred generally to isolated short-range observations, but some persons apparently realized that birds could be tracked for many miles. It was not until some years later that it was established that radar could be really useful for studying bird movements and that birds were an important source of radar angels.

By about 1956 biologists were beginning to make good use of radar for studying bird migration, the flights of birds from roosting to feeding areas, etc.[2] Radar echoes from birds and visual sightings were correlated in several studies, and the ability of radar to track birds was firmly established. Successful radar studies of birds have been carried out in Great Britain, in Switzerland and elsewhere in Europe, in the eastern and midwestern sections of the United States, and in Canada. The Audubon Field Notes are now receiving the benefit of radar observations of birds at the London, Ontario, airport. The subject of radar ornithology has recently come of age by having an entire book, by Eric Eastwood, devoted to it.[3] A historical account of radar observations of birds, technical information about the adaptation of radar for this purpose, and results of radar studies of birds are thoroughly documented by Eastwood, who has also carried out important research on the subject himself. A brief general account of the use of radar for bird study can also be found in a book by Donald Griffin.[4] Groups that have made notable contributions include the Swiss[5,6]; Lack's group at Oxford University[7]; Eastwood's group at the Marconi Company in England[8]; Drury, Nisbet, and Richardson in Massachusetts[9,10]; the Illinois State Natural History Survey team[11–13]; and the Associate Committee on Bird Hazards to Aircraft in Canada.

Although radar was used successfully for studying birds from about 1956 on, much controversy and misunderstanding continued to exist about radar angels in general and about radar echoes from birds in particular. The continued controversy about radar angels was perhaps understandable, since birds constitute only one type of radar angel. In fairly recent years, definitive studies of radar angels have been made at the Joint Air Force–NASA facility at Wallops Island Station, Va., and the understanding of the subject has increased considerably.[14] Birds, insects, and inhomogeneities in the atmosphere itself are all responsible for radar-angel echoes. Echoes from birds and insects constitute dot (discrete, sharply defined) angels. Echoes from atmospheric inhomogeneities, such as turbulent layers, boundaries of convective cells, etc., have a diffuse appearance on radar indicators. The dot and diffuse echo intensities vary differently as a function of radar frequency and can be distinguished on that basis as well as by their general appearance. The intensity of bird echoes is quite high compared with the intensities of echoes from insects and atmospheric inhomogeneities, which have tended to be of more interest in the Wallops Island investigations than have the more intense bird echoes. The Wallops Island 10-cm radar can track a honeybee to a distance of 10 km.[15]

The evidence concerning the detection of birds by radars that are used for aircraft surveillance is rather contradictory. On the one hand, the ability of such radars to detect birds is well established and well appreciated in some circles. On the other hand, many persons, including some concerned with radar operations, are quite unaware of this capability. Operators who have worked with radar for many years, for example, may be quite surprised to learn that birds can be detected. There are probably at least three reasons for the lack of familiarity with bird echoes on the part of some radar personnel. First, they have been busy with their assigned duties, and either have not been informed about bird echoes or have had little incentive to be interested in them. Second, it is necessary to know how to look for bird echoes, which may not be obvious in normal operations. Third, it has been widely assumed that special types of sensitivity–time control (STC) circuits have eliminated bird echoes, when in fact they have not. The active misunderstanding that has existed recently among radar engineers has revolved mainly about this last point rather than about the inherent ability of radar to detect birds.

Radar personnel with experience in areas of high bird concentrations tend to be more familiar with bird echoes than others, as might be expected. The Gulf Coast of Texas and Louisiana, for example, have large concentrations of birds in the winter, as well as in the spring and fall migration periods, and the occurrence of bird echoes seems to be rather widely recognized there. Air Force personnel are often familiar with bird echoes because of incidents that have occurred when pilots, investigating unknown radar targets, discovered flocks of birds.

Individuals having a strong interest in ornithology can well appreciate that radar is useful for studying bird movements, especially when such studies can be carried out on a compatible basis with normal radar functions. People who are responsible for the operation of Federal Aviation Administration (FAA) and military radars, though perhaps not interested in birds as such, also have reason to be interested in radar echoes from birds. Their concern is directed toward certain "practical" considerations, such as the radar clutter caused by birds and the fact that radar may be able to help reduce the hazard of collisions between birds and aircraft.

How to detect birds by radar

The radars of principal interest to this discussion utilize a PPI (plan position indicator), which plots a "radar map" of its surroundings on a cathode-ray tube as the radar antenna rotates. It may be quite difficult for even an experienced observer to recognize bird echoes by merely looking at the normal PPI presentation. Bird echoes tend sometimes to appear merely as noise or as randomly flashing small bright spots on the screen. A time-exposure photograph, with a duration of the order of 2.5 to 10 minutes depending upon sweep length, however, may show streaks or trains of dots, which can be readily recognized as caused by birds on the basis of velocity. Birds typically fly at speeds of 25 to 80 km/h. Photographs made by the use of a Polaroid camera are very convenient for the quick recognition of bird echoes. A lens setting of *f*/45 gives generally good results with 3000-speed Polaroid film and an exposure time of ten minutes. For taking data continuously it is desirable to use cameras that accommodate rolls of 35-mm or 16-mm film and that advance the film automatically by one frame after each exposure. Most bird echoes tend to occur within about 93 km (50 nmi) of the radar, and radar sweep lengths of 37 to 93 km (20 to 50 nmi) are usually suitable for observing bird echoes. Powerful, sensitive radars, however, might detect large birds at ranges as great as about 185 km (100 nmi), and thus an 185-km range may be useful under some conditions.

Another method for quickly recognizing bird echoes uses radar indicators having some form of memory or persistence. FAA flight controllers use units of this type called scan converters, which have a television-type display and a target-trail control. When this control is set for maximum persistence, or target trail, and a sufficiently short radar range is used, bird echoes can be readily recognized. They then have somewhat the form of a comet trail, bright in the front and diminishing in intensity toward the rear. In normal use, however, the target-trail control may not be set at a very high level. Also, ranges as great as 370 km may be used, and it is usually only when the sweep length is reduced to about 93 km or less that movements of bird targets become obvious in the period of one antenna rotation.

A dynamic picture of bird movements is obtained by taking one exposure per antenna rotation and then projecting the developed film at a rapid speed, so that the activity of a 24-hour period can be viewed in a few minutes. Finally, a very simple procedure is to use a grease pencil to mark successive target positions on the face of a cathode-ray tube and to identify a target as a bird by its velocity. The use of a grease pencil does not, of course, give as complete a record as a photograph and is most expeditious when there are only a few well-defined echoes.

The foregoing remarks about the identification of bird echoes refer primarily to birds that are migrating or following a more or less direct path for a period of time. Birds that are flying about in a very localized region may be more difficult to identify, but radar evidence combined with information about the local geography and the habits of birds in the area may allow identification with a high probability of being correct. Severe ground clutter and severe weather conditions may tend to mask bird echoes and make identification difficult at any time. Ground clutter may also appear similar to bird echoes at times but does not generally involve sharp, discrete echoes that leave parallel trails, which can be tracked for relatively long distances. Furthermore, ground clutter does not regularly reach a maximum at the same times and places that bird activity does.

Figures 1 through 4 are photographs of PPI indicators at the FAA Denver Air Route Traffic Control Center, located at Longmont, Colo. The center receives radar signals from six long-range Air Route Surveillance Radars located at Lusk, Wyo.; North Platte, Nebr.;

Parker, Grand Junction, and Trinidad, Colo.; and Gallup, N.Mex. Figure 1 shows bird echoes on the Lusk radar and Fig. 2 shows intense bird echoes on the North Platte radar. These two locations are on the Central Flyway and have heavy bird traffic during migration. Birds flying over the station and over the Arizona desert are shown in Fig. 3. All of these photographs were taken during the migration period when bird movements are at a peak. On January 31, 1968, the continuous recording of radar signals from the North Platte FAA radar was begun. The February records for North Platte and observations at the Houston FAA center in January indicate significant bird activity in winter as well, the winter bird echoes being caused largely by wintering waterfowl. In the Platte Valley the bird activity seen on radar in the winter consists largely of evening and morning flights of mallard ducks between their resting places and fields where they feed; see Fig. 4.

FAA centers throughout the country perform the vital function of aircraft guidance and control. Though conventional, the FAA Air Route radars are ideal for bird detection in certain respects, having high power (4 MW), high sensitivity (116 dBm with integrated video), and MTI (moving-target identification) circuitry. A representative Air Route Surveillance Radar installation, located at Parker, is shown in Fig. 5. Operating at frequencies near 1350 MHz (L band), the radars record bird echoes readily, although a somewhat higher frequency might be better for small birds. One limitation of the observations at Longmont to date has been that it has not been possible to tell what kinds of birds were causing the radar echoes. Waterfowl or cranes are suspected, however, as the cause of large "blobs" on the screen. The L-band radars are apparently well suited to long-range surveillance, whereas X-band (10 000-MHz) radars may be preferable for short-range, high-resolution studies. The X band is more subject to weather clutter than the L band, generally offers lower peak power, and is not as suitable for long-range operation. The FAA Airport Surveillance Radars, operating in the S band (3000 MHz) but having lower peak power (400 kW) than the Air Route Surveillance Radars, are useful for monitoring bird movements and seem to represent an attractive compromise between L- and X-band radars.

The U.S. Air Force operates radars that are comparable to those used by the FAA and equally suitable for detecting bird echoes. Observations in Alaska have shown that the ACW and DEW radars there have the capability of detecting bird echoes, although the two systems are not identical and each site has its own special characteristics.

The U.S. Weather Bureau now operates a system of WSR-57 radars (S band) having peak powers of 500 kW, which have been used extensively in the midwestern and eastern portions of the United States.[12]

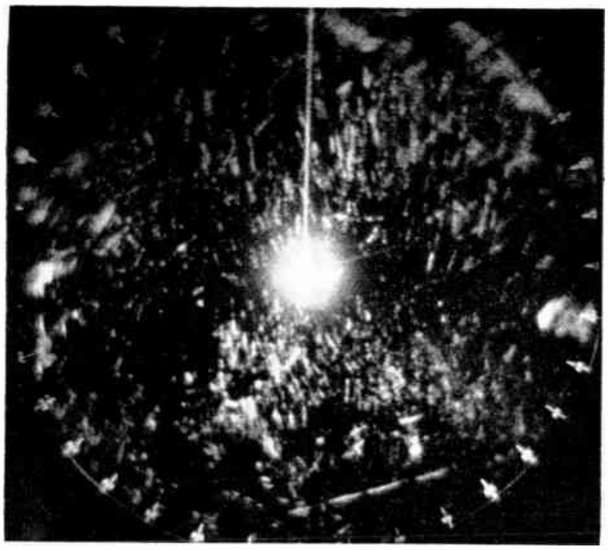


FIGURE 1. Bird echoes on FAA Lusk radar, 10:10 p.m., MST, April 14, 1967. Exposure time is 5 minutes, and sweep length is 93 km (50 nmi). The radial line indicates north.

FIGURE 2. Intense bird echoes on FAA North Platte radar, 9:20 p.m., CST, April 23, 1967. The exposure time is 5 minutes, and the sweep length is 46 km (25 nmi).

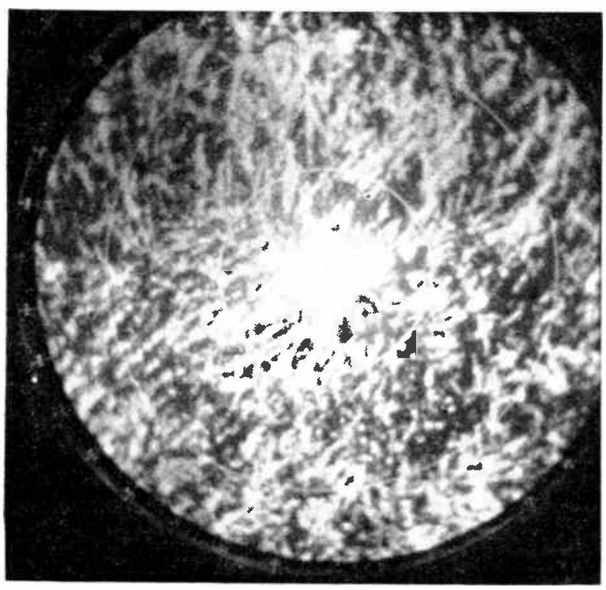
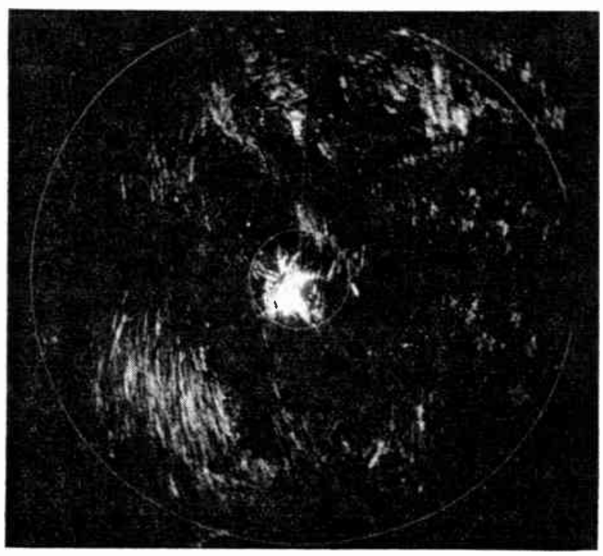


FIGURE 3. Bird echoes on FAA Gallup radar, 9:55 p.m., MST, April 28, 1967. The exposure time is 5 minutes, and the sweep length is 93 km (50 nmi).



Recent developments in the use of the Weather Bureau radars make them increasingly attractive. In the spring of 1968 Weather Bureau radars were used to track the movements of whistling swans from the Chesapeake Bay area to Canada.

The remarks in this article refer primarily to search radars that utilize the PPI type of presentation, but other types of radar offer advantages for certain purposes. RHI (range-height indicator) radars can provide height information, which search radars are incapable of providing. Tracking radars can record what can be called the radar signature of a bird or flock of birds. This type of equipment, which can lock onto and follow a single target, can record how signal amplitude varies with time. Visual or spectral analysis of such records can then allow some degree of identification, indicating whether the target is a bird or not and perhaps the type of bird (on the basis of how rapidly the bird beats its wings, etc.). Work on "radar signatures of birds" has been carried out by in Switzerland,[16] as well as in Great Britain[17,18] and at Wallops Island.[19]

Radar clutter caused by birds

In normal radar operations bird echoes have been considered to be merely a type of radar clutter that should be eliminated as far as possible. Special forms of sensitivity-time control (STC) circuits have been devised to minimize bird clutter. These circuits reduce the Air Route Surveillance Radar sensitivity out to a certain range, and therefore a single bird of the nominal size of a gull (0.01 square meter in radar cross section) cannot be detected by the radar. But a number of birds may be in the common scattering volume of a radar at one time, especially in the case of birds that migrate in flocks. Thus the use of an STC type of circuit cannot eliminate all bird echoes, although STC circuits can help considerably to reduce bird clutter under certain conditions.

Figure 2 shows a case of extreme clutter caused by birds and was taken when circuitry to minimize bird echoes was being used. This photograph tends to confirm the opinion (see Ref. 20, for example) that bird clutter can be a serious problem. On the other hand it should be noticed that the photograph is a 5-minute time exposure. The PPI did not look as bad to the eye. Also, it is pertinent that the sweep length (46 km) is shorter than those in normal use by aircraft controllers. The clutter intensity diminished considerably beyond 93 km, and aircraft controllers may have had only part of their display seriously cluttered. Moreover, it is possible to tolerate a fair amount of clutter, especially when working with aircraft that have beacons, which provide a larger and more distinctive signal than the purely reflected signal.

Collisions between aircraft and birds

The problem of collisions between birds and high-speed aircraft is serious and deserves more attention than it has received in the United States. Fatal accidents have resulted from such collisions. An astronaut was killed piloting a plane in Texas, a commercial airliner crashed on takeoff at Boston, and another commercial airliner crashed in Maryland after colliding with a whistling swan, to mention some examples. The U.S. Air Force alone experiences aircraft damage costing about $10 million or more per year because of collisions with birds. Jet engines are particularly susceptible to such damage. In 1965, for example, bird strikes required the replacement of 75 jet engines costing up to $130 000 each. Damage also results to windscreens, wings, noses, and other aircraft components. The possibility of collisions can never be completely eliminated, but the probability can be reduced by appropriate measures. Interesting discussions of the bird-hazard problem have been presented by Drury[21] and Hillaby.[22]

Consideration should be given to bird hazards when locating airports and Air Force bases. Airports should not be placed in locations where birds tend to congregate. In the case of established airports, consideration

FIGURE 4. Bird activity in the Platte Valley, west of North Platte, Nebr., 7:15 a.m., CST, near sunrise, February 4, 1968. The exposure time is 5 minutes, and the sweep length is 93 km. The radial line indicates north.

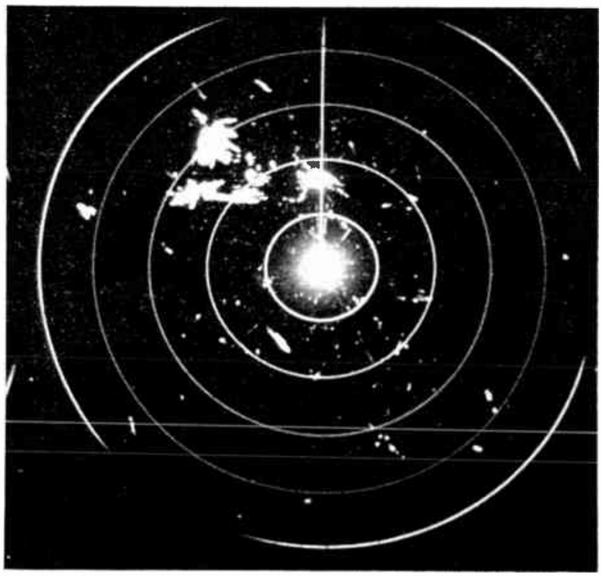
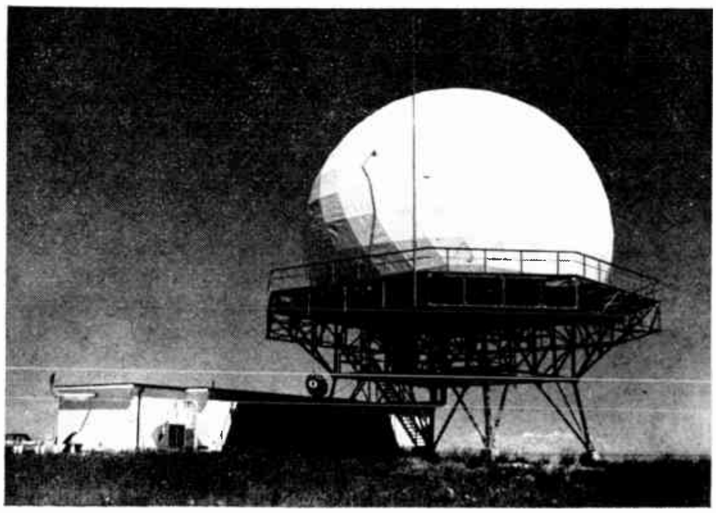


FIGURE 5. FAA Air Route Surveillance Radar facility at Parker, Colo., near Denver. (Courtesy Denver Area Office, Federal Aviation Administration)



should be given to making the immediate area unattractive to birds, in so far as practical. Measures for dispersing birds may be needed. The principal concern of this article, however, is for the possible role of radar in alleviating the hazard of collisions.

A use of radar to reduce collisions between fighter aircraft and birds in the vicinity of the Cold Lake training base in Alberta was reported in the March 17, 1967, issue of *Time*. After several fighters had crashed because of collisions with birds, bird movements in the area were monitored by radar. An empirical scale of bird hazard was developed, based on the appearance of time-exposure photographs; when the hazard was too great, flight operations were curtailed.

