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NOISE: THE FOURTH POLLUTANT

by Daniel P. Loucks

Environmental noise is often called the fourth pollutant, joining the more widely recognized material contaminants in our air and water and on our land.

Environmental noise is also sometimes called the new pollutant, though evidence indicates that it is far from new. Julius Caesar, bothered by noise from chariot driving in Rome, decreed restrictions on the activity. Noise from housewives being beaten by their husbands, apparently a common practice in some sections of London in the late sixteenth century, caused Queen Elizabeth's administration to ban that activity—after 10 p.m. (I am told this law still stands.) In our own capital, jet aircraft noise so disrupted an open-air concert attended by one of our recent presidents that he ordered an aide to call Washington National Airport to stop or reroute air traffic for the duration of the event.

All of us do not have these options for reducing noise that irritates us. Environmental noise is a particular kind of noise pollution, not easily controlled by those who must endure it; it includes what is referred to as community or outdoor noise. Recent surveys sponsored by the Department of Housing and Urban Development have consistently shown that noise is the most frequently cited undesirable characteristic of neighborhoods, mentioned more often than even crime.

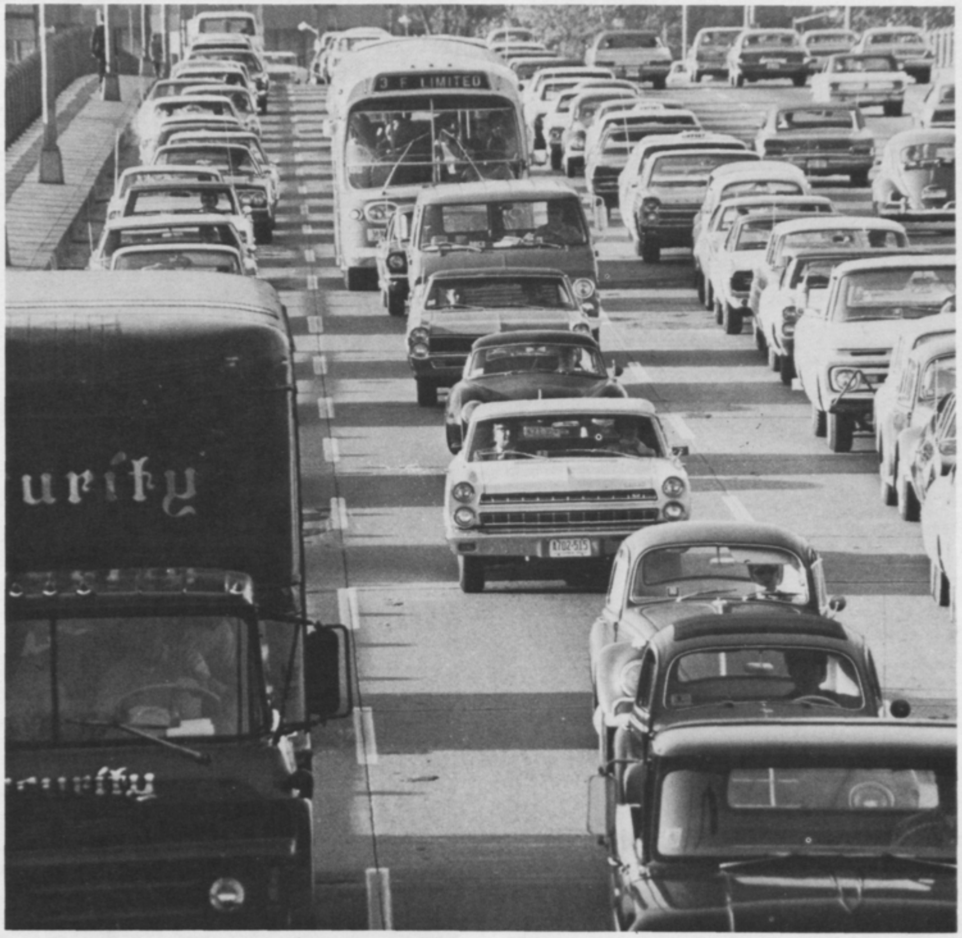
In some urban areas, noise is more than irritation. During certain periods, urban noise approaches the level that can cause permanent hearing damage. The individual living in an industrialized society, subjected to everyday noise at work and at home, cannot hear nearly as well as the African bushman stalking his next meal, though the anatomy of their ears is identical. Darwin might have cited this as an example of modern people adapting to their environment. Nevertheless, the adverse physiological and psychological effects of hearing loss, and the large number of people who suffer such loss, are ample reasons for concern and for the planning and implementation of measures to reduce and control environmental noise.

Urban areas are probably most in need of such control. This is evidenced by the increasing number of public-awareness programs and noise-control laws in the major cities of the United States, and by the continued tightening and enforcement of noise regulations in many European and Asian cities. While the general approach to managing or controlling urban noise can be extended to all environmental-noise problems, urban noise has received the most attention because of its magnitude, damaging effects, and complexity.

DECIDING ON A PLAN FOR NOISE ABATEMENT

A systematic approach to environmental-noise management requires the definition and evaluation of numerous noise-abatement alternatives based on one or more management objectives. This in turn requires the identification of the most significant noise sources and their characteristics, the prediction of sound attenuation from each noise source to each designated receptor site, and the prediction of the effectiveness and cost

Imagine yourself on a trip to New York City or to the West Coast, driving your rent-a-car convertible up the center lane of the lower deck of the George Washington or the San Francisco–Oakland Bay Bridge: five or more lanes of freeway with the acoustic qualities of an echo chamber. Behind and in front of you, moving at the same speed, are two rows of diesel trucks and buses laboring up the grade. On your right and left are two semitrailer trucks; they are legally muffled, but because of their nearness to you, you are receiving 110 decibels from each. Beyond them, in the outer lanes, are two more trucks. The noise of these vehicles surrounding you, plus that of other cars, trucks, and motorcycles jammed in front and back, echoes from the deck above. And overhead, four jet aircraft scream by in full afterburner. Suddenly your vision begins to blur and your skin feels as if it were burning. You are experiencing an extreme case of environmental noise pollution.



of noise-reduction alternatives at each source, at each receptor site, and in the paths between. In cities this prediction is made more difficult by the presence of complex configurations of buildings, surfaced with various materials, that form irregular street canyons (which tend to increase sound reverberation and reduce sound attenuation) and barriers (which may decrease or increase sound attenuation, depending on the location of the source and receptor sites).

Also required are predictions of the effectiveness of the various noise-reduction alternatives in terms of the total decrease (or increase) in intensity or duration of noise at various locations, and a knowledge of the effects of the remaining noise on each receptor. Information about how much various noise-control and management alternatives would cost and how they might alter the time distribution and intensity of the noise at various sites within an area must also be assembled. All these factors must be considered simultaneously to arrive at a "best" set of alternatives. This systematic approach may be complex, but its use should lead to more effective policies for environmental-noise management.

CHARACTERIZING ENVIRONMENTAL NOISE

It is neither necessary nor practical to identify and characterize all sources of environmental noise, simply because they do not contribute equally to the total noise level and impact. Instead, attention can focus on distinct noise sources that are heard above the gen-

Sound Source	Decibels	Intensity Factor	Equivalent Baby Mice
Threshold of Hearing			
One baby mouse (3 feet)	1		1
Rustling leaf	10	10^1	10
Quiet room	20	10^2	100
Whisper	30	10^3	1,000
Soft music	40	10^4	10,000
Low conversation	50	10^5	100,000
Ordinary conversation	60	10^6	1,000,000
Automobile	70	10^7	10,000,000
Busy street	80	10^8	100,000,000
SAFE RANGE			
Truck	90	10^9	1,000,000,000
Metalworking shop	100	10^{10}	10,000,000,000
Jackhammer	110	10^{11}	100,000,000,000
DANGER ZONE			
Propeller airplane (at 50 meters)	120	10^{12}	1,000,000,000,000
Threshold of Pain			
Rivet gun	130	10^{13}	10,000,000,000,000
Jet aircraft (at 25 meters)	140	10^{14}	100,000,000,000,000
INJURIOUS ZONE			

Figure 1. Sound intensities in the range of human hearing. The "equivalent baby mice" unit is based on a representation (proposed in a popular magazine–see the text) of the intensity of a 1-decibel (dB) sound, which is barely audible to the human ear.

Sound intensities are commonly rated on the dB scale, which has as its zero point the threshold of hearing at 1,000 hertz, and which increases logarithmically with sound pressure. For example, a rise of 10 dB from a given level means that the sound intensity has become ten times higher, but a rise of 100 dB indicates a 10^{10} or 10-million-fold increase in intensity. If a 1-dB sound is defined as that made by a baby mouse, then the 140-dB noise from a jet aircraft at a distance of 25 meters would be equivalent to 100 trillion baby mice.

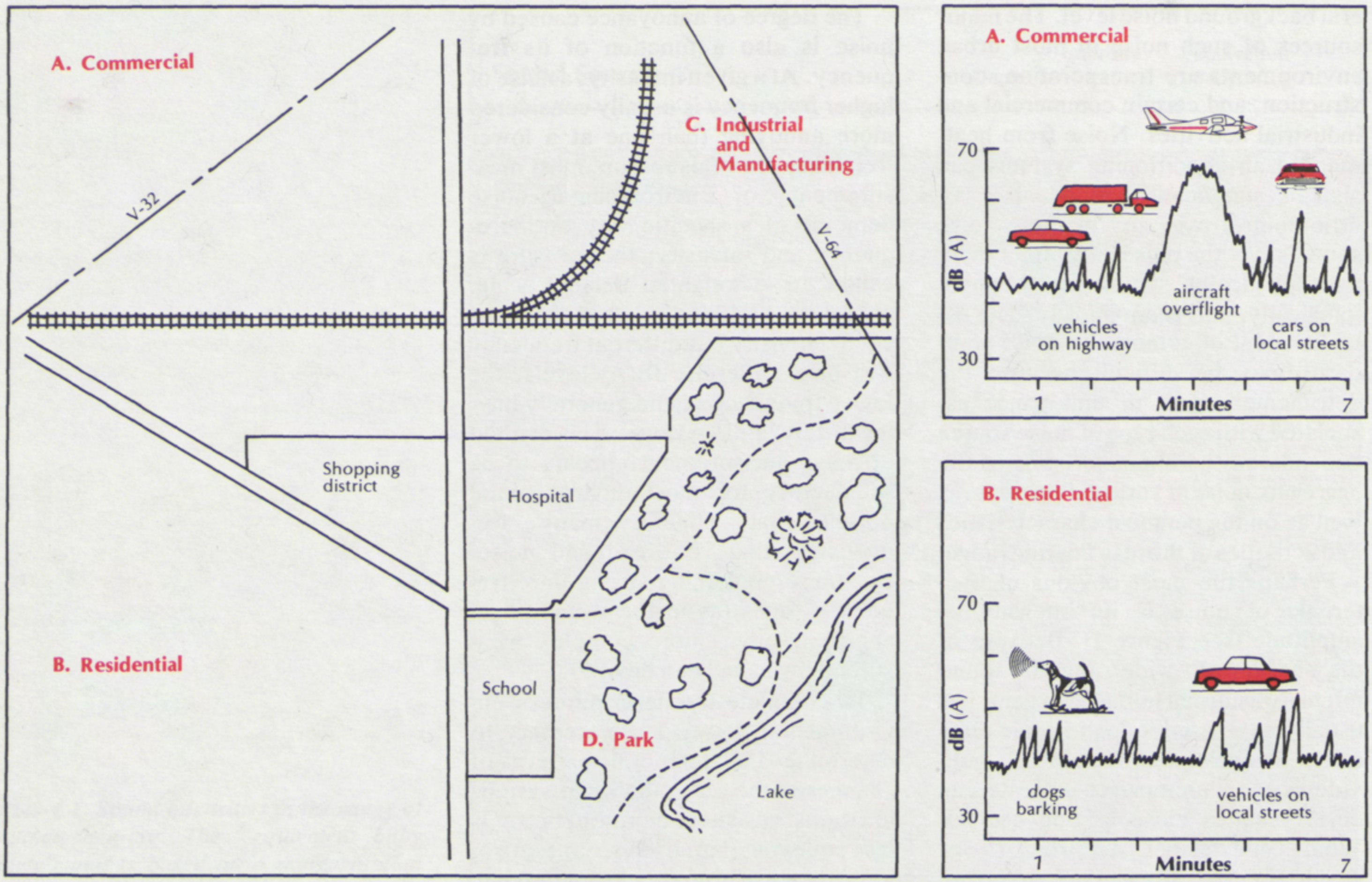
eral background noise level. The major sources of such noise in most urban environments are transporation, construction, and certain commercial and industrial activities. Noise from heating and air-conditioning systems can also be significant. Individuals have little control over any of these noise sources, yet the noise may affect them psychologically, sociologically, physiologically, and economically. The establishment of community noise standards may be difficult because the detrimental effect or annoyance associated with each type of noise source depends on the characteristics of the aggregate noise at various locations, as well as on the personal characteristics and activities of those in hearing range.

Perhaps the most obvious characteristic of noise is its intensity or amplitude (see Figure 1). Because of the enormously wide range of sound intensity a normal human can hear, it is usually expressed in logarithmic units called decibels, abbreviated dB. Individuals with unimpaired hearing can detect sounds close to one decibel. What is one decibel? According to one writer in the May 1967 issue of *Playboy*, "the softest sound the human ear can hear is that of a baby mouse urinating on a dry blotter three feet away, roughly one decibel." Jet aircraft, on the other hand, can generate as much as 140 dB, an intensity that is one hundred trillion times that resulting from one baby mouse. Such intensity can temporarily, if not permanently, decrease one's ability to hear, cause some blurring of vision, and, in all but a very few individuals, produce a burning sensation on the skin. Obviously, most environmental noises have intensities between these two values.

The degree of annoyance caused by noise is also a function of its frequency. At a given intensity, a noise of higher frequency is usually considered more annoying than one at a lower frequency. For this reason, most measurements of environmental noise combine in a specific way both frequency and intensity: the measure is called an A-weighted decibel scale, abbreviated dB(A). Two sounds of equal intensity but different frequency will have different dB(A) levels, the lower-frequency sound generally having the lower dB(A) level. This method of noise measurement appears to be satisfactory for most environmental noises that contain many frequencies—that is, broadband noise. For noise containing strong pure frequency tones (as in the whine of jet engines), other more complex measurements have been devised.

To complete the description of environmental noise, it is necessary to determine the temporal pattern of changes in the dB(A) levels at various locations. A short-duration noise is less annoying than a longer one. Also, a steady noise is usually less annoying, if it is not too loud, than one of varying intensity, especially if the variations are random. (Some people even purchase phonograph records of white noise, called "acoustical perfume," to mask quieter but less desirable noise.) One way of including the temporal pattern of noise in an overall description is to weight the dB(A) pertaining to each noise source according to its duration and regularity. A more easily comprehended method is to describe the temporal distribution of aggregate noise levels, in dB(A), by means of a continuous graph recording.

"During certain periods, urban noise approaches the level that can cause permanent hearing damage."



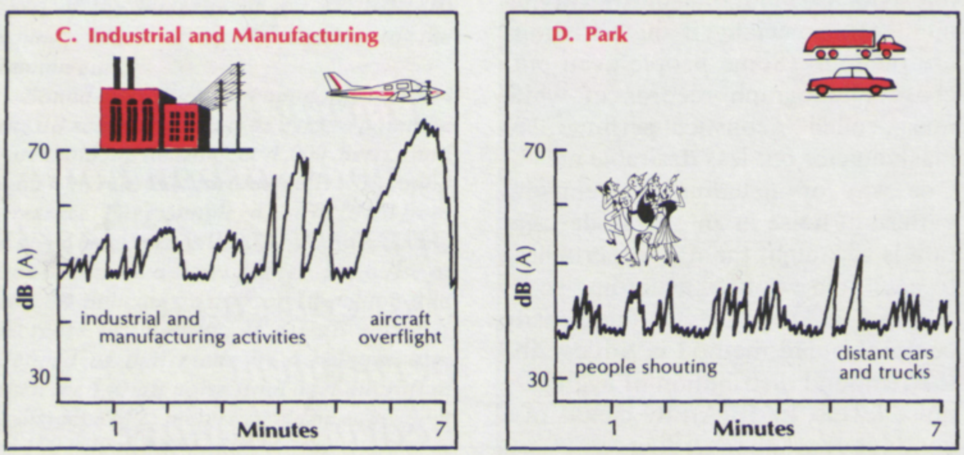


Figure 2. Characterization of urban environmental noise. Various areas designated on the large map have typical kinds and levels of noise, as indicated in the four small sketches.

