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THE NEW ELECTRONICS
The New Electronics: The Design and Operation of Microwave Devices

Despite cutbacks in federal support, growth prospects for the electronics industry remain good. Particularly promising are new solid state microwave devices, discussed technically and in terms of their potential applications by Professor G. Conrad Dalman, who has been a research leader in this field since it began opening up in the 1960s.

The New Electronics: Crystals for Microwave Communication

Professor Lester F. Eastman, of the long-standing “Dalman and Eastman” research team at Cornell, discusses the development of an imminent new era in electronics, comparable in scope to that of transistor applications. Cornell contributions to the advancement of the “new electronics” are highlighted.

Commentary

The responsibility that engineering schools must assume in the area of environmental and other social concerns is discussed by Walter R. Lynn, director of the School of Civil and Environmental Engineering at Cornell.

Vantage

Academic Rush Week, student-to-student counseling, the Engineering Counseling Center, Cornell News Briefs, faculty workshops—all new and part of the College’s expanded advising and counseling services for freshmen and sophomores—are shown in a photoessay.

Register

Four retiring engineering professors are saluted, and D. Ray Fulkerson is welcomed as the incoming Maxwell M. Upson Professor of Engineering in the Department of Operations Research.

Faculty Publications

Editorial
Anyone today voicing optimism for electronics engineering might well be considered unrealistic in view of our changing national priorities. Funding by the Department of Defense, which accounted for almost half of the income of the electronics industry during the past decade, is now being drastically reduced and the emphasis in federal support is shifting to such areas as pollution control, biomedical research, and socially oriented research. The electronics industry is faced with the necessity of creating large new commercial outlets for its products if it is to expand or even to continue operations at the present level.

Fortunately, many new markets appear on the horizon. Particularly promising is the enormous commercial potential of solid state devices operating in the microwave range, devices which can, in fact, bring about a revolutionary change in communications systems because of their low cost, high reliability, low power consumption, and small size. The large number of frequencies available in the microwave region is opening up a vastly increased number of communications channels, and the simultaneous transmission of millions of messages of various kinds is now possible. Microwave devices can be used, for example, to transmit huge amounts of information to or from large-scale digital computer systems (and so represent the needed next step in the utilization of these systems, which were themselves made possible by the earlier development of transistors and integrated circuits). It is also possible for the industry to design and build new low-cost, highly reliable navigational aids, aircraft altimeters, traffic controllers, and television and telephone transmission systems, all based on solid state microwave devices.

In fact, the U.S. Department of Commerce forecasts in its *U.S. Industrial Outlook 1971* that the phenomenal growth of the electronics industry over the past ten years should be almost repeated over the next decade. This prediction parallels and confirms conclusions drawn from the results of a recent independent survey made by Albert Socolovsky, editor of *The Electronic Engineer*, a news magazine for specialists in this field.

The pioneering work of W. T. Read of Bell Telephone Laboratories, C. Hilsum of the Royal Radar Establishment in England, and J. B. Gunn of IBM, which showed that certain crystals such as gallium arsenide, silicon, and germanium can, under certain conditions, generate or amplify electrical signals at microwave frequencies, proved to be revolutionary discoveries in solid state electronics. Their work has made possible microwave solid state devices with high power and efficiency, high operating frequencies, broader bandwidths of energy transmission, and low operating noise levels, all of which can be incorporated into new or significantly improved systems of great commercial importance.

Perhaps if we examine how one of these new microwave solid state devices is built and how it operates, a better insight into this novel and growing field of electronics will be gained. The IMPATT diode, a version of Read's avalanche transit time diode,
furnishes a good example.

IMPATT is an acronym of IMPact ionization Avalanche Transit Time. Diodes of this type are efficient generators and amplifiers of microwave signals: continuous power levels ranging from a few milliwatts to a few watts can be produced at frequencies from about 2,000 megahertz to about 300,000 megahertz.

The diode consists of a layer of lightly doped n-type silicon (N in Figure 1) adjacent to a heavily doped p-type silicon layer (P⁺ in Figure 1). “Doped” means that an impurity in just the amount needed for the desired electrical effect is added to the semiconducting crystalline material during its preparation; “n-type” and “p-type” refer to materials that have negatively charged carriers and those that contain positively charged “holes” created by loss of electrons through impact.

There are two important zones within an IMPATT diode: (1) a thin avalanche zone near the P⁺-N boundary (see Figure 1) where charges gain sufficient energy from a strong applied field to produce an ionization upon

Figure 1. The IMPATT diode.
Work with graduate students is an important part of Professor Dolman's research activities. In recent years, most of the thesis research conducted under his supervision has been in the area of bulk and transit time microwave solid state devices. Among current projects is a program sponsored by the Air Force for the development of the art of peak power generation in LSA oscillators, and an NSF-supported investigation of noise in microwave semiconductor oscillators and amplifiers. The IMPATT diode discussed in this article is among the devices whose ultimate capabilities are now being explored.
impact with the crystal lattice, the total effect being a large multiplication of charge carriers within the crystal; and (2) the drift zone, which occupies practically all of the N silicon layer and through which the current amplified in the avalanche zone passes with no change in amplitude but with a delay in phase. All other parts of the diode shown in Figure 1 are required as thermal and/or electrical contacts to the avalanche and drift zones.

HOW THE IMPATT DIODE GENERATES A SMALL SIGNAL

When the diode is operating normally, a large electric field appears across the avalanche zone and a cascading impact ionization takes place. Thus, a small current "injected" into the zone can be greatly multiplied. One interesting and important characteristic of this "avalanching" is that there is a time delay in the process. Figure 2 shows what happens to the theoretical values of avalanche current as a function of time when a constant voltage is suddenly applied to zones biased to provide either positive, infinite, or negative values of multiplication of current. By superimposing a sine wave on the bias required for $M \approx \infty$ (see Figure 2), the multiplication is alternately switched from negative to positive values, resulting in sharp spikes of current. The first harmonic of this current is delayed in phase, with respect to the applied field, by 90°, because of the inductive properties of the avalanche zone.