In general, further radar data on bird movements should be gathered and analyzed so that the hazard of collisions can be better estimated in advance as a function of time of year, time of day, geographical area, altitude, proximity to airports, etc. Evidence at present indicates the hazard to be greatest during spring and fall migration, at night, along major flyways, and at low altitudes. Bird movements are often the heaviest in the early hours of the night, and it is fortunate that they do not tend to be as heavy in the daytime. Most birds fly below about 2500 meters (8000 feet), with peak numbers perhaps between 300 and 1200 meters or even lower; however, flights at about 3000 meters are not extremely unusual, and some radar records have shown altitudes above 6000 meters. Geese have been visually observed flying over the Himalayas at an estimated height of 9000 meters.[4] Considerable radar data have already been obtained about the Mississippi Flyway by the use of Weather Bureau WSR-57 radars.[12]

In addition to providing information for advance planning, radar may be able to provide real-time warning to avoid flocks or concentrations of birds by changes in altitude and route assignments. The use of scan converter displays, with the target trail control set for maximum persistence, could probably be advantageous for this purpose. Other measures that can be used to reduce hazards are to reduce aircraft speed and to reduce the time used in approaching and leaving airports.[12] Further study is required to determine exactly what operational procedures would be optimum. In any case, bird echoes should not be regarded in general merely as clutter to be eliminated but rather as signals conveying valuable information much of the time. In military operations, low-level training flights should probably be curtailed during times when the bird hazard is indicated to be high, on the basis of a combination of advance knowledge about bird migration and radar warning.

Canada has been a leader in recognizing and combating the problem of the bird hazard to aircraft. The active and efficient Associate Committee on Bird Hazards to Aircraft has worked on the problem for several years.

Conclusion

Most conventional radars used by the FAA and the Armed Forces have the capability of monitoring bird movements and to some degree are subject to radar clutter caused by birds. Radar clutter and the hazards of collisions between birds and aircraft need further study. Special forms of STC do not necessarily interfere seriously with the ability of radars to detect birds or insure their freedom from clutter caused by birds.

Birds are part of the environment in which radar systems operate. Persons responsible for the operation of radar systems should see that all pertinent aspects of system environment are understood as thoroughly as possible. It can be expected that research on the hazard of birds to aircraft and on topics related to this problem will increase in the future.

The cooperation of Federal Aviation Administration and U.S. Air Force personnel has made the observations reported here possible. F/L Warren B. Lange of the Royal Canadian Air Force played a major role in studies that were carried out at the Longmont FAA Center in the spring of 1967, and Howard Sargent is carrying out the same function at the present time. The Air Force Office of Scientific Research, through Research Grant No. 68-1377, and the Kettering Foundation, through the BUILD program of the Colleges of Engineering of the Universities of Colorado and Illinois, are presently supporting radar studies of bird movements at the University of Colorado.

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Spacecraft infrared imaging

Principles and applications

Infrared imaging is expected to become a powerful tool for exploring planetary environments from orbiting spacecraft. Among the disciplines to benefit are meteorology; oceanography, seismology, and volcanology

John J. Horan RCA

This first part of a two-part article deals with the principles of infrared imaging and the applications of these principles. The second part, to appear in July, will discuss the systems of IR imaging and their relation to the spacecraft and mission. The general concept of imaging can best be understood in terms of the source and receiver of electromagnetic radiation, and the differences between an image made by reflected external illumination and by self-emitted luminance. There is then the problem of choosing an appropriate spectral region in terms of the maximum emitted energy, the transmission of the atmosphere, and the characteristics of the receiver scanning. This installment concludes with a review of satellite imaging experiments to date and a description of future applications of these techniques.

The concept of photographing, or recording an image of a given scene, reduces basically to the interception of energy traveling from all parts of the scene concerned. There must be a source of energy to "illuminate" the scene (we may consider the flash lamp of a film camera as an immediate source of energy) and a receiver of energy with a response reasonably proportional to the amounts of incident energy from various portions of the scene. The word "illuminate" is in quotation marks because, in the usual sense, it means an external source irradiating a scene. Herein, it is intended to describe any source of energy, whether it is from an external source (that is, reflected energy) or is self-emitted (for example, an incandescent lamp), so long as the energy arriving at the detector has the geometric intensity distribution that is an analog of the scene.

From an orbiting spacecraft looking at a planet, the sources of energy for imaging are considered to be (1) the directly reflected energy from the sun and moon (that from other heavenly bodies is negligible), (2) the delayed reradiation of energy absorbed from these sources and redistributed throughout the planet, and (3) the internally generated energy due to radioactivity, etc. This last source is extremely weak and generally can be ignored. The first source (the sun) is well known to all photographers. This article is concerned with the second source—the reradiated energy—since its energy distribution lies almost entirely within the infrared (IR) parts of the spectrum.

The geometric configuration and the contrast of a scene being photographed are determined by the extent of absorption and reflection of the incident illumination, or by the relative amounts of energy emitted—that is, the relative geometric distribution of energy reaching the detector. Atmospheric features such as clouds, which are white, reflect an amount of the incident visible solar energy that is large when compared to the energy reflected by ground or water. Conversely, the clouds emit less energy than the ground in the infrared region. Thus, an infrared photograph can be doubly valuable, since it records features different from those shown in a visible-light photograph and also can be compared with the visible-light photograph for orientation, in terms of the more familiar image that the eye would observe directly. It is possible, in effect, to look at various layers of a planet's atmosphere by the choice of suitable detection bands in the IR spectrum. By the same token, many surface and subsurface features of a planet not photographable by visible light are readily revealed by infrared.

Recording an image by techniques other than film cannot accurately be called photography. Image formation by scanning in spectral regions outside the visible may properly be called television, but popular usage generally enforces the visible-region restriction. Thus, the general term "imaging" has been adopted for all image-formation techniques, including photography and television.

The earth and surrounds can be described in the various scientific disciplines of meteorology, geology, hydrology, etc. These have been combined in an overall discipline called "environmental sciences." Along these lines, the Weather Bureau and the Coast and Geodetic Service have been combined into the present Environmental Science Service Administration (ESSA).

Fundamentals of infrared

Visualize an iron poker that has been heated to white heat. When it is removed from the fire and viewed in the dark, the light intensity diminishes and the color of the light that it emits changes slowly to orange-red, then red, then dull cherry red. Soon all light disappears, but by placing a hand near the hot end, one can still feel "heat" being radiated from it. Eventually, the poker cools to room temperature; but even at room temperature, it is still emitting energy. In fact, it would continue to emit energy until it was cooled to absolute zero (−273°C). The spectral distribution and intensity of the emitted energy are related to the temperature of the poker over the whole range of temperatures. If the poker were an ideal "blackbody," exact mathematical relationships would exist between temperature and radiation. These are expressed in laws named after several early scientists: Stefan, Boltzmann, Wien, and Planck. The mathematical expressions for these laws are as follows:

Stefan–Boltzmann law

$$W = \epsilon\sigma T^4$$

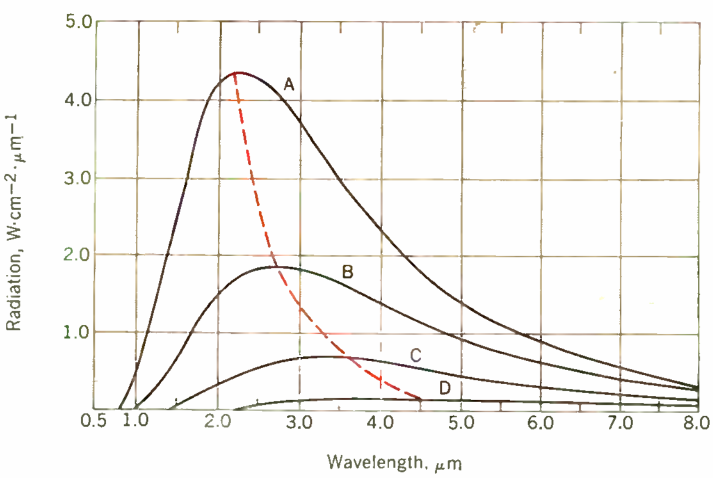
Wien's displacement law

$$\lambda_m = \frac{b}{t}$$

Planck's equation

$$W_\lambda = \frac{C_1\lambda^{-5}}{e^{C_2/\lambda T} - 1}$$

FIGURE 1. Blackbody radiation curves. Blackbody temperatures: A—1000°C; B—800°C; C—600°C; D—400°C.



where

W = radiant flux emitted per unit area, $W \cdot cm^{-2}$
ϵ = emissivity (unity for blackbody source)
σ = Stefan–Boltzmann constant
= 5.673×10^{-12} $W \cdot cm^{-2} \cdot °K^{-4}$
T = absolute temperature of source, °K
λ_m = wavelength of maximum radiation, μm
λ = radiation wavelength, μm
b = Wien displacement constant, 2897 μm·°K
W_λ = radiant flux emitted per unit area per unit increment of wavelength, $W \cdot cm^{-2} \cdot \mu m^{-1}$
e = Naperian base = 2.718 28
C_1 = $2\pi c^2 h$ = 3.740×10^4 $W \cdot cm^{-2} \cdot \mu m^{-1}$
C_2 = hc/k = 1.438×10^4 μm·°K
c = velocity of light = $2.997\,93 \times 10^{11}$ $cm \cdot s^{-1}$
h = Planck's constant = 6.6252×10^{-34} $W \cdot s^2$
k = Boltzmann's constant = $1.380\,42 \times 10^{-23}$ $W \cdot s \cdot °K^{-1}$

The radiation is due to molecular vibrations in the blackbody, but even at any one temperature, all the molecules are not excited to the same degree of agitation. These laws describe the statistical distribution of emitted energy as a function of blackbody temperature.

Since oscillating electric charges radiate electromagnetic energy, the thermal agitation of electrons at temperatures above absolute zero will thus cause the radiation of electromagnetic energy. The distribution of this energy corresponds to the distribution of electron agitation; therefore, electromagnetic radiation is emitted over a wide range of wavelengths.

The solid lines in Fig. 1 show plots of Planck's law for various temperatures, and the dashed curve shows Wien's displacement law. We can see that the curves for different temperatures never intersect each other. From this it follows that if one can measure the amplitude of the radiated energy at any wavelength, one can determine the temperature of the blackbody radiator.

Satellite applications

Thus far, we have been concerned with the principles of infrared radiation. In the following discussions, we shall consider their application to the planet earth, since we have the greatest knowledge here. However, the principles described are applicable to other planetary explorations. The earth is warm, say 300°K, and nearly a blackbody (actually a gray body). The emitted energy will have a distribution similar to the curves in Fig. 1, but the peak of the curve at this temperature will be at 10 μm (in what is sometimes termed the far-infrared region). However, space is very cold, about 4°K. Thus an astronaut with infrared vision would see the nighttime side of the earth "shining" in a black sky. But it would not be equally bright all over since the ground might be at 300°K (73°F) on a hot summer night, whereas the cirrus clouds overhead might be at 200°K (−96°F).

A satellite with suitable infrared "eyes" (or radiometers) could measure the temperatures of the earth, the clouds, and the oceans. From these data can be deduced many important meteorological and geoscientific facts: one, for example, is the heat budget of the earth (that is, the exchange of energy between the sun, earth, and space).

Assume for a moment that the earth were very cold. As the sun's energy was absorbed by the earth, the temperature of the earth would rise; and as the temperature rose, the earth itself would radiate energy. The hotter it got, the more energy it would radiate, until it reached a temperature at which it radiated the same amount of energy as it received from the sun. This radiation balance affects our very existence on this planet, and is the driving force for all our weather phenomena, bringing water from the ocean as rain for our crops.

Spectral region

Professor Verner Suomi, pioneer in the use of space instruments for meteorology, once said, "The atmosphere of the earth is like the skin of an apple." This analogy describes the relative dimensions of the earth and its atmosphere. But this thin atmospheric "skin" presents many problems.

Since we can deduce the blackbody temperature by observing the amount of radiation at any wavelength, it would seem reasonable to make our observations near the peak of the curve. For 300°K this would be at a wavelength of 10 μm; for 200°K, it would be at nearly 15 μm. But we must consider whether we can see through the atmosphere down to earth at these wavelengths. Early measurements of atmospheric transmission were made by Taylor and Yates[1] across the Chesapeake Bay. Figure 2 is an example of some of these measurements. This of course, was a horizontal measurement, as opposed to the vertical measurement that would be made by a satellite. The fine structure of these transmission curves is due to the gases in the atmosphere. Gaseous emission and absorption are not like a blackbody—that is, a continuum—but rather are composed of bands or lines, hence the complex structures in Fig. 2.

Gaseous absorption and emission is an extremely complex subject. We shall make a few simplifying assumptions in order to explain the gross phenomenon. The amount of energy absorbed or emitted by a gas is a function of: (1) the wavelength of the energy, as we saw in Fig. 2; (2) the path length of gas through which the energy must travel; (3) the concentration of the gas with respect to other gases; and (4) the pressure of the gas. It is important to note that in spectral regions, where gases are good radiators, they are also good absorbers; in regions where they are poor radiators, they are poor absorbers. Let us consider carbon dioxide, an important gas in our atmosphere. If we had a tube of pure CO_2 at atmospheric pressure, all of the IR energy radiated by the gas more than 10 cm from the surface would be absorbed by the outer layers of gases. As the pressure is decreased, the path length increases. These variations in transmission can be seen in Fig. 3, which is a plot of horizontal transmission versus wavelength for various altitudes. The changes in the shape of the carbon dioxide band at 15 μm are attributable primarily to the decrease in pressure with increasing altitude. The amount of water vapor in the atmosphere will alter the transmission. Since the amount of water vapor is variable, transmission curves will be different for different times and locations. The disappearance of the 6.3-μm water-vapor band at higher altitude is the result of both the decreasing pressure and the decreasing amount of water vapor.

Selection of spectral interval

Many factors must be considered in the selection of the proper spectral region for optimum imaging. This spectral interval must have (1) a good atmospheric transmission characteristic, (2) relatively high energy content, (3) good contrast between the target of interest (say clouds) and the background, and (4) freedom from spurious emissions. Of course, a suitable detector with useful response in the chosen spectral region must also be available. The earth can be seen from a satellite in certain regions and not in others—for example, in the 0.42- to 0.70-μm (visible) region, the 3.5- to 4.2-μm region, the 8- to 13-μm region, and the 18- to 22-μm region. These regions are called "windows." The better the transmission in a window, the "cleaner" the window; conversely, the poorer the transmission, the "dirtier" the window.

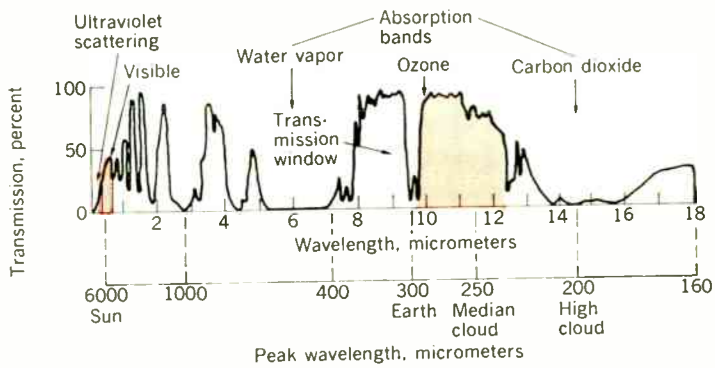
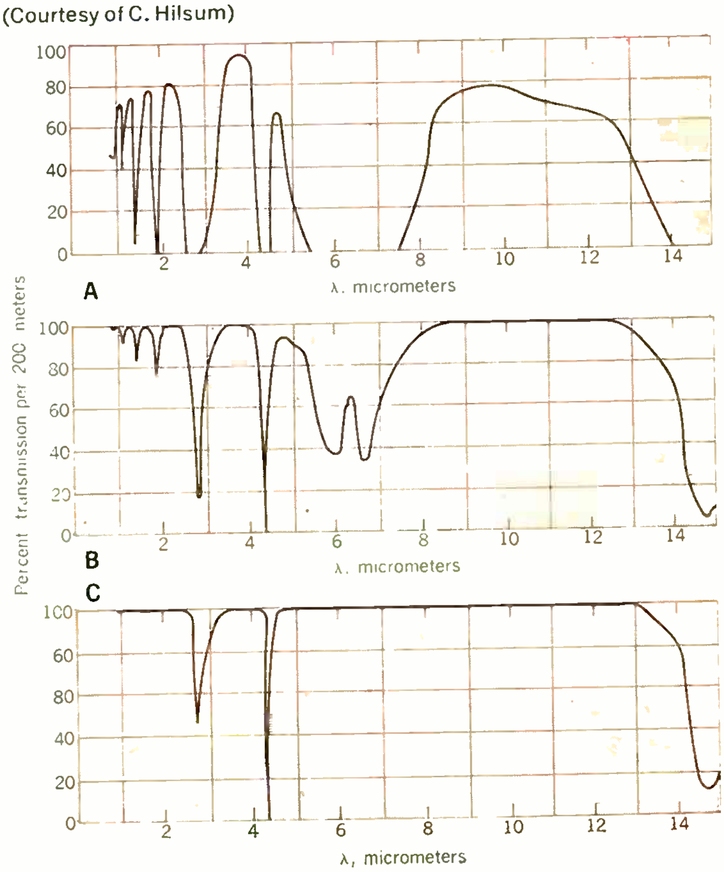


FIGURE 2. Horizontal transmission through the atmosphere as a function of wavelength, with maximum-emission wavelengths of various blackbody sources.

FIGURE 3. Horizontal transmission at various altitudes. (Courtesy of C. Hilsum)



The main differences between the long-wave and short-wave window regions involve the amount of reflected sunlight and the amount of self-radiated energy. A radiometer measures only radiance; it cannot distinguish between reflected radiance from the sun and self-emitted radiance from a target. If the energy reflected from the sun constitutes a reasonable portion of the total energy received by the radiometer, it is almost impossible to determine the ratio of self-emitted to reflected radiation because of a large number of other variables, such as

1. Cloud/terrain reflectivity values.
2. Variation in reflectivity with wavelength.
3. Variation in reflectivity with illumination and viewing angle.
4. Atmospheric backscattering and transmission.

However, if the sun's energy constitutes only a very small percentage of the total reflected energy, it can be ignored and a direct measure of the self-emitted radiance from the target can be obtained. For example, it may be assumed that the ratio of reflected sunlight (50 percent albedo) to emitted energy from a 200°K blackbody in each of the window regions is only about 7.8×10^{-4} for a 3.5- to 4.2-μm window, whereas the ratio is 18 for an 8- to 13-μm window. It is therefore evident that the reflected sun energy in the former region is many times greater than the 200°K target, whereas in 8- to 13-μm region, the reverse is true. Under nighttime conditions, the available energy (radiance of a 200°K blackbody) at 8 to 13 μm is nearly 100 times greater than at 3.5- to 4.2-μm window, whereas the ratio is 18 for an 8- to 13-μm window. It is therefore evident that the reflected sun energy in the former region is many times greater than the 200°K target, whereas in the 8- to 13-μm region the reverse is true. Under nighttime conditions, the available energy (radiance of a 200°K blackbody) in the 8- to 13-μm window is nearly 100 times greater than in the 3.5- to 4.2-μm window.

Although the contrast (that is, the difference in radiance for a given difference in temperature) is greater in the 3.5- to 4.2-μm region than the 8- to 13-μm region in terms of ratios of available energy, it is not true in terms of measurability with a radiometer. For example, two adjacent targets that are at 200°K and 205°K exhibit a 65 percent difference in emitted energy as measured in the 3.5- to 4.2-μm region, but only a 21 percent difference as measured in the 8- to 13-μm region. However, while a radiometer produces an output voltage proportional to a change in radiance, this output signal is limited by system noise. Thus, the greater available energy in the 8- to 13-μm region will provide a corresponding increase in signal-to-noise ratio.