Three major features of urban noise are illustrated in this figure: (1) aggregate noise levels vary with time over a range of more than 30 decibels; (2) identifiable loud sounds are superimposed on a background or residual noise level; and (3) different sources (such as aircraft as compared with local street traffic) produce different characteristic patterns of intensity versus time.

REPRESENTING AN URBAN NOISE ENVIRONMENT

Illustrations of how environmental noise can be characterized are given in Figure 2. The large drawing is a simplified map of a portion of a hypothetical urban community containing a number of different types of settings: manufacturing and industrial areas, commercial and shopping districts, thoroughfares and railroads, school and hospital areas, a residential section, and a park. The major noise sources include the highway traffic, the railroad, aircraft flying on two airways (V-64 and V-32) that cross over the commercial and industrial portions of the community, industrial and manufacturing operations, construction equipment, and, in the residential area, trash collection equipment, barking dogs, lawnmowers, and snowplows. Obviously, there are many other sources that contribute to the total noise level at any particular time or place.

The intensities of outdoor noise at the locations marked A,B,C, and D on the map might be as indicated by the temporal patterns shown in the small sketches. Although each of these patterns refers to a different kind of urban setting, each illustrates three features of most urban noise environments.

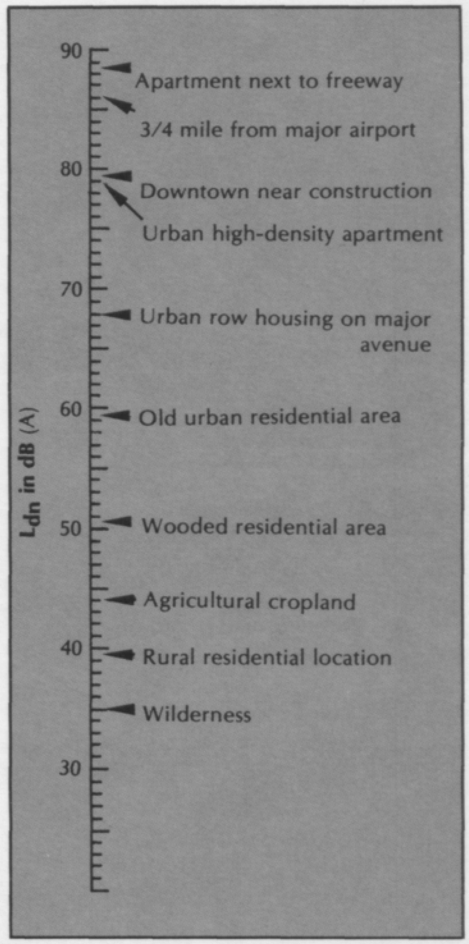
The first feature is that the aggregate noise level can vary with time over a range of more than 30 dB(A). This is usually perceived as an eight-fold range of noisiness, since a change of approximately 10 dB represents a doubling or halving of perceived loudness of a sound, and therefore a 30-dB(A) increase represents three doublings (2x2x2) or eight times the original noisiness.

The second characteristic typical of urban noise is that distinct, relatively loud sounds from clearly identifiable sources are superimposed upon a fairly steady lower noise level, called the residual or background noise level, that originates in sources not easily identified. Such superimposed, or intrusive, sounds are usually the most annoying of the urban noises; in general, the greater the difference between the intrusive noise level and the background level, the greater the annoyance. The introduction of "acoustic perfume" to the residual noise would narrow the difference between the two levels, but this is not usually considered a reasonable option for outdoor use. The main concern in managing environmental noise is, therefore, to reduce intrusive noise.

The third feature noticeable in the Figure 2 noise samples is the distinctive patterns of the intensity-versus-time graphs pertaining to the different locations. Aircraft noises, for example, continue for relatively long periods of time, but occur less frequently than noises from surface vehicles. Such pattern variations are significant, since the rapidity of reoccurrence as well as the duration determines how annoying a sound can be.

A factor to be noted is that individuals who travel from one place to another during the day experience different noise environments. For example, a person might live at location B, work at location A or C, and spend some time during the week in still other locations. Another consideration is that the noise-duration patterns would probably be different at various periods of the day or night, and also at different times of the year.

Figure 3. Typical day-night average sound levels measured in various outdoor locations. The index here is the day-night sound level *(L_{dn}), which incorporates a 10-decibel penalty on sound levels occurring between 10 p.m. and 7 a.m. This index is frequently used in characterizing the noise levels of residential neighborhoods. (Adapted from a report of the Environmental Protection Agency.)*

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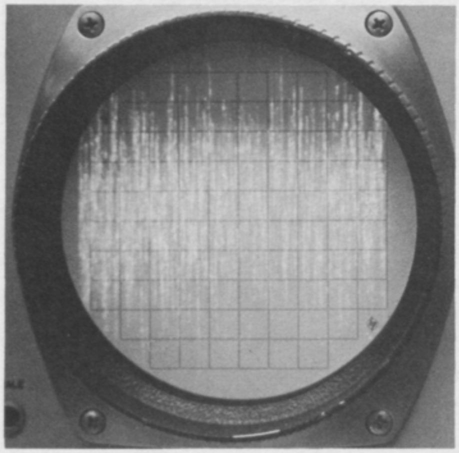


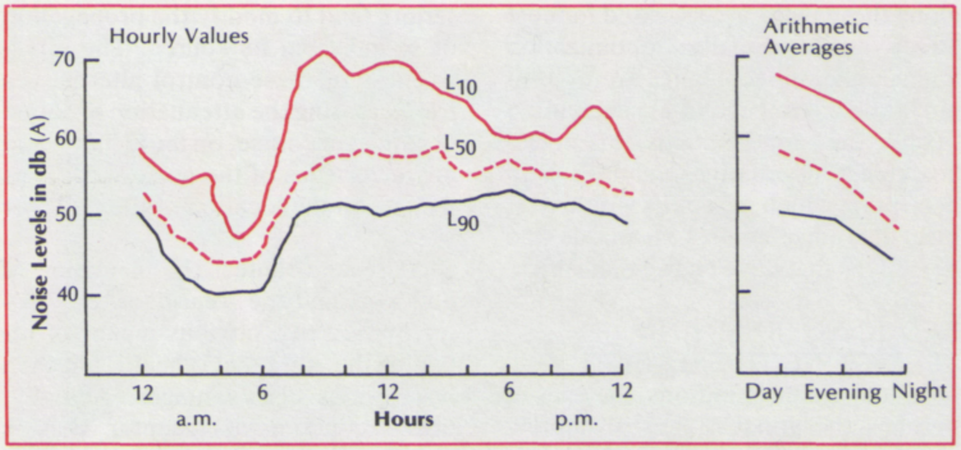


Figure 4. A typical noise environment for an individual over a 24-hour period. The three curves represent noise levels that are exceeded 90 percent of the time (L_{90}), 50 percent of the time (L_{50}), and 10 percent of the time (L_{10}). The residual level is generally considered as L_{90}.

The plots of arithmetic averages of hourly values show daytime levels declining during the evening hours and reaching their lowest values at night.

Figure 4 illustrates what an individual's daily noise environment might be during, say, the summer season. For the purpose of measurement, the residual noise level is often defined as that which is exceeded 90 percent of the time (L_{90}), and in which there are no identifiable noise sources. In the Figure 4 example, the residual noise level drops after midnight, reaches a minimum at about 5 a.m., and rises between 6 and 8 a.m. to an almost constant daytime value. The median level (L_{50}) is exceeded half the time; L_{10} represents a level that is exceeded only 10 percent of the time.

ENVIRONMENTAL NOISE MANAGEMENT: AN APPROACH

Environmental noise control can be approached in ways similar to those used for the control of other waste residuals. Air-quality, water-quality, and solid-waste management are familiar terms that imply economically efficient strategies for controlling the wastes that reduce the quality of our airsheds, waterways, and land. Noise management has similar implications.

A cost-effective strategy for environmental noise management is one that adequately reduces the noise—at the sources, at the receptor sites, or in between—at minimal cost. Because the effects of noise, like those of other mass and energy residuals released into the environment, are difficult to quantify, the specific objective is usually to meet predefined environmental quality standards with the greatest economic efficiency. For an urban area, the noise-control standards are expressed as the maximum noise levels, weighted according to duration and frequency, that are allowable at various locations. The task of the environmental engineer is to assess the available noise-abatement alternatives in terms of their ability to meet these standards economically.

In current practice, decisions about the expenditure of funds for the maintenance or improvement of environmental quality are often made on the basis of a mostly qualitative integration of numerous economic, political, social, and technological objectives. The explicit tradeoffs among these objectives (which are usually partially complementary and partially conflicting) have not always been clear, and consequently the results have not always been as good as anticipated or hoped for. The relatively new area of noise control promises to be no exception. Often the approach that is taken is simply to focus on certain particularly troublesome noise sources; but while this is administratively easy, it may fail to solve environmental-noise problems adequately.

In environmental management, the decision-making process is complicated by the uncertain effects of factors beyond the control of any decision-maker. In addition, there is the difficulty, even with the use of computers, of simultaneously considering all the relevant information. The technique that engineers and planners have developed in order to cope with these difficulties is to construct simplified models of the management problem and use them in processing whatever information is available. The models can range from those that are wholly conceptual and contained within the mind of the analyst or decision-maker, to those that are specified by sets of algebraic equations designed to be solved on high-speed computers. Whatever their form, the models enable one to predict and evaluate the possible outcomes of various policies. They permit a quantitative approach that can be a valuable aid, though not a determinant, in responsible decision-making.

A workable modeling approach that has been studied and developed at Cornell involves a number of carefully executed steps. First, each intrusive noise source is identified and measured, and similar measurements are made at a variety of receptor sites selected for their importance and for their coverage of the entire area of interest. In subsequent steps, alternative methods for reducing noise intensity or duration at the sources or at the receptor sites are identified and evaluated for cost effectiveness. In addition, all significant paths along which sound can travel between each source and each receptor are identified, and ways in which the sound could be attenuated along these paths are assessed for cost effectiveness. Finally, optimization and simulation techniques are used to aid in the overall economic evaluation of all the combinations of noise-abatement alternatives, and to help determine which measures would best meet the noise-control standards and objectives that have been established.

REDUCING NOISE AND PREDICTING THE EFFECTS

Of all these considerations, the ones of perhaps the greatest general interest are the alternative methods for noise reduction and the ways in which noise propagation and attenuation can be predicted in urban areas.

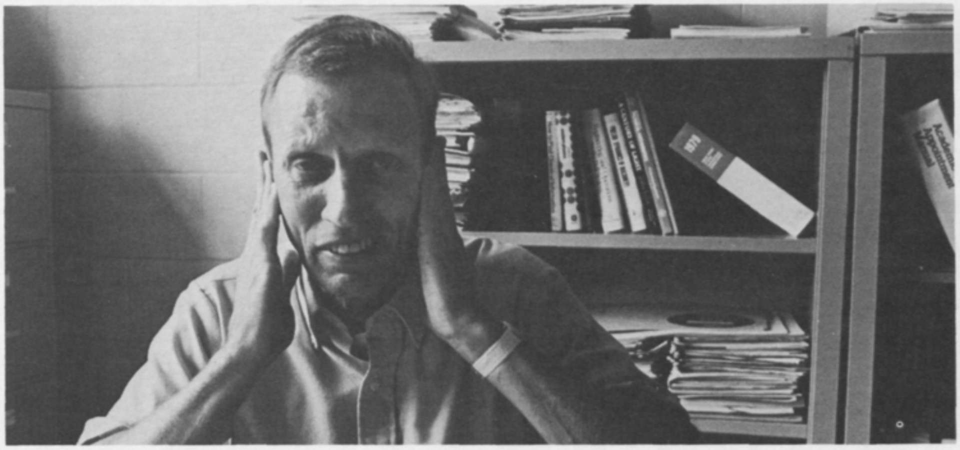
Noise can be reduced at most sources by improving the design of the object that emits acoustical energy, by shielding the object, or by a combination of design changes and shielding. It may also be possible to relocate the noise source, or change the time or duration of its operation. In some cases, changing the mode of operating certain kinds of equipment can substantially reduce the noise level. And simply enforcing noise-abatement procedures already required by law can have considerable effect.

Examples of methods for controlling noise at its source include shielding and improving the muffling of combustion engines and air compressors, restricting the operation of noise-producing equipment to certain hours of the day, reducing motor-vehicle speed and the number of stops required along city streets, and rerouting surface and air traffic. Constructing solid barriers, planting belts of trees and other vegetation, and modifying the material and shape of building exteriors tend to modify the propagation of sound from its source. The effectiveness of these control alternatives for increasing the attenuation of sound depends, of course, on the location and characteristics of the noise source, as well as on the location of the receptor sites.

At receptor sites, the insulation of buildings and the wearing of ear protectors are two obvious means of reducing the noise that is heard, but each has serious disadvantages. Actually, noise reduction at receptor sites is usually considered only when the social and economic cost of other noise-reduction alternatives is excessive.

The prediction of noise propagation and attenuation in an urban area, an essential part of the development of an urban noise-control strategy, is complicated by the existence of numerous obstructions of different shapes, sizes, and materials. Nevertheless, it is possible to estimate the attenuation of noise from each source to each receptor site along each path by the application of a series of rules pertaining to the various situations encountered. There may be free-field (unobstructed) conditions, or modifying structures may be present: barriers of buildings or trees, surfaces that absorb or reflect sound, or street canyons and intersections. Local meteorological conditions also have an effect.

Sound attenuation can be estimated by using either physical models or sound measurements at the actual site. Then the noise that each identifiable source contributes to each receptor site can be derived from a knowledge of the intensity of the noise source and the total attenuation along each path from that source to the receptor site.



Once this is known, it is relatively simple to predict the effect of any noise-abatement measure (applied at a source, within the transmission medium, or at the receptor site) on the aggregate noise level at any particular place.

A systematic approach to the definition and evaluation of alternatives for environmental-noise control obviously involves a lot of work. However, the success of similar techniques applied to the control of other waste discharges suggests that the method could be benefically applied to environmental-noise problems as well.

Since the passage of the Quiet Communities Act of 1978, there is hope that systematic approaches, specific to each particular environmental noise problem, will be more widely accepted and implemented. This act provides federal funds from the Environmental Protection Agency to develop and strengthen noise-control programs of state and local governments, and also to support ten regional Noise Technical Assistance Centers located at universities. Besides actually reducing environmental noise in certain cities, these activities are expected to demonstrate the feasibility of well designed noise-abatement programs. They should also help us all understand how environmental noise affects our hearing and our emotions, and what can be done about it.

Daniel P. Loucks, a specialist in environmental systems engineering, has had an active research program in the area of water resources planning and environmental quality control. His work has been in the development and application of methods involving mathematical programming, probability theory, and economics.

Loucks, a professor and chairman of the Department of Environmental Engineering at Cornell, has been a member of the faculty since he received his Ph.D. here in 1965. He holds the B.S. degree from the Pennsylvania State University and the M.S. from Yale University. During the 1950s he served for four years as an aviator in the United States Navy and continues to participate as a captain in the Naval Air Reserve.

His professional activities have included numerous international assignments. He has participated in exchange programs with the Soviet Union; served as a consultant to United Nations programs for development planning in Chile, Poland, Romania, and Yugoslavia; worked with the World Bank project on economic development in Brazil; and served on an advisory panel on resources and environmental problems for the United States representative to the International Institute for Applied Systems in Austria. At the present time he is helping the United Nations plan a regional development program for Honduras.

He has spent sabbatic leaves at Harvard University and the Massachusetts Institute of Technology, and with the World Bank as an economist. Since 1975 he has been a visiting professor for several weeks each summer at the International Institute for Hydraulic and Environmental Engineering in Delft, the Netherlands. He serves on two advisory panels for the National Academy of Sciences.