The electric field in the drift zone is normally so high that the velocity of the charge carriers is saturated; that is, they travel throughout the entire drift zone with constant velocity. As a consequence there is no bunching or debunching of the charge carriers and the current pulses injected into the drift zone propagate through it with no change in amplitude but with a delay in phase. As the charges move through the zone, they induce, on the diode contacts, surface charges which flow from the external battery source; the time rate of change of this charge flow is called the induced circuit current. An important characteristic of this effect is that if the phase delay of a current pulse in the drift zone is theta, the corresponding delay in the induced current is $\theta/2$, a property well known to microwave tube engineers. If $\theta = 180°$, then the induced current will be delayed by 90°.

Thus it is possible for the induced circuit current to be 180° out of phase with the circuit voltage: 90° due to the delay in the avalanche zone and another 90° due to the drift zone delay. The effective resistance of the diode is therefore negative and hence it is a source of alternating current power. The original source of power, of course, is the direct current power supply; the IMPATT diode essentially converts dc power into ac power.

CONTEMPORARY PROBLEMS AND SOLUTIONS

As microwave solid state devices are improved through refinements of materials, electrical design, thermal design, circuit design, etc., further demands on their performance are imposed by electronic systems engineers. For example, the spectral purity and stability of the signal is an essential requirement in some applications.
"Microwave solid state applications are still in the early period of development and clearly represent a growth area for the electronics industry in the 1970s."

In many cases the IMPATT sources are not adequate to meet these stringent requirements, but some of the problems can be solved by means of well-known techniques that were successfully used in the older field of vacuum tube electronics. An example is illustrated in Figure 3, which shows power spectra of a pulsed IMPATT oscillator. The spectrum in Figure 3a was obtained for an operation in which the oscillator was repeatedly on for a period of $3 \times 10^{-6}$ seconds and off for a period of $25 \times 10^{-6}$ seconds. The measured spectrum indicates that an excessive frequency change is occurring during the "on" period, making the diode unsuitable for many applications. However, when the well-known technique of frequency locking — in which a small stable signal (continuous in this case) is used to prime the oscillator — is employed, the practically ideal spectrum shown in Figure 3b is obtainable. This example shows that while under normal conditions a device may be found unsuitable...
for certain applications, often some simple expedient can transform it into an exceptionally high-performance component.

Another important problem of interest is electrical noise. Engineers and physicists who are familiar with avalanche processes know that high levels of random noise are usually associated with them. Indeed, when IMPATT diodes are used in some applications, such as in local oscillators, their noise is excessive and they are poor competitors to Gunn and other types of oscillators. Where they are used as reflection amplifiers of amplitude-modulated signals, their performance is less than spectacular, although IMPATTs of gallium arsenide rather than silicon are now being developed and are showing promise of low noise operation. For frequency-modulated systems, however, interesting amplifier noise characteristics have been observed. This is illustrated in Figure 4, where the ordinate is proportional to frequency-modulation noise and the abscissa represents the frequency away from the carrier. Curve A shows the recorded FM noise spectrum of the signal before amplification. This noise spectrum is characteristic of the particular signal generator used in the experiment. The signal was then fed into an IMPATT reflection amplifier with a gain of 9.3 decibels and the amplified signal was measured for noise. The result obtained is shown as curve B of Figure 4. From a comparison of curves A and B, it can be seen that there is practically no detectable difference between the measurements before and after amplification. This shows that the IMPATT diode is essentially noise free when used as an FM amplifier and that it should, therefore, find wide application in FM systems.

These examples were randomly selected to illustrate some of the problems being considered and solutions being offered. There remain innumerable and interesting problems in the field of solid state microwaves. For example, solid state devices today can provide only a few watts of average power, although important potential applications require kilowatts.
Microwave solid state applications are still in the early period of development and clearly represent a growth area for the electronics industry in the 1970s.

G. Conrad Dalman, professor of electrical engineering at Cornell, has been a member of the faculty for fifteen years and has supervised more than thirty graduate theses in the School of Electrical Engineering.

Professor Dalman, a native of Winnipeg, Canada, earned his bachelor's degree in electrical engineering from the City College of New York in 1940, and his master's and doctor's degrees, also in electrical engineering, from the Polytechnic Institute of Brooklyn in 1947 and 1949. He received a Certificate of Distinction, awarded to alumni of the Polytechnic Institute, in 1958.

Before coming to Cornell in 1956, Professor Dalman spent fourteen years in industry. He served as a manufacturing engineer at RCA from 1940 to 1945, as a member of the technical staff of the Bell Telephone Laboratories for the next two years, and then as a section head at the Sperry Gyroscope Company from 1949 to 1956. While at Cornell, he has served as a consultant to numerous concerns, including Westinghouse Electric Corporation, Cornell Aeronautical Laboratory, Raytheon Company, and Varian Associates. With Professor Lester F. Eastman, he founded Cayuga Associates, a small organization engaged in the design and manufacture of prototype microwave devices.

During the academic year 1961–62, Professor Dalman was on leave as manager of a project sponsored by the United Nations to help establish an electronics research laboratory at Chiao Tung University in Hsinchu, Taiwan. He has traveled extensively throughout Europe and the United States, giving invited lectures in his areas of expertise, and has published a number of technical papers.

He is a fellow of the Institute of Electrical and Electronics Engineers, and a member of the American Association for the Advancement of Science, the American Physical Society, Tau Beta Pi, Eta Kappa Nu, and Sigma Xi.
The invention of the semiconductor transistor more than twenty years ago generated a whole new array of electronic equipment operating in the audio and radio frequencies. Small, durable, reliable devices capable of amplifying and controlling electronic signals took the place of bulky vacuum tubes in radios and many kinds of specialized electronic equipment. But there was one important type of electronic device that transistors could not be used for. Equipment operating in the microwave frequency range — and this includes up-to-date satellite communications systems for weather observations and television transmission between continents, and radar and navigational aids — still had to depend on vacuum tubes.