To illustrate the "contrast" idea further, consider the curves shown in Fig. 4 (which are of the same shape as Fig. 1), plotted on a log-log scale for two temperatures. They show 200°K and 300K° blackbody radiance versus wavelength and outlines of the two window regions. The difference in radiation for each spectral region is the true area between the curves (remembering that this is a log-log curve). The 3.5- to 4.2-μm region has the greatest area, hence the greatest contrast. However, to achieve this maximum contrast in this region, the sensor sensitivity must be many orders of magnitude greater than that of the 8- to 13-μm system, as shown by the arrows. Therefore, it appears that the latter region represents the more desirable spectral interval.

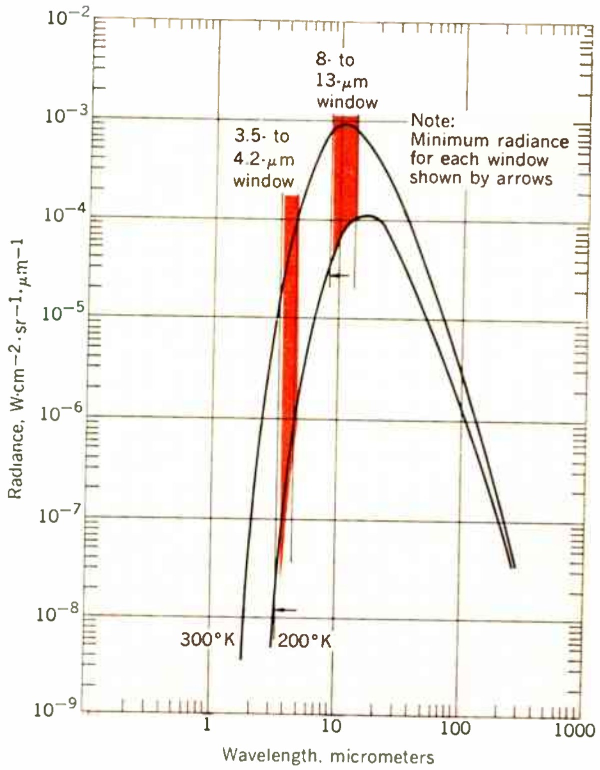
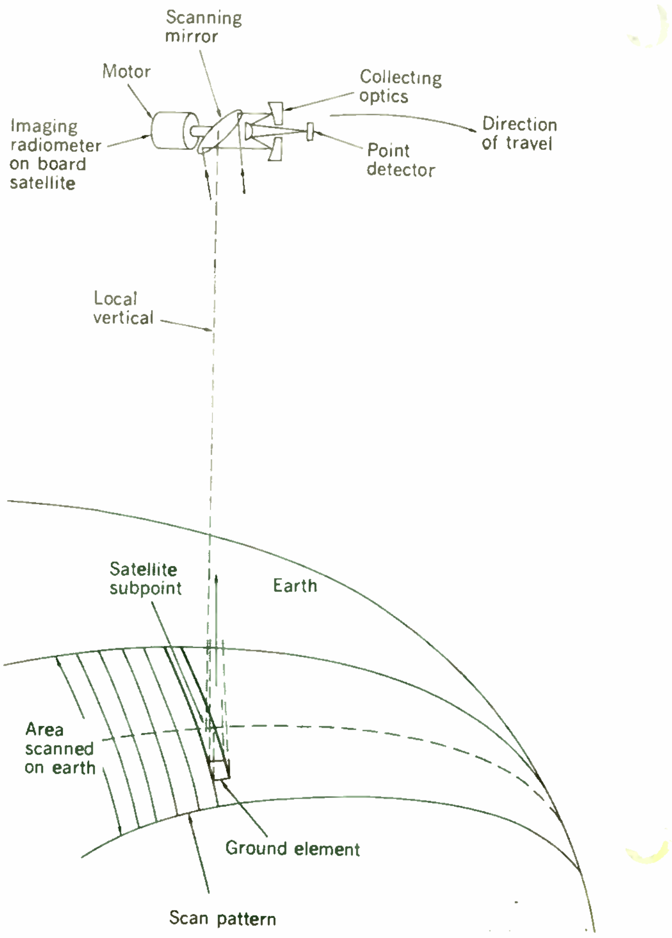


FIGURE 4. Blackbody radiance as a function of wavelength for 200°K and 300°K blackbodies.

FIGURE 5. Mechanical scanning system.



Scanning

Unlike television systems, IR imaging systems generally use mechanical rather than electrical scanning techniques, since IR-sensitive surfaces of point detectors are somewhat superior to those of television pickup tubes (such as vidicons and image orthicons). The field of view (or cone of acceptance) subtended by the detector must be scanned in two dimensions. In an orbiting spacecraft, motion (or rotation) can provide scanning on one axis, and the IR instrument need scan only the second axis. For a single "point" detector, some type of mechanical scan is generally used in which a mirror deflects the optical axis of the radiometer from side to side. Such a scanner is shown schematically in Fig. 5. As will be shown in Part II of this article, many different combinations of scanning mechanisms and detectors can be used; furthermore, there is a parametric relationship between resolution and sensitivity that enables the prediction of system parameters.

Satellite experiments to date

The television and infrared observation satellite (TIROS) carried one of the earliest infrared space experiments. There were two IR devices: a heat-balance radiometer, which responded to the self-emitted infrared energy of the earth and the reflected solar radiation; and a five-channel radiometer, which "looked" in various visible and IR bands. Neither of those instruments was primarily an imaging device, although the field of view scanned the earth.

The first true imaging radiometers were flown on the Nimbus spacecraft. One of these was the high-resolution infrared radiometer (HRIR). This was a mechanically scanned radiometer, operating within the 3.5- to 4.2-μm window, and was intended primarily for use at night, when there is no reflected solar energy. This unit scans a line across the earth's surface; the satellite motion provides the scanning in the other direction. (The scan pattern is shown in Fig. 5.) The output signal from the detector is a time-amplitude function analogous to a normal television video signal.

William Nordberg[2] has described some of the measurements made by the HRIR on Nimbus, which was primarily a meteorological satellite; as such, the primary interest was in clouds and cloud formation. He also has described how the video signal (which is proportional to infrared radiation) can be corrected to a signal proportional to temperature by use of the blackbody laws previously mentioned herein. Figure 6 shows an IR picture, from the HRIR, of Hurricane Gladys and the accompanying video signal of one scan of this picture. The height of the various clouds scanned by the radiometer is deduced from the temperature data by knowledge of the lapse rate (or rate of temperature decrease of the atmosphere with increasing altitude). The "eye" of the hurricane is clearly visible in the picture. The clouds surrounding it turn out to be at a very high altitude—about 14 km (45 000 feet).

Conclusions

Besides measuring the heights and spatial location of clouds, IR imaging can perform other remote sensing tasks. The new scientific discipline of environmental sciences has as one of its subdivisions the area of remote sensing. Multispectral imaging is the most important tool in this area. Applications of remote sensing techniques have included oceanography, forestry, seismology, and volcanology. For example, seawater temperature distributions and gradients have been measured remotely by the Fish and Wildlife Service of the Department of the Interior in studies of fish migrations and ocean ecology. Fischer[3] has measured remotely the temperature of the ground in the volcanic regions of Hawaii. By remote IR imaging, soil moisture content has been measured. Present-day instrumentation has limited such measurements to aircraft rather than satellites. However, Nimbus has made, and TIROS will soon make, IR images for meteorology. Probably the next major satellite system to make significant operational use of IR imaging is the proposed EROS system—a national resources satellite that will be used to make measurements to meet some of the environmental sciences requirements in agriculture, forestry, and other fields.

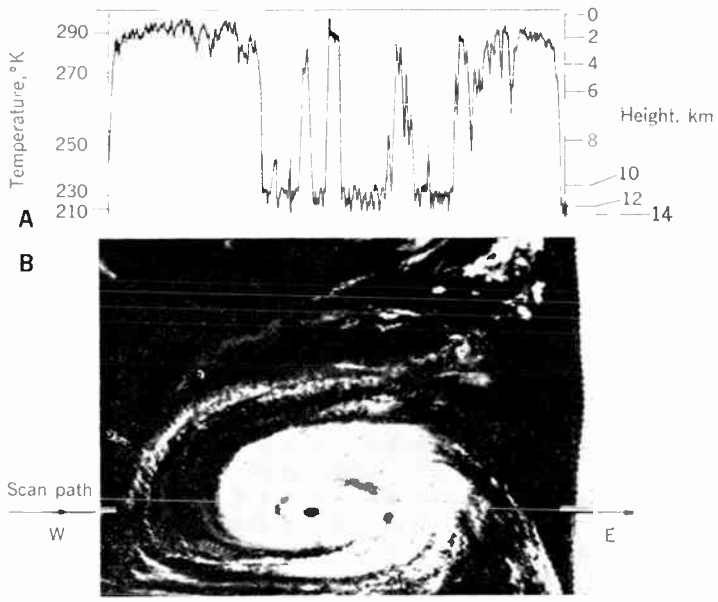


FIGURE 6. Infrared picture of Hurricane Gladys. (Photo courtesy of W. Nordberg)

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The technosphere, the biosphere, the sociosphere

Their systems modeling and optimization

In any optimization study one focal point of the analysis is the establishment of an appropriate performance criterion. When optimizing a social system, however, a problem arises in that such a criterion is almost impossible to define

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In this article the author presents some suggestions as to how we may bring a systems approach to bear on analyzing—and perhaps optimizing—our problems in the broad areas of the geosphere, biosphere, technosphere, and sociosphere, in other words, in the complex world in which we live today. He points out that while we enjoy the advantages of the energy and information revolutions, we must make sure that the structures of our society are flexible enough to adapt to the impact of technological change.

During the past century technology has been a primary agent in forcing the vast changes in the geosphere and sociosphere in which we live. There has not been complete agreement in our society that these changes all represent improvement, but no groups of significant size try to operate without utilizing available technological advances. Thus, it may be said that the technologist has had society's tacit support, even if he has not formally represented society's ideal. During this period, when the advantages of technological advances have been so obvious to society, the technologist unfortunately does not seem to have felt it his duty to point out the concomitant disadvantages, which often tend to become obvious and costly only after some lag. Nor, indeed, would it seem justified to consider him particularly culpable here, since society has not really encouraged consideration of the esthetic and ethical aspects of technological advance, especially if they entail higher immediate cost. Consequently, a technologist may feel puzzled when he now finds himself as much blamed as praised. The tendency to assign blame comes when societies begin to realize that things are not going quite according to plan but yet it is not really clear as to why. Certainly, few would now agree with Dr. Pangloss, the philosopher in *Candide*, that "All is necessarily for the best in this best of all possible worlds."

It seems clear that the technologist must increasingly take a view that is broad enough to include the problems of social values, and that he must be prepared to take more of a lead in pointing out how such goals as beautification, and the prevention of pollution, will trade off in overall optimization of the system. Then, although it will remain true that the complex problems that we are now producing for ourselves will not have simple answers, nevertheless, society will be encouraged to ponder how human values should be entered into the systems equations. It is probable that not every technological development will be automatically accepted. On the other hand, societies are always adapting, if only slowly, and, therefore, it will seldom be possible to predict with certainty whether any given innovation will remain unacceptable.

Geosphere

As part of the geosphere, we classify those vast natural processes in and upon the earth that are not inherently or necessarily concerned with living processes. These physical systems involve such complicated interlocking dynamics that they are only now beginning to be understood, in the sense that adequate mathematical models are becoming available.

Perhaps the most obvious dynamic phenomena in the geosphere are the daily and annual cycles due to the varying exposure of the earth to the sun. There is also, of course, the lunar cycle. Thus, genuine and fairly strict cycles exist in such atmospheric conditions as temperature and precipitation, which, in turn, have widespread influence upon our biosphere, technosphere, or sociosphere. Other major phenomena depend to a greater or lesser extent upon these cyclic forcing inputs, in particular, the circulation of water in the oceans, the circulation of air in the atmosphere, and the rainwater cycle itself: rain—water flow—pooling in the seas—evaporation—cloud formation—rain.

Some of the effects are unidirectional only, in the sense that what goes in one "direction" is not necessarily returned in the other. A specific important example arising in the rainfall circulation of water is that of erosion of the the earth, and, specifically, of minerals into the sea. As one consequence, the sea cannot, in the long term, constitute a constant environment for life.

Biosphere

Since all living organisms exist close to the earth's surface, it is not surprising that many of the relevant major phenomena of the biosphere are closely coupled with those in the geosphere. The result of these interactions is that the geosphere itself has been considerably modified. For example, as a result of life in general, and man's social system in particular, the carbon dioxide content of the atmosphere has increased. In turn, this increase is producing significant effects on climate.

The major ability that living things have added, over what exists in the nonliving world, is the ability to trap high-energy electromagnetic radiations from the sun, on a relatively permanent basis; the energy is transformed through photosynthesis, with consequent production of organic materials, cells, high organisms—and, ultimately, our own societies.

Since organisms have not evolved that live forever, an essential feature of maintaining life has been the ability to procreate, and with it the possibility of evolution. Evolution through competition embodies what in systems theory is called adaptive ability, which is implemented by some hill-climbing scheme. From a slightly different viewpoint, the ability of evolution to select the "best" may be considered a process of the positive feedback, unstable type. This mechanism can potentially build up regimes of ever-increasing order, rather than suffer the fate prescribed by the second law of thermodynamics, of degradation to uniform low order. The high-order regimes that living forms have generated are possible because living systems are able to "open" themselves to the high-energy source of the sun.

Technosphere

Historically, it is hardly justifiable to consider that technology started only centuries ago. Such is the nature of exponential growth, however, that for present purposes we can say the industrial age started with a small initial condition in the 18th century. Specifically, the industrial revolution of the 18th and 19th centuries relieved man of the requirement to obtain all his nicely controlled mechanical power through the use of muscle. This revolution, of course, has had tremendous social implications; nevertheless, it has probably been only a small factor in producing the problems we face today. The major factor contributing to these problems has been the recent second industrial revolution, which has relieved man of the need to perform all his own data processing. This revolution has been extremely rapid; within the course of some 25 years from the inception of the large-scale computer, we find ourselves affected in a wide variety of ways. Part of our trouble lies in the fact that this new slave does accurately and fast so many of the tasks society has found necessary, but which humans find tedious and therefore do not perform well. Nevertheless, although the daily tasks of such workers may have generally been decried by them, such work has constituted much of the basis for their self-respect. Hence, it becomes necessary to define what is necessary to enable man to find enjoyment in life, and to experience satisfying emotion and purposeful activity. It is generally presumed that these areas are not ones in which a computer excels, and yet when one tries to define exactly how man differs in a "superior" way from the computer, the matter becomes very perplexing.

Consequent upon the industrial revolutions, our technosphere now seems capable of providing, at least in principle, large integrated industrial processes that are automated and computer-controlled. One example of this is the possibility of completely integrating the steel industry—from the mining of metal ores to the inventory control of finished products such as automobiles, almost without human intervention. In other words, given certain sensible and yet fairly unrestrictive constraints on any of man's material needs, he can now aspire to a society in which it is not necessary for the national production of material and informational products to be tied essentially to the amount of manpower available. Theoretically, man should now be free to develop the higher human qualities with which he believes himself specially endowed. The unfortunate fact that this does not seem to be working out probably relates to the problems of the sociosphere, which we may be able to tackle if we can first define them.

Sociosphere

It has been noted that many of today's problems arise partly because technological advances have occurred much faster than the normal rate at which adaptive changes in social behavior can accommodate to them. Some of these problems arise specifically because the result of technological change has been to call into question certain concepts and beliefs that were long thought either to have been handed down to the world by divine inspiration, or else to have been adequately proved by long human experience. Indeed, for much of human history, the changes were of a sufficiently slow nature that they could be adapted to, without doing great violence to traditional beliefs. Evolution was possible. Today, however, technological advancement has brought such dramatic changes that absurd situations are arising. Some outstanding examples would seem to be the following.

1. The subject of *human population*, and the need for its rational control by the societies involved. Having tampered with the death rate so effectively that a runaway condition exists, it would seem to represent elementary good husbandry for us to consider some overall objectives for the size of human populations, before panic measures prove necessary.

2. The matter of *work–leisure relations* in an affluent and automated society. A specific basic problem here concerns how we may accomplish change in the deeply ingrained protestant ethic that makes it difficult for people to feel themselves fulfilled, and thus to maintain their necessary self-pride, if they cannot be working members of the community. It should be noted that this difficulty seems largely independent of whether they are provided adequate sustenance by their society. The teaching of a nontechnological age, that unremitting toil is good and necessary, has now become inappropriate, and this has happened too rapidly for society to adapt to the situation.

3. The problem of *aggression and interpersonal fear*, which leads especially to the problems of warfare and ethnic strife within a particular state.

4. The problem of unacceptably *large and probably increasing differences* between the developing societies and the affluence of the developed societies. It should be noted that this is one of the inevitable effects when subsystems having positive feedback are placed in competition with each other.

Let us ask what may in some reasonable sense be considered the purpose of the people within their societies, and even of the societies themselves. Many needs of an individual already seem identifiable: to be closely involved in a "family," and in contributing to the creation and training of the new generation; to be valued by one's neighbors for contributions one can make to his immediate community; to be able to call upon the community in times of need; and, finally, to be able to contribute to the advancement of society toward some inspiring long-term goal. It is important to note in this last regard that people do not need to be in a state of great affluence to feel that they are fulfilling themselves satisfactorily in a society, but only that the society is moving toward a better state by their effort.

These comments suggest that societies can meaningfully be planned with some overall optimization in view. Unfortunately, it is very hard to find historical evidence for this assumption, perhaps because we are restricted to history on which many stages of editing have been performed. Furthermore, since societies contain so much positive feedback, there is always the danger that prophecies may become self-fulfilling. Given these conditions, it is not for trivial reasons that the sociosphere is an area of the "soft sciences." The problems are admittedly extremely complex, but the complexity would seem to emphasize how urgent it is that we as societies bring many of our best scientists to work upon the problems.

On the problems

Many of society's problems arise because change from some established conditions is necessary. The codification and implementation of these conditions have generally supported the development of a cadre of professionals, which tends to resist any changes suggested by its "lay electorate," though the professionals themselves may generate amendments, or even major changes, in pursuing their maintenance task. It follows that changes—such as amendment of laws—necessarily occur in discrete jumps and at discrete intervals of time, since for each change the pressure to reform must reach a threshold level. It may be useful to think of this as a relaxation oscillation.

The tendency of the establishment to resist change is not in itself necessarily unhealthy, because this procedure represents a reasonable way in which to filter out the high-frequency "noise," for which no change in the rules is really required. On the other hand, society's nontrivial problem in this respect is that of judging how to match the desirable time constant of the filter so that substantial changes in the "signal" can be adjusted for as rapidly as desirable, while the high-frequency noise is filtered out. Note that use of the word "desirable" in this sense begs an important question, since in order to ascertain what is desirable, an observer of godly powers is required.

When changes are made, they may fall into either of two general types. In the first type, change is merely an amendment; the values of parameters are changed but the general principles of operation remain the same. The second type of change is revolutionary, in that the whole structure is changed, and obviously this will occur only at a higher threshold. One classic example of the second type arises when a small one-man business prospers so well that in a relatively short time it becomes restructured to include professional managers, accountants, salesmen, etc. A frequent result of such a change is that the original owner—still proud of his success—finds himself increasingly frustrated, in that the business is now no longer a direct extension of himself and under his control.

Most enterprises involving large staffs have grown in a groping manner. Growth has usually been most efficient when the enterprise has been focused on achieving the objective of some individual. On the other hand, once it reaches the stage where it is essentially a "corporate" enterprise, its objectives can become distinctly modified by the staff, and especially by the managers. It has been the well-documented experience of the systems analyst that when he attempts analysis of such enterprises, his very attempt immediately requires that many questions as to corporate purpose and information flow be asked, and that the questions bring about significant improvements almost automatically. The second result of a systems study, usually, is to introduce complicated data-processing and control schemes for the organization. As the operation improves, the cost of the analyst and of the computing time necessary for the optimization studies becomes significant, until finally the cost of the analytical effort exceeds the economy gained. However, the advantages of analytical optimization studies may be realized only after a considerable delay; in such cases, an immediate economic loss is quite acceptable in view of the profit to be gained later by the experience acquired.