His honors include the 1970 Walter L. Huber Civil Engineering Research Prize awarded by the American Society of Civil Engineers, and a Fulbright-Hayes fellowship. He is a member of a number of professional and honorary societies.

INDUSTRY AND AIRCRAFT
Major Problem Areas for Noise Control

by A. R. George

In those days, the world teemed; the people multiplied, the world bellowed like a wild bull, and the great god was aroused by the clamour. Enlil heard the clamour and he said to the gods in council, "The uproar of mankind is intolerable and sleep is no longer possible by reason of the babble." So the gods agreed to exterminate mankind.
—from a translation by N. K. Sandars of *The Epic of Gilgamesh*, a Babylonian story believed to be the forerunner of the flood story in the Bible.

Noise appears to have been a problem even in ancient times, but, having averted the fate decreed by the gods in the Babylonian epic, civilized mortals have continued to increase the level of their noise. The Industrial Revolution, which transformed human life in so many ways, raised the decibel level by a large increment. But only in recent years has our society become less than tolerant of excessive noise, along with other undesirable byproducts of technology, particularly air and water pollution. Attention to acoustics and noise control has become significant only in the last twenty years or so.

The primary reason that noise has become more troublesome is simply that the amount of available *power* has increased dramatically in industrial societies. A rough approximation is that about 10^{-5} of the gross power produced by a machine is radiated as sound, and although this is a very small fraction—too insignificant to be worried about in terms of energy loss—it represents a large amount of sound as perceived by the ear. A 130-horsepower engine that produces 100 kilowatts of mechanical power may produce only one watt of acoustic power, but that one watt of sound is roughly equivalent to the maximum acoustic output of a home stereo system. Of course, the fact that acoustic power loss is so small compared with the useful energy output of a machine has meant that there has been little incentive for the manufacturer to reduce sound radiation. Actually, the steps needed to quiet a machine are usually detrimental to its ease of operation and its efficiency. Noise reduction has become an important objective only as our knowledge and awareness of the physically damaging and psychologically distressing effects of excessive sound have broadened, and as the evidence has become more conclusive.

Both the damaging and the annoying aspects of noise pollution are particularly significant in connection with aircraft and with industrial processes. The problems encountered in devising control measures are quite different in these two areas, however. I will discuss some of the advances that have been made in both aircraft and industrial noise control, and the problems that remain.

ASSESSING NOISE AND ESTABLISHING CRITERIA

Many experts believe that even a normal life in our society leads to significant hearing loss. Studies of African tribesmen who are never exposed to loud sounds show that they maintain into old age a keener hearing than that of most people in industrialized countries. The detrimental effects of noise


(Courtesy Pan American Airways)

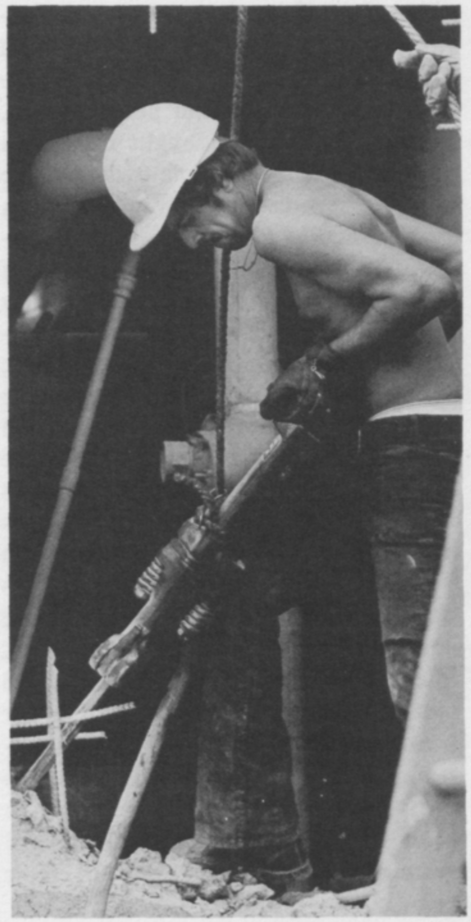
are, of course, greatly increased for individuals who are routinely or occasionally exposed to unusually loud sounds.

Retrospective studies of factory workers and others exposed to loud sounds led to the development of criteria to quantify hearing damage, and in the past fifteen years, the federal government has moved toward the enactment and enforcement of increasingly strict regulations designed to protect the hearing of industrial and other workers. The standards that have been set are based on the idea that a worker should not be exposed to a sound level higher than 90 decibels, or dB(A), during an eight-hour day. (The decibel scale is based on a logarithmic function of the power ratio of two sound energies. For example, 10 dB corresponds to a ten-fold increase in power output over a zero-dB sound, which is the lowest intensity sound that can be detected by the average human ear; 20 dB corresponds to a 10^2 or one-hundred-fold increase; and 90 dB to a 10^9 increase, amounting to a billion times the power of a zero-dB sound. The dB(A) scale is weighted to take into account frequency as well as intensity.)

What does the criterion of 90 dB(A) per eight-hour working day mean in terms of hearing? Many experts agree that about ten percent of the people exposed to this much sound will develop hearing impairment. Hearing impairment is defined as a hearing loss of 25 decibels, and means that the person will have difficulty with ordinary conversation. Obviously, the government standard is far from stringent, but even so, it is difficult to meet in many industrial environments. The large costs of meeting even more exacting standards have so far kept them from being imposed.

WHAT IS THE DIFFERENCE BETWEEN SOUND AND NOISE?

Even if it is not physically damaging to the hearing, sound can be annoying, and a realistic assessment of noise pollution must take into account this aspect of the problem also. Annoyance is even more difficult to measure than damage potential, however, because there are so many psychological vari-



ables. One of the more succinct definitions of the difference between sound and noise is that sound is what I make and noise is what other people make. Stereo music late at night may be a source of pleasure to the owner of the set, but a noise to his neighbor. A person driving an unmuffled motorcycle may be pleased by that sound of "power," but the people in the vicinity may find it obnoxious. There are interesting complications. For example, vacuum-cleaner manufacturers have found that a quiet machine will not sell well; consumers perceive the quiet one as having less power and therefore less cleaning ability than the noisier models. Nevertheless, if sounds that are in some way desirable are ruled out, it is possible to make measurements of the annoyance of sound. The dB(A) scale, interestingly, turns out to be a good measure for annoyance as well as for hearing-damage potential, a circumstance which suggests that these aspects are related and that people have been endowed with "well designed" systems for the protection of their hearing.

PROBLEMS IN CONTROL OF AIRCRAFT NOISE

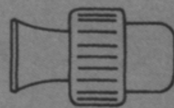
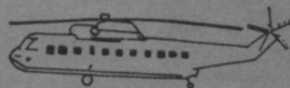
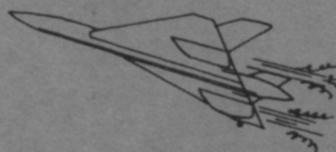
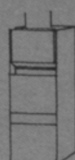
One of the most serious noise problems, particularly considering the large number of people who are unwillingly exposed to the sound, is caused by jet aircraft. The power output of jet engines is measured in megawatts; a typical large jet engine produces an amount of power comparable to the electric power used by a small city such as Ithaca, New York. Even when only 10^{-5} of this power is radiated as sound, it creates a severe problem, as anyone who has lived near an airport can attest.

The problem of controlling aircraft noise is compounded by the fact that the noise sources have not been completely identified and understood, and therefore control measures are difficult to prescribe. In contrast, the sources of industrial and machinery noises are, generally speaking, well defined, and most basic control ideas have been well established since around the turn of the century.

Concern about aircraft noise began to develop in the 1930s, when the problems were associated mainly with reciprocating engines and propellers. In the latter part of the decade, some progress was made in understanding the mechanisms of sound radiation from propellers, but the work was put aside with the outbreak of World War II. By the end of the war, jet aircraft had been developed, and their noise rapidly became the focus of attention.

Progress in understanding and reducing jet noise was slow, however, until 1952, when Sir James Lighthill developed his seminal ideas on aerodynamic noise generation. Previously, the generation of sound by the motion of a surface in a fluid medium (as in a loudspeaker) was understood, but there was very little comprehension of how the motion of the fluid itself, or the motion of a fluid near a surface, could generate sound. What Lighthill did was to manipulate the governing equation of fluid motion into a form that grouped the terms in such a way that they could be clearly interpreted as expressions of the sources of sound. This interpretation of Lighthill's equation is shown in Figure 1.

Figure 1. LIGHTHILL'S EQUATION FOR FLUID MOTION

In words:		In mathematical formulation:
[Sound sources]		$\frac{1}{c_o^2}\frac{\partial^2 p}{\partial t^2} - \frac{\partial^2 p}{\partial x_i^2}$
=[Unsteady addition of fluid]		$= \frac{\partial Q}{\partial t}$
+[Forces applied to the fluid]		$- \frac{\partial F_i}{\partial x_i}$
+[Interfluid forces, as in turbulence]		$+ \frac{\partial^2}{\partial x_i x_j}(\rho\, u_i u_j - \sigma_{ij})$
+[Entropy and working fluid changes, as in combustion]		$+ \frac{\partial^2}{\partial x_i^2}(p - c_o^2 \rho).$

The first term, identified as *unsteady addition of fluid*, corresponds, for example, to the creation of sound by a siren, in which a rotating perforated disc allows air to be released to the atmosphere periodically. Similarly, this term represents the origin of the sound of a pulse jet—a kind of engine used, for example, in the German V-1 missile of World War II. The second term, pertaining to *forces applied to the fluid*, is of more interest in modern applications because it governs the sound generated by moving parts: in loudspeakers, for instance, or in propellers and helicopter rotors. The third term, expressing *interfluid forces*, has perhaps the most significant implications for noise reduction in aircraft, for it pertains to the noise caused by turbulence in the exhaust of jet engines. The kind of noise represented in the fourth term is most commonly generated by *combustion* systems; an example is the sound of an oil-burning furnace. Research developments related to the second- and third-term effects will be discussed briefly.

"improvements in . . . noise control . . . will come about as the result of pressures."

(Courtesy Hughes Helicopters)

SOUND GENERATED BY HELICOPTERS

The rotating blades of helicopters make a wide range of sounds, depending on the flight conditions. The familiar bop-bop-bop-bop that is associated with cruising or descending helicopters is actually caused by two quite different mechanisms. One occurs during descent, as the rotor blades pass through the disturbed air that has been pushed downward by the rotor in sustaining the helicopter's weight; this interaction with disturbed air creates forces on the blades that radiate sound energy. This sound from descending helicopters is of particular concern near airports and in the maneuvering flight of helicopters in military operations. The other mechanism occurs during high-speed forward flight, when the forward-moving blades approach the speed of sound relative to the surrounding air. The resulting disturbance is built up into a sound wave propagating primarily in the forward direction, and this wave radiates a sound that is very similar to the characteristic descent noise, though perhaps closer to a repeated banging.

Considerable research on the high-speed helicopter noise has been conducted at Cornell and at other laboratories over the past decade; it is now quite well understood, and ways of reducing it are being developed. The noise due to the interaction of the blades with the disturbed air poses a more difficult problem, also under study at Cornell. Although research at NASA and at various helicopter companies has led to some promising ideas for a partial alleviation of this sound, there is still an incomplete understanding of the unsteady transonic flow interactions that generate the force between blade and disturbed air, and therefore the effects of various helicopter modifications cannot be accurately predicted.

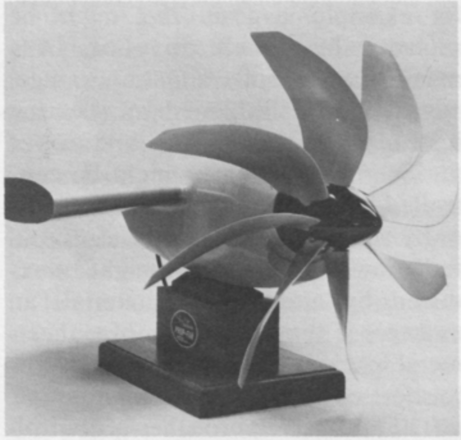
Another kind of helicopter rotor noise is the "rushing" heard when the craft is in hover, a noise that is an annoyance at locations close to heliports. Research at Cornell over the past eleven years has helped elucidate the generation of this sound and has led to methods for predicting it. We have been able to show mathematically how natural atmospheric turbulence interacts with the rotating blades to produce randomly varying forces which generate and radiate the rushing noise. In addition to the natural turbulence, there is also turbulence generated by the blades themselves, and recent work here has been concerned with the prediction of sound from this source as well. As a result of the Cornell studies, the rushing noise can be predicted and, conversely, noise reduction can be made by design changes based on investigations of the effect of various rotor design parameters.

The work on helicopter noise has some bearing on other aircraft noise as well. We believe that in the future, as projected reductions in jet engine noise are actually made, a dominant sound of landing jets will come to be *airframe noise*, generated on the aircraft surfaces by the same kind of forces that produce the rushing sound of a hovering helicopter's rotor.

TURBULENCE AS A SOURCE OF JET ENGINE NOISE

Although the mechanism of turbulence is extremely complex, and still under study at Cornell and other research laboratories all over the world, Lighthill's basic ideas on aerodynamic noise generation have provided guidance in the development of quieter jet engines for more than twenty-five years. Only recently have significant improvements been made on his way of looking at sound radiation from jets.

Lighthill's analysis showed that the sound power radiated from a jet engine exhaust varies as the exhaust velocity raised to the eighth power. This ex-



(Courtesy Hamilton Standard)

Left: A return to propellers for transport planes is a possibility for the future. Advanced high-speed turboprop engines would be less noisy and consume less fuel than jets. This propeller, the 24.5-inch-diameter SR-3 Prop-Fan model of the Hamilton Standard Corporation, is under test by NASA.

Below: Another indicated development is increased attention to the control of noise near airports. This vehicle is being used by Transport Canada to monitor environmental noise around Vancouver International Airport and other locations in the Pacific region. Data-gathering is the current phase in a program aimed at reducing aviation-related noise in communities near federally-operated airports.

The noise-monitoring vehicle shown is equipped with a rooftop microphone system that supplies signals at a rate of 36,000 an hour. Analysis instrumentation provides a continuous recording of sound-level variations and a statistical analysis of data over a period of time. By monitoring air and ground communications, the sound levels can be correlated with the operation of specific aircraft.

(Courtesy Transport Canada)

tremely large power law implies that the most efficient way to reduce jet noise would be to reduce the exhaust velocity. Fortunately, such a modification would have the additional advantage of reducing fuel consumption, and the double incentive has pushed the development of aircraft engines toward engines of larger diameter that move more air, but at lower exhaust speeds.

An interesting extrapolation of this trend is a possible return to the use of propellers on transport aircraft, since large propellers would provide the most efficient way of moving a large amount of air at a lower exhaust speed. Indeed, NASA and the Hamilton Standard Corporation are now working on transonic tip speed propellers to be used on a future generation of transport planes. It is ironic that this research was initiated at just about the time that the last propeller aircraft were being withdrawn from major airline passenger service in the United States. Unfortunately, the proposed new high-speed propeller aircraft, though more fuel-efficient, may develop some noise problems of their own, and considerable research will be required to develop acoustically acceptable designs. One of the noise mechanisms of such propellers is the generation by the blade tips of a series of repeating waves somewhat analogous to the sonic boom of supersonic jet aircraft. NASA and various aircraft companies are working on ways of minimizing the penetration into the cabin of this irritating noise. It is not yet known whether this noise will be a serious problem on the ground.

The sonic boom generated by supersonic aircraft is one of the most difficult current noise problems. Research at Cornell in the late 1960s and early 1970s established the fact that certain minimal levels of sonic boom could not be avoided by aircraft of given size under supersonic operation, and it may be necessary to continue the current regulation that permits aircraft such as the Concorde to fly at supersonic speeds only over the oceans. Nevertheless, it is probable that supersonic planes will become more and more economically competitive with subsonic aircraft, and that eventually most intercontinental passenger aircraft will fly supersonically, at least over oceans.