All that changed abruptly with the discovery, nearly a decade ago, of the Gunn effect in gallium arsenide (GaAs) semiconductor crystals. As a result of this discovery and that of the microwave avalanche diode, a new generation of microwave electronic equipment, paralleling the lower-frequency transistor applications of the 1950s, is now imminent.

LONG LIFE, LOW COST, AND ONE TENTH THE SIZE
What are the remarkable advantages that these new semiconductor microwave devices have over their vacuum tube counterparts? First and foremost is the outstanding long life of semiconductor devices. Some early Gunn devices have been running continuously for more than five years already, and at least twenty years of operating life is predicted for present-day devices. Compare this with the life expectancy of the key microwave transmitter vacuum tube in an aircraft altimeter radar, which is only one and a half months.

The next most important improvement is in cost. The ultimate cost of the semiconductor device in, say, the aircraft altimeter will be less than one quarter of the cost of the tube it can replace. Then there is the advantage, crucial in some applications, of decreased size and weight: the semiconductor oscillator can be less than a tenth as large and heavy as its vacuum tube counterpart. A final benefit
is that the semiconductor needs only a single, low-voltage battery supply rather than the one or more high-voltage supplies, plus an extra cathode heater supply, that are commonly needed for vacuum tubes.

THE UNIQUE PROPERTY OF GaAs CRYSTALS

The device that makes all these attractive features possible is a diode capable of generating microwave signals. Most semiconductor materials absorb high frequency signals rather than generate them, and when J. B. Gunn made his discovery that GaAs crystals are capable of oscillating at high frequencies, he was observing a unique electrical property. An explanation of this property — why it exists in certain materials and how it determines the way a diode functions — is basic to an understanding of how solid state microwave devices work.

The unique electrical behavior of gallium arsenide is due to the influence of the crystal structure on the properties of electrons. Electrons ordinarily have a very low mass and so move rapidly in response to an electric force of even small magnitude. But in GaAs crystals another phenomenon can occur. When the applied electric field is high, some electrons acquire an energy and therefore an effective mass that is higher than usual, and these “heavy” electrons respond more sluggishly to the applied electrical force. The two types of electron response can occur simultaneously, but as the strength of the applied field is increased, a larger and larger fraction of the electrons in the crystal assumes the sluggish condition. As the voltage across a GaAs crystal is increased, the average electron velocity becomes slower and slower, with a resultant decrease in the electric current.

The overall effect, the so-called GaAs bulk effect, is that when the electric force on the electrons in the crystal increases above a critical, threshold value, further increase in applied voltage is accompanied by a decrease in current. Thus the crystal exhibits a negative resistance, with alternating current a half cycle out of phase with the alternating voltage, and this generates signals. Most semiconductors exhibit positive resistance that absorbs signals.

Early work in England by B. K. Ridley, T. B. Watkins, and C. Hilsum predicted the possibility of negative resistance, but it was not discovered experimentally until 1963 when Gunn made his measurements. In 1966 J. A. Copeland of Bell Telephone Laboratories showed how powers larger than those obtained by Gunn could be generated. Copeland named his condition for high power generation the limited space charge accumulation (LSA) condition.

THE CORNELL BUILDUP

Gunn came to Cornell in late 1963 to give a seminar that was quite convincing. He later visited the campus on a regular basis several times each year during a buildup of research activities in the field of Gunn effect and other new microwave semiconductors. Soon a group of nearly fifty people was engaged in a large-scale research effort supported at a level of nearly a half million dollars a year. Ridley came from England and other senior scientists came from Scandinavian, English, Australian, and American
Figure 1. Pulses of power in the microwave region are needed for radar and transponder applications which depend on an intermittent and sometimes coded signal. These curves show the highest values of peak power and average power that have been generated so far in experiments with LSA oscillators over the useful range of microwave frequency. Since the ordinate is logarithmic, the ratio of peak to average power is greater than 1,000 to 1.

The tiny GaAs crystals, about the size of a pinhead, are cut from a larger crystal grown by a unique technique which produces specimens containing an extremely uniform concentration of electrons. The mother liquid is a gallium melt that has had raw gallium arsenide dissolved in it, and crystal growth is initiated on one surface of a seed crystal. An early technique was to cool the melt in contact with the
seed crystal, but with this method there is a problem of nonuniformity of the desired chemical impurity (a tiny amount of tin) in the final crystal, even though the dilute concentration of the impurity stays constant in the melt. Cornell graduate students S. I. Long and D. W. Woodard were able to obtain extremely uniform growth (detected by laser analysis) by keeping the temperature fixed during the crystal growth period and using a carefully controlled temperature difference between the cooler seed crystal and the hotter raw crystal.

Circuitry techniques for generating pulses of high-peak power were also initiated in the Cornell laboratories. By using a specially developed computer program which accurately accounted for the critical microwave electrode geometries, W. O. Camp, Jr., a graduate student, succeeded in simulating the complete buildup of LSA oscillations. This simulation, coupled with continuing experimental studies, brought about an understanding of the complex, nonlinear operation of the LSA oscillator. Efficiency has been increased tenfold as a result of this study, and it is now possible to nearly achieve the theoretical optimum efficiency of 20 to 30%.

Careful attention has also been given to other aspects of operation. For example, effective application to radar and communications systems requires an increase in average power during pulsed operation. Average power obtained in early experiments was only a few milliwatts, but it is now possible to obtain from 0.1 to 1.0 watt...
of average power as a result of studies, by graduate student J. S. Bravman, of heat flow effects and the physics of the change in performance with increasing crystal temperature.