In any optimization study, one focal point of the analysis is the establishment of an appropriate performance criterion. When the analyst is searching for this criterion, he often finds that he must ask questions for which answers are not readily available, and that many of the answers that are available are not answers to useful questions. In defining the performance criterion, one of the most difficult tasks relates to establishing quantitative values for the social aspects, an extreme example being the value of a person's life. In fact, some react with horror to the idea that such an evaluation can even be considered. Such reactions are clearly not rational—since, in fact, we place great reliance upon insurance schemes, which necessarily quantify such matters—but they do point out the nature of reactions that must be considered in any realistic analysis.

Another problem concerning inquiries into social beliefs and behavior is that it is almost impossible to ask any question of a human being without having the respondent feel that the question is loaded. He may not answer in an entirely frank way, and may even be quite dishonest. Of course, in view of the simultaneously held incompatible beliefs that any respondent holds, it is probably improper to attach any stigma to the word "dishonest" in this context.

On the phenomena

Complex systems such as we have been discussing often exhibit aspects that can be classified under simple headings: growth and positive feedback; oscillations; unidirectionality; psychological and man-machine interactions; minimal principles; extreme-value statistics.

Growth and positive feedback. The expression "positive feedback" conveys some common meaning to most engineers in a qualitative way, but care must be taken before it is used in a quantitative way, especially if any value judgments are to be involved in the matter. The term "vicious circle" is commonly used to connote a closed chain of effects, of which at least one is not desired. However, positive feedback is fundamental to all growth processes, whether in living or nonliving systems. Positive feedback is responsible for the rapid growth in the initial stages, although the subsequent decay of growth rate to zero, so that some steady state is reached, is due to other feedbacks. Examples from the domains described include:

1. *Fire.* This tool and menace must necessarily start as a small initial condition, and then grow rapidly until the equilibrium conditions are approached, when a leveling off of growth occurs.

2. *Growth of organisms, journals, and capital.* The very archetype of growth is the division of cells, which, after relatively constant periods of nutrition, produces the classic exponential growth. To continue the classic picture, however, the usual later growth pattern is modeled reasonably well by the so-called logistic or S curve, in that the decay of growth rate is essentially a mirror image of the initial increase, until a steady state is reached (see, for example, Ref. 1). At present, knowledge, journals, and information are in a stage of exponential explosion. DeSolla Price points out that although specific subsets of such knowledge systems—for example, universities—show the classic S curve of growth over defined periods, they often set off on a new growth curve after some dramatically new condition has appeared.[2] With regard to money, it obviously grows exponentially if invested with compound interest at a constant rate.

3. *Bandwagons, fashions, and vicious cycles.* All these terms are used to describe phenomena exhibiting positive feedback in the social domain. A few random examples are growth of discussion about a new and important subject, once someone has first raised the question; the arousal of passion in mobs; the spread of fashion in such matters as clothing and usage of words.

Another important aspect of growth in complicated systems is that positive feedback may stimulate the growth of a particular subsystem, but there must often be inhibition for other similar, but less successful, subsystems in the surrounding domain. For example, a competition develops between the individual tiny trees in the initial stages of growth of a number of seedlings in the forest so that once some particular trees prevail strongly enough as by an appropriate advantage in height, etc., they can continue to grow preferentially whereas the others are inhibited and die off. In turn, of course, further stages of competition arise as the saplings grow larger, until the end result is a few "mighty oaks" for each acre of mature forest. Similar growth examples exist for animal species, as in a colony of flour beetles in a jar of flour; the female beetle lays eggs almost continually in the tunnels but there is an extremely high probability that these eggs will be subsequently eaten by mature beetles. Thus, although chance may set the initial conditions by which certain eggs are overlooked, once these newly hatched beetles have survived to a certain size their probability of survival becomes ever greater. At higher levels of social organization, the same initial stage of selecting candidates occurs, usually followed by a rallying around or "climbing onto the bandwagon," then by elimination of competitors, then by a period of comparative stability and unchallenged leadership, until eventually the leader's performance decays and the competition starts up again.

In the matter of gaining leadership and then inhibiting competition, the first important feature is an initial condition sufficiently superior for one object to excel over its competition. Once this superiority has been accepted, the leader essentially loses most of his competition and usually survives for some period after his performance has fallen below the threshold of superiority that was originally necessary. We say that habits, laws, beliefs, and systems tend to be carried along by their own momentum even after people start to become dissatisfied with them. When we view the matter in terms of the "capital" invested in the system, whether emotional or financial, then such tolerance is not unreasonable. In any case, the result is typically that of the stick-slip friction model.

An interesting and relevant sociotechnological example concerns the circumstances by which the gauge separating the two tracks of railroads became standardized. It provides a classic example of those growth situations in which apparently unimportant decisions, made in the early stages, become inevitably frozen into the design of huge systems. Today's railroads apparently developed from their embryonic form of horse-drawn coal carts. In the 18th century, these carts were first carried over wooden planks, then on iron plateways, and then on crude rails after the invention of the flanged wheel. The essentials of the modern system started in England at the beginning of the 19th century, and as the typical explosion of railroad building occurred there did not seem any compelling reason at any stage to change from the first gauge, 4 feet, 8½ inches, which had "just happened"—at least no compelling reason, in particular, for the original inventor Stevenson, and subsequently his son, who were responsible for building most of England's early railroad trackage. There was competition, symbolized by the engineer Brunel, who realized that this gauge was not technically optimum, and therefore built the Great Western Railway on a gauge of 9 feet. Technical passions were raised over this matter, but ultimately it was resolved in favor of the narrow gauge on the basis of total capital investment rather than on technical merit alone.

A further pertinent aspect may be pointed out concerning this case history. England, as the originator of railroads, was strongly involved in developing railroads all over the world. Thus, the decision concerning gauge standardization affected all, but was made by only a few.

Oscillations. Oscillations occur in many social systems, especially in those where mutual interaction exists. Many ecologists consider that an ecology cannot be considered to have reached optimal conditions if considerable oscillation continues in the subpopulations of the system. Evidently, as ecologies become more mature, oscillatory behavior decreases. Boulding[1] comments that we are no longer interested in merely understanding why our economic systems oscillate; because such oscillations produce profound human misery, we wish to control them.

In contrast, the evdence is increasing that the normal condition of state variables within organisms such as man, animals, and even plants, is often one of continual cycling. In any one case, the oscillation is in relatively narrow spectral bands; typical examples are the approximately one-second heart cycle; a ten-second "engine" cycle at the

capillary level of blood, as noted by Iberall[3]; cycles of temperature, metabolic activity, etc., of the order of one day; the three- to five-day water cycle; the monthly ovarian cycle; and the various generational cycles.

Most of the technological systems that have been designed with adaptive and optimizing aspects require a cycling action. A system that has once adapted so as to reach maximum performance "on top of the hill" is not satisfactory in general, since the hill may subsequently have moved. A hill-climbing scheme is therefore necessary in which direction and rate information can be provided for climbing again toward the optimal condition. Thus, it is at least conceptually possible that much of the cycling found in living systems relates to the possibility that they continually optimize themselves. However, there are other, equally plausible explanations; the oscillation may be difficult to filter out and in itself is not harmful, or it may help implement the necessary sharing of materials in such economies as those of cells.

Unidirectionality

Asymmetry is a particular form of nonlinearity found widely in the operation of systems, but perhaps especially in biological and social systems. It is likely that the relative infrequency of nonlinearity in technological systems merely reflects the limitations of the designers, in that there is a fairly coherent theory only for linear systems. However, with the advent of more powerful theories, and of the computer, the engineer is increasingly beginning to design his systems to be nonlinear.

A major reason for asymmetry in many living systems is that, for many variables, negative quantities cannot exist. For example, the firing frequency of neurons can only be at a positive rate. In the detailed design of biological systems, this fundamental unidirectional nature of certain of the components is overcome by providing a parallel channel, which utilizes the same operating principle but is connected in the reverse sense. Particularly obvious examples are agonist–antagonist pairs of muscles and the stimulatory–inhibitory connections of neurons.

Some very interesting and advantageous system characteristics arise from dynamic unidirectionality of the type specially pursued by Clynes.[4] The general effect is that dynamic asymmetry tends to emphasize changes of condition, a process noted earlier as being ubiquitous in living systems. Such dynamic unidirectionality provides espe-

cially good response characteristics at the high-frequency end of the spectrum.

Another steady-state effect of static unidirectionality worth mentioning is that in systems exhibiting oscillation or statistical variation, the rectifying effect of unidirectionality can result in an irrevocable loss of system capacity. The prototype for this effect may be the capacity of a facility with a waiting line. In particular, when vehicles arrive with some statistical variation, there is an irrevocable loss of service capacity as compared with the situation when arrivals are regular. The classic result is that as the mean arrival time decreases and approaches the mean service time, the length of the waiting line extends—in simple theory—to infinity. The physical basis for this result is that whenever chance decrees that no vehicles are waiting for service, this otherwise available service time is lost forever.

Psychological and man–machine interactions. In man–machine systems, and indeed in any systems where the psychological characteristics of man contribute significantly, any satisfactory analysis depends upon obtaining good data regarding the psychological aspects. This point is well illustrated by the study of how the flow of vehicles through a single-lane facility can be maximized. In the case of one of the New York tunnels, a well-defined curve was obtained relating the number of cars passing through the tunnel per hour to the speed at which the cars were constrained to travel steadily. To the untrained intuition, it may seem rather surprising that the maximum throughput rate occurred when the controlled speed was close to 20 mi/h (32 km/h), and that the throughput function was fairly steep-sided. The explanation is that, with very good reason, the driver at high speed is not prepared to remain as closely behind the car in front as he would at a lower speed. If the spacing increased as the square of the speed, therefore being proportional to kinetic energy, the driver would be assured of being able to brake to a full stop without an accident, even if the car in front came to an instantaneous halt, as it might in a head-on collision. In practice, drivers can generally see conditions somewhat ahead of the car in front; the experienced driver usually chooses some spacing relation intermediate between quadratic and linear with velocity, and this fact gives rise to the optimal condition already stated.

It should perhaps be pointed out that this particular optimal condition was not recognized until the appropriate experimental work had been done; indeed, tunnel signs frequently caution the motorist: "Maintain 40 mph." The systems analyst can obtain such answers, but it is most unlikely that drivers themselves would ever arrive at the best solution if left to their own resources. We have all experienced frustrating situations, especially in traffic jams, where the overall system degenerates to an obviously nonoptimal condition as a result of people operating individually in what seem to be their own best interests. The resulting breakdown of the complete system shows that their interest is not being well served, but the subsystems are powerless to be better.

Minimal principles and optimality. A number of minimal principles are recognized in physics. A formulation of such principles may be worded roughly as follows: The particular process "selected" by a physical system will be that one out of the possible family of processes—all consistent with given constraints—which minimizes a certain "cost." Thus, a ray of light moves through media of arbitrary refractive indexes in least time, and a mechanical system that conserves total energy moves along that path which minimizes the quantity defined as "action." When slightly generalized to minimize "virtual displacement" rather than action, the principle of least action becomes consistent with that most general minimal principle of physics, Hamilton's principle. The major drawback to universal application of this principle is that only conservative systems can be so treated directly.

Minimal principles have been of considerable philosophical importance in physics but have not become necessary working tools for normal problems. In part, this is true because the mechanical, hydrodynamic, electrical, and other laws that are derivable from the minimum principle are already well known (and indeed were usually discovered first), but also because the ubiquity of dissipation renders the principles inapplicable.

With the recent development of a comprehensive control theory,[5] the Hamiltonian and its derivative Euler–Lagrange equations have become of renewed importance. In this case, the Hamiltonian represents a function of the performance criterion, being in detail comprised not only of the criterion, but also of constraints on the system.

The situation in biology is somewhat different and more promising than in physics; as Rosen points out in his recent book,[6] "...it is possible to give at the outset a coherent, if qualitative, argument which will to some extent justify a search for such principles in biology, and help in their formulation. This argument is based on the phenomenon of natural selection, and the pressure which selection exerts on nearly every aspect of the structure, function, and performance of biological individuals. ...It is now possible to make the fundamental hypothesis that biological structures, which are optimal in the contest of natural selection, are also optimal in the sense that they minimize some cost functional derived from the engineering characteristics of the situation. This most natural assumption has been called the principle of optimal design.[7,8] Usually, however, the appropriate cost functional is not immediately obvious; therein lies the art and difficulty of the entire subject." We might add that it is not likely that most cost functionals will prove simple enough to allow this direct analytical attack even when they can be plausibly defined. It is of interest that Rosen then considers the vascular system, and by assuming a reasonable cost functional related to the metabolic cost of maintaining the system plus the hydrodynamic power loss in the system, is able to show that the results of an optimality analysis are consistent, as regards blood vessel size and the geometry of branching, with the structure found in dogs.

There is some first rather qualitative evidence that optimality principles apply also in social systems, where the interacting variables are probably more related to information flow than to energy flow.[9]

Extreme-value statistics. Since nature's various populations and evolutionary experiments involve very large numbers, some of the small samples constituting our experimental research will inevitably differ from the mean by many standard deviations; they will fall into the area of extreme-value statistics. For example, if the probability of an event such as a particular genetic combination is less than, say, 10^{-9}, nevertheless, such events may occur with reasonable regularity in some of nature's populations. In particular cases, sufficient numbers of these extremely improbable events have happened, so that some form of evolution has operated upon them. Slobodkin points out that hydra, a simple animal, provides an example here in its evolution of unlikely methods of escaping either in space or time from unfavorable conditions.[1]

A trade-off situation certainly occurs in systems involving extreme-value statistics, but in general it is difficult to attach quantitative values to the relevent variables. In these situations, at least one new component is added to the performance criterion, representing the expected value or cost of the unlikely events. An expected value or cost equals the probability of the event multiplied by the value or cost of the event, should it happen. Numerically, this value can be significant, and even comparable to other cost components of the performance criterion, even if the probability of the event is very small, provided that the cost attached to the event is large. Consider a simplified example of deciding what strength should be designed into buildings to combat the possibility of collapse due to earthquakes. If it is assumed that earthquakes are distributed in some reasonable and known statistical manner, then a probability value can be assigned to the occurrence of earthquakes exceeding a given strength during an appropriate period of time. Clearly, the construction cost will increase as the design strength against earthquakes is increased, and for an optimal design this must be traded off against the expected cost due to the finite possibility of collapse. Thus, as design strength is increased, construction cost increases, whereas the expected cost decreases because of the decreasing probability that an earthquake will cause collapse. It may be expected that an economic optimum point exists when mathematically the derivatives of the two costs, plotted as functions of construction strength, are equal in magnitude although opposite in sign.

Such an analysis forces us to confront the difficult issue of whether or not we are prepared to accept a possibility of accidental building collapse. There is nothing wrong with carrying out the analysis as long as we in society are prepared to say whether we are satisfied with the results following the incorporation into the performance criterion of all values that concern us. Specifically, the difficult problem revolves about the cost of people's lives potentially lost in a collapse. This is certainly not an easy matter to resolve, but our society's nominal claim, that we must not allow any risk of accidental death at all, is clearly not carried out either individually or en masse in our normal affairs. As we increasingly generate new systems—such as universal medical care—where such considerations will be forced upon us, rational but ethical guidelines will have to be developed. For example, in medical systems there is not only the problem of optimizing the system with regard both to the cost of medical care and the expected value of extended survival of life or mitigation of pain, but also the problem of whether social pressures may allow any rational thinking about the value of prolonging life. Here we move rapidly into the technological, legal, ethical, moral, and religious domains.

On tampering and optimizing: some conclusions

The problem of optimizing a social system is especially difficult because it is as yet almost impossible to define a suitable performance criterion. Hard facts regarding costs of materials, and the like, have to be compared with "soft facts" concerning such social aspects as esthetics and fulfillment. Furthermore, a satisfactory overall criterion must consist of a weighted collection of criteria that comprise the preferences of all the subsystems, namely, we who constitute the electorate for the overall systems planners and controllers, and are therefore (we hope) the ultimate controllers. The criteria that we choose will certainly be different from the ones we would choose if we were in a "dog-eat-dog" situation in which each would have to optimize his own subsystem without regard to his neighbors. As Freud[10] points out, this is why societies have successively adopted the otherwise undesirable constraints of a civilized system. However, the energy and information revolutions make such constraints increasingly irksome. While we enjoy the advantages of these revolutions, we must arrange legal and social structures, and our systems planning, to be adequately flexible and adaptable. In particular, they must try to anticipate the impact of technological change. This need requires a vastly greater acceptance by the technologist and scientist of responsibility for reporting to society their predictions regarding social effects of technological change, and a vastly greater acceptance by the social scientists and humanists of their need to understand something not only of the general systems approach, but also of technological principles.

This article is a condensation of the presidential address presented at the Annual Meeting of the Society for General Systems Research, New York, N.Y., December 1967. The address will appear in full in the "Yearbook" of that society.

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IEEE Reports for 1967

Introduction

S. W. Herwald *President IEEE*

I am pleased to report to you that the general state of health of the IEEE is good. Quantitative as well as qualitative evidence of this vitality can be found in the Secretary's Report and Treasurer's Report, which follow.

Let me emphasize some important facts that are brought out in these reports and also call your attention to some new developments that have occurred during the first six months of 1968.

With the increase in dues, our financial situation is much improved over what it was a year ago. As Treasurer Harold Chestnut points out in his report, the net results for 1967 show an improvement over 1966 of an amount in excess of $928 000, thereby enabling us to begin replenishing our reserves.

The question of taxability of income derived from our International Convention and Exhibition is still unresolved. As Walt MacAdam mentioned in his report in IEEE SPECTRUM one year ago, the Board of Directors has authorized legal counsel to proceed to obtain a judicial determination of our alleged liability. No formal action has yet been taken pending further consideration of the matter by the Internal Revenue Service.

The membership of IEEE as of March 31, 1968, was approximately 4000 more than at the same time in 1967. This increase in membership was accomplished in spite of the dues increase that became effective in January of last year, and more than offsets the 1.1 percent decline in membership in 1967 that is mentioned in Secretary Oliver's report.

Attendance at the 1968 IEEE International Convention and Exhibition was up from 1967 by more than 4500. In 1968, 63 749 persons attended as compared with 59 196 in 1967. Some of this increase in attendance must be attributed to the excellent work done by Ed Herold's Technical Program Committee in reshaping some fundamental thinking about how the technical program should evolve.

The newly formed Long Range Planning Committee, under the chairmanship of Walt MacAdam, has had its first meeting. This committee is responsible to the Board of Directors for reviewing the trends of science and technology as they may concern the Institute, the profession, and the public, and for recommending such changes in the Institute's objectives, organization, and operations as may be indicated by these trends.

Another new, forward-looking group is the Educational Activities Board. Part of its responsibility is the planning of specific activities in continuing education and the making of policy recommendations to the Board of Directors.

As another important development in IEEE's efforts to serve you better, I am pleased to announce that we have arranged to utilize a new IBM System/360 model 40 computer with a disk-oriented file and remote terminals. It is to be installed in 1969. The faster processing speed of this third-generation computer will enable us substantially to reduce the time required to handle our increasing work load. The time made available should provide IEEE Data Processing with the opportunity to expand our fulfillment capabilities by participating in emerging computer usage techniques.

Lest I sound complacent, let me also emphasize, as I did in my report in the January 1968 issue, that our main problem continues to be one of communications. The Institute is very complex in its organization and although we would like to simplify its operation we have not yet found a way to do so to any significant degree without sacrificing your best interests in the process. However, we are making some progress.