PROBLEMS OF INDUSTRIAL NOISE CONTROL

Industrial noise control presents problems markedly different from those encountered with aircraft. The mechanisms of noise generation by most industrial processes, by machinery, and by consumer products have been reasonably well understood for decades; the challenge is to alleviate the damaging and other undesirable effects of noise in response to heightened public concern.

Industrial noise control begins with an analysis of sound sources, propagation paths, and receiver sites. A rule of thumb in noise-control engineering is that the best results are usually obtained by working on the sound sources, and therefore these are the object of most attention. A requirement, of course, is that each important sound source be precisely identified, often a formidable task. Recently developed equipment, such as computer-based spectrum analyzers that can break up sound into its component frequencies, has been a great help, and it is now possible to diagnose accurately the sources of sounds in many kinds of machinery and products. For example, an engineer can determine the relative importance of the different sounds due to a diesel engine's intake, exhaust, fan, gears, cylinder-block vibration, and process of combustion.

Once a sound source has been identified, a number of measures can be taken to reduce the noise. One possibility is to change a machine process; for example, a gear drive might be replaced by a belt drive or, in a manufacturing-noise situation, a steel part could be fashioned by shearing instead of by stamping. Vibrations of various machine parts might be controlled by altering the design stiffness or by adding damping material. Sound radiation from a surface might be reduced by altering the material; an example is the perforation of a sheet-metal machine cover so as to allow air to short-circuit sound radiation.

The alternate approaches of controlling industrial or machine noise along its paths or at the receiver sites are sometimes tried. A path can be interrupted by sound barriers—materials that block or absorb sound energy in a factory, room, vehicle, or appliance. Or the receiver of the sound can be protected by an enclosure or by the provision of ear muffs or plugs.

LOOKING TO THE FUTURE IN NOISE CONTROL

Progress in aircraft noise reduction involves serious tradeoffs among the cost of noise-control measures, engine performance, and energy efficiency, and the problems of finding the best solutions are compounded by a lack of detailed knowledge about the sound sources and the available means of control. In some areas, such as the reduction of airframe and helicopter noise, in which not much research has been carried out, much more study is needed and significant advances in our understanding and capabilities can be anticipated. In other areas, such as the reduction of jet-engine exhaust noise, one suspects that the large amount of research already carried out has pushed knowledge close to its limits—at least until some new breakthrough is made—and that in the foreseeable future, progress will be made by improving and applying techniques that are already understood, if imperfectly. Most of the support for research in the overall field of aircraft noise control can be expected to come from the Federal government.

In the area of industrial noise control, costs and government regulations are the driving forces behind the application of what is basically existing knowledge. The need here is for applied research to find the most economical and convenient ways of implementing already available techniques. We can look for a gradual reduction in noise associated with manufacturing, machinery, and consumer goods, as regulatory standards are tightened, older machines are replaced with quieter models, and knowledge of noise-control methods becomes more widespread.

In the long run, I believe that improvements in these important areas of noise control, as in most aspects of technology, will come about as the result of pressures. Aircraft noise will be reduced in response to public demand. Industrial noise levels will diminish as a result of continuing efforts to enact more stringent government regulations. Noisy consumer products will be replaced by better-selling quiet ones. The impetus has been set in motion and we may be on our way to restoring a measure of quiet to our world.

Albert R. George, professor and director of Cornell's Sibley School of Mechanical and Aerospace Engineering, has conducted recent research on helicopter rotor noise, sonic boom, and aerodynamics.

George studied at Princeton University for the B.S.E. degree in aerospace engineering and the A.M. and Ph.D. degrees in aerospace and mechanical sciences. After receiving the doctorate in 1964, he spent several years as a research associate at Princeton and as a member of the faculty at the University of Washington before coming to Cornell in 1966. During a sabbatic leave in 1972-73, he was a senior visiting fellow in aeronautics at the University of Southhampton in England.

In 1970 George received the Ralph E. Teetor Award of the Society of Automotive Engineers. He has been selected three times as an Outstanding Faculty Adviser by the American Institute of Aeronautics and Astronautics (AIAA).

He has served as a consultant to several industrial firms in the United States, and to the Aeronautical Research Council in Great Britain. He is a member of the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the AIAA.

RURAL QUIET OR EAR PLUGS?

The Increasing Problems of Agricultural Noise

by L. Dale Baker

At the turn of the century most of the noise on a farm was produced by animals, and the people who were exposed to it—mostly members of the farm family—accepted it as part of their way of life. In the last eighty years, however, the character of rural noise has changed and so have attitudes toward it. Noise has become an issue in rural areas as well as in cities, and agricultural engineers are increasingly finding it necessary to deal with noise problems.

Much of the difficulty stems, of course, from the mechanization that has drastically changed both agricultural practices and rural living. A tractor obviously produces more noise than a team of horses. In addition, mechanical equipment produces a different kind of noise. Animals may be loud, but their sounds are likely to be of short duration; a modern tractor is not only loud but continuously noisy, and audiometric studies in several states have indicated that farmers today are experiencing serious hearing loss. Equipment like grain dryers, which have begun to appear on relatively large farms in recent years, produces a steady noise that can be very annoying.

Another factor that has emerged only in comparatively recent times is the influx of city families into rural areas. Nonfarm residents now constitute a significant portion of the rural population in many parts of the nation. These people are apt to expect quiet to be an attribute of the rural environment, and since they have no vested interest in the farming operations that create noise, they are less likely to tolerate it.

NOISE AS AN OCCUPATIONAL HAZARD OF FARMERS

Following World War II, the incidence of hearing loss among farmers began to rise with increased mechanization. By 1976 the federal Occupational Safety and Health Administration was considering the development of a noise-level standard for agricultural workers. It soon became apparent, however, that the regulation of agricultural noise presents difficulties not characteristic of industrial situations. For one thing, agricultural noise is seasonal and often it is intermittent. Furthermore, agricultural noise is quite varied; it is difficult to identify all the particular noise sources and propose acceptable exposure limits for each of them. The result is that there are currently no standards for allowable exposure to agricultural noise.

Some attempts at noise testing and control have been made at the University of Nebraska, which since 1919 has operated a special laboratory for tractor testing. By state law, a model of any tractor sold in Nebraska must be tested in this laboratory. Originally, the primary concern was durability of the tractors; current tests emphasize horsepower under a variety of load conditions, and fuel economy. In the late 1960s, however, staff members at the laboratory began to study the feasibility of recording noise levels. Measurements showed that the operator of a 100-horsepower tractor was likely to experience a noise intensity of at least 100 decibels [dB(A)]. A code for measuring sound levels was adopted, and since 1971, the report on

New farm equipment is likely to be equipped with an operator enclosure, which reduces noise heard by the operator, as well as providing ventilation and roll-over protection.

each tractor has contained information about its sound level.

The tractor-test reports for the decade of the 1970s document some progress made by manufacturers in reducing the noise levels experienced by operators. Cabs are available for most tractors, and on several lines an operator enclosure has become standard equipment. Such an enclosure provides a well ventilated and sometimes air-conditioned environment, and the surrounding structure provides roll-over protection. Moreover, inside such a structure the sound level in virtually all cases is less that 80 dB(A), a level that may be compared with the current allowable exposure of 90 dB(A) over an eight-hour day for industrial workers. More than half the tractors sold in 1980 are likely to be equipped with a sound-reducing operator enclosure.

The use of hearing protection, another approach to the prevention of hearing loss, is increasing slowly among farm workers, although the standard logic for not wearing it is often applied: it is not necessary; it is

too hot; it is uncomfortable. Older workers sometimes say it is too late to begin worrying about hearing loss. The younger generation, though, seems more receptive to the idea of using hearing protection.

Continued research at the University of Nebraska may provide information regarding two important unresolved questions. One is: Are there unique sources of noise on a farm that are likely to produce hearing loss? Over the past two or three years, a number of farm employees have been wearing noise dosimeters to provide data for a study of the causes of hearing loss. Although the results so far are inconclusive, such studies may eventually help in the identification and reduction of particularly troublesome noises. The other question is: To what extent will the sound attenuation in a cab be affected by normal use of a tractor over a period of time? Continual vibration, exposure to dust, and possibly limited maintenance are considered likely to reduce the effectiveness of the cab in reducing noise at the ear of the operator. To resolve this question, a selected sample of used tractors will be tested.

ENVIRONMENTAL NOISE AND THE RURAL RESIDENT

Until the advent of the automobile, urban workers were not able to live much beyond the boundaries of their city. Today many people who work in the city routinely commute long distances and the countryside has undergone a transformation. Housing for nonfarm families has become both accessible and available. With mechani-

An environmental-noise problem of comparatively recent origin is caused by the proximity of rural residences to noisy agricultural operations. This new house for a nonfarm family (1) is situated close to a noise-producing grain dryer (2), which may be in continuous operation during the season. The culprits are the fans (3), located inside the shed. (In this facility, grain is fed to the dryer through the hopper and stored in the cylindrical tank.) Residents who have no stake in the farming operation are apt to complain about the intrusive noise, particularly out-of-doors (4).

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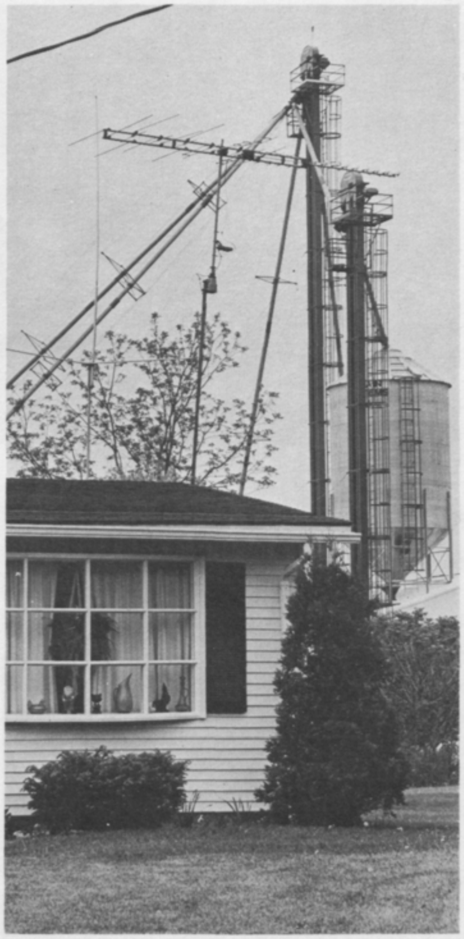

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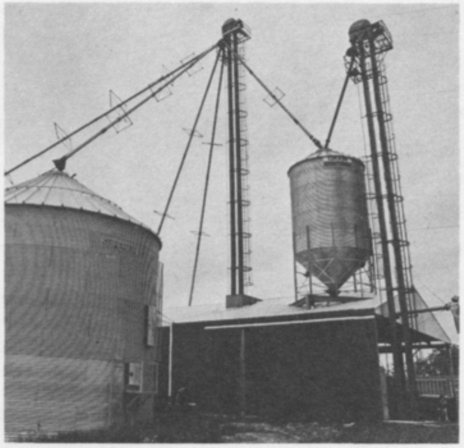

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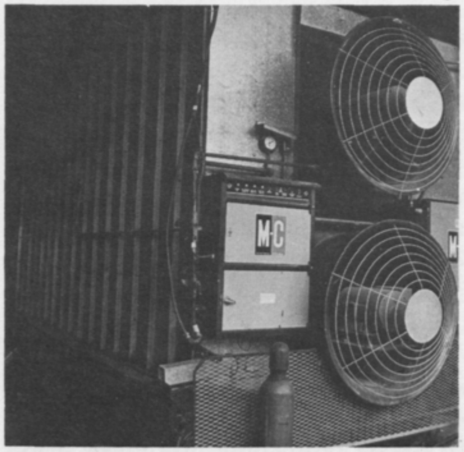

zation farms have become larger; a farm owner may purchase additional property and the farmhouse on the newly acquired land may be put up for rent or sale. Or a strip of land along the highway may be sold for a housing tract. Nonfarm people now frequently live adjacent to a farm operation.

The transient noise from seasonal field operations does not, in most cases, represent a major irritation for the nonfarm community. Battle lines are drawn when a long-term steady noise is developed from a stationary source such as a grain dryer or a saw mill. While a grain dryer is used only seasonally, it may be in operation twenty-four hours a day and constitutes a noise assault, particularly in the early morning hours.

A few states have enacted ordinances designed to protect nonfarm residents from noise. Typically, these laws specify a maximum decibel level that is permitted at the property line. Local governments have also tried to deal with the situation; a town ordinance in New York State, for example, contains an environmental section

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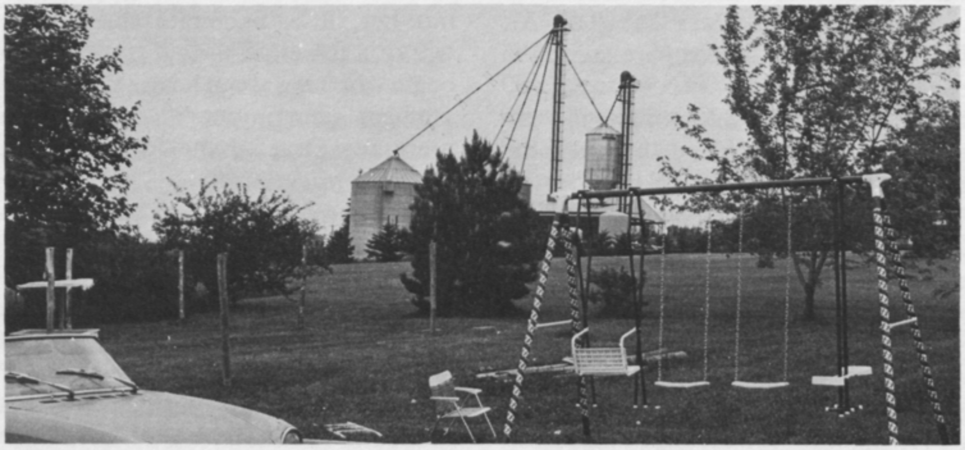


"Rural noise problems can be better solved by mechanical and agricultural engineers than by physicians or lawyers."

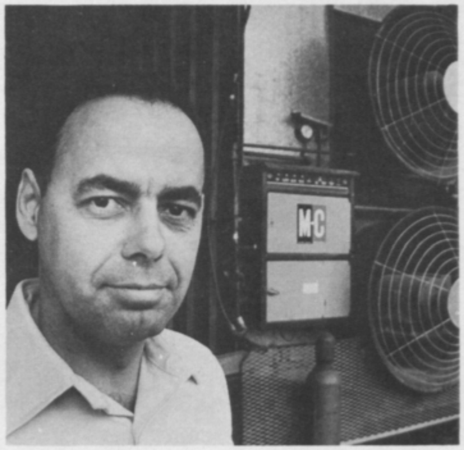
stating, in part, that "noise from any source should be muffled so as not to become objectionable due to intermittence, beat, frequency, shrillness or intensity."

From the standpoint of the farmer, there is no economic incentive to invest in noise-abatement measures, since these are nonproductive expenditures. Some reduction of the sound leaving a noise source can be relatively inexpensive, however. Surrounding the fan of a grain dryer with a stack of hay bales at a safe distance can be somewhat effective in reducing the noise. Placing a continuous barrier constructed of slabs of wood between the stationary engine of a saw mill and the offended neighbors may be effective to some degree. Experience shows, though, that once a noise has been identified as objectionable, reduction does not suffice; aroused residents tend to seek complete elimination of the irritation. The best strategy for farm operators is to reduce noise before the neighboring residents become offended. The real challenge is to find effective ways to do so.

ENGINEERING SOLUTIONS TO ENGINEERING PROBLEMS

Agricultural noise control is a rather new area of concern, but one that seems certain to receive more attention. The issues are of concern not only to farmers and rural residents, but to others interested in public health and environmental quality. At Cornell, extension engineers are encountering noise-related problems more and more frequently, and consideration of noise abatement measures have been introduced into the course work in agricultural engineering.