THE VERSATILITY OF MICROWAVE OSCILLATORS

Gunn diodes and other types of semiconductor microwave diodes can be adapted for a great many uses. Applications that have been developed for low-power continuously operating Gunn diodes include laboratory models that can be operated at fixed or variable frequencies; local oscillators in radar and communications receivers; intrusion alarms; transmitters for short-range vehicular doppler radars such as are used by police in traffic control devices; and broadband communications amplifiers. Possible ramifications of such applications are extensive. For instance, one can conceive a computerized traffic-monitoring system for an entire highway.

Other semiconductor microwave devices function as high-power pulsed LSA oscillators. An example of this kind of application is in radar devices for vehicles such as boats and airplanes. An aircraft altimeter operates by measuring the delay time between the emitted pulsed signal and the returned one. Pulsed radar systems designed to detect approaching vehicles and thus help avoid collisions between aircraft, sea vessels, or even automobiles, are being developed. An emergency beacon for lifeboats, detectable by search plane radars, is another ingenious application.

TRANSPONDERS AS NAVIGATIONAL AIDS

The ability to “code” signals by varying the pulse intervals and frequencies opens up another whole area of possible applications. An especially interesting and useful application is in navigational and vehicular transponders. A transponder is a device that is used in conjunction with a radar to locate or identify navigational hazards or objects such as aircraft. When a radar signal is received by a transponder, a coded return signal is transmitted back to the radar. This shows the location of the transponder on the radar screen and identifies the particular transponder by its code. Coast and channel marking by transponders will aid ship navigation. Oil tankers cruising remote, unpopulated regions, such as around the Alaskan coast, could rely on battery-operated transponders to prevent accidents that would spill oil. A computer-controlled vessel’s course, with the expected transponder codes recorded in the computer memory, could be followed in conjunction with the ship’s radar. Even automobile driving under conditions of poor visibility could be facilitated by the use of transponder-radar systems. Each automobile could be equipped with a radar unit that would detect signals from transponders placed at the edges of roadways.

TRANSFORMING THE WORLD OF COMMUNICATIONS

It is apparent that because of the low cost and long life of the new semiconductor devices, great changes in microwave electronics technology are imminent. In the area of communications alone, one can foresee the simultaneous use of hundreds of television channels because of the greatly in-
A laboratory demonstration of how semiconductor microwave devices can be used for transmission of TV signals. The object photographed (below) is transmitted by means of a Gunn diode to a receiver in another location (right). Such systems can provide cheap private TV transmission within a range of about twenty-five miles and are highly suitable for such applications as educational television or communication within school systems or office complexes.

increased number of frequencies available in the microwave region. Millions of simultaneous telephone conversations could be transmitted through a single microwave amplifier. Long-distance transmission could be effected with the use of satellites or microwave towers which would receive and retransmit signals in any desired direction without the visual detraction of wires and poles. Although high-power microwave transmission is potentially dangerous, it can be safely conducted through shielded cables or underground tubes. For many applications safe, lower powers can be used.

The new semiconductor microwave devices are, indeed, opening up a whole new era of electronics, and their advent may be as far-reaching in its implications as the "breakthrough" development of the transistor.

Lester F. Eastman, truly a Cornellian, joined the faculty of the College of Engineering in 1957 after earning all his degrees at Cornell: the Bachelor of Electrical Engineering in 1953, the Master of Science in 1955, and the Doctor of Philosophy in 1957.

He has maintained an interest in physical electronics throughout his research career and has been actively engaged in microwave solid state electronics since its beginnings in the early 1960s. He has published more than forty technical papers based on his research. He has also been active in organizing and presiding over national and international conferences dealing with microwave phenomena and has participated in exchanges of visits and lectures with researchers in this field all over the world.

Professor Eastman participated in an international exchange program in 1960–61, teaching and conducting research in microwave and plasma electronics at the Chalmers Institute of Technology at Gothenburg, Sweden. During his sabbatical leave in 1964–65, he did research on microwave semiconductors at the RCA Laboratories at Princeton, New Jersey.

With Professor G. Conrad Dalman, he founded Cayuga Associates, a small firm in Ithaca which is engaged in the development of prototype microwave semiconductor devices. Professor Eastman has served as a consultant to several electronics firms and has taught in-plant courses for Westinghouse Electric Corporation at Elmira, New York, and Sylvania Electric Company at Waltham, Massachusetts.

In 1969 he was elected a fellow of the Institute of Electrical and Electronics Engineers. He is a member of the honorary societies Eta Kappa Nu, Sigma Xi, Tau Beta Pi, and Phi Beta Phi.
COMMENTARY

Environmental Concerns and Engineering Education

A few months after assuming the directorship of the School of Civil and Environmental Engineering last fall, Walter R. Lynn discussed one of the central concerns of his School at a state-wide conference of engineering educators. The occasion was the Conference on Engineering Education and Environmental Problems, sponsored by the New York State Education Department's Office of Science and Technology. Excerpts from Professor Lynn's address are given in this Commentary.

For many engineers the topic of "environmental concerns" is troublesome, for it brings forth emotional responses that are alien to the mystique of cool, rational objectivity which we like to believe characterizes our professional contributions to society. However, engineers will have to play a central role in controlling the environment, for it is through their technological skills that existing problems can, hopefully, be brought under control and new environmental deterioration avoided or minimized.

Engineering education has a clear responsibility in this area. It must provide training in new kinds of expertise that are required to handle the complex environmental control problems we face. And it must meet a need for young men and women who have technological skill that is tempered with biological insight and sensitivity to social concerns. The fact is, however, that a number of the issues which are central to the environmental problems we face are largely ignored in engineering education.

The more traditional aspects of environmental concerns — problems of water supply and the treatment of wastewater — have been encompassed by that branch of engineering that may be called sanitary/environmental engineering. Until comparatively recent times, the education of engineers in this field centered on these subjects, and so did a great deal of the basic and applied research. Water chemistry, the development of better processes for treating waste products, biological mechanisms associated with degradation of organic materials in various natural environments, and the study of streams (limnology) have been the traditional areas of investigation.