For a more complete picture of IEEE today, I call your attention to the following reports and the information they contain. There probably is no better way for you to determine whether or not your IEEE is spending its time, money, and talents wisely. Read them—and if you think there are areas in which improvement is needed, please let me know.

Report of the Secretary—1967

Bernard M. Oliver

To the Board of Directors
The Institute of Electrical and Electronics Engineers, Inc.

Gentlemen:

The Report of the Secretary for the year 1967 is presented herewith.

Membership declined about 1.1 percent during the year. This drop was substantially lower than that projected in light of the increase in membership dues that took effect on January 1, 1967. Student membership increased by 16 percent and about 10 000 graduating students were transferred to the higher grades.

There was a steady increase in Group memberships, with almost 12 000 new enrollments in 1967. Approximately 50 percent of the membership now participate in the Group program. Group Affiliates increased by 112.

Some 37 222 editorial pages were published in 1967, compared with 29 414 in 1966. Publication of Group Transactions pages increased by nearly 4 percent in the year. In 1967 publications for members in Regions 8 and 9 were introduced.

The major activity of the Information Services Department, organized in 1967, was negotiation of an agreement between the IEEE and IEE London to jointly publish *Electrical and Electronics Abstracts*.

New features of this annual Report of the Secretary are brief summaries of standing committee and board activities and changes taking place in the Headquarters staff.

These data indicate a general growth trend with increased services to members and continued improvement in the effectiveness of the Headquarters management.

Respectfully submitted,
Bernard M. Oliver
Secretary

Technical publications

General. The year 1967 saw the continued growth in the scope of the publication activities of the Institute and increased attention given to evaluating the quality and effectiveness of the resulting services. It was a year that also saw Information Services established as a separate department of the Institute staff. Its activities are therefore covered separately in the section that follows.

During the year, the Editorial Department processed 3526 papers and 1374 correspondence items for printing in IEEE publications, excluding the translated journals, giving a total output of 29 729 editorial pages, a slight increase over the preceding year.

Considerable effort was devoted to evaluating the quality of the publications of the IEEE. A task force of the Publications Board was formed to review the current output of the Group Transactions and Journals to provide data that would assist the Technical Activities Board and the Publications Board in determining how best to

I. IEEE membership by region, grade, percentage; as of December 31, 1967

Region	H	F	SM	M	A	Student	Total	Percentage
1	2	925	6 237	23 624	3 706	5 040	39 534	25
2		522	4 958	15 834	1 851	2 716	25 881	16
3		249	2 298	8 207	834	2 301	13 889	9
4		241	2 776	10 276	1 447	3 702	18 442	12
5	1	185	2 088	7 328	847	2 860	13 309	8
6		471	4 733	20 054	2 136	2 981	30 375	19
7		65	856	3 977	1 137	1 533	7 568	5
8		126	807	2 243	500	447	4 123	3
9		12	199	961	187	420	1 779	1
10	1	18	390	1 546	261	228	2 444	1
U.S. overseas military		3	69	679	82	19	852	1
U.S. possessions	.	..	...	17	3	1	21	..
Total	4	2 817	25 411	94 746	12 991	22 248	158 217	100

use Institute general funds in support of Group publications in 1968. It is expected that the information obtained from this review will also be helpful to the Groups in strengthening their publications. The Institute also arranged for an outside firm to conduct an extensive personal interview and mail survey among members regarding their attitudes and technical needs, an important part of which concerned their views on SPECTRUM, the PROCEEDINGS, and Group publications. The results of the survey will be an important aid to the Publications Board in developing improved publication programs in 1968.

Considerable attention was also given by the Publications Board to examining the publication needs of Student members and evaluating the respective roles of the STUDENT JOURNAL and SPECTRUM in meeting these needs. As a result of this study, which was conducted over a period of two years, the Board of Directors decided that starting in the fall of 1967 all students should be given the choice of receiving either the STUDENT JOURNAL or SPECTRUM as part of their dues.

Following a study of long-range Group publication finances by a joint committee of the Publications Board and the Technical Activities Board, the Board of Directors agreed to permit the adoption of voluntary page charges by those publications that desire them, subject in each instance to the approval of the Publications Board

II. IEEE Group membership, December 31, 1967; four-year comparison

		1967						
Group No.	Group Name	Student Discount	Students, Regular	Other Members	1967 Total	1966 Total	1965 Total	1964 Total
1	Audio and Electroacoustics	317	199	3 972	4 488	4 302	4 230	4 054
2	Broadcasting	128	103	1 687	1 918	1 755	1 592	1 492
3	Antennas and Propagation	508	47	4 327	4 882	4 605	4 256	3 864
4	Circuit Theory	1 296	233	6 434	7 963	7 020	6 636	6 085
5	Nuclear Science	179	142	2 043	2 364	2 181	1 939	1 761
6	Vehicular Technology	42	43	2 003	2 088	1 911	1 705	1 579
7	Reliability	17	17	2 588	2 622	2 602	2 431	2 264
8	Broadcast and Television Receivers	164	66	2 008	2 238	2 043	1 835	1 770
9	Instrumentation and Measurements	104	144	4 600	4 848	4 650	4 488	4 143
10	Aerospace and Electronic Systems	724	128	8 910	9 762	10 021	10 397	13 415
12	Information Theory	244	173	4 048	4 465	4 306	4 031	3 896
13	Industrial Electronics and Control Instrumentation	81	110	3 283	3 474	3 370	3 059	2 655
14	Engineering Management	356	72	5 739	6 167	5 791	5 453	5 449
15	Electron Devices	1 916	96	6 148	8 160	6 674	5 558	4 852
16	Computer	1 999	255	10 986	13 240	11 136	9 999	9 254
17	Microwave Theory and Techniques	344	231	5 554	6 129	5 830	5 527	5 290
18	Engineering in Medicine and Biology	537	200	3 530	4 267	3 796	3 517	3 163
19	Communication Technology	782	216	7 379	8 377	7 253	6 448	5 392
20	Sonics and Ultrasonics	23	22	1 175	1 220	1 176	1 139	1 064
21	Parts, Materials and Packaging	15	16	2 370	2 401	2 526	2 738	3 362
23	Automatic Control	918	153	5 341	6 412	5 874	5 189	4 608
25	Education	29	52	1 756	1 837	1 630	1 368	1 238
26	Engineering Writing and Speech	52	93	2 012	2 157	2 067	1 920	1 737
27	Electromagnetic Compatibility	10	7	1 662	1 679	1 687	1 638	1 424
28	Man-Machine Systems	16	47	995	1 058	936	788	719
29	Geoscience Electronics	54	76	1 413	1 543	1 458	1 278	1 168
31	Power	782	35	11 344	12 161	10 820	9 391	7 108
32	Electrical Insulation	5	4	1 086	1 095	985	851	645
33	Magnetics	65	26	1 862	1 953	1 757	1 434	193
34	Industry and General Applications	173	24	3 954	4 151	3 578	2 609	913
35	Systems Science and Cybernetics	164	301	3 021	3 486	2 918	1 524	. . .
		12 044	3 331	123 230	138 605	126 658	111 968	104 557
	Journal of Quantum Electronics (G-15)	112	89	1 433	2 634	1 493	1 238	
	Journal of Quantum Electronics (G-17)	45	16	520	581	636	608	
		157	105	1 953	2 215	2 129	1 846	
	Journal of Solid-State Circuits (G-4)	1 296	233	6 434	7 963			
	Journal of Solid-State Circuits (G-15)	107	56	759	922			
	Journal of Solid-State Circuits	63	38	1 007	1 108			
		1 466	327	8 200	9 993			

12 234 or 55.0 percent of the Student members are enrolled in Groups.
64 076 or 47.1 percent of grades other than Student are enrolled in Groups.

III. IEEE publications output, 1967

	Editorial Pages	Advertising Pages and Filler	Total Pages	Number of Papers	Number of Letters
Regular journals:					
IEEE SPECTRUM	1 308	744	2 052	86	85
PROCEEDINGS OF THE IEEE	2 289	312	2 601	158	573
Group Transactions and Journals	17 528	...	17 528	2 252	716
IEEE STUDENT JOURNAL	312	...	312	40	...
Subtotals	21 437	1 056	22 493	2 536	1 374
Other publications:					
Translated journals	7 493	...	7 493	864	361
Convention Record	2 216	...	2 216	291	...
Conference Records*	2 236	...	2 236	417	...
Preprints	3 840	...	3 840	282	...
Subtotals	15 785	...	15 785	1 854	361
Totals	37 222	1 056	38 278	4 390	1 735

*Produced through Editorial Department.

and the Technical Activities Board. Under the page-charge system, which has been adopted by a growing number of scientific and engineering society journals, the author's company is asked to pay a charge on a purely voluntary basis to help support the cost of publishing the results of their research and development work. The voluntary page charge was established at $50 per page for 1968. Five publications have adopted page charges for the coming year: the TRANSACTIONS ON ANTENNAS AND PROPAGATION, INFORMATION THEORY, AEROSPACE AND ELECTRONIC SYSTEMS, ELECTRON DEVICES, and the JOURNAL OF QUANTUM ELECTRONICS.

IEEE Spectrum. The year 1967 marked the fourth year of publication of this core publication of the Institute. C. Chapin Cutler of Bell Telephone Laboratories continued as editor, and he was assisted throughout the year by an Editorial Board of distinguished engineers.

A total of 86 articles were published during the year. Most of these were invited or contributed, but eight were written by members of the editorial staff. In addition to 27 letters published in "IEEE forum," 58 letters were published in "Technical correspondence."

The total pages published in SPECTRUM during 1967 numbered 2052. Of these, 1308 were devoted to technical and editorial material, 579 to paid advertising, and 165 to related filler.

Two new assistant editors, Harold L. Hoffman and Marcelino Eleccion, were added to the SPECTRUM staff in 1967.

Proceedings of the IEEE. As in 1966, the PROCEEDINGS was guided throughout 1967 by its appointed editor, M. E. Van Valkenburg of Princeton University, and its Editorial Board. Members of the latter continued to play an active day-to-day role in the editorial process by selecting appropriate reviewers for all contributed papers. This procedure is used to assure that papers are reviewed by the most competent people available.

Nine invited papers reviewing progress in areas of wide general interest were published during the year. These were procured with the assistance of the Editorial Board and were written by people at the forefront of research in the areas covered. Because these invited papers have been so well received, the groundwork was laid for substantially increasing the number to be published in 1968.

As usual, the highlights of the PROCEEDINGS year were the special issues, each of which was devoted to a single subject area of major interest. Four were published, the subjects covered being redundancy reduction (March), radio measurement methods and standards (June), high-power semiconductor devices (August), and computer-aided design (November).

"Proceedings Letters" continued as a widely accepted vehicle for quickly and briefly announcing new research results. To increase the usefulness of this section, improvements were made in the review procedures to assure a fast but adequate review of letters submitted for publication. During the year, 618 pages were devoted to the printing of 573 letters. As a comparison, 592 letters, taking up 642 pages, were published in 1966.

The year saw the appearance of 2601 pages in the PROCEEDINGS, of which 2289 were editorial pages, 195 were paid advertising, and 117 were related filler. The total number of papers published was 158, of which 107 appeared in special issues.

Group publications. The Group publications again encompassed the major share of the IEEE publication output. A total of 164 issues constituting 17 528 pages were published. This represents an increase of nearly 4 percent over the 16 852 pages published in Group publications in 1966.

No new titles were added during the year, so the number of Transactions published remained at 31 and the number of Journals at two. In 1967, four Group publications were issued monthly, seven bimonthly, 15 quarterly, and seven appeared aperiodically.

With its September 1967 issue, COMPUTER GROUP NEWS became the first Group publication to carry advertising. This was made possible by a policy adopted by the IEEE Board of Directors that allowed advertising to be carried in a publication if the Group requested it and if a study indicated that an advertising market existed. The sale of advertising is handled by the IEEE Advertising Manager.

With the assistance of the Staff Director of Publishing Services, those Groups on a regular publication schedule began changing from third-class to second-class mailing at the end of the year. The change is expected to reduce postage expenses and speed delivery through the mails.

IEEE Student Journal. The Student membership was served during 1967 through this bimonthly student publication. Forty signed articles as well as other technical material and career information were included in 312 pages. During the year, editing and production of the STUDENT JOURNAL were brought into IEEE Headquarters and Alexander McKenzie took responsibility for staff support as managing editor. As in previous years, an extra 20 000 copies of the September issue were sent to IEEE Counselors in colleges and technical institutes for distribution to potential Student members.

At the beginning of the year, T. A. Hunter retired as editor, a position he had held since the STUDENT JOURNAL began publication in 1954. In recognition of this service and the key part he played in founding this student publication, Mr. Hunter was presented with a plaque by the Board of Directors and was given the honorary title of Founding Editor of the IEEE STUDENT JOURNAL.

Translated journals. The Institute continued its program of translating and publishing papers from four Russian and two Japanese technical journals with the support of the National Science Foundation. The year 1967 saw the appearance of 4664 pages translated from the Russian and 2829 translated from the Japanese. Advance tables of contents of issues to be translated were carried each month in SPECTRUM, as were signed critical reviews of selected papers that had been published in English.

Special publications and preprints. The papers presented at the 1967 International Convention were published in summary form in the Convention Digest and in full in a 14-part, 2216-page Convention Record. In addition, ten special Conference Records were published, comprising 417 papers and 2236 pages. Finally, a total of 282 papers, amounting to 3840 pages, were individually preprinted by photo-offset means for four meetings.

Information services

The new Information Services Department began its work during 1967, with much activity both external and internal to the Institute.

The major external activity was the negotiation of an agreement with the Institution of Electrical Engineers (London) to become joint publisher of *Electrical and Electronics Abstracts* (also known as *Science Abstracts—Series B*). The agreement between IEEE and IEE covers sales—with IEEE the agent for the Americas— and editorial participation, with IEEE agreeing to supply the indexed abstracts of its own literature, and possibly some specialized literature more readily available in the United States. The agreement is expected to return a surplus to the IEEE, which can be used for further development of its information services.

An important part of the work with the IEE is in the joint development of improved indexing vocabularies for the electrical and electronics field.

External activity by the new department also included extensive interaction with the Engineering Index, looking toward close cooperation in developing information products for the American market, and in the development of indexing vocabulary.

The department also participated on panels, on boards, on committees of the EJC, Tripartite Committee, Engineering Societies Library, U.S.A. Standards Institute, SATCOM (Committee on Scientific and Technical Communication of the National Academy of Sciences/National Academy of Engineering), and ISTIM (President's *ad hoc* Committee on Interchange of Scientific and Technical Information in Machine Language). In addition, meetings were held with information services staff personnel of several scientific and engineering societies.

Activities internal to the Institute have centered on modernization and extension of the year-end indexing, as a first step toward development of a human-and-machine compatible indexing method. The extension planned was in usability and quality, and in use of modern computer-based techniques. Unfortunately, the extension that happened was also an extension in time, because of problems in obtaining satisfactory performance from a contractor. Plans for the 1968 indexes are for the same indexing approach, but earlier schedule, and better control of the mechanized processes through greater capability within the staff of the Institute.

The creation of a master bibliographic file of IEEE 1967 published literature was attempted, and ran into delays. It is planned for completion in 1968, along with the master file of 1968 literature.

A major feature of 1967 IEEE indexing was author participation, and a majority of IEEE 1967 authors filled out author-indexing worksheets that proved to be of substantial value in raising the quality of 1967 indexing. The policy of using author participation will be extended and enhanced in 1968.

Other internal activity was largely concerned with planning for a number of projects to be carried out in the near future, such as the creation of microform editions of IEEE literature, and the more effective and perhaps automatic dissemination of reprints.

Regional publications

The year 1967 saw the inauguration of the Institute's first two Regional publications and the laying of plans for a third.

As further evidence of its nonnational character, the Institute's first non-English technical publication was inaugurated with the appearance of IEEE ELECTROLATINA. Published quarterly in Mexico City by the Latin American Region (Region 9), the new publication contains technical articles and news in Spanish and Portuguese, carries advertising, and is distributed free to all members residing in Region 9, numbering 1700.

In December, Region 8, serving 4000 members in Europe, the Middle East, and North Africa, began publication of a newsletter containing Institute announcements of particular interest to the Region and also Regional, Section, and Student news. It is planned to publish the newsletter two or three times a year. Meanwhile, consideration is being given by Region 10 to the possibility of starting a newsletter in 1968 for members in Asia and Africa.

Section publications

A major activity of many Sections is the publication of a monthly Bulletin for the announcement of the local activities. Sixty-nine IEEE Sections are now issuing monthly publications.

Electrical Engineering

The year 1967 marked the year that this "management newsletter on IEEE operations—to encourage communication among Committees, Groups, Sections and Staff" moved from a quarterly publication to a bimonthly. In addition, under the able guidance and leadership of its new editor, Dr. Ivan S. Coggeshall, a number of supplements were included with each issue. Included in the supplements were: Speakers Listing; Guidelines for Arrangements for Invited Visitors to the United States from the Soviet Union and Eastern European Nations; Bylaw Revisions; Policy Statements; and a series on committee common lore written by the editor. The total number of Newsletter pages published in 1967 was 42. The total number of pages of supplements was 225.

Technical activities

Technical Activities Board, Groups, and General Committees. In 1967, all categories of technical activities continued at higher levels than in 1966. The Transactions and Journals published a total of 17 528 pages in 164 issues, compared with 16 830 pages in 1965. The conferences, symposia, and seminars or workshops sponsored or cosponsored by Groups, Regions, and Sections offered greater variety and coverage than in any previous year. This reflects the rapid advances that are being made on many technical fronts of interest to IEEE. The Standards Committee acted on 33 new or revised standards. The IEEE dictionary was organized on a project basis, with the Editorial Department at IEEE Headquarters taking responsibility for publication. By the end of the year, more than 20 000 entries had been submitted and were processed for inclusion in the new dictionary.

The membership in IEEE Groups, which is an index to the technical activity of IEEE, increased in 1967, with a year-end total of 139 436, compared with 127 377 memberships at the end of 1966. These 1967 memberships were held by 76 310 individuals, which represents 48 percent of the IEEE members, compared with 42 percent a year ago. A study of detailed membership records for a few Groups in 1966 indicated not only a growth but also a significant rotation or turnover. For 1967, careful records were kept of Group membership renewals and new memberships. There were variations, of course, between Groups, but in broad terms about one quarter of all Group memberships were new. Many individuals switch from one Group to another. A switch may represent a change in job assignment and technical interest. Or it may mean that the individual was seeking something and, not finding it in one Group, switched to another. This is a challenge that requires attention.

Further steps were taken to clarify the financial picture for all technical activities, particularly the interaction between IEEE support and the resources of the individual Groups. As a partial solution for the problem of rising publication costs, the IEEE Board adopted a permissive policy on voluntary page charges. Four Transactions and one Journal will have page charges in 1968. Display advertisements are being published in the COMPUTER NEWS, the first such undertaking since adoption of a revised IEEE policy pertaining to Group publications. Group fees and conference registration schedules show upward trends to compensate for rising costs and broader requirements for financial support. The Publications Board established a special task force to evaluate the Transactions and Journals, thus providing important information needed in the preparation of budgets for 1968. Strong IEEE support for publications at the top of the evaluation ratings is clearly indicated. At the other end of the scale, the rationale was less obvious; some Groups had little hope of significantly improving their publications unless extra help was offered.

A significant change was made in the IEEE administrative structure, as reflected in the revision of the IEEE Bylaw 308 pertaining to the Technical Activities Board. The new arrangement parallels that of the IEEE Board and Executive Committee, with the TAB reporting to the Board and TAB Operating Committee reporting to the Executive Committee. In order to insure a close tie between the Groups and the TAB OpCom, a special provision was made by Bylaw 308.2 for a strong TAB voice in the selection of the members at large. Internal, administrative communications received attention and new or revised procedures were adopted to facilitate these communications; individual members of TAB OpCom and the TAB Finance Committee were assigned responsibilities for a few Groups, thereby encouraging studies of Group problems in depth.