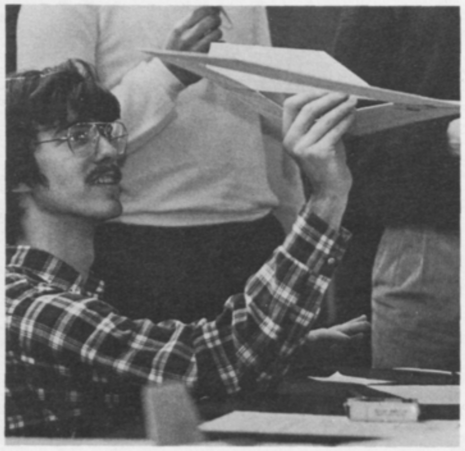
The major targets at the moment are manufacturers of agricultural equipment, who will be increasingly under pressure to produce quieter vehicles and machines to preserve and protect workers' hearing and to reduce environmental noise. Rural noise problems can be better solved by mechanical and agricultural engineers than by physicians or lawyers, however, and engineers should be encouraged to direct their attention to the solution of agricultural noise problems at their source.



L. Dale Baker, an extension safety engineer at Cornell for the past six years, works in conjunction with the Department of Agricultural Engineering.

He studied at the University of Nebraska for the B.S. and M.S. degrees in agricultural engineering, and spent two years as an instructor at Michigan State University. He is a member of the American Society of Agricultural Engineers, the Human Factors Society, the Farm Division of the National Safety Council, and the National Institute for Farm Safety.

VANTAGE



A Season of Capers with an Engineering Slant

■ To judge from contests sponsored this spring by local student chapters of professional societies, Cornell engineers endorse the old adages to fly right, keep afloat, and land safely.

A model glider and paper airplane contest was staged in Barton Hall by the Cornell chapters of the American Institute of Aeronautics and Astronautics (AIAA) and the American Society of Mechanical Engineers (ASME). A team from the American Society of Civil Engineers (ASCE) built and raced two concrete canoes in the annual national contest. And the ASME chapter sponsored an egg drop contest, in which entries were released from the fourth floor of Upson Hall.

The flying contest, held in March, was the first of the season. Some four hundred spectators showed up to watch the performance or catastrophic failure of more than one hundred model gliders and paper airplanes. The planes were made by folding 8½ by 11-inch sheets of paper provided free with the 50-cent entry fee. The glider models could be made of anything—the only stipulation was that they had to fit inside a box two feet square. Prizes in both categories were provided by the East Hill Flying Club and the Ithaca Soaring Club; they were a flying lesson for the entrant whose paper plane or model traveled the farthest, and a sailplane ride for the contestant whose plane or model stayed aloft the longest.

In this spring's concrete canoe race, Cornell teams competed against those of seventeen other civil engineering schools to take two third places and

one fourth place. Two Cornell-built canoes—*Teoman's Tub* (named for Professor Peköz, faculty adviser on the construction) and *Snap, Crackle, Pop* (a name derived from the shell's response to flexural stress)—were paddled by eight two-person teams. All the winners were in the 200-pound *Tub*. Coming in third were Jerry Burke and Jane Anderson in the mixed division, and Lesle Blythe and Kinga Gergely (wife of Professor Peter Gergely) in the women's race. In the faculty race, Richard White and Bill Day (graduate teaching assistant) took fourth place. In addition, the Cornellians named themselves winners in the unofficial submarine contest; Mike Rolband and Luc Chabot valiantly paddled *Snap, Crackle, Pop* to the finish line even after it had swamped. The races were held in April at West Point.

Left: Barton Hall was the scene for the model glider and paper airplane contest. A winner was a balsa glider (not this one) launched by Gary Armitage, a junior in applied and engineering physics; it flew 15.8 seconds over a distance of 176 feet, 5 inches to capture first place for both distance and endurance. A better endurance record was actually achieved with a down feather, which floated for 28 seconds, but its sponsor, mechanical and aerospace engineering major William Kane, magnanimously accepted only an honorable mention for the most original entry. An unofficial entry, a balsa glider launched by AIAA faculty adviser David Caughey, flew over 200 feet for nearly 16 seconds.

In the paper airplane contest, Todd Spindler, a senior in applied and engineering physics, achieved the longest flight time of 11.8 seconds. Lawrence Kawano, an arts college freshman, won for the longest distance, 102 feet, 5 inches.

Above: Juniors Jane Anderson (in the bow) and Lori Smith failed to win a prize in the women's division of the race, but at least they finished.

Right: The canoes were built by applying concrete over a mesh-covered wooden form (under construction here), which was removed after the cement had hardened. Styrofoam insulation was used as a flotation material. About twenty-five ASCE members took part in the six-month construction project. Co-chairmen were Tom Williams '80 and Marshal Haggard '81.

The idea of the egg drop contest was to design ingenious packaging that would permit an egg's safe arrival on concrete after a fall of thirty-seven feet. Sixteen of forty-five entries were successful, while the rest splattered onlookers with debris from vehicle and payload: cardboard, paper, coat hangers, wire, foil, balloons, styrofoam, parachute cloth, raw egg, water, and jello.

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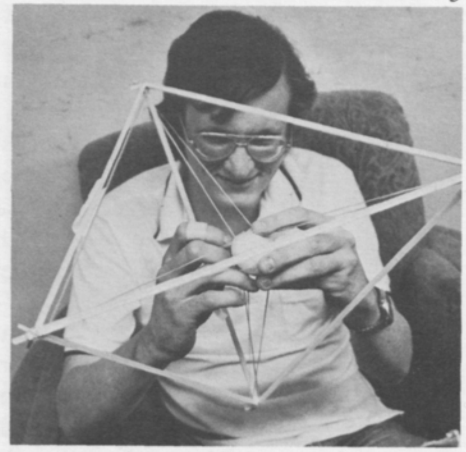

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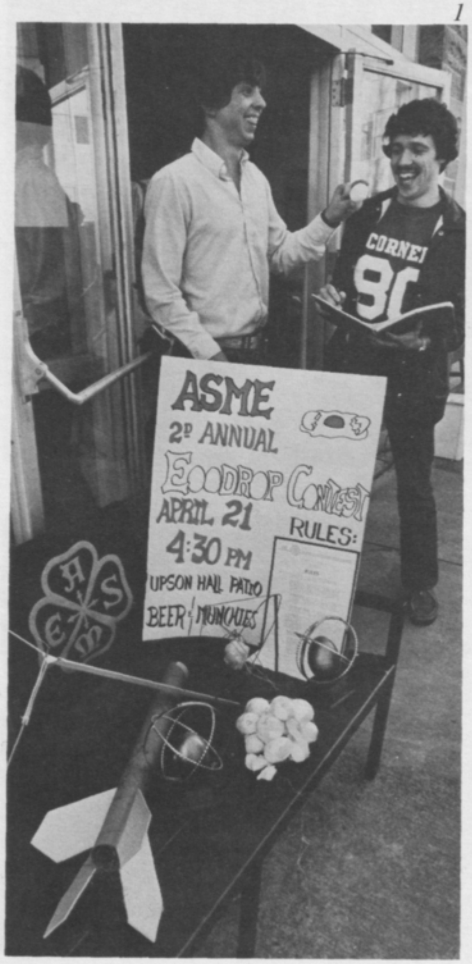

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Manning the registration table (1) for the egg drop contest were George Stromeyer '80, ASME president (at left) and Charles D'Angelo '80, treasurer. The contest was open to all comers.

Vehicles included a plastic glove (2) inflated and launched by Charles Harrington, Cornell staff member, and a balsa frame (3) designed and built by Pierre Boehler '80.

Most of the spectators ringed the Upson Hall patio (4), where the eggs dropped, but some had a vantage point (5) in an upper-story window.

A successful descent was made by a handkerchief parachute equipped with a yogurt-container gondola (6 and 7).

The winners and judges were, left to right: Bill Welsh, graduate student in M&AE; Elizabeth Bolgiano, secretary; Siegfried Janson, graduate student in M&AE; David Carlson '81; Judge Richard Kenyon, dean of the College of Engineering at the Rochester Institute of Technology; George "Jordy" Writer of Northeast Elementary School (son of Jack, Cornell soccer and tennis coach, and Chris, M&AE School staff member); Judge Richard Phelan, professor in the M&AE School; Peter Van Davelaar '81; Pierre Boehler '80; David Brodie '82; and William Textores '83.

8

REGISTER

■ A two-day symposium and the establishment of a professorship named in his honor were Cornell's tributes to Andrew Schultz, Jr., at the end of his final year of teaching and administration in the College of Engineering. Both the symposium and the professorship were surprises to Schultz.

The symposium attracted some one hundred fifty of Schultz's colleagues, students, former students, friends, and professional associates from all over the United States. Titled "The Evolution of Industrial Engineering and Operations Research," it featured talks on this subject and on current research and professional activities in that field at Cornell.

Speakers at the opening session were Emeritus Dean Robert H. Roy of Johns Hopkins University; Professor Salah E. Elmaghraby of North Carolina State University; John R. Boehringer '52 of Boehringer Associates; and W. Ben McAllister '65 of the Procter & Gamble Company. Byron W. Saunders, Cornell emeritus professor, was moderator.

On the following day the speakers were George L. Nemhauser, director of Cornell's School of Operations Research and Industrial Engineering; Associate Professor Michael J. Todd; Professor William L. Maxwell '56 (who coordinated the symposium arrangements); L. Jack Bradt '52, chairman of SI Handling Systems, Inc.; Ronald Nawrocki '76 of Xerox Corporation; Richard E. Turner, Jr. '77 of Theodore Barry Associates; and Kurt Wurl, student in the Master of Engineering degree program.

The establishment of the Andrew Schultz, Jr. Professorship of Industrial Engineering was announced at a dinner concluding the opening day of the symposium. It was attended by more than two hundred friends and associates of Schultz, including members of the Engineering College Council. The professorship, which will provide for a new faculty position, was accepted by Cornell President Frank H. T. Rhodes. Under the chairmanship of Bradt, a special committee has already solicited pledges for about 85 percent of the $800,000 needed to fund the chair.

Schultz, the Spencer T. Olin Professor of Engineering, emeritus, served as dean of the College of Engineering from 1963 to 1972 and as acting dean for several months in 1978.

His entire career has been centered at Cornell: he received the degree of Bachelor of Science in Administrative Engineering here in 1936 and the Ph.D. in 1941, and with the exception of World War II service in the Army, taught at Cornell ever since. His service to the College includes a major role in establishing the Department of Industrial Engineering and Administration and acting as its first head, and later in developing the unit that is now the School of Operations Research and Industrial Engineering.

A specialist in systems analysis, he helped establish computer science at Cornell as a discipline and as a department, and he provided leadership in the development of computer-based operations research techniques. He has been active also in developing the professional status of engineering, particularly as a board member of the Engineers' Council for Professional

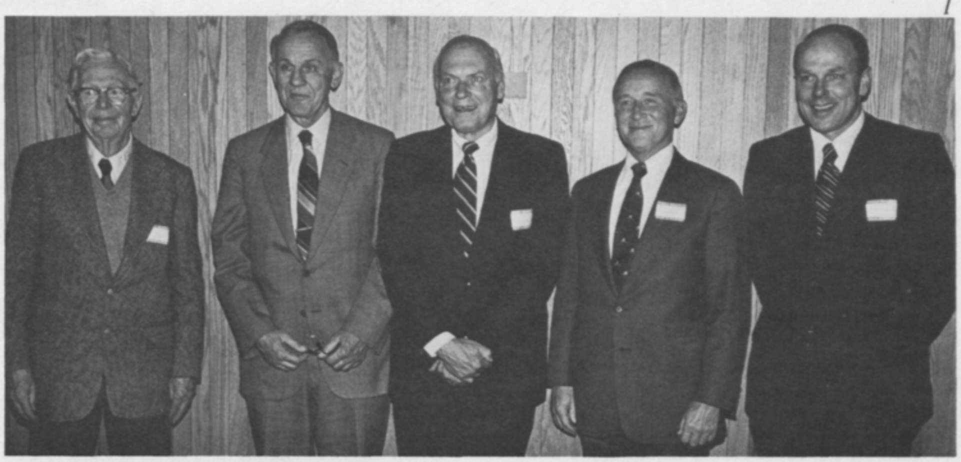
1. Present at the symposium dinner were all five men who have served as dean of the College of Engineering over the past forty-three years. Left to right are S. C. Hollister, dean 1937-59; Dale R. Corson (Cornell president, emeritus, and chancellor), dean 1959-63; Andrew Schultz, Jr., dean 1963-72 and acting dean, 1978; Edmund T. Cranch (now president of Worcester Polytechnic Institute), dean 1972-78; and Thomas E. Everhart, dean since 1979.

2. Mary Schultz and L. Jack Bradt were at the speakers' table. Bradt headed the organizing committee for the Schultz chair.

3. Charles W. Lake, Jr. (at left) was master of ceremonies at the dinner honoring Schultz (at right). Lake, chairman and president of R. R. Donnelley & Sons Company, chaired the Engineering College Council during Schultz's deanship.

4. Schultz is applauded after the announcement of the new chair. Those nearby are Cornell president Frank H. T. Rhodes (at left); Corson (in rear); Everhart; and Hollister.

1



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Development and as a member of the Commission on Education of the National Academy of Engineering.

Throughout his academic career, he has functioned also as an industrial consultant and as a member of government panels and advisory groups, and he continues as a director of several corporations.

Schultz is a fellow of the American Institute of Industrial Engineers and the American Association for the Advancement of Science, and a member of other professional and honorary societies. In 1972, when he completed his term as dean, he received the Cornell Engineering Award.

He and his wife, Mary, have two grown children: Susan, an engineer, and Andrew, a geologist.

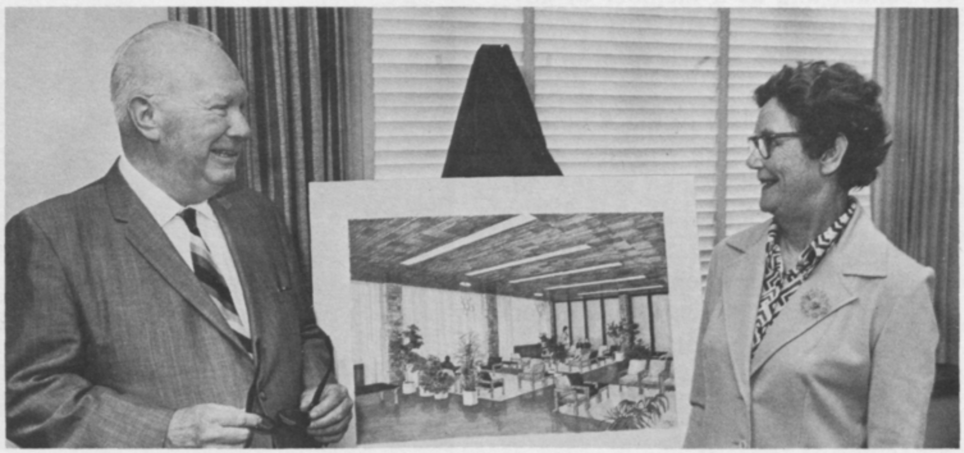
■ John F. McManus, a Cornell civil engineering graduate who retired this summer after an administrative career at the College of Engineering that spanned almost four decades, was honored by the College with the Cornell Engineering Award and the designation of the John F. McManus C.E. '36 Lounge in Hollister Hall. Since 1970 McManus had been associate dean with responsibility in the areas of financial management, personnel, and facilities modifications.

The lounge, which is being completely refurbished, is one facility modification that McManus had nothing to do with: the project was undertaken as a surprise tribute and the remodeling and refurnishing are being funded by contributions from civil engineering alumni and friends of McManus and the School of Civil and Environmental Engineering. According to Richard N. White, director of the School, changes in design and decor "will reflect John's character, conveying a sense of both strength and friendliness that will enrich and warm the lives of the many thousands of future users of the lounge." The room, which is located on the ground floor, is the focal point for much of the activity in the school, White said.

McManus

A bronze medal representing the Cornell Engineering Award was presented by Dean Thomas E. Everhart at the luncheon meeting of the Engineering College Council on May 9. Announcement of the planned dedication of the lounge was made on the same occasion.