In recent years research interest, encouraged by the availability of federal support, has broadened to include such topics as air pollution control, the disposal of solid and agricultural wastes, the treatment of radioactive waste materials, and the management and operation of water resource systems. However, the tendency has been toward a concentration of effort in certain specialties at certain institutions, rather than a general broadening of the field of sanitary/environmental engineering. Furthermore, work in these new areas has been focused on scientific and technological aspects, with little attention given to the nontechnical aspects of environmental problems.

An increase in the scope of sanitary/environmental engineering began in the last decade with the introduction of programs designed to encompass economic and political aspects of the planning and operation of water supply and wastewater systems. The Harvard Water Program, for example, involved the participation of economists and political scientists as well as
"The most apparent developments in this rapidly expanding field, and perhaps the most important, are in those areas which impinge on the social sciences . . . Our increased sensitivity to the environment places greater demands upon us as engineers and, more importantly, as human beings."

engineers and applied mathematicians, and new insights into pollution and water supply problems were gained. Accompanying these developments was the introduction of an analytical approach to the planning, operation, and management of water-resource and other public-sector systems. This "systems analysis" approach provided a means of integrating the technological with the social, economic, and political aspects of these complex systems.

The most apparent developments in this rapidly expanding field, and perhaps the most important, are in those areas which impinge on the social rather than the physical or biological sciences. Not everyone accepts this value judgment, and many consider this kind of development to be an assault upon a reputable area of knowledge. Whatever the consensus may be, it is apparent that there are facets of environmental issues which engineers are ill prepared to handle, and which must be incorporated into engineering educational programs.

Two examples of contemporary environmental problems will serve to illustrate the need for effective interaction between technology and the social sciences. While in each of these cases technology has an important role, it is unlikely that solutions will be found in terms of technology alone.

1. Auto hulks. The junked car is generally conceded to be esthetically offensive, and detrimental to the environment for this reason. Since it is technically feasible to reprocess auto hulks and since there is a demand for reprocessed scrap from United States and foreign steel manufacturers, one might ask why auto-hulk disposal presents a problem. The answer is that the market forces are inadequate to meet the socially perceived need to remove this form of visual blight. The problem is basically economic and political. Solutions appear to lie in various forms of subsidy programs that would encourage optimum use of scrap material, and in legislative programs that would require the owner of an auto to pay a larger share of the cost of abandoning it. While the development of more efficient ways of processing the scrap or more ingenious means of delivering hulks to the processor (or vice versa) would be advantageous, it is unlikely that these developments alone can solve the problems.

2. Solid wastes. Our society has been captivated and is currently being assaulted by "convenience packaging" which is creating a massive problem of solid waste disposal. The traditional solution has been to create processes to remove inoffensively (bury) whatever materials our society discards. As long as burial plots were available and accessible, this modus operandi appeared to be acceptable. In this new era of ecological consciousness and burgeoning metropolitan populations, however, such simplistic solutions no longer suffice. Institutional, political, and economic measures will have to be employed to effect a reduction in the flow of waste material and to direct the cost of disposal to the consumer and the producer of packaged products.

Many other issues could be cited to illustrate the need for control beyond the purely technological. For example, there are the problems of how to meet the increasing demand for electrical energy and for public services such as
water supply and sewage disposal. The development of regionalized waste-management systems is a complex issue. Population control and problems associated with economic growth have obvious non-technological aspects.

A good general assessment of the nature of environmental problems was made in the first annual report of the federal Council on Environmental Quality in August 1970:

Efforts to solve the problems in the past have merely tried—not very successfully—to hold the line against pollution and exploitation. Each environmental problem was treated in an ad hoc fashion, while the strong, lasting interactions between various parts of the problem were neglected. Even today most environmental problems are dealt with temporarily, incompletely, and often only after they have become critical.

The report states that "... long-range environmental improvement must take into account the complex interactions of environmental processes. In the future, the effects of man's actions on complete ecosystems must be considered if environmental problems are to be solved."

In a recent article in Civil Engineering (October 1970), Professor Abel Wolman commented that the "... real challenge to the engineer is in his capacity to meet these (environmental) hazards and insults esthetically and with minimum damage to collateral social, behavioral and natural values." Clearly, the "real challenge to the engineer" lies in integrating the physical and social sciences.

Much of the responsibility for integrating technology and social concerns falls to the institutions which educate engineers. If the engineer's role is to serve society, he must be acutely aware of how his skills affect the society he serves, and this attitude and knowledge should be communicated to the student. Unfortunately, engineering educators rarely accept this responsibility.

Part of the trouble is that the curricula in engineering institutions have become dichotomized into a technical/scientific stem and a humanistic/social science stem. The university engineering student is apt to feel that he is being sent off to the arts college to receive a "liberal education," as though this kind of exposure had little relevance to the real work of the engineer. Very rarely are engineering students exposed to the host of value judgments, social attitudes, and political pressures that pervade even the most technical aspects of engineering. And it is precisely in this neglected area of overlap that environmental concerns fall.
Who should deal with this region in engineering education? Arts colleges should not have to accept this responsibility, nor are they equipped to do so. The alternate solution — incorporation of these areas into the engineering curriculum — entails several difficulties. One is the time limitation: how can a student achieve a high level of expertise in an engineering specialty and at the same time devote a considerable amount of his effort to its social implications? It is unlikely that this problem will ever be resolved in a completely satisfactory way. A second, less complex difficulty is the competence of the faculty to deal with these kinds of issues. In a sense the principal problem here relates to the engineer's "fact mystique": many faculty members are reluctant to become involved in societal value issues in the classroom because they feel unable to provide the "right answers." They may also feel a genuine lack of knowledge of these issues. These "hangups" are unfortunate but can be overcome. The point is that it is far more useful to ask questions than to provide answers. It is absolutely essential that faculty members make themselves and their students fully aware of the social values that are subsumed in engineering technology.