Joint Technical Advisory Committee (JTAC). This committee, sponsored by the IEEE and the EIA (Electronic Industries Association), held five regular meetings during 1967. Five subcommittees have been active during the year.

Subcommittee 63.1—Electromagnetic Compatibility endeavored to undertake a study of the needed technical areas and to formulate objectives for dealing with this subject. A report is in the final stages of preparation and it will be the first time that (1) frequency coordination and monitoring resources in the U.S. have been reported in a study; (2) a system for determining spectrum usage information has been developed; (3) there has been a detailed study on the antenna farm problem leading to classification and recommended procedures; (4) a complete survey of all available data on man-made noise has been compiled; and (5) the relationship between man's use and natural phenomena has been suggested as an area for better organized study.

Subcommittee 65.1—Future Needs and Uses of the Spectrum; relative to the continuing nature of the aspects of this area of study, the scope, considered to be wide, was undefined. In conjunction with the Office of Telecommunications Management, the subcommittee has conducted a survey to develop information on prospective future uses of the electromagnetic spectrum resulting from research now under way and being contemplated. A report on the combined survey will be made available when completed.

Subcommittee 66.1—Maritime Mobile Communications was constituted to study the potential technical and economic advantages in reallocation of the maritime frequencies in the 50-kHz and 2-MHz bands.

Subcommittee 66.2—Testing Sharing of TV Channels by LMRS was set up to assist the FCC in the tests now being conducted by the Commission on the feasibility of sharing television channels by stations in the land mobile radio services.

Subcommittee 67.1—Spectrum Utilization Aspects in the Use of Space Techniques was established in February 1967 to study spectrum utilization aspects of space techniques and issue a report that possibly could become a supplement to "Radio Spectrum Utilization." This study was initiated in view of the changing conditions brought about by the enormous strides that have taken place in satellite communications.

Educational activities

During 1967 two concurrent general educational activities got under way. The first involved the continuing program of the Educational Committee, which included appointment of over 60 inspectors for the ECPD accreditation activities; development of criteria for assisting the Engineering Education and Accreditation Committee of ECPD in evaluating both electrical engineering curricula and engineering technology curricula; and development of programs in Continuing Education.

The second general educational activity involved the work of the *ad hoc* Committee on Educational Activities of the IEEE Executive Committee. The work of this committee culminated in a comprehensive report submitted to and accepted by the IEEE Executive Committee and Board of Directors and published in the November issue of SPECTRUM. There were numerous far-reaching recommendations made by this committee, all or many of which will come into function as a result of the enactment of the following two recommendations: (1) IEEE should establish an Educational Activities Board having a status comparable to the Publications Board or to TAB, the chairman of the EAB to be a member of the Executive Committee. (2) The EAB should be responsible for planning specific activities in continuing education, for monitoring ECPD accreditation activities and developing guidelines for our representatives on the ECPD accreditation committees, for developing IEEE relations with educational institutions, for making policy recommendations to the Board of Directors.

Activities of the Student Branches Committee during 1967. The Student Branches Committee held two meetings during 1967. The annual Vincent Bendix Award program was administered with grants to six Student Branches totaling $2284.50. The committee conducted a special survey and made recommendations concerning actions that could be taken to activate Student membership at the Regional and Sectional level of IEEE. Under the sponsorship of the Student Branches Committee, the first Student Branch Counselors meeting was held at the 1967 IEEE International Convention. In addition, plans were completed for holding a four-day Student Branch Chairman Convocation at the 1968 International Convention. The IEEE Student Branch Manual was revised by an *ad hoc* committee of the Student Branches Committee and issued to all IEEE Student Branches.

Board and standing committee activities

Admission and Advancement Committee. During the 12 full-day meetings of this committee in 1967, all held at IEEE Headquarters, 1527 applications for admission and transfer to Member and Senior Member grades were reviewed, and action taken as follows:

	Senior Member	Member
Admissions approved	228	644
Admissions rejected	72	109
Transfers approved	304	98
Transfers rejected	48	24
	652	875

Following action taken by the Board of Directors, the number of references required was reduced to three for both Member and Senior Member applications. The application forms and reference forms were redesigned to incorporate these changes and to secure more pertinent and more responsive answers from references. Copies of the application are now forwarded routinely to each reference.

Seventeen Swedish and 22 French members were upgraded to Senior Member as a result of action taken by the respective Section Executive Committees under the upgrading procedures approved by the Executive Committee.

Awards Board. The major function of the Awards Board is to consider and approve recommendations that have been received from its committees for candidates for IEEE Awards and to submit to the Board of Directors for final approval recommendations for recipients for the IEEE Awards. In 1967 recipients were recommended for the following: Medal of Honor; major annual awards—Edison Medal, Founders Award, Lamme Medal, IEEE Education Medal; Field Awards—Harry Diamond Memorial Prize Award, William M. Habirshaw Award, IEEE Award in International Communication in honor of Hernand and Sosthenes Behn, Mervin J. Kelly Award, Morris E. Leeds Award, Morris N. Liebmann Memorial Prize Award, David Sarnoff Award, Vladimir K. Zworykin Award; Prize Paper awards—W. R. G. Baker Prize Award, Browder J. Thompson Memorial Prize Award, Institute Student Prize Award; scholarship awards—Charles LeGeyt Fortescue Fellowship, Volta Scholarship.

The Field Awards were presented to the recipients at special affairs held during meetings and conferences in Dallas, Boston, Pittsburgh, Chicago, San Francisco, and New York. The IEEE Medal of Honor, major annual awards, and Prize Paper awards were presented at special functions held in New York during the International Convention.

In addition, the Awards Board recommended nominees for the National Medal of Science, which is the "Government's highest award for distinguished achievement in science, mathematics and engineering."

The IEEE participates in intersociety award activities and early in 1967 the Awards Board was assigned the responsibility of appointing IEEE representatives to the following intersociety boards of awards and committees: Alfred Noble Prize Committee (ASCE), Hoover Medal Board of Award (ASME), John Fritz Medal Board of Award (UET), Sperry Board of Award (ASME), Washington Award Commission (WSE). Six new appointments were made to replace those representatives whose terms expired and one representative was reappointed.

During the year the Awards Board held three meetings; two in New York and one in Boston. At its last meeting the Awards Board proposed a change in Bylaw 305 regarding the administration of the Field Awards. The purpose of the revision was to simplify the method of operation and this was approved by the Board of Directors.

Fellow Committee. At the first meeting of the committee in March, the general schedule of committee activities was reviewed and approved. During the period June–September, committee members examined and scored 321 candidates for Fellow grade. At the second (and last) meeting in October, action was taken to select 125 candidates to recommend to the Board of Directors for elevation to Fellow grade. The accompanying citations were also developed at the same time. Refinements continue to be made in the Fellow scoring procedures.

The "Call for Nominations" was expanded in 1967 to include more details and instructions considered helpful to sponsors of Fellow grade nominations.

A "Handbook for Fellow Grade Nominations" is now in preparation. With the approval of the Fellow Committee and the IEEE Executive Committee, copies will be furnished to all organizational units of the IEEE in 1968.

Finance Committee. In 1967 this committee held five meetings. During all of these meetings it reviewed the trends and financial results of operations of IEEE and compared them with the predetermined plan as expressed in the 1967 budget.

The committee selected FMR Investment Management Service, Inc., to be IEEE's investment counselor. In order to obtain the maximum benefits from the use of this outside counselor, discretionary investment powers were granted. The investment counselor currently informs the IEEE of all such transactions as they are implemented.

The Finance Committee approved the solicitation for a new computer that would be capable of performing the functions of IEEE's data processing center. The results of these bids were later forwarded to the Executive Committee, who approved the selection of the new equipment, which is to be delivered in early 1969.

The results of the annual audit, performed by independent Certified Public Accountants, were accepted by the committee and the statements as certified by Price Waterhouse were recommended for printing in SPECTRUM.

The committee decided to eliminate realized capital gains on our investments from consideration when planning the operations for the year. This was deemed necessary since the amount of realized capital gains can vary so substantially from year to year and may have been earned in a prior period.

History Committee. The activities of the 1967 committee were concentrated on obtaining articles on historical subjects for referral to the SPECTRUM editor for publication consideration. Two manuscripts have been recommended for this consideration, and several others are in various stages of preparation, review, or revision.

Among a number of other projects with which the History Committee is involved, the preparation of a history of the merger of the IRE and the AIEE to form the IEEE is of particular significance. This project is being carried out under the auspices of the committee by Nelson Hibshman, retired IEEE Executive Consultant.

Although two formal meetings were held, much of the committee work was done by correspondence.

Intersociety Relations Committee. During 1967 the ISRC continued its review of IEEE relationships with other organizations (EJC, ECPD, IEC, etc.). Following this review, procedures for the implementation of Policy 21, concerning appointments of IEEE representatives to outside organizations, were developed and put into effect. Responsibility for such appointments was delegated to the chairmen of appropriate IEEE boards and standing committees. In addition, sample report forms, schedules, etc., were developed and supplied to these chairmen so that the overall ISRC objective of a yearly review of an IEEE-representatives' assessment of IEEE's relation with that organization would be initiated.

The ISRC also reviewed and acted upon such policy matters as: payments by IEEE Groups to outside organizations; IEEE association with the College Placement Councils; GRAD Program; amendments to AFIPS Constitution and Bylaws; involvement in Intersociety Awards; a proposed constitution for EUSEC; IEEE relations with VITA; interactions of IEEE and IEE in the area of abstracts.

The ISRC Subcommittee on Scientific and Cultural Exchanges between the United States and the Soviet Union and Eastern European nations further clarified IEEE policy with respect to such exchanges and through the ISRC and Executive Committee promulgated Policy Statement 2-Q. This subcommittee also selected the 13-man delegation to the Popov Society meeting and generally looked after the requirements of this activity. It produced and distributed an extensive guide for use by the IEEE delegation.

Internal Communications Committee. 1967 marked this committee's first full year as a standing committee of the Institute. The ICC held six meetings during the year.

The ICC reviewed and commented on many Institute communications activities, including comprehensive billing and solicitation letters in connection with the 1968 Directory; and recommended new function or job title groupings, as well as new categories for industry classifications, for use in the next survey for the Directory, and reorganization of the Organizational Chart in the semiannual organization roster. The committee has looked into the handling of correspondence at the Institute and found it to be adequate. The committee also assisted the Life Member Fund Committee with its final solicitation to the Life Members. In addition, in accordance with the ICC's specifications, the Executive Committee approved new Group Chairmen, Section Chairmen, and Life Member pins, which are in the process of manufacture.

ELECTRICAL ENGINEERING is published under the jurisdiction of the ICC and the committee is responsible for the new format of this bimonthly newsletter. Additional details concerning this newsletter may be found under the Publications Section of this report.

Life Member Fund Committee. The committee decided that the investment portfolio of the Life Member Fund should be handled administratively, together with the General Institute Funds. To this end $80 477 was placed in the IEEE Institute and Section Investment Fund for which 7 400 568 shares were received.

Full support of the Regional Student Prize Contest winners in Regions 8, 9, and 10 was agreed to. This means that the cost of bringing the winners of the Regional contests in Regions 8, 9, and 10 to the 1968 IEEE International Convention will be borne by the Life Member Fund.

It was reaffirmed that $10 000 a year is available to the Standards Committee to finance expenses of delegates to International Standards meetings or to the Secretariat until 1970. To date it is interesting to note that in 1966 only $1125 and in 1967 only $847 was spent on this activity.

A plan was initiated to have Student prize winners present their papers at a special session of the IEEE International Convention.

A statement of the background of the Life Member

Fund Committee together with a description of the uses to which the fund is being put was written by Messrs. Renne and Llewellyn and included with the Life Member Fund solicitation, which was sent out in November 1967.

Long Range Planning Committee. The Long Range Planning Committee was created at the November 1967 Board of Directors meeting. The committee is responsible to the Board of Directors for reviewing the trends of science and technology as they may concern the Institute, the profession, and the public, and for recommending such changes in the Institute's objectives, organization, and operations as may be indicated by these trends.

The Long Range Planning Committee consists of the Junior Past President as chairman, the Treasurer, and two other members of the Board of Directors who are not members of the Executive Committee.

Membership and Transfers Committee. Three meetings of the committee were held in 1967. The activities can be summarized as follows:

Following the recommendations of this committee: (1) the Executive Committee approved a new policy to establish a registration fee differential for members and nonmembers at all IEEE-sponsored conferences, meetings, symposia, etc; (2) authorization was given for members of the IEEE staff to operate a Membership Services Desk at the maximum number of IEEE-sponsored conferences; (3) the Bylaws were changed to liberalize the requirements for Student Associate grade membership to allow any bona fide student who is so interested to join IEEE as a Student Associate grade member.

A new reinstatement application form was designed and printed for the use of inactive members in reinstating their membership in the IEEE.

An Associate application form was designed and printed to use primarily in promoting membership during the major IEEE conferences.

Actions were taken to stimulate the enrollment of women members in the IEEE. The Society of Women Engineers cooperated in this area by publishing in its *Newsletter* an article about the benefits of IEEE membership. Student Counselors furnished the names of young women enrolled in the electrical engineering curriculum, and special letters were written to them inviting them to join the IEEE.

Group Membership Committee Chairmen were invited to attend the committee meetings and to participate in joint efforts to promote IEEE and Group membership.

A membership drive was launched in November 1967, known as "Operation GIT" (growth, improvement, transfers). In the memorandum, issued to all organizational units of the IEEE, they were asked to support and cooperate in this drive. The objective is to obtain a 10 percent net gain in membership in the calendar year 1968.

Nominations and Appointments Committee. Three meetings of the committee were held in 1967. At the first meeting in March, the committee considered all nominations submitted by organizational units of the IEEE and selected candidates for the elective offices of the IEEE for recommendation to the Board of Directors.

This committee is also concerned with recommending the names of chairmen and members of those committees and boards reporting to the Board of Directors.

At the August meeting, the committee reviewed and agreed upon the candidates to be recommended to the Board of chairmen of standing committees and boards for the ensuing year. Following appointment by the Board, the chairmen-elect were requested to submit their recommended slates for consideration by the Nominations and Appointments Committee. Those slates, as well as all other nominations received from organizational units of the IEEE, were reviewed at the November meeting, when committee and board slates for the new year were developed for consideration by the Board.

In 1967 a special *ad hoc* study committee was appointed, charged with the task of reviewing the existing nomination procedure and recommending action to be taken to encourage maximum participation by individual members and IEEE organizational units in the submission of names of suitable candidates to be considered by the Nominations and Appointments Committee for the elective offices and for the Standing Committee and Board appointments.

Professional Relations Committee. A considerable amount of committee effort has been expended in reviewing and recommending an IEEE policy and position with respect to Canons of Ethics. A continuing dialogue has developed between the Professional Relations Committee and the Executive Committee to clarify views in this area. In addition, the Professional Relations Committee, through its members, has been intimately involved in the ECPD Development of Young Engineers Committee, the ECPD Ethics Committee, and the National Council of Engineering Examiners. The Professional Relations Committee also sponsored a well-attended special session at the 1967 IEEE International Convention entitled "Professional Relations and the Institute," chaired by C. F. Savage.

Sections Committee. The activities of this committee were considerably expanded in 1967 by the establishment of six *ad hoc* study committees created to study and recommend actions to be taken in areas found worthy of consideration by the committee. Recommendations developed by the *ad hoc* study committees were considered at three meetings of the Sections Committee, and actions taken can be reported briefly as follows:

Long Range Planning for Sections. The recommendations of this committee were referred to the chairman of the newly established Long Range Planning Committee for consideration.

Effective Programs for Continuing Education at the Section Level. The report of this committee was referred to the chairman of the newly established Educational Activities Board for information. A draft of a "Section Manual on Continuing Education" is in preparation for review by the Sections Committee.

Section Relationship with Group Chapters, Groups, and Student Branches. Following the suggestion of this *ad hoc* committee, the Board of Directors approved action to recognize the establishment of a Section Student Branch. All Sections have been encouraged to cultivate mutually beneficial relations between the Section, Students, and recent graduates.

Communications Between Sections and the IEEE. Several of the recommendations of this *ad hoc* committee, which were referred to the Publications Board and to the IEEE General Manager for consideration, have been implemented; other recommendations are still under study.

Improving the Operating Efficacy of Sections. This *ad hoc* study committee developed revisions to the IEEE Section Manual, incorporating additional information considered useful in Section operations. A new Section Manual, together with a new separate "IEEE Section Public Relations and Publicity Guide," have been provided to all Sections.

Improving Sections Committee Structure, Including the Forum for Section Chairmen. The plan of assigning specific tasks to *ad hoc* committees of the Sections Committee, which proved effective in 1967, is being continued in 1968. Studies continue on improvements to be made in the program and conduct of the Forum for Section Chairmen.

Tellers Committee. The IEEE Constitution provides that on or before September 1 a ballot shall be mailed to the voting membership to vote for the elective offices of the IEEE. All ballots received by 12:00 o'clock noon on the first working day following October 31 are counted. The Tellers Committee met on the afternoon of November 1, 1967, to supervise the counting of the ballots, with a report submitted to the Board of Directors showing the results of the vote.

In 1967 the necessary programs were developed to make it possible for the votes to be tallied on the computer at IEEE Headquarters.

Headquarters staff activities

As of December 31, 1967, there were 279 permanent employees, plus two part-time consultants, on the IEEE staff.

Personnel changes during the year included the following: Howard E. Tompkins joined the permanent staff on July 1, 1967, when the new Information Services Department was formed. Nelson S. Hibshman, Executive Consultant, retired in February 1967. J. Howard Schumacher joined the staff as Manager of Technical Services on September 5, 1967.

Report of the Treasurer—1967

Harold Chestnut

It is a pleasure to report on the financial results of IEEE operations for the year 1967. The financial statements, as audited and certified by Price Waterhouse & Co., are included on the following pages. The results of last year's activity reflect the responsible fiscal action taken by the Board of Directors under the capable presidency of Walter K. MacAdam and the membership dues change made by the prior Board under Dr. W. G. Shepherd as President.

The net results for the 1967 operations show an excess of income over expense of approximately \$342 000 from normal operations and an additional \$373 000 gain on the sale of securities. Combined, this excess of income over expenses of \$715 000 represents an improvement over 1966 of an amount in excess of \$928 000. This goes a long way toward strengthening the financial position of the Institute and partially restoring the reserves available immediately prior to the merger. During the four years following the merger, \$1 195 000 had been removed from our reserve funds to support current operations.

Membership, entrance fees, and dues accounted for 46 percent of the 1967 operating income. This is a substantial increase from the 35 percent level of the year 1966. A firm platform has now been built upon which we may construct the plans for increased services in such fields as continuing education, information services, and career guidance. The continuing growth of the membership and the related dues and fees of the Institute enable us to plan these services more effectively with less dependence upon other sources of income. With the reduction of approximately \$164 000 in advertising revenue it becomes increasingly important for the Institute to rely upon its membership dues and fees for the major source of income. Nevertheless, actions are being taken to strengthen the amount of income received from advertising.

Of the \$373 000 of gains realized from the sale of securities during 1967 only \$24 000 represented the increase in the value of those securities during the year. There is a wide fluctuation in this type of income from year to year. The market value of the securities held for the entire year 1967 increased 15.7 percent whereas in 1966 the Institute's holdings of stock and bonds decreased 8.7 percent. The decision was made not to count on these capital gains in planning our operations for future years. The market conditions experienced during the last six months reflect the wisdom of this decision. A new investment counselor, FMR Investment Management Service Inc., has been retained to manage the Institute's investments.

The estate of Frank A. Cowan bequeathed \$140 000 to IEEE during 1967 to develop an award fund in his memory. The income from this fund is to be paid yearly to an electrical engineer who shall be credited with having effected an outstanding, noteworthy accomplishment and advance in the field of creative or scientific communication techniques.