McManus first came to Cornell as a student in 1932; he was graduated in 1936 with the degree of Civil Engineer. After working for four and one-half years as a structural engineer with the Eastman Kodak Company in Rochester, he served during World War II as resident director of Cornell's Engineering Science and Management War Training Program in the Buffalo area. He also spent a term on campus teaching civil engineering. For two years after the war he was in New York City as chief planning engineer for the National Dairy Company, but in 1948 he returned to the College of Engineering as administrative assistant to Dean



S. C. Hollister, and he has remained on the staff during the administrations of five deans.

For many years, McManus coordinated the Cornell information for the educational and accreditation program of the Engineers' Council for Professional Development, and worked also with the New York State accreditation program. He has been active in the American Society for Engineering Education, and is a member of the American Society of Civil Engineers and of the honorary societies Tau Beta Pi, Chi Epsilon, and Phi Kappa Phi.

At Cornell he was in charge of commencement arrangements for twenty-one years, and served on numerous College and University committees. He has been secretary of the Engineering College Council and president of the Statler Club. In the Ithaca community, he was active over a period of years in the Boy Scout organization.

He and his wife, Elizabeth, have two sons, John, a Cornell civil engineering graduate, and William, a graduate of Cornell's College of Agriculture and Life Sciences.

Left: John and Betty McManus view the architect's drawing of the John F. McManus C.E. '36 Lounge as it will look after remodeling and redecorating have been completed. The occasion was a luncheon attended by colleagues, associates, and friends. At that time McManus was also presented with the Cornell Engineering Award "in recognition of his service to the college."

Below: Informal reminiscences and tributes from the five deans with whom John F. McManus worked were collected for a special Cornell Engineering Award leaflet and a wall display to be placed in the Hollister Hall lounge. Excerpts are reprinted here.

Everyone who has ever worked with him swears by John. He has a credibility that surrounds him.

–S. C. Hollister
Dean 1937-1959

His long association with the College, his understanding of its workings, and the warmth, friendliness, and cooperative nature of his whole approach to life made the association a happy one.

–Dale R. Corson
Dean 1959-1963

John was always there to provide backup, continuity, and understanding of institutional history and traditions. . . . He knew when to connive, when to refuse, when to cajole, and when to ignore, and he accomplished what was needed to be done with grace, humor, conscientiousness, and tact.

–Andrew Schultz, Jr.
Dean 1963-1972

The College has prospered in large part because, for more than four decades, it has harbored in its midst one Unsung Hero. Consider the criteria. An Unsung Hero must: Possess absolute integrity . . . Maintain a deep commitment to an outstanding institution, even when one is torn by problems of the times . . . Use excellent judgment in all things personal and professional . . . Understand the meaning of forgiveness . . . Understand the alchemy of transmuting money into worthwhile ventures . . . Take delight in the successes of others, and demonstrate kindliness, warm personal interest, and deep human feeling toward all associates.

–Edmund T. Cranch
Dean 1972-1978

The absolute integrity John McManus has shown, coupled with a deep personal concern for his colleagues among the faculty and staff, have set a standard for all of us . . .

–Thomas E. Everhart
Dean 1979-

■ Charles D. Gates, a member of the Cornell faculty since 1947, was named professor, emeritus, of civil and environmental engineering this summer. A specialist in water quality control and waste management, he has been active as a consultant and researcher in these areas throughout his teaching career.

Gates received the B.A. degree in chemistry from Williams College in 1937 and the M.S. in sanitary engineering from Harvard University in 1939. Before coming to Cornell, he spent several years as an engineer on flood-control projects and in the development of desalination techniques.

At Cornell he has served for many years as graduate faculty representative in the graduate Field of Water Resources, and has been program director for an Environmental Protection Agency graduate training grant in water quality control engineering. He headed the sanitary engineering group in the School of Civil and Environmental Engineering, served as chairman of the former Department of Water Resources Engineering and as acting chairman of the Department of Environmental Engineering, and was director of the Center for Environmental Research.

He spent sabbatic leaves from Cornell at Harvard University in sanitary engineering research, at the Water Quality Branch of the Tennessee Valley Authority (TVA), and with the Raritan Bay Water Quality Study of the federal Public Health Services.

His research in recent years has been in the areas of urban water runoff and its effects on water quality; on environmental impacts of new energy technologies; and on the characterization and treatment of wastes in water-treatment plants.

Gates

Sampson

In activities outside the Univesity, he has worked, for example, with the Corps of Engineers on the Oswego River Basin Studies and with the American Water Works Association in a study of the disposal of wastes from water-treatment plants. He has served as a consultant to the New York State Environmental Facilities Corporation, the TVA, Abt Associates, and the New York State Electric and Gas Corporation. Locally he was vice chairman of the Cayuga Lake Basin Planning Board and chairman of a survey committee for a comprehensive sewerage system.

In 1971 he received a Presidential Citation for his contributions in the area of water-pollution control.

He and Mrs. Gates are "looking forward to a change of pace in the tidewater Virginia countryside," where he expects to "continue his water-related activities, but with a different emphasis." The Gates have three grown children, one of whom is now a student at Cornell.

■ Martin W. Sampson was appointed professor, emeritus, of operations and research and industrial engineering this summer after thirty-nine years on the Cornell faculty and staff. At the time of his retirement, he was dean of the Division of Summer Session and Extramural Courses.

Sampson is a Cornell alumnus as well as professor and administrator. He received the B.S. degree in administrative engineering in 1939, and after a year and a half as an engineer with the Chevrolet-Buffalo division of the General Motors Corporation, returned to the University as a graduate student and instructor in administrative engineering. He was awarded the M.S. degree in industrial engineering in 1945 and remained as a member of the faculty. In addition to his on-campus classes, he taught numerous extension and adult education courses at nearby industrial plants.

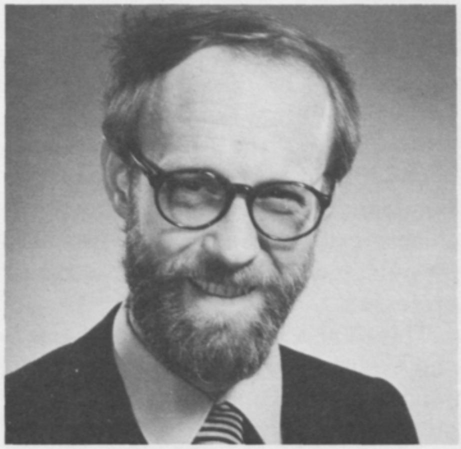
He began his administrative service as acting director of the Division of Unclassified Students in 1965, became acting director of the Division of Basic Studies in the College of Engineering the following year, and then served as director of the Division of Unclassified Students from 1967 to 1973. In 1968 he was also appointed director of the Division of Summer Session and Extramural Courses; he was named dean of that division in 1971.

His extensive experience in foreign countries has included a Fulbright lectureship at the University of the West Indies in Trinidad in 1967. During earlier leaves he worked in Mexico as a consultant in job analysis and evaluation for the International Cooperation Administration, and in Turkey teaching production management at the Middle East Technical University in Ankara in a project of the Agency for International Development.

At Cornell Sampson has served on numerous committees, including those on undergraduate and Fulbright scholarships, on the economic status of the faculty, on athletics, and on student conduct. He has been president of the Cornell chapter of the American Association of University Professors (AAUP) and a member of the board of directors of the Cornell United Religious Work, and he served three terms in the University Senate. He is a member of the American Institute of Industrial Engineers, the American Society for Engineering Education, and the AAUP.

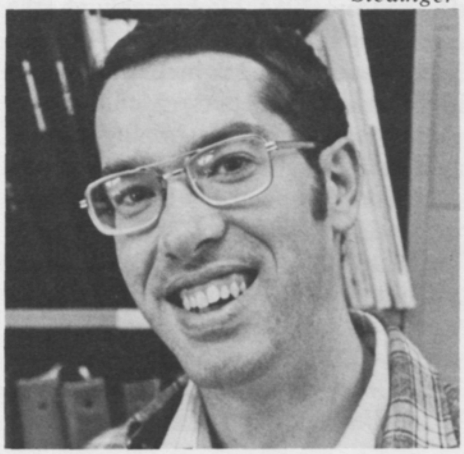
Sampson is a native of Ithaca (his father, the late Martin W. Sampson, Sr., was chairman of the Department of English at Cornell), and he and his wife, Anne, will maintain their home here. They have two children, Martin 3rd, an assistant professor of political science at the University of Minnesota, and Deborah, a nurse at Connecticut Hospice in Branford.

Lovelace



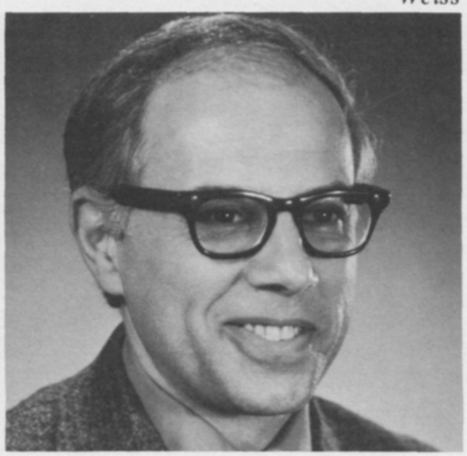
■ Richard V. E. Lovelace, associate professor of applied and engineering physics, was chosen for this year's Award for Excellence in Engineering Teaching. The award is sponsored by the Cornell Society of Engineers and the student honorary society Tau Beta Pi, and includes a $1,000 prize. The recipient is chosen on the basis of student nominations. Lovelace teaches courses in fluid dynamics, electricity and magnetism, and cosmic electrodynamics. A Cornell Ph.D., he has been on the faculty here since 1972.

Stedinger



■ The 1979-80 CEE Professor of the Year is Jery R. Stedinger, an assistant professor here since 1977. The recipient of this annual award is chosen by vote of all students in the School of Civil and Environmental Engineering, and the award is presented by the honorary society Chi Epsilon. Criteria are excellent teaching skills, concern for learning, and a good relationship with students. Stedinger's specialty area is mathematical modeling for environmental and water resources system management.

Weiss



■ Lionel I. Weiss, professor of operations research and industrial engineering, was chosen for this year's Outstanding Teacher Award in the School of Operations Research and Industrial Engineering. The selection is made by student vote administered by the student chapter of the American Institute of Industrial Engineers. A specialist in statistical decision theory, sequential analysis, and nonparametric statistics, Weiss has taught at Cornell since 1957. He was the 1973 recipient of the Excellence in Engineering Teaching Award.

Liu

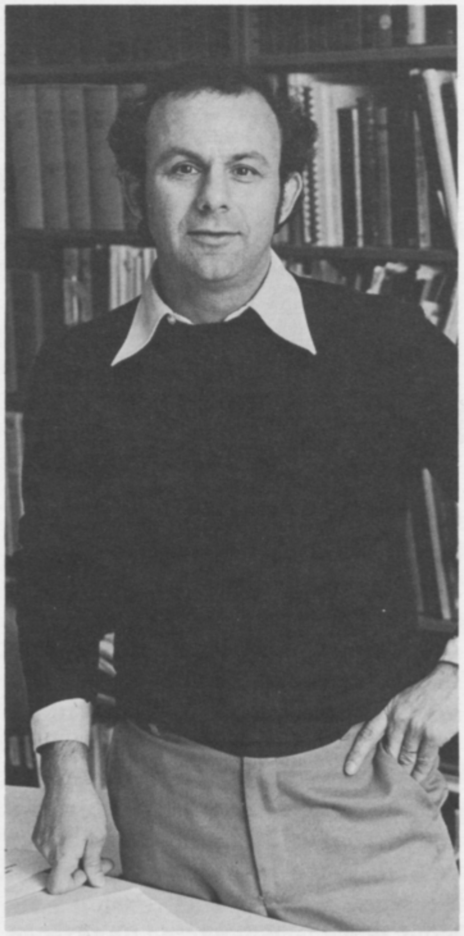
■ Three College faculty members were among eleven Cornell professors and 276 scholars, scientists, and artists nationwide who were awarded Guggenheim fellowships for 1980-81. The three from the College are Philip L.-F. Liu, associate professor of civil and environmental engineering; David N. Seidman, professor of materials science and engineering; and Michael J. Todd, associate professor of operations research and industrial engineering. All three will be on sabbatic leave.

Liu, a specialist in fluid mechanics, hydraulics, coastal engineering, and oceanography, will continue theoretical and experimental studies of wave hydrodynamics at the California Institute of Technology. He has also received an Engineering Foundation fellowship for this work. A Ph.D. from the Massachusetts Institute of Technology, he joined the Cornell faculty in 1974. In 1978 he received the Walter L. Huber Civil Engineering Research Prize of the American Society of Civil Engineers and also the Justice Foundation faculty fellowship in engineering at Cornell, which is awarded for outstanding service as an assistant professor.

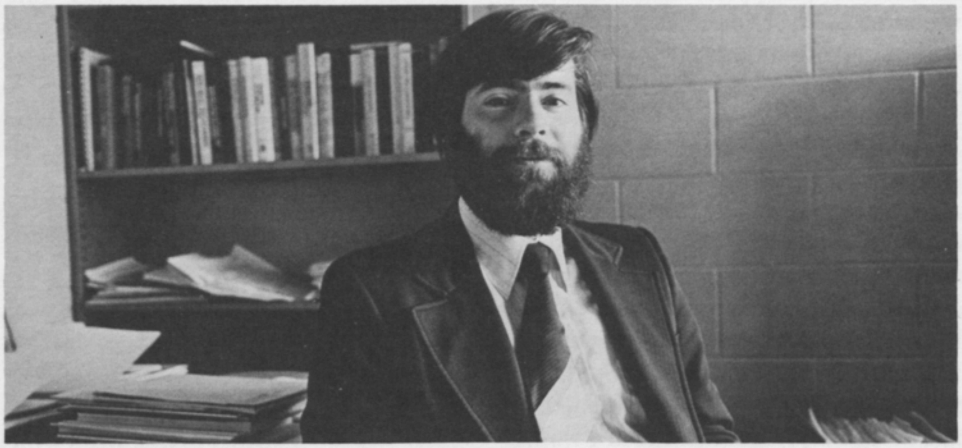
This year's Guggenheim is the second awarded to Seidman. He plans to conduct research in Israel and France on problems related to defects in semiconductors. Seidman came to Cornell in 1964 after receiving the Ph.D. from the University of Illinois. His previous honors include the 1967 Robert Lansing Hardy Medal of the American Institute of Mining, Metallurgical and Petroleum Engineers.

Todd will spend his leave at Cambridge University, England, his undergraduate school, conducting research on numerical techniques for solving nonlinear equations. He came to Cornell in 1973 after earning the Ph.D. at Yale University and teaching for a year at the University of Ottawa.

Seidman



Todd



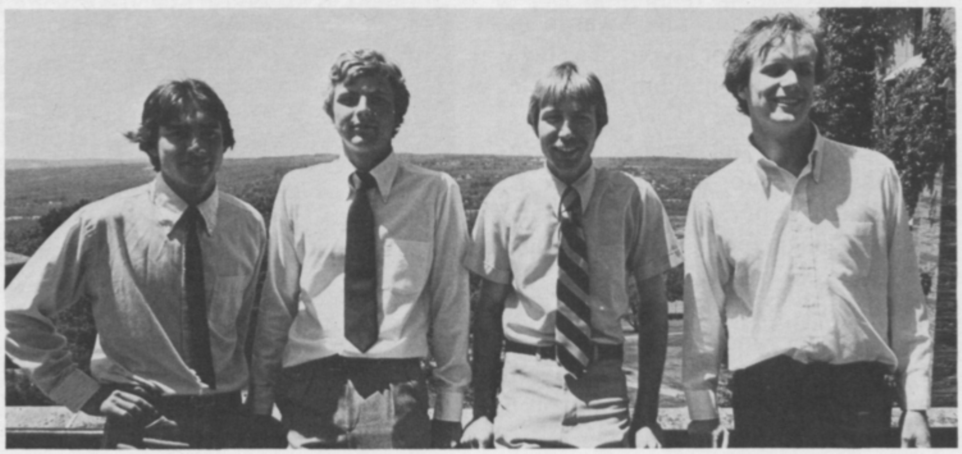
■ The Byron W. Saunders Award in Operations Research and Industrial Engineering was established this spring and announced at a luncheon on May 10 that concluded the Cornell symposium on OR&IE. The new $200 prize, which will be awarded annually to the top senior in the School of Operations Research and Industrial Engineering, was divided this year among four (see the picture caption) who achieved perfect records.