For the past two years at Cornell we have conducted an experimental course on The Social Implications of Technology, a joint offering by faculty members of the College of Engineering and the College of Arts and Sciences that is part of a broad University program on Science, Technology, and Society. One very important effect of the course has been to entice members of the engineering faculty to act as group discussion leaders, and this in turn has encouraged many of them to examine a variety of social issues that are related to their specific technical fields of interest. This approach appears to be most effective in accomplishing the goal of integrating technology and social concerns in the educational process. Considerable care
must be exercised in generating special "socially relevant" courses for engineering students: there is a danger that these offerings tend to become specialties themselves, and as specialties they do not serve the purpose of making the student aware of the broader implications of engineering and technology in terms of his particular engineering interest.

This point brings up the recurrent controversy over specialists as distinguished from generalists. It is not clear why this issue creates so much heat, since there is obviously a need for both. The important requirement is that specialists and generalists have a common base in order to be able to communicate. For example, there is and will continue to be a great demand for "specialists" who can design physical/chemical/biological treatment processes in all their elaborate detail. General issues surrounding and affecting the processes they design may be outside their area of expertise, however; they might very well be unqualified to undertake such responsibilities as the establishment of effluent controls, the determination of design limitations in terms of economic, political, and esthetic factors, and the assessment of the social costs of the process. In order to work effectively within the social context, the specialists must adhere to a set of socially determined "boundary conditions," and they should be aware of these limitations. On the other hand, those who set the boundary conditions — the generalists — must have some knowledge of treatment processes and their limitations in order to deal effectively with such questions as whether a treatment facility should be built at all, how big it should be, how it should be financed, and what the marginal costs of raising (or lowering) the quality of the environment will be.

Beyond this cooperation between different sorts of engineers is the need for interdisciplinary effort in engineering research and practice. Coping with an environmental issue requires more knowledge and wisdom than any individual in one professional field can hope to acquire; there is a great need for individuals with different skills and special areas of knowledge to contribute jointly to solutions of these pressing problems.

"Our society is currently being assaulted by 'convenience packaging' which is creating a massive problem of solid waste disposal."
Professor Lynn's course in Engineering Economics and Systems Analysis includes discussion of the social aspects of technology.

Environmental concerns present challenges not only to sanitary/environmental engineers who deal directly with environmental management and control problems, but also to those in other specialties who should be concerned with the impact of their technological innovations upon the environment. Our increased sensitivity to the environment places greater demands upon us as engineers and, more importantly, as human beings.
It used to be that freshman and sophomore engineers had their courses of study pretty well laid out for them. But last year the College instituted several changes in curriculum requirements that augmented the recent trend toward more individualized undergraduate programs. Underclassmen found themselves faced with the necessity of making a number of curriculum decisions, and it became apparent that they needed more information and help in planning their study programs.

The College responded to the situation in a number of ways. Two introductory freshman courses were offered to help provide a sound and broad background: Elements of Engineering Communication and Engineering Perspectives, which became better known as the "mini courses". More faculty members were called upon to serve as underclass advisers. New information resources—such as a monthly newsletter, Cornell Engineering Briefs, which was produced to better acquaint underclassmen—and prospective students—with the opportunities in various engineering fields. Another flyer, giving biographical sketches of faculty advisers, was mailed to all freshmen the summer before their matriculation. Below, a student browses through some of the collection of printed material available to all engineering students at the Engineering Counseling Center in Hollister Hall.

Aspects of the new advising and counseling program are explored in this Vantage photo-essay.
Above, freshman and sophomore faculty advisers met in monthly workshops to hear discussions of topics such as why students fail, social sciences offerings available at the University, and University services in such areas as mental health, housing, vocational counseling, and reading and study skills. Left, coffee break during one of the workshops. Below left, a group of freshmen helps assess the advising and counseling program in an informal meeting near the end of the year. Below right, Professor Richard N. White, one of twenty-five freshman advisers, meets with an advisee.
Heading the advising and counseling program for the College in 1970-71 and responsible for the introduction of many innovations was Donald F. Berth, assistant dean, shown below (center) with an advisee. Three seniors — a chemical engineer, an electrical engineer, and an industrial engineer — staffed the new Engineering Counseling Center. In addition to talking with students who dropped by the office, the three were involved in a number of studies intended to help define advising and counseling needs. Below (right) is Gerry Ostrov of Brooklyn, New York; shown at the bottom of the page is Lavoy Spooner from Germantown, Ohio. The third staff member, Robert Green of Shaker Heights, Ohio, was out of town the day the photographer came by. Below (left), John Silcox, chairman of the Department of Applied and Engineering Physics, leads a group of freshmen through a research laboratory in Clark Hall. Open-house tours such as this were among a number of efforts made to acquaint students with the activities going on in various units of the College.
One of the best received of the advising and counseling services was “Academic Rush Week,” staged in mid-March 1971. Some twenty late-afternoon meetings were held in an effort to stimulate personal investigation of career opportunities in different fields of engineering. More than one hundred faculty members participated, and total student attendance was about 900; a little more than half of the underclassmen came to one or more of the meetings. A variety of group programs is being planned for the 1971 - 72 academic year.
The spectrum of "Academic Rush Week" activities is shown by the group of photographs on these pages.
1. A student peruses a collection of articles, monographs, and books by mechanical engineering faculty members.
2. Professor Jeffrey Frey demonstrates microwave phenomena in an electronics laboratory.
3. Professor Paul Ho responds to questions about materials science after interested students have toured some research labs.
4. At the conclusion of the chemical engineering presentation, upperclassmen meet informally with freshmen and sophomores.
5. Chemical lasers are discussed by Terrill Cool of Thermal Engineering in this laboratory tour.
6. Otis Sprow (at right), a mechanical engineering graduate student, was one of several master's degree candidates who described their design projects at the various meetings.
7. The experimental physics laboratories attracted the interest of many students. Here Trevor R. Cuykendall, chairman of the undergraduate engineering physics program, explains an experimental set-up.
8. Analog computers are employed in mechanical systems simulation, described by Allan I. Krauter of the Department of Mechanical Systems and Design.
9. Fluid dynamics research, particularly in sonic boom effects, is discussed by a graduate student in aerospace engineering.
The Register combines a farewell to four retiring faculty members and a welcome to the new Maxwell M. Upson Professor of Engineering. Named professors emeritus by the Cornell University Board of Trustees were John R. Moynihan, Roger L. Geer, Clyde E. Ingalls, and George B. Dubois. Beginning his tenure in the Department of Operations Research is D. Ray Fulkerson. Biographical sketches of all five men follow.