The membership of the Finance Committee has been expanded to include the Vice President, Publication Activities, and the Vice President, Technical Activities. It is believed that the inclusion of these individuals, who are responsible for major financial expenditures of the Institute, will improve the planning of the operations and the budget of the IEEE.

Auditors' report

Price Waterhouse & Co.

60 Broad Street
New York 10004
February 23, 1968

To the Board of Directors of
The Institute of Electrical and
Electronics Engineers (Incorporated)

In our opinion, subject to the final determination of the Institute's income tax liability, if any, as referred to in Note 1, the accompanying statement of financial position, the related statement of income and operating fund, and the statement of changes in restricted funds present fairly the financial position of The Institute of Electrical and Electronics Engineers (Incorporated) at December 31, 1967, and the result of its operations for the year, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year. Our examination of these statements was made in accordance with generally accepted auditing standards and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances

Price Waterhouse & Co.

THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (INCORPORATED)

COMPARATIVE STATEMENT OF INCOME AND OPERATING FUND

	For the year ended December 31	
	1967	1966
Operating income:		
Membership, entrance fees, and dues	$3,077,131	$1,971,608
Advertising	908,147	1,072,194
Periodicals subscriptions	893,879	745,289
Other publications and sales items	306,340	393,716
International Convention	1,094,814	1,043,826
Investment income	226,714	202,473*
Miscellaneous other	206,902	211,309
Total	6,713,927	5,640,415
Operating expenses:		
Headquarters services to members	847,237	829,184
Support of Regions, Sections, and Branches	547,839	424,551
Support of Groups	975,651	846,725
Periodicals publication	1,794,745	1,677,025
Other publications and sales items	290,806	403,187
International Convention	892,432	792,220
General administration	1,022,769	929,806
Total	6,371,479	5,902,698
Excess of operating income over operating expenses	342,448	(262,283)
Add—Gain on the sale of securities	373,188	49,715*
Excess (deficit) of income over expenses for the year	715,636	(212,568)
Operating fund balance, January 1	2,604,897	2,817,465
Operating fund balance, December 31	$3,320,533	$2,604,897

*Reclassified for comparative purposes.

THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (INCORPORATED)

COMPARATIVE STATEMENT OF FINANCIAL POSITION

	December 31 1967	December 31 1966
Operating Fund		
Current assets:		
Cash including $2,027,000 in certificates of deposits and a savings account (1966—$1,602,000)	$2,506,334	$2,167,117
Marketable securities, at cost, market value $5,161,000 (1966—$4,261,000) (Note 2)	4,331,862	3,731,323
Notes and accounts receivable, less doubtful accounts	269,900	297,423
Prepaid expenses, inventory, etc.	314,934	235,604
Total current assets	7,423,030	6,431,467
Less—Current liabilities:		
Accounts and accrued expenses payable	539,286	590,008
Funds held for the use of Professional Groups	919,833	895,916
Deposits by Sections (Note 2)	87,913	59,953
	1,547,032	1,545,877
Deferred income:		
Dues	1,801,871	1,760,404
Subscriptions	463,075	397,066
Convention	723,778	637,125
	2,988,724	2,794,595
Total current liabilities	4,535,756	4,340,472
Working capital	2,887,274	2,090,995
Note receivable, 6%, installments due after 1968	20,863	65,710
Fixed assets:		
Office equipment and leasehold improvements, at cost, less accumulated depreciation and amortization $358,255 (1966—$288,385)	412,396	448,192
Operating fund balance (accompanying statement) (Note 1)	3,320,533	2,604,897
Property Fund		
Advance to United Engineering Trustees, Inc. (Note 3)	265,000	265,000
Restricted Funds		
Cash	201,226	82,140
Marketable securities, at cost, market value $172,698 (1966—$133,321)	134,521	98,206
Restricted funds balance (accompanying statement)	335,747	180,346
Total funds	$3,921,280	$3,050,243

THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (INCORPORATED)

STATEMENT OF CHANGES IN RESTRICTED FUNDS FOR THE YEAR ENDED DECEMBER 31, 1967

Restricted Fund	Fund balance January 1, 1967	Receipts from contributions and marketable securities	Disbursements for awards and related costs	Fund balance December 31, 1967
Life Member Fund	$ 83,677	$ 18,648	$3,725	$ 98,600
International Electrical Congress—St. Louis Library Fund	6,710	199		6,909
Edison Medal Fund	14,323	2,243	573	15,993
Edison Endowment Fund	8,788	262	933	8,117
Lamme Medal Fund	9,406	345	333	9,418
Mailloux Fund	1,037	44		1,081
Volta Memorial Fund	15,494	610	1,245	14,859
Kettering Award Fund	2,457	107		2,564
Browder J. Thompson Memorial Prize Award Fund	5,902	181		6,083
Harry Diamond Memorial Prize Award Fund	1,189	41		1,230
Vladimir K. Zworykin Television Award Fund	4,570	2	500	4,072
W. R. G. Baker Award Fund	9,835	481		10,316
William J. Morlock Award Fund	5,663	225	625	5,263
W. W. McDowell Award Fund	10,482	409	925	9,966
William D. George Memorial Fund	813	21		834
Frank A. Cowan Award Fund		140,442		140,442
Total	$180,346	$164,260	$8,859	$335,747

NOTES TO FINANCIAL STATEMENTS

NOTE 1: In 1964 the Institute was notified by the Internal Revenue Service that the Institute's annual international conventions (and those conducted by its predecessor, The Institute of Radio Engineers Inc.) involve the operation of an unrelated trade or business and the net income therefrom, if any, is subject to federal tax. If the Service's position, which should be applicable to 1954 and subsequent years, were ultimately sustained, the amount of potential liability for taxes and interest would be material.

The Institute has filed both a tax return with respect to the test year 1954 and claims for refund in the amount of the taxes and interest paid for that year. The claims for refund have been denied. Pending further study by the Service of its position with respect to the taxation of income derived from conventions such as that conducted by the Institute, the Institute has been granted an extension of the time within which it must sue to recover the amounts in controversy.

NOTE 2: Marketable securities include $87,913 deposited by certain Sections of the Institute. Such funds with pro rata share of income and unrealized gains or losses can be withdrawn by the Sections concerned at the end of any fiscal year or quarter.

NOTE 3: In accordance with a Founder's agreement between the Institute and the United Engineering Trustees, Inc., the Institute has agreed to maintain permanently its principal offices in the United Engineering Center, which currently involves an annual lease payment of approximately $180,000. The $265,000 advanced to United Engineering Trustees, Inc., is repayable only out of available reserved funds on dissolution of United Engineering Trustees, Inc., and carries interest at an annual rate of 4 percent.

NOTE 4: The Institute has voluntary noncontributory pension plans covering its employees. The pension cost for the year for such plans was $73,143, which included amortization of past service cost over 20 years. Unfunded past service cost at December 31, 1967, is approximately $180,300.

During 1967 the plan was amended to provide vested benefits for employees who meet certain minimum requirements. This amendment has been approved by the Internal Revenue Service.

Scanning the issues

Transportation: Cosmic Needs. Suppose, writes John E. Gibson in the opening paper of a colossal special issue of the PROCEEDINGS OF THE IEEE, as President of the United States, you were considering the social and political payoff of a proposed "national goal." You would certainly require it to be simple and specific enough for the average voter to understand and capable of stirring his imagination. "A man on the moon in this decade" admirably fits these criteria but it rates somewhat lower on certain other important indexes such as direct social benefit to the average voter. The "Great Society" on the other hand rates very high on those criteria of social usefulness in which the space race is lacking, but it poses an obvious though unanswerable question. How will we know the "Great Society" has arrived?

For contrast, Gibson goes on, consider another possible national goal: a new industry that is potentially four to five times as big as the space business, which will call upon the same high level of technical and scientific imagination as space but in addition will provide a use for the great bulk of our present industrial production and indeed absorb more relatively unskilled workers than we can presently use. The goal would be one all our citizens could watch being achieved and one whose attainment would provide a measurably better life for all our people. The goal is: *to provide high-speed transportation between all of the major cities of the continental United States, free for all citizens, by 1985.*

In light of all the multiple forces we know now to be working in American society, and in view of the shattering social effects technology has had on all contemporary civilizations, Gibson's statement has a breathtaking appeal, and one which all of us should weigh most seriously. In this respect, the PROCEEDINGS' special issue on transportation is probably one of the most important such issues to appear in some time. It concerns a subject of the widest possible interest and responsibility. For, in dealing with systems of transportation at this stage in our development, one is dealing with the whole fabric, torn as it now is, of our technological society.

The consciousness of this importance registers itself across the pages of this issue. The questions inherent in such a "megaproposal" must have reverberations at every level of our lives. If one reads Gibson's paper alone in this superb issue, one must be emotionally obtuse not to be moved. But having read Gibson's "National Goals in Transportation," which he calls "thoughts that occurred to one of the board of editors in the process of assembling the issue," one will want to read much more.

There are 29 papers, almost all invited, organized under three major categories: socio-politico-economic aspects of transportation; transportation system engineering; and specific systems and components. The issue covers transportation by land, by sea, and by air. Only space travel is excluded.

In terms of Gibson's proposed goal, there are, of course, very searching questions that must be asked, as he notes. Does such a goal make technical and economic sense? What will such a transportation system do to our society? The technical questions involved, which should be approached by considering the overall transportation system of the United States and perhaps the world, will surely begin to be taken up by the new U.S. Department of Transportation (DOT). As Alan S. Boyd, the Secretary of DOT, reports in an article on that Department, although it is less than a year old, the Department has 94 000 employees and is already the fourth-largest department in the President's Cabinet. And, adds Boyd, the Department is big because transportation is big. DOT has already published several reports on the research and development needs in such special areas as high-speed ground transportation (HSGT). However, Gibson warns that DOT may have its hands full in the near future with already established transportation elements such as automobiles and railroads; furthermore, the mandate to regulate transportation questions is fractionated among three U.S. Departments—DOT, the Department of Commerce, and the Department of Housing and Urban Development (HUD)—thus creating a potential hindrance to large-scale systems studies.

Gibson relates that there has been no systems study of national transportation needs as a whole. This is most obvious at the interconnection points (so-called interfaces) between the existing disparate elements. For example, there is not a single major airport in the United States today that presently provides adequate ground transportation. Not a single airport is adequately connected to the subway or traction system of the city it serves. Air transportation, in other words, was simply superimposed on other forms of transport with no thought given to consequent incongruities. Addition of jumbo jets and the supersonic transport (SST) will further intensify the problem. Of course, Gibson reflects, there was nobody with the required responsibility or authority to have done anything about it on a national scale even if adequate systems planning had been prosecuted immediately after World War II when the escalation to air transport really began. More to the point, there were no people trained to do such system studies even if the need for such planning had been recognized 20 years ago. Today, this is not true. The people and the techniques, Gibson writes, are ready. In fact, there are a number of corporations that claim such systems analysis techniques as their special competence.

Granted all this, what's the rush to do such systems analysis? Gibson admits this is a bad time to be proposing expensive new government projects. Why not wait ten years till we really need it? His own answer is to cite several of the articles in the special issue, such as J. C. Beckett's description of the San Francisco Bay area transportation plan, for which the first study was completed in 1957 and which is not yet operating, and the SST, for which the first study began in 1952. If these relatively small elements of a national plan take 15 to 20 years to mature, Gibson writes, it seems apparent that without a crash program a skeleton national system could not be in operation before 1985 to 1990. We must begin *now*, he urges, if a fully integrated system is to be operating in the year 2000.

Furthermore, he sees it as apparent that such a national system must be planned and directed by the Federal Government. This point is reinforced, he notes, in "TALUS: The Detroit Regional Transportation and Land Use Study," by I. J. Rubin, who points out that transportation must be integrated with other elements of city planning. It seems apparent, Gibson continues, that the United States is entering a period of increasing emphasis on urban renewal. It would be tragic if such planning were done without regard to the importance of the national transportation problem. We do not lack for transportation at present, he stresses, we lack for a *system*. A city or a state cannot be expected to take the national view when deciding issues that will have a major local economic effect, yet difficult decisions of this sort will abound in planning the national system.

Naturally, very deep social questions cannot be ignored, for the way transportation is treated will influence local commerce and industry. That is, though technically the problem is to move goods and people efficiently, the creation of transportation links will *cause* people to move in ways they would not otherwise have dreamed of.

Another point is that planners who think in terms of 20- to 30-year periods should almost ignore the shape of the cities as they are now in order to concentrate on how they should be. City planners now despairing on the interchange problem in future urban mass-transit schemes for grid or radial cities are working, Gibson says, on the wrong problems. Furthermore, the systems analyst working in transportation must consider land use as well and indeed the entire sociological and ecological fabric of our society. Moreover, he must help weave this fabric while it is being used.

Gibson also brings up the goal of a constant elapsed time for any journey on the globe, a time that he says should not exceed four hours (e.g., one might go up to 300 km or so in a personal vehicle in four hours, and go halfway around the globe in an SST in four hours). In an integrated transport system, for instance, a city 80 km long and four blocks wide would be *square* in the sense of time, because it would take, say, 20 minutes to walk across it, and 20 minutes to ride its length in a 400-km/h transit system.

In the context of this argument, Gibson notes that Constantinos Doxiadis, the internationally known city planner, has pointed out that to be truly viable the urban environment must be one that can be navigated on foot. Either this should be recognized or the city should be redesigned to take into account rapid transportation of the kind stipulated for the linear or squared-in-time city.

Constantinos Doxiadis himself is represented in this issue by an article, "The Emerging Great Lakes Megalopolis," which in itself merits real attention. It deals at length with the emergence of a new type of human settlement in this century, huge tightly bonded regions with large populations. For those who do not read about megalopolises in this special issue, there may perhaps be a future occasion for them to find in SPECTRUM more about Doxiadis and *ekistics*, the science of human settlements, which brings architects, engineers, city planners, political scientists, and many others, to work together on an equal footing.

Other matters of interest in Gibson's relatively brief but rich essay are hybrid personal vehicles, computer-controlled transport systems, and high-speed ground transportation.

Not to be neglected, either, among the broad background papers is "The Status of Transportation," by William W. Seifert.

The second part of the special issue—which examines transportation systems theory, recent experiences with several studies, and specific technical areas having broad significance in transportation—and the third part—which reports on a group of exciting subsystems and components—have been neglected here in favor of the larger, even cosmic, perspective offered in the papers mentioned.

What about that "free" part of the goal proposed by Gibson? What will it do? What would, Gibson asks, increased mobility do to our social structure? Would local government be destroyed? Would regional differences vanish? Would citizens develop a complete indifference to local betterment, feeling they could always move on?

Humanists sometimes argue, Gibson concludes, that technology drops strange burdens on them without warning. Well, here is a ten-year warning concerning a very basic commodity in our present life, transportation. Now, Gibson urges, you humanists, get busy!

Although Gibson doesn't say it, there is no reason whatsoever why engineers should not feel fitted for his category of humanist, and consequently feel the responsibility of being called upon. (*Proc. of the IEEE*, April 1968.)

Superstaticlogilisticsensoraliocious. A sure way to get attention in a field overwrought with publications is to select a suitable and, if not suitable, catchy title. Ian Watson and Raymond Krekel have succeeded with their tactic. Their article title, which includes the verbal concretion above, for which we adopt here, for the one and only occasion, the acronym "SOS," is "SOS or Automation—Where Next?" Their subject is automation in the cement industry, and they envision a lot of it.

Our motto here in the Scanning Department is that it's O.K. to have fun, but writers for the IEEE publications who wish to have their articles scanned had better be warned that we do not intend to be taken in by such foul trickery again. Those who are mystified by SOS or who have an interest in cement will, of course, seek out the appropriate TRANSACTIONS. (I. M. Watson and R. J. Krekel, "SOS or Automation—Where Next?" *IEEE Trans. on Industry and General Applications*, January/February 1968.)

Reading Machines for the Blind. The efforts to devise reading machines with a sound output for blind persons has been going on for some years now but without much real success. Those who are concerned with these endeavors should be interested in an inexpensive reading machine reported in a recent paper by Michael Beddoes.

An early form of simple reading machine, the Optophone, has been exhaustively explored by investigators throughout the world. Generally, this machine has been found to fulfill the requirements of being cheap and portable, both of which are important for a "personal" machine. But it has also been unfortunately the experience that reading English text with the Optophone is so exceedingly slow and difficult that all but a very few talented blind people are deterred from using it.

In his paper, Beddoes suggests that an alternative auditory code might embody features that would alleviate the reading problem. He suggests a "musical" code that has a high degree of coalescence, and which physically takes the form of a frequency-modulated square wave. All the letters of the alphabet, both lower case and upper case, as well as numbers, can be identified by their corresponding code sounds. The code sounds are reported to be quite pleasant.

Beddoes also describes experiments using a time compressor, and he suggests that this machine can simplify the code signals and make the task of identifying one code sound from another easier. (M. P. Beddoes, "An Inexpensive Reading Instrument with a Sound Output for the Blind," *IEEE Trans. on Bio-Medical Engineering*, April 1968.)

Advance abstracts

The IEEE publications listed and abstracted below will be available shortly. Single copies may be ordered from IEEE, 345 East 47 Street, New York, N.Y. 10017. Prices are listed with the abstracts of each publication; libraries and nonmembers outside the United States and Canada should add $0.50. (M—Members; L—Libraries; NM—Nonmembers.)

Copies of individual articles are not available from IEEE but may be purchased from the Engineering Societies Library at the foregoing address.

Proceedings of the IEEE

Vol. 56, no. 6, June 1968
M—$2.00; L—$3.00; NM—$4.00

(Special Issue on Studies of Neural Elements and Systems)

Specifications for Nerve Membrane Models, *J. W. Moore*—The limitations of models that can generate "action potentials" are discussed and reasons are given for testing all proposed membrane models by comparison with voltage-clamp data. Some background information is provided and the voltage-clamp methodology reviewed. Many of the membrane electrical characteristics measured by this technique are discussed and some recent observations are given to illustrate the additional data against which models should be tested now. Selected proposals for membrane models are reviewed and compared with one another and with voltage-clamp measurements.

Fluctuation Phenomena in Nerve Membrane, *A. A. Verveen, H. E. Derksen*—The fluctuations of the voltage across the resting membrane of myelinated nerve fibers have been analyzed. They show a $1/f$ spectrum and a Gaussian amplitude distribution and are related to the net flow of potassium through the membrane. When the average membrane voltage is made more negative by means of an external current, depolarizing deflections can be observed. They cause an asymmetry in the noise amplitude distribution and a marked increase in the subaudio spectral components of the noise. The depolarizing deflections can be attributed to batch-wise inflow of sodium ions. Possible mechanisms of both types of membrane voltage fluctuations are discussed.

Synaptic Physiology, *C. F. Stevens*—The sequence of events from axon terminal depolarization to integration of information by summation of separate synaptic effects is described. Following depolarization of the terminal, transmitter substance is released probabilistically in integral multiples of a basic quantity, the transmitter unit. The average rate of unit release depends upon membrane potential, ion concentrations (particularly calcium) in the bathing medium, the quantity of transmitter available for release, and the history of synaptic use. After diffusing across the synaptic cleft, transmitter molecules interact with receptor sites on the postsynaptic membrane and cause the conductance for certain ions to increase; meanwhile, the transmitter is destroyed enzymatically or lost from the vicinity of the postsynaptic membrane by diffusion. The effects from the simultaneous action of many synapses add—often linearly—to permit information from many sources to be combined in a single neuron.

Using Electronic Circuits to Model Simple Neuroelectric Interactions, *E. R. Lewis*—The Hodgkin–Huxley description of electrically excitable conductances is combined with the Eccles description of synaptic conductances to provide the basis of an electronic model of nerve-cell membrane. The models are used to explore neuroelectric interactions between spatially distributed regions of a single neuron and neuroelectric activities in very small groups of neurons. Among other things, oscillations are found to conduct with progressively increasing phase lead along an axon model. Miniature reflected spikes from a trigger region are able to reset slow potentials in an integrative region. Spike synchrony is found to be common in a mutually inhibiting pair of neural models. Spike bursts occur in a mutually exciting pair. Electrical connection between trigger regions is found to be excitatory or inhibitory, depending on phase relations. A simpler electronic model is described and shown to be reasonably adequate for simulation of small neural nets.