The award was named in honor of "a man who devoted his energies for many years to the encouragement of excellence in academic performance by undergraduate students." Saunders became professor, emeritus, in 1979, after serving for thirty-two years as professor, head of the industrial engineering department, director of the School, director of continuing education in the College of Engineering, and finally as elected dean of the University faculty.

He holds the B.S. degree from the University of Rhode Island and the M.S. in engineering economics from Stevens Institute of Technology. Before beginning his teaching career, he spent ten years in industry, and has remained active as a consultant. He is a fellow of the American Institute of Industrial Engineers, belongs to other professional organizations, and has participated in the accreditation program of the Engineers' Council for Professional Development.

Saunders

Below: Winners of the initial Byron W. Saunders Award are (left to right) Peter Crampton, James Gingrich, Samuel Mallette, and Christopher Jones.



■ A flurry of student prizes accompanied the concluding weeks of the academic year. The *Quarterly* received word of the following.

Rodney E. Thompson '80, a chemical engineering major, was awarded the American Institute of Chemists Medal for scholastic achievement and leadership.

Four civil and environmental engineering seniors received awards in the structural design competition sponsored by the James F. Lincoln Arc Welding Foundation. *William C. Dass* and *Maryann R. Wagner* shared a $1,000 first prize for the design of a large convention and exhibition center with a steel space frame roof. *Thomas E. Higgins III* and *Timothy R. Miller* won a fourth prize of $250 for their design of a steel arch bridge over the Bisby Creek Gorge site south of San Francisco. In addition, the Department of Structural Engineering received a $500 award in recognition of the instruction received by the students in a class taught by Teoman Peköz and Richard N. White.

The Department of Geological Sciences reported two special memorial prizes. *David Harding* received the $1,000 Chester Buchanan Memorial Scholarship Award, given each year to an outstanding male senior recommended by the faculty. The award, established in 1936, is in memory of a Cornell geology graduate who was killed in an airplane accident. *Ellen Kappel* is the recipient of the Michael W. Mitchell Memorial Scholarship Award, presented to a senior who has proved adept in other fields as well as in geology. This award commemorates a 1956 geology graduate who died in a mining accident in 1959.

Wilson

■ An engineering graduate who studied art throughout his undergraduate years culminated his senior year with a sculpture exhibit as well as the receipt of a B.S. degree in mechanical and aerospace engineering. Nicholas G. Wilson had his one-man show in the M&AE lounge of Upson Hall. The exhibit included large steel abstract sculptures and smaller figures of clay or cast in plaster and painted. The opening was attended by students and faculty members in both the arts and engineering.

Announced at graduation exercises were several prizes won by mechanical and aerospace engineering seniors. *Douglas E. Ruth* won both the ASME student-section prize for the outstanding senior and one of two Sibley Prizes (established in the 1880s) for highest grades. The other Sibley Prize winner was *Chikong Yeung*. The AIAA Outstanding Achievement Award went to *Hans J. Dall*. Winner of the $125 McManus Design Award (named for emeritus professor Howard McManus) was *Eric Gustafson*.

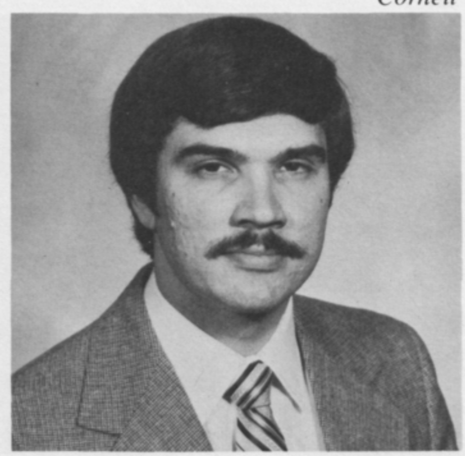
Honored seniors in the School of Operations Research and Industrial Engineering included *James Gingrich*, who was awarded both the George B. Raymond, Sr. Memorial Scholarship of the Material Handling Institute, and one of four Byron W. Saunders Medals (see the separate story about this new award). *Douglas Ehmann* was selected as outstanding teaching assistant, and *Jeffrey Goldberg* as outstanding M.Eng. degree student, respectively. Goldberg also won third place in this year's Silent Hoist and Crane Company Materials Handling competition.

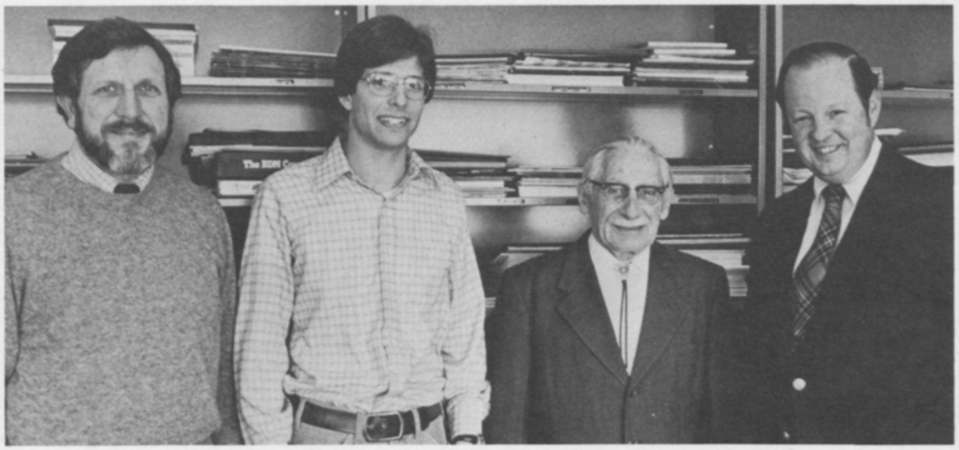
First prizes of $125 in the Silent Hoist and Crane competition went to *A. Robert Florio III, Steven G. Horowitz,* and *Elizabeth A. Kiskin,* who submitted their M.Eng. (OR&IE) project report, "Analysis of Warehouse Utilization for Unit Load Storage." Second prize was won by *Samuel R. Wennberg,* a senior in mechanical and aerospace engineering. Entries are based on problems encountered in course or project work.

The *Cornell Engineer*, a student publication, won several prizes in the Engineering College Magazine Association competition. The awards included first places for layout of a single issue and for a nontechnical article. Staff members were *Charles D. Pevsner* '80, a computer science and English major, editor-in-chief; *Ivan L. Lustig* '80, an operations research and industrial engineering major, managing editor; *Kenneth Gruskin* '82, design director; *Russell Gerry* '80, publicity manager; and *Carol E. Johnson* '81, an electrical engineering major, assistant managing editor. Johnson is the current editor-in-chief.

■ Ronald G. Cornell, who holds three degrees from the University, has been named the Outstanding Young Electrical Engineer for 1979 by the national honorary society Eta Kappa Nu. Cornell worked with H. C. Torng for his Ph.D., awarded in 1973. Since then he has been at Bell Laboratories in Naperville, Illinois; he is now head of the Special Features Department, developing software for an advanced mobile telephone service system. Earlier work culminated in the first production of a voice storage system.

Cornell





■ The one-thousandth student in the Engineering Cooperative Program entered this spring in the program's heaviest enrollment since its beginning in 1947. The "milestone" student was Richard H. Swope, Jr.

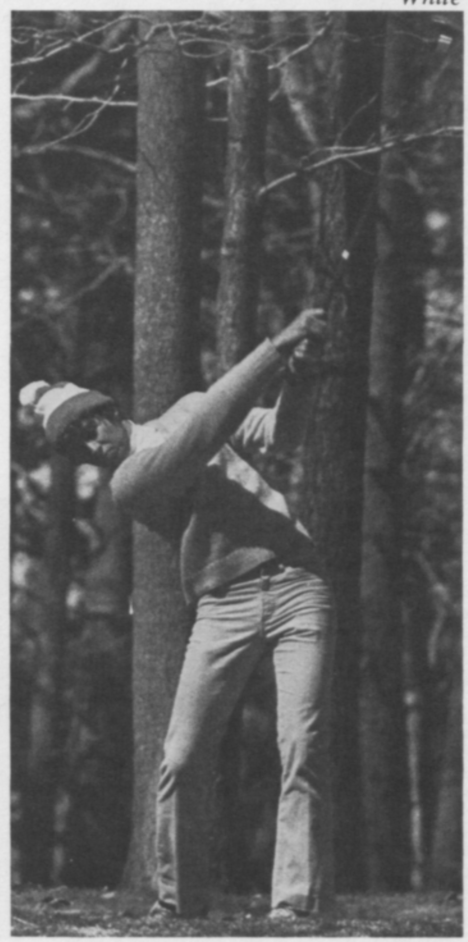
The work-study program began with six students employed by the Philco Corporation and has expanded to its current record size of 160 students, including 110 who entered this summer, and sixty-five employers. Past directors are emeritus professors Everett M. Strong and Robert N. Allen. Current directors are Richard H. Lance, associate professor of theoretical and applied mechanics, and Donald F. Berth, director of engineering development and special projects.

Under the program, students spend a semester and one or two summers in paid employment during their undergraduate years. The program is unique because the scheduling permits the students to graduate on schedule. The jobs provide work closely related to the students' engineering specialties; opportunities are available in all of the College's major subject areas.

Above: Richard H. Swope, Jr., the one-thousandth Engineering Cooperative Program student, is welcomed by the present and founding directors. From left to right are Richard H. Lance, co-director; Swope; Everett M. Strong, organizer of the program; and Donald F. Berth, co-director. The one-thousand mark was reached during the annual assignment this spring of incoming Coop participants. Swope, a sophomore at the time he enrolled in the program, is majoring in electrical engineering and will work at the Raytheon Corporation, a work-study employer since 1959.

■ The individual medalist at the Ivy League Golf Tournament this spring was an engineering senior, Tom White, who shot a three-round score of 227 at the Cornell course and placed on the All-Ivy team. (Princeton won the tournament with a team score of 931; Cornell was second with 960.) White's score was four points below the second-place tie, and included a par-72 final round. An agricultural engineering major, White may pursue a career in technical sales or marketing—or he may become a golf pro.

White



■ A colloquium honoring S. C. Hollister, emeritus dean of the Cornell College of Engineering, was held at Princeton University June 2. Titled "Perspectives on the History of Reinforced Concrete in the United States, 1904-1941," it focused on Hollister's pioneering work in concrete, one of several fields in which he contributed. The colloquium, the third in a series on "Civil Engineering: History, Heritage, and the Humanities," was sponsored in part by the National Endowment for the Humanities.

Above: Hollister spoke briefly at the dinner that concluded the colloquium events. Most of the papers read during the meeting were by Cornell structural engineering professors, and will be featured in the autumn issue of this magazine.

Left: Delegates from Cornell included Professor John Abel (at left) and President Frank H. T. Rhodes.

Below: David Billington (at left, with Hollister), professor of civil engineering at Princeton, directed the conference.

■ A chemical engineering alumna who is now an executive of the Exxon Corporation returned to Cornell this spring to give a talk sponsored by the local chapter of the Society of Women Engineers (SWE). Marjorie Leigh Hart '51 discussed "Reflections on a Career in Energy." She is a member of the University Board of Trustees.

Below: Julian C. Smith, director of the School of Chemical Engineering, talks with Cynthia Addonizio '80, president of SWE, and guest speaker Marjorie Hart '51.

FACULTY PUBLICATIONS

The following publications and conference papers by faculty and staff members and graduate students of the Cornell University College of Engineering were published or presented during the period December 1979 through February 1980. Earlier entries inadvertently omitted from previous listings are included here in parentheses. The names of Cornell personnel are in italics.

■ AGRICULTURAL ENGINEERING

Baker, R. C.; Darfler, J. M.; and *Rehkugler, G. E.* 1980. Electrical energy use and time consumed when cooking foods by various home methods: eggs. *Poultry Science* 59:545–9.

Cowell, M. J., and *Irwin, L. H.* 1979. Effects of compaction delays and multiple treatments on the strength of cement-stabilized soil. *Transportation Research Record* 702:191–8.

Furry, R. B.; Hicks, J. R.; Jorgensen, M. C.; and *Ludford, P. M.* 1979. Effects of Ethylene on Controlled Atmosphere Storage of Cabbage. Paper read at Winter Meeting of American Society of Agricultural Engineers, 11–14 December 1979, in New Orleans, La.

Hayes, T. D.; Jewell, W. J.; and *Kabrick, R. M.* 1980*a*. Heavy metal removal from sludges using combined biological/chemical treatment. In *Proceedings of 34th industrial waste conference*, ed. J. M. Bell, pp. 529–43. Ann Arbor, Mich.: Ann Arbor Science.

__________. 1980*b*. Removal of Heavy Metals from Sewage Sludge Using Autoheated Aerobic Thermophilic Digestion and Controlled Acidification. Paper read at 52nd Annual Meeting of New York Water Pollution Control Association, 22 January 1980, in New York, N. Y.

Irwin, L. H. (1979). Equipment and methods for deflection-based structural evaluation of pavements. In *Proceedings of 1979 Forest Service geotechnical workshop*, pp. 58–69. Washington, D.C.: U.S. Forest Service.

Kabrick, R. M.; Jewell, W. J.; Salotto, B. V.; and Berman, D. 1980. Inactivation of viruses, pathogenic bacteria and parasites in the autoheated aerobic thermophilic digestion of sewage sludges. In *Proceedings of 34th industrial waste conference*, ed. J. M. Bell, pp. 771–89. Ann Arbor, Mich.: Ann Arbor Science.

Loehr, R. C. 1979*a*. Potential pollutants from agriculture—an assessment of the problem and possible control approaches. *Progress in Water Technology* 11(6):169–93.

__________. 1979*b*. Utilization of Agricultural and Agro-Industry Residues. Paper read at Workshop on Agricultural and Agro-Industrial Residue Utilization in the ESCAP Region, 10–14 December 1979, in Pattaya, Thailand.

Loehr, R. C.; Martin, C. S.; and Rast, W., eds. 1980. *Phosphorus management strategies for lakes*. Ann Arbor, Mich.: Ann Arbor Science.

Marshall, R.; Scott, N. R.; Barta, M.; and *Foote, R. H.* 1979. Electrical conductivity probes for detection of estrus in cattle. *Transactions of the ASAE* 22:1145–51, 1156.

Reitsma, S. Y., and *Scott, N. R.* 1979. Modeling milk flow rate from the dairy cow's teat. *Transactions of the ASAE* 22:1471–4.

Van Tienhoven, A,; Scott, N. R.; and *Hillman, P. E.* (1979). The hypothalamus and thermoregulation: a review. *Poultry Science* 6(6):1633–9.

■ APPLIED AND ENGINEERING PHYSICS

Barak, L. S.; Yokum, R. R.; *Nothnagel, E. A.;* and *Webb, W. W.* 1980. Fluorescence staining of the actin cytoskeleton in living cells with NBD-phallacidin. *Proceedings of the National Academy of Sciences U.S.A.* 77:980–4.

Maeda, T.; *Eldridge, C.;* Toyama, S.; Ohnishi, S.; *Elson, E. L.;* and *Webb, W. W.* 1979. Membrane receptor mobility changes by Sendai virus. *Experimental Cell Research* 123:333–43.

Rhodin, T. N., and *Capehart, T. W.* 1979. Analysis of photoemission from chalcogen adsorption on Ni(111). *Surface Science* 89:337–43.

Seabury, C. W.; Rhodin, T. N.; Purtell, R. J.; and *Merrill, R. P.* 1980. Chemisorption and reaction of NH_3 on Ni(111). *Surface Science* 93:117–26.

■ CHEMICAL ENGINEERING

Clancy, P.; Gubbins, K. E.; Machado, J. R. S.; Lobo, L. Q.; and Staveley, L.A.K. 1979. Excess Properties and Phase Equilibria in Cryogenic Mixtures: Experiment and Theory. Paper read at Annual Meeting of American Institute of Chemical Engineers, 25–29 November 1979, in San Francisco, Calif.