A total of 122 years of service in the College of Engineering was completed at the end of the 1970–71 academic year by four retiring faculty members. Appointed professors emeritus were John R. Moynihan, who has the impressive record of forty-two years of service; Roger L. Geer, with thirty-two years; and Clyde E. Ingalls and George B. Dubois, with twenty-four years each.

Moynihan, who was professor of theoretical and applied mechanics and assistant chairman of the Department, came to Cornell as an instructor in 1929. At various times he served as chairman of the Department of Materials, as acting chairman of the Department of Mechanics, and as secretary of the faculty of the College of Engineering. Moynihan was also educated at Cornell, receiving the degrees of Mechanical Engineer in 1926 and Master of Mechanical Engineering in 1932.

In addition to his work at Cornell, Professor Moynihan served as a consultant to the Lincoln Laboratory at the Massachusetts Institute of Technology from 1952 through 1955, to the Applied Research Laboratory of Johns Hopkins University from 1951 through 1956, and to Therm, Inc., of Ithaca, from 1959 through 1968. He is a registered professional engineer in New York state, and is a member of the American Society for Metals, the American Society for Testing Materials, Tau Beta Pi, Sigma Xi, Phi Kappa Phi, and Pi Tau Sigma.

In presenting the formal notification from the Board of Trustees of Moynihan’s appointment as professor emeritus, College of Engineering Dean Andrew Schultz, Jr., commented, “I do not know of a single professor who is recollected more fondly than Professor Moynihan, and by more engineering alumni.” He noted that Moynihan had “provided the College with over forty years of teaching at a level of high quality and with excellent humor.”

Geer, a specialist in industrial engineering, was honored during his final year as professor of mechanical engineering by receiving the 1971 Education Award of the International Society of Manufacturing Engineers for his contributions to “the cause of engineering education and the ultimate realization of manufacturing engineering as an academic discipline and as an industrial imperative.” In 1967 he received the award of merit from the American Society of Tool and Manufacturing Engineers.

Professor Geer was graduated from Cornell in 1930 with the degree of Mechanical Engineer and spent the following nine years in industry before joining the College of Engineering faculty. He was a production control and methods engineer with the Perfection Stove Company of Cleveland from 1930 to 1934, and after a
year at the Chicago Pneumatic Tool Company of Cleveland, he served as a methods and tool engineer for the L. C. Smith and Corona Typewriters Company.

During recent sabbatic leaves, he was associated with the Warner and Swasey Company of Cleveland, working on a variety of problems in machine tooling. He has also served as a consultant to a number of industries near Cornell, including the National Cash Register Company plant in Ithaca, the Universal Instruments Corporation in Binghamton, and the General Electric Company's Johnson City plant.

Among his special educational activities at Cornell was the development and teaching of a twenty-session course on Manufacturing Engineering for Western Electric Company trainees during the summers of 1962 and 1963. During the spring of 1967 he served as a consultant to the Hampton Institute of Hampton, Virginia, helping in the development of new teaching services for manufacturing engineering.

Professor Geer is a member of the American Society of Tool and Manufacturing Engineers, the American Ordnance Association, the American Society for Engineering Education, and the Cornell Society of Engineers, and is an honorary member of Pi Tau Sigma.

Ingalls, professor of electrical engineering since 1947, is known for his contributions to early developments in radio, television, and radar. He also built the first computer at Cornell and was chairman of the committee which initiated the University's program in computer science and service.

Professor Ingalls received the degree of Electrical Engineer from Rensselaer Polytechnic Institute in 1927 and served as an instructor in electrical engineering and physics there for two years. In 1929 he joined the Stromberg-Carlson Telephone Manufacturing Company, where he served as a radio engineer and as head of the research laboratory and the instrument development laboratory. As part of his work with Stromberg-Carlson, Ingalls was in charge of the development of the company's first television receiver. In 1941 he became a section chief at the Radiation Laboratory of the Massachusetts Institute of Technology. In this capacity he was in charge of all work on fire control radar receivers which were ground-based or ship-borne, and he developed a system which was designed to reduce jamming of radar scans.

During his association with these organizations, he did graduate work in electrical engineering and mathematics at RPI, in physics and mathematics at the University of Rochester, and in electrical engineering communications at MIT.

During his years at Cornell, Ingalls contributed to the introduction of many educational ventures. He introduced at least a dozen courses that were new in both content and objective and is especially known for his innovation in laboratory instruction. Most recently he helped in the development of a design project program for the Master of Engineering (Electrical) degree curriculum.

Since 1946 Ingalls has conducted a private consulting practice in areas ranging from electronic organs and architectural acoustics to radar. He
holds five patents.

Professor Ingalls's honors include two citations for work during World War II, and he is listed in Who's Who in Engineering and in American Men of Science. He is registered as a professional engineer in New York state and is a member of the Acoustical Society of America, the Institute of Electrical and Electronics Engineers, and the honorary societies Sigma Xi and Tau Beta Pi.

DuBois, who was professor of mechanical engineering, was educated at Cornell. He earned the A.B. degree in mathematics and physics in 1927 and received the degree of Mechanical Engineer in 1929.