The Tracing of Pathways in the Central Nervous System, *L. Heimer*—Fiber connections in the central nervous system are studied both in normal material—especially with the aid of the Golgi technique—and in experimental material. Following an experimentally induced lesion of a nerve fiber or its cell body, the fiber peripheral to the point of the lesion starts to degenerate, a process termed anterograde degeneration. The first morphological sign of degeneration is an irregular outline of the fiber followed by varicosities and "drop-like" disintegration of the axon. The degenerated nerve fiber can be impregnated, and thus traced to its termination, with silver-impregnation methods, most of which are modifications of the reduced silver-impregnation technique described independently by Bielschowsky and Ramón y Cajal at the turn of the century. Although the silver-impregnation technique is extremely demanding, it can, when conditions are optimal, identify the synaptic fields of fiber tracts with a clarity equalled by no other method. The electron-microscope technique has recently been introduced into experimental neuroanatomy, and we are currently witnessing one of the most dramatic developments in the study of interneuronal connections. The ultrastructural features of anterograde degeneration—including, among others, a general increase in electron density of the axoplasm—are specific enough to allow for an electron-microscope diagnosis of degenerating terminal end structures, and electron-microscope identification of axon degeneration is rapidly becoming a routine procedure in neuroanatomic laboratories. It must be emphasized, however, that successful application of the electron microscope in experimental neuroanatomy requires a continuous "feedback" from adequate light-microscope observations. Moreover, the serial combination of light-microscope analysis, with Golgi or reduced silver techniques, and electron-microscope analysis of one and the same specimen has very recently opened up some most promising lines of inquiry. Although remarkable progress in the study of interneuronal connections has been made during the last few decades, there is a never-ceasing need for more refined and more sensitive neuroanatomic techniques. Clearly, technical improvements, in both the design and performance of neuroanatomical methods, must be given highest priority if neuroanatomy is to remain abreast of neurophysiology in the joint attempt to elucidate the composition of neuron circuits.

Structuro-Functional Considerations of the Cerebellar Neuron Network, *J. Szentágothai*—The neuronal network of the cerebellar cortex is discussed with strong emphasis upon its structure but taking into consideration the recently revealed functional properties of its various neuronal elements. From the viewpoint of the experimenter this neuron network has the unique advantage of being arranged in the form of a highly regular rectangular lattice and being built up of relatively few well-known structural elements. After consideration of certain structural features of the granular layer (the receiving area of one of the two main lines of input), suggesting some important preprocessing of the arriving information, the mode of transmission of this excitation to the main part of the cortex is discussed. A functional model of the operation of the main neuron network is then proposed, based on the known geometry and functional properties of the elements involved. Some additional speculations are made about the possible functional significance of the most unusual structural feature of the cerebellar cortex: the complete separation in space (compartmentalization) of the Purkinje cell dendritic trees.

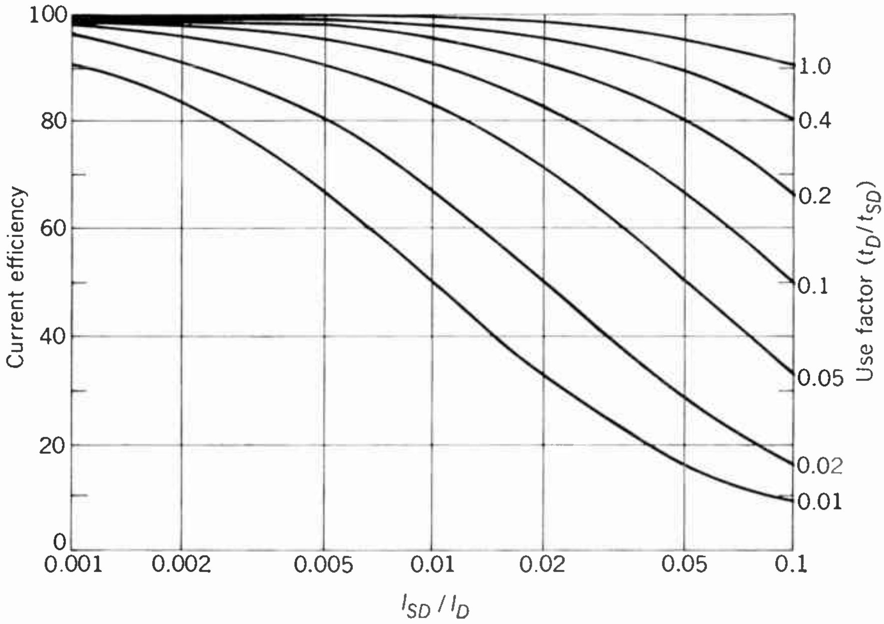
Neural Coding in the Bullfrog's Auditory System: A Teleological Approach, *L. S.*

Technical correspondence

Correction!

In the article on "Electrochemical Vehicle Power Plants" by D. A. J. Swinkels in the May issue of IEEE SPECTRUM (pp. 71–77), the printer inadvertently reversed the color plate, and thus the shape of the curves, for Fig. 1 on page 73. The illustration should appear as below.

Figure 1. Current efficiency as a function of self-discharge and use factor; Eq. (3).



Engineering education

I am very disturbed by the article on "Education for Innovation" by D. V. De Simone (January IEEE SPECTRUM). The case for innovation in engineering education, although eloquently stated, is disappointingly barren of imagination. Granted, there is a need to encourage inventiveness and creativity in engineering, as well as other professions. However, it seems illogical to expect every engineer to be an inventor, just as illogical as it is to expect that creativity can be taught in school. The creativity of a student can be enhanced greatly, but if the seeds are not there to begin with, the greatest teacher could not provide the student with the tools to be creative.

It is a sad thing to have to admit, but the average engineering student is far from being endowed with creative abilities, which, if nourished, would change the world for the better.

Dr. De Simone lists seven examples of how students could be given better opportunities for development. It is with these proposals that I find the most disagreement. Dr. De Simone tries to apply conventional and unimaginative means to solve a problem (I see a broader problem—one concerning education in general) that requires creativity and innovation.

Every aspect of life has changed drastically through the years, with the exception of education. Essentially, what is thought to be the education of an individual is actually a programming—exactly as one would program a computer, specifying certain facts and asking him to store them. A computer is much more efficient and much less fallible for storing information, so why not relegate that task to computers?

Another example of Dr. De Simone's unimaginative approach is his "analog of the medical internship and the legal clerkship. . .for engineering education." This system of "engineer internship" has been in use in Europe for years, and is not a new idea.

The author suggests that the system of "feedback" is not the ideal one, but he proposes nothing to replace it. He also hints that an undue amount of emphasis is placed on grades, and yet he can only weakly state that a system of pass–fail is being used in few instances and that it does have some advantages over regular grading systems.

Dr. De Simone's article talks about "education for innovation." The phrase is a very catchy one, but I am afraid that is all it is—a phrase. Before we can talk about teaching the student to be an innovator, we have to come to grips with some practical problems that seem to be avoided or overlooked by most educators and people in positions to do something about them.

These problems are:

1. The fact that students study only to do well on exams and not necessarily to learn. Under these circumstances, grades lose their meaning. What started out as a measure of learning, the grade, has become an end in itself. The fact that fraternity files are full of copies of old exams only points to the realization that a student can look over the previous tests and be able to solve a few specific problems and reap the undeserved rewards of a good grade. The aim of education, at one time, was to learn; now, it is to get good grades. There is something basically disturbing in this situation.

2. The faculty is made up of incapable teachers, for the most part. The fact that someone has a Ph.D. degree and that he "knows his stuff" does not mean that he has the ability to impart this knowledge to a group of students. There are very few dedicated people with teaching ability in our colleges, and the few who do have these attributes are usually more preoccupied with their research than the class they teach. There is nothing more boring than sitting for an hour and listening to some professor, talking in a monotone, read his notes, which are usually a poor paraphrase of the textbook (with mistakes to boot). A situation such as this not only will stifle inventiveness, but will make the student lose all interest in the subject matter.

3. The very content of the engineer-

ing curriculum is obsolete. There is a great time lag between innovations in the field of engineering and their adoption by colleges as material for study. A perfect example of this is in microelectronics: printed circuits are being used widely (even in simple projects of magazines like *Popular Electronics*), yet very few colleges offer courses dealing with this vital aspect of electrical engineering. The second aspect of this obsolescence, brought out by Dr. De Simone, is the "cookbook" type of approach that dulls the imagination of the student.

4. Obtaining an engineering degree from colleges, as they exist today, is a boring experience. The whole setup of educational institutions is such as to make going to school a "drag." Why should this be so? Any psychologist will agree that the happier, the more motivated, a student is, the better he is going to perform and the easier he will learn. This applies to all phases of education, from grade school through postgraduate studies.

I have attempted to summarize some of what I consider to be the basic inadequacies of the educational systems of today. I do not have all the answers or easy solutions to the problems I have cited. I do, however, have some ideas that are, although unorthodox, practicable, and that should be brought out for consideration. Even if my ideas are not put into practice, I feel certain that they would at least point out some new directions in educational procedures, not only in engineering but in all areas of education.

M. M. Cirovic
Jackson Heights, N.Y.

Either there has been a failure of communication or Mr. Cirovic is knocking down open doors. First of all, the article does not purport to "wrap up" the problems of education (nor does the book, which covers much, much more), and there is not the faintest suggestion that such propositions as internships are novel.

Second, there are few truly outstanding inventors, innovators, and entrepreneurs, and nobody expects all engineering students to reach that level of attainment. But a pintful is just as full as a gallonful, and every student's creative potential, whether it measures a pint or a gallon, ought to be fully encouraged. That is what self-fulfillment is about. Is there a higher aim for education?

Mr. Cirovic states that "if the seeds are not there to begin with, the greatest teacher could not provide the student with the tools to be creative." How are Mr. Cirovic's "seeds" to be identified, and what of the rest? What is needed is not "tools," but an *environment* in which creativity can fluorish, whatever its measure.

A final note of puzzlement: Mr. Cirovic excoriates the writer for his criticism of the system of grading and then, *mirabile dictu*, embraces this theme as the first problem with which we have "to come to grips."

D. V. De Simone
National Bureau of Standards
Washington, D.C.

I enjoyed the excellent article in the January issue of IEEE SPECTRUM by Dr. D. V. De Simone on "Education for Innovation." Right at the outset, I shall pledge my agreement with the author on most basic points. However, when reading his article, as soon as one reaches the conclusion and the résumé of the six themes that Dr. De Simone proposes, it is almost like reading one of those "dreary Ph.D. engineering theses."

In other words, what can the engineering educator do about education for innovation today in his classes? Or, perhaps, the engineering educator is not the most appropriate element of this feedback loop at which to start. Certainly, the most dominant parameters of this loop are the government, the foundations, and industry. They are mainly influencing and paying for engineering research, although their deeper motive can hardly be characterized as "loving them (the creative individuals) and what they do." This quotation of Jacob Rabinow points perhaps to the core of the problems that creative students and engineers encounter.

It is often suggested, and endorsed by Dr. De Simone in his article, that an analog of the medical internship and the legal clerkship should be considered for engineering education. It is doubtful whether an analogy can be established here. The medical profession is dealing with a human-animal design that has been precisely the same for the last 20 000 years. The legal profession is more concerned about the past than the future; an "established precedent" is revered more than anything else.

On the other hand, the engineering profession has to deal with problems of today and tomorrow, problems extremely fluid and everchanging, problems that are not yet even clearly defined in some instances, problems whose solutions are very little assisted by the experience of the past.

Consequently, any kind of "internship" offered by the engineering schools runs the risk of becoming quickly obsolete or not relevant to new industries. That is why industry assumed the role of providing this "internship" itself by giving training periods to fresh graduates, etc., thus being able to orient this training toward its particular interests and products.

That is also one of the reasons why engineering has turned more and more toward the fundamentals and the structure of scientific knowledge; because the procedures and designs of yesterday will not necessarily solve the problems of today and tomorrow.

But surely engineering has overdone it. I must agree with Dr. De Simone—that when an alarming majority of Ph.D. theses profess no interest in the application of new knowledge to the solution of practical problems, when it is possible to obtain a Ph.D. degree in engineering via applied mathematics, it is about time for the pendulum to start swinging toward the other direction, as many engineering educators undoubtedly recognize. Perhaps an event more startling than the launching of the Russian Sputnik ten years ago is needed today to reverse the course of the pendulum.

One last comment about the role of computers in higher education. The computer is not by any measure an encephalic syringe that will instill knowledge, wisdom, and creativity into the minds of the students. That has always been and most probably always will be a time-consuming and rather slow process.

In conclusion, I want to express my hope that some influential people in the universities, the government, the industry, the foundations, and the professional associations read Dr. De Simone's forthcoming book, and that they decide to do something about education for innovation.

T. J. Jordanides
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Although I agree with, and indeed applaud, Daniel V. De Simone's article, "Education for Innovation," I must nevertheless put forward one point in defense of the American universities' grading system and its British equivalent, the dreaded annual examination.

My point is simply that, until the

engineering student has acquired at least a modicum of factual knowledge, he is in no position to indulge in any form of creativity whatsoever. In this, he differs from the student of English, for example, who can, on entry, already read and write, or the student of music, who can both perform adequately and is familiar with musical notation.

In other words, the prospective engineer learns *his* grammar, syntax, and notation at the university rather than at high school.

The real danger lies in the disinclination of most engineering departments to allow free rein to a creative student as soon as he demonstrates that his memory banks are sufficiently well stocked, thus stultifying his development as a useful engineer.

This danger is, however, recognized by some schools, including my own (the University of Wales), where the class of degree eventually awarded depends to great extent upon the quality of an original design or investigation, which the student carries out during his final year. Moreover, as soon as any creative talent is recognized in a student (which usually becomes evident about halfway through his course), he is allowed to abandon normal laboratory experimentation and pursue original work. Also, again noting Dr. De Simone's comments, design projects for higher degree work (including Ph.D.) are actively encouraged, providing that the level of endeavor promised by the project is sufficiently high.

It may be that the lack of interest in engineering design has its roots in that part of the academic community which feels that, to conform with current ivory-tower requirements (and, incidentally, obtain promotions), it must produce highly analytical papers in "respectable" journals. This is entirely analogous to the situation in departments of English, for example, where it is apparently more praiseworthy to produce a critique of a work rather than the work itself.[1]

In engineering, it is sometimes the case that ideas and designs of high originality appear first in the academically disdained commercial glossies, to be followed much later by painstaking but usually sterile analyses in the more "respectable" press.

J. Watson
University of California
Davis, Calif.

REFERENCE

1. Quartermain, P. A., and Watson, J., "English, engineering, and creativity," *J. Creative Behavior*, vol. 1, no. 4, 1967.

Book reviews

Mahlon Loomis—Inventor of Radio, Thomas Appleby—*Loomis Publications, P.O. Box 6318, Washington, D.C., 1967; illus., pbbk., $3.25.* This is a carefully documented review of the life efforts of a dedicated experimenter, and constitutes a contribution to the literature of scientific history concerning persons credited with making new basic discoveries or inventions. The book discloses almost every facet of Loomis' life, his fascination with scientific questions, his natural inclination to innovate, his experiments and apparatus, his accomplishments and disappointments, and it displays apparently all the documentation that could be found.

Loomis gave up the profession of dentistry to pursue, at his own expense, experimental verification of his concept that the upper strata of the atmosphere could conduct electricity and therefore might be used for communication by electric telegraphy. Taking note of the earlier discovery that the earth could be used as a return conductor for telegraphy so that only one wire was required, he reasoned that this single wire could be done away with by using the atmosphere in its place. The concept also embodied the idea that the atmosphere contained vast charges of electricity as demonstrated by lightning, from which energy could be taken to power such a telegraph system and for other purposes. Following some encouraging experiments, Loomis was able to secure a U.S. Patent and then planned to span the oceans using, for example, the Rocky Mountains and the Alps for terminals. Failure to secure a money grant from the U.S. Congress and the drying up of other promising sources of capital forced him to return to the practice of dentistry in order to survive. He died in obscurity, a lonely and disappointed man.

Loomis apparently envisaged a dc telegraph system. Stating that the electricity in the atmosphere was oppositely charged to that in the earth, he believed that currents would flow through air and ground by tapping the atmosphere with two elevated grounded wires put on mountain tops. The instrumentation he used implemented this simple plan. A galvanometer in such a wire at one location should respond to the expected flow of electricity in a similar wire at another location and intelligence could be conveyed by interrupting this flow with a telegraph key inserted in that wire. The evidence indicates that intelligible signals were transmitted in this manner, although Loomis' notes on his experiments were lacking in detail and statements by witnesses were not very illuminating. Explanations of his method did not include how it could be applied in practice, such as the problem of transmitting several messages simultaneously.

The last half of the 19th century was replete with the gradual unfolding of basic scientific information, particularly on electricity. In Loomis' day little of this had been revealed, and many phenomena were mysteries even to the scholars who made discoveries. These new insights captivated the learned and stimulated interest in many social circles. People tended to explain the unknown with speculative theories, just as is done today; and some were carried away by their enthusiasm. Mankind profited greatly from their energy and devotion to the cause of progress.

Loomis, whose vocation was not that of a scholar pursuing scientific researches, was one of these enthusiasts. He had, for some years, informed himself on the state of the art of electrical phenonema. His unique concept was evolved in 1864. Maxwell's classical paper on electromagnetic wave theory appeared a year later, and was experimentally verified by Hertz two years after Loomis died in 1886. All evidence disclosed in the book indicates that Loomis had no conception of radiated energy and electromagnetic waves. It seems that his experimental successes derived not from his thesis but from wave radiation resulting from spark discharges when his transmitting wire was opened since this wire traversed fields having large electric potential differences. The dc galvanometer apparently responded to the corresponding oscillatory currents induced in the receiving wire because of fortuitous circumstances inherent in the instrument and its environment of which he was unaware.

The appellation, "Inventor of Radio," must be evaluated in the light of these circumstances. It was perfectly natural for Loomis not to understand what he was dealing with at a time when basic knowledge was so rudimentary. However, when comparing his work with that of other pioneers, it should be realized that there is a considerable difference in degree of accomplishment accorded those who made or stumbled onto discoveries without understanding the underlying scientific principles and those such as Hertz, Marconi, Popov, and others, who were aware to a considerable degree of the natural phenomena involved

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Microwave Communications, D. J. Angelakos and T. E. Everhart—*McGraw-Hill Book Company, Inc., 330 W. 42 St., New York, N.Y., 1968; 240 pages, illus., $11.50.* This book is intended as the text for a one-semester course for seniors. Chapter headings appear as electromagnetic fields, microwave amplifiers and oscillators, solid-state microwave devices, antennas, propagation of radio waves, noise, and specific microwave communication systems.

Any instructor using this book will find that there is need for considerable increase in scope well beyond the somewhat narrow limits the authors have established for themselves. For example, the chapter on microwave amplifiers and oscillators is restricted to a discussion of the limitations of conventional tubes and a discussion of the two-cavity and reflex klystrons as well as the traveling-wave tube. There is no mention of the magnetron or BWO. The chapter on solid-state microwave devices is limited to a discussion of the tunnel diode, parametric amplifier, and maser. In view of the present state of the art it seems quite strange that such a book (appearing in 1968) should not discuss the microwave transistor, the varactor harmonic generator, etc. The chapters on antennas, propagation, and noise are informative though perfunctory. It was surprising to the reviewer that the specific microwave communication system discussed was an unsophisticated radar system.

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Fiber Optics—Principles and Applications, N. S. Kapany—*Academic Press, Inc., 111 Fifth Ave., New York, N.Y., 1967; 351 pages, illus., $17.50.* This