DuBois joined the faculty of the College of Engineering in 1947 after eighteen years of professional engineering experience. He worked with the Sperry Development Company and the Lycoming Division of the Avco Corporation, and for eleven years he was a project engineer for the Wright Aeronautical Division of the Curtiss-Wright Corporation, rising to be in charge of the design of production models of radial aircraft engines.

During his Cornell tenure, Professor DuBois contributed significantly to the literature in lubrication research, and his work with the late Professor Fred Ocvirk on short bearing theory received international recognition. He was especially active in developing course work in conceptual engineering design, as well as in design for manufacture. During the fall term of 1967-68 he was a visiting professor at the University of Hawaii.

A registered engineer in New York state, Professor DuBois is a member of the American Society of Mechanical Engineers, the Society of Automotive Engineers, Sigma Xi, Phi Kappa Phi, and Tau Beta Pi.

A new chair holder at the College of Engineering is D. Ray Fulkerson, who has joined the Department of Operations Research as Maxwell M. Upson Professor of Engineering.

Fulkerson, a specialist in network flow theory, combinatorial analysis, and linear programming, was associated with the RAND Corporation for twenty years before coming to Cornell. His university teaching experience includes visiting professorships at Stanford in 1966 and at the University of California at Berkeley in 1963. He has also given short courses in operations research at the University of Michigan and the University of California at Los Angeles.

He received his B.A. degree from Southern Illinois University in 1947, and his M.S. and Ph.D. degrees, both in mathematics, from the University of Wisconsin in 1948 and 1951, respectively.

Fulkerson is the co-author, with L. R. Ford, Jr., of Flows in Networks, published by Princeton University in 1962, and he has published more than fifty papers on mathematical topics. In 1967 he received one of the annual Ford Awards of the Mathematical Association of America, which are given in recognition of outstanding expository articles published in the Association's periodicals.

He is an associate editor of four professional journals — the Journal of Combinatorial Theory, the
Fulkerson


The Professorship to which Fulkerson has been named was established in honor of the late Maxwell M. Upson, who was chairman of the board of Raymond, International, a structural engineering firm. Upson was an 1899 graduate of the Sibley School of Mechanical Engineering at Cornell, and he served on the University’s Board of Trustees for thirty-five years. Among his many gifts to the University is Upson Hall, which houses the department Fulkerson has joined, the Department of Operations Research. The Professorship is endowed in part by a bequest from Upson’s wife, the late Mary Shepard Barrett Upson, and in part by the Ford Foundation.
The following publications and conference papers by faculty members and graduate students of the Cornell College of Engineering were published or presented during the period November 1970 through April 1971. Earlier publications inadvertently omitted from previous listings are included here with the date in parentheses. The names of Cornell personnel are in italics.

**AEROSPACE ENGINEERING**


**AGRICULTURAL ENGINEERING**


The text provided is a collection of bibliographic entries. Each entry contains information about a publication, including the author(s), title, and details about the publication such as the conference, meeting, or journal where it was presented. The entries are formatted in a consistent manner, indicating the year, title, and other relevant details. The text does not appear to contain any natural language content but rather is a compilation of scientific references.


### CHEMICAL ENGINEERING


### CIVIL AND ENVIRONMENTAL ENGINEERING


York State Science and Technology Foundation report no. 7004.


———. 1971. Major Planetary Gravita-
tional Analysis. Paper read at 52nd Annual Convention of the American Geophysical Union, 12–16 April 1971, Washington, D.C.

■ COMPUTER SCIENCE


INDUSTRIAL ENGINEERING AND OPERATIONS RESEARCH


MATERIALS SCIENCE AND ENGINEERING


MECHANICAL ENGINEERING


——, and Mackenzie, J. F. A prediction of changes in the thermal cycle of a stratified lake used to cool a 1000 MW power plant. Cornell University Water Resources and Marine Sciences Center publication no. 32.


THEORETICAL AND APPLIED MECHANICS


On August 17 – 19 the third in a series of biennial electrical engineering conferences on high frequency generation and amplification will be held on the Cornell campus. This year’s special subject is devices and applications, an area of technology in which the featured authors in this issue, Professors G. Conrad Dalman and Lester F. Eastman, have long been active.

What strikes me about these men, whom I have known for a decade, is the sustained zest they have shown in their work. Their enthusiasm is genuine and contagious. Also unusual is their long-standing and highly productive collaboration as a research team, for university faculty members tend to be individualists. The team approach to the definition and solution of real problems, including analytical and qualitative aspects, is becoming more fashionable these days, but Messrs. Dalman and Eastman have known for more than fifteen years that it is an effective work mode for obtaining meaningful results.

Their abilities are not restricted to the research laboratory alone. Both are effective teachers, and both are serving as advisers to freshmen and sophomores. Also, both have a solid footing in the practical aspects of their specialty of semiconductor microwave devices. A conversation with them over lunch is a revealing experience, giving a glimpse of vital and active minds at work transforming ideas into potentially useful applications.

The troubled electronics industry — and engineering faculties across the country — could use more Dalmans and Eastmans, not only for their enthusiasm, but for the capacity they seem to have to stay on productive forefronts in their field.

THE EDITOR

A Special Note: The theme of the next issue of the Quarterly will be Capstones of Century I. This will be a special commemorative issue highlighting a number of significant anniversaries of the College of Engineering at Cornell, beginning with the graduation of the University’s first engineers a century ago. We think you’ll enjoy this special autumn issue, which will have many more pages and will include a section of color photographs of the Engineering Quadrangle today. If you would like extra copies for your friends or for secondary school students who are considering an engineering career, please let us know by 1 October 1971. Extra copies may be purchased at $3.00 each. Address your request to Anniversary Issue, ENGINEERING: Cornell Quarterly, 254 Carpenter Hall, Ithaca, New York 14850. Publication date is October 20.