Haller, H. D., and *Finn, R. K.* 1979. Biodegradation of 3-chlorobenzoate and formation of black and color in the presence and absence of benzoate. *European Journal of Applied Microbiology and Biotechnology* 8:191–205.

Kargi, F., and *Shuler, M. L.* 1980. An evaluation of various flocculants for the recovery of biomass grown on poultry waste. *Agricultural Wastes* 2:1–12.

Lobo, L. Q.; Staveley, L. A. K.; *Clancy, P.;* and *Gubbins, K. E.* 1980. Enthalpy of mixing of liquid hydrogen chloride and liquid xenon; comparison of experiment and theory. *Journal of the Chemical Society, Faraday Transactions I* 76:174–9.

Murad, S., and *Gubbins, K. E.* 1980. Structure factor of liquid vanadium tetrachloride. *Molecular Physics* 39:271–5.

Steele, W. A., and *Streett, W. B.* 1980. Computer simulations of dense molecular fluids. I. Time-dependent statistical properties of single diatomic molecules. II. Translation-rotation coupling in the motion of single molecules. *Molecular Physics* 39:279–310.

■ CIVIL AND ENVIRONMENTAL ENGINEERING

Beech. J. F., and *Ingraffea, A. R.* 1980. *Three-dimensional finite element calibration of the short-rod specimen.* Cornell University School of Civil and Environmental Engineering report 80–3.

Bisogni, J. J., Jr. 1979. Kinetics of methylmercury formation and decomposition in aquatic environments. In *Biogeochemistry of mercury in the environment,* ed. J. O. Nniagu, pp. 211–27. Amsterdam: Elsevier/North-Holland.

Brutsaert, W. (1979). Hydrologic Processes in Climate Models. Paper read at Special Study Workshop on Hydrologic Processes, 24 September 1979, at Goddard Space Flight Center, Beltsville, Md.

Carrasquillo, R. L.; Nilson, A. H.; and *Slate, F. O.* 1980. *Microcracking and engineering properties of high strength concrete.* Cornell University School of Civil and Environmental Engineering report 80–1.

Fagundo, F.; *Gergely, P.;* and *White, R. N. 1979. The behavior of lapped splices in reinforced concrete beams subjected to repeated loads.* Cornell University Department of Structural Engineering report 79–7.

Fisher, G. P. 1980. Using IGTDS in a Transportation Education Environment. Paper read at Transportation Research Board Conference, 20–25 January 1980, in Washington, D.C.

Hubbell, W. D., and *Kulhawy, F. H.* (1979). *Coastal construction materials. Environmental loads in coastal construction.* Contract reports to New York Sea Grant Institute, Albany, N.Y.

Ingraffea, A. R., and Heuze, F. E. 1980. Finite element models for rock fracture mechanics. *International Journal for Numerical and Analytical Methods in Geomechanics* 4:25–43.

Jirka, G. H. 1979. Discussion of "Line Plume and Ocean Outfall Dispersion" by P. J. W. Roberts. *Proceedings of the ASCE, Journal of the Hydraulics Division* 105:1573–5.

Kulhawy, F. H., and Peterson, M. S. 1979. Behavior of sand-concrete interfaces. In *Proceedings of 6th Pan-American conference on soil mechanics and foundation engineering,* vol. 2, pp. 225–36. Lima, Peru: Organizing committee of conference.

Lackman, D. A. 1980. Parking Policy Analysis for a College Campus by Using IGTDS. Paper read at Transportation Research Board Conference, 20–25 January 1980, in Washington, D.C.

Lavine, M. J., and *Meyburg, A. H.* (1977). Energy analysis and environmental analysis in transportation planning. In *Energy use management,* vol. 3, ed. R. A. Fazzolare and C. B. Smith, pp. 859–74. New York: Pergamon.

Lim, K. W., and *Meyburg, A. H.* 1979. A linear systems model of freight demand within a comprehensive planning approach. *Transportation Research Record* 668:1–3.

Meyburg, A. H., and *Thatcher, R. H.* 1979. The use of mobile communications in the trucking industry. *Transportation Research Record* 668:21–2.

Ngab, A.; Nilson, A. H.; and *Slate, F. O.* 1980. *Behavior of high strength concrete under sustained compressive stress.* Cornell University School of Civil and Environmental Engineering report 80–2.

Orloff, N. 1979. Buttressing the traditional approach to enforcement of environmental requirements: noncompliance penalties under the Clean Air Act. *Environmental Law Reporter* 9:50029–40.

Petrina, P.; Sexsmith, R. G.; and *White, R. N.* 1979. *Safety analysis of nuclear containment structures.* Nuclear Regulatory Commission report CR–1097.

Pimentel, D.; Shoemaker, C. A.; La Due, E. L.; Rovinsky, R. B.; and *Russell, N. P.* (1979). Alternatives for reducing insecticides on cotton and corn: economic and environmental impact. Environmental Protection Agency report EPA–600/5–79–007a.

Ruesink, W. G.; *Shoemaker, C. A.;* Gutierrez, A. P.; and *Fick, W. G.* 1980. The systems approach to research and decision making for alfalfa pest control. In *New technology of pest control,* ed. C. B. Huffaker, pp. 218–47. New York: Wiley.

Sangrey, D. A., and *Philipson, W. R.* (1979). *Detecting landfill leachate contamination using remote sensors.* U.S. Environmental Protection Agency report EPA—600/4–79–060.

Shoemaker, C. A. 1979. Optimal timing of multiple applications of pesticides with residual toxicity. *Biometrics* 35:803–12.

__________. 1980. The role of systems analysis in integrated pest management. In *New technology of pest control*, ed. C. B. Huffaker, pp. 26–49. New York: Wiley.

Shoemaker, C. A., and *Harris, M. O.* (1979). The effectiveness of soil and water conservation practices in comparison with other methods for reducing pesticide pollution. In *Effectiveness of soil and water conservation practices for pollution control*, ed. *D. A. Haith* and *R. C. Loehr*, pp. 206–86. Environmental Protection Agency report EPA-600-3-79—106.

Shoemaker, C. A., and *Stedinger, J. R.* 1979. Controlling weevils and worms: the use of optimization methods in pest management. *Engineering: Cornell Quarterly* 14(3):26–35.

Slate, F. O. 1979. Higher education in low-cost housing. In *Low-cost housing technology*, ed. L. J. Goodman *et al.*, pp. 291–307. New York: Pergamon.

Stedinger, J. R. 1979. Parameter Estimation, Streamflow Model Validation and the Effects of Parameter Error and Model Choice on Derived Distributions. Paper read at Fall Meeting of American Geophysical Union, 3–7 December 1979, in San Francisco, Calif.

Stopher, P. R., and *Meyburg, A. H.* 1979. *Survey sampling and multivariate analysis for social scientists and engineers*. Lexington, Mass.: Heath.

Stewart, J. P., and *Kulhawy, F. H.* 1980. *Behavior of drilled shafts in axial uplift loading*. Niagara Mohawk Power Corporation contract report B-49(5).

Tasuji, M. E.; *Slate, F. O.*; and *Nilson, A. H.* 1979. Biaxial stress-strain relationships for concrete. *Magazine of Concrete Research* 31:217–224.

White, R. N. 1979. Professional registration: an educator's viewpoint. In *Proceedings of 1979 ASEE annual conference*, pp. 67–71. Washington, D.C.: American Society for Engineering Education.

■ COMPUTER SCIENCE

Hartmanis, J. 1980. On the succinctness of different representations of languages. *SIAM Journal on Computing* 9:114–20.

Salton, G. 1980. The SMART system 1961–76—experiments in dynamic document processing. In *Encyclopedia of library and information science*, vol. 28, pp. 1–36. New York: Dekker.

Schneider, F. B. 1980. Ensuring consistency in a distributed database system by use of distributed semaphores. In *Distributed data bases*, ed. C. Delobel and W. Litwin, pp. 183–9. New York: North-Holland.

■ ELECTRICAL ENGINEERING

Ballantyne, J. M. 1980*a*. Characterization of GaAs for Optical Receivers. Seminar Paper read 14 February 1980, at University of Cincinnati, Cincinnati, Ohio.

__________. 1980*b*. Photoconductive Detectors for High Speed Optical Communications. Seminar Paper read 31 January 1980, at Arizona State University, Tempe, Ariz.

Barnard, J.; *Huang, R.-S.*; and *Frey, J.* 1979. PROSUS Program and Cornell Work on High Speed Optical Detectors. Seminar Paper read 7 December 1979, at Digital Equipment Corporation, Maynard, Mass.

__________. 1980. SOS MESFET processing technology for microwave integrated circuits. In *Proceedings of 1979 international electron devices meeting*, pp. 281–4. Washington, D.C.: Institute of Electrical & Electronics Engineers.

Basu, A., and *Ballantyne, J. M.* 1979. Second and higher-order waveguide grating filters. I. Theory. II. Experiment. *Applied Optics* 18:3620–32.

Basu, S., and *Kelley, M. C.* (1979). A review of recent observations of equatorial scintillations and their relationship to current theories of F region irregularity generation. *Radio Science* 14(3):475–85.

Capranica, R. R. 1980. Neural basis for detection of complex sounds. In *Advances in prosthetic devices for the deaf*. Rochester, N. Y.: National Institute of the Deaf.

Fejer, B. G.; *Farley, D. T.*; Johnston, P.; and Balsley, B. B. 1980. Type 1 echoes from the equatorial electrojet with double peaked Doppler spectra. *Journal of Geophysical Research* 85:191–6.

Fejer, B. G.; *Gonzales, C. A.*; *Farley, D. T.*; *Kelley, M. C.*; and Woodman, R. F. (1979). Equatorial electric fields during magnetically disturbed conditions. 1. The effect of the interplanetary magnetic field. *Journal of Geophysical Research* 84:5797–802.

Fletcher, R. M.; *Wagner, D. K.*; and *Ballantyne, J. M.* 1980. Spatial Variation of Diffusion Length in Polycrystalline GaAs. Paper read at 14th IEEE Photovoltaic Specialists' Conference, January 1980, in San Diego, Calif.

Gammel, J. C., and *Ballantyne, J. M.* 1980*a*. A high-speed photoconductive integrated optical receiver. In *Technical digest: topical meeting of integrated and guided-wave optics*, pp. WD2, 1–4. New York: Optical Society of America.

__________. 1980*b*. An integrated photoconductive detector and waveguide structure. *Applied Physics Letters* 36:149.

Gammel, J. C.; *Metze, G.*; and *Ballantyne, J. M.* 1980. An epitaxial photoconductive detector for high speed optical detection. In *Technical digest: international electron devices meeting, 1979*, pp. 634–7. Washington, D.C.: Institute of Electrical & Electronics Engineers.

Gonzales, C. A.; *Kelley, M. C.*; *Fejer, B. G.*; Vickrey, J. F.; and Woodman, R. F. (1979). Equatorial electric fields during magnetically disturbed conditions. 2. Implications of simultaneous auroral and equatorial measurements. *Journal of Geophysical Research* 84:5803–12.

Holmgren, G.; Bostrom, R.; *Kelley, M. C.*; *Kintner, P. M.*; Lundin, R.; Fahleson, U. V.; Bering, E. A.; and Sheldon, W. R. (1979). Artificial stimulation of auroral electron acceleration by intense field aligned currents. *Geophysical Research Letters* 6:789–92.

Kelley, M. C. 1979. Equatorial spread F: a review of recent experimental results. In *Wave instabilities in space plasmas*, ed. P. J. Palmadesso and K. Papadopoulos, pp. 291-306. Dordrecht: D. Reidel.

Kim, M. 1979. How control theory improves cancer therapy. *Engineering: Cornell Quarterly* 14(3):10-16.

Mudry, K. M., and *Capranica, R. R.* 1980. Evoked auditory activity within the Telencephalon of the bullfrog. *Brain Research* 182:303–11.

Rheinlaender, J.; Gerhardt, H. C.; *Yager, D. D.*; and *Capranica, R. R.* 1979. Accuracy of phonotaxis by the green treefrog. *Journal of Comparative Physiology* 133:247–55.

Thorp, J. S. 1979. Preventing blackouts. *Engineering: Cornell Quarterly* 14(3):3–9.

Varaiya, P., and *Walrand, J.* 1980. A minimum principle for decentralized stochastic control problems. In *Mathematical concepts and methods in science and engineering*, vol. 19: *Dynamic optimization and mathematical economics*, ed. P. T. Liu, pp. 253–66. New York: Plenum.

Vickrey, J. F.; *Swartz, W. E.;* and *Farley, D. T.* 1979. Ion transport in the topside ionosphere at Arecibo. *Journal of Geophysical Research* 84:7307–14.

■ GEOLOGICAL SCIENCES

Barazangi, M., and *Isacks, B.* 1979*a*. A comparison of the spatial distribution of mantle earthquakes determined from data produced by local and by teleseismic networks for the Japan and Aleutian arcs. *Bulletin of the Seismological Society of America* 69:1763–70.

___________. 1979*b*. Subduction of the Nazca plate beneath Peru: evidence from spatial distribution of earthquakes. *Geophysical Journal of the Royal Astronomical Society* 57:537–55.

Bird, J. M.; Bassett, W. A.; and *Weathers. M. S.* (1979). Widmanstaetten patterns in josephinite, a metal-bearing terrestrial rock. *Science* 206:832–4.

Bloom. A. L. 1980. Late Quaternary sea-level change on South Pacific coasts: a study in tectonic diversity. In *Earth rheology, isostasy, and eustasy*, ed. N.-A. Morner, pp. 505–16. Chichester, U.K.: Wiley.

Brewer, J.; Smithson, S.; Oliver J.; Kaufman, S.; and *Brown, L.* 1980. The Laramide orogeny: evidence from deep crustal seismic profiles in the Wind River Mountains, Wyoming. *Tectonophysics:* 12:165–89.

Caldwell, J. G., and *Turcotte, D. L.* 1979. Dependence of the thickness of the elastic oceanic lithosphere on age. *Journal of Geophysical Research* 84:7572–6.

Chin, D.; Isacks, B.; and *Barazangi, M.* 1980. High-frequency wave propagation in western South America along the continental margin, in the Nazca plate, and across the Altiplano. *Geophysical Journal of the Royal Astronomical Society* 60:209–44.

Clark, J. A., and *Bloom, A. L.* 1979*a*. Effect of the Patagonian ice sheet on relative sea levels along the Atlantic coast of South America: a numerical calculation. In *Proceedings of 1978 international symposium on coastal evolution in the Quaternary*, ed. K. Suguio, *et al.*, pp. 61–76. Sao Paulo, Brazil: Instituto de Geosciencias, Univ. de Sao Paulo.

___________. 1979*b*. Hydro-isostasy and Holocene emergence of South America. In *Proceedings of 1978 international symposium on coastal evolution in the Quaternary*, ed. K. Suguio, *et al., pp. 41*–60. Sao Paulo, Brazil: Instituto de Geosciencias, Univ. de Sao Paulo.

Davis, G. A.; *Ando, C. J.;* Cashman, P. H.; and Gouilaud, L. 1979. *Cross section of the central Klamath Mountains, California*. Geological Society of America Map and Chart Series MC–281.

Karig, D. E. 1980. Material transport within accretionary prisms and the "knocker" problem. *Journal of Geology* 88:27–39.

Karig, D. E.; Lawrence, M. B.; Moore, G. F.; and Curray, J. R. 1980. Structural framework of the forearc basin, NW Sumatra. *Journal of the Geological Society of London* 137:77–91.

Kay, R. W. 1980. Zone refining at the base of the lithospheric plates: a model for a steady state asthenosphere. In *Developments in geotectonics*, vol. 14: *Ocean ridges and arcs*, ed. M. N. Toksoz, *et al.*, pp. 217–225. Amsterdam: Elsevier.

Kay, R. W., and *Kay, S. M.* 1980. Chemistry of the lower crust: inferences from magmas and xenoliths. In *Continental tectonics*, pp. 139–150. Washington, D.C.: National Academy of Sciences.

Marthelot, J.-M.; Coudert, E.; and *Isacks, B.* 1980. Tidal tilt from localized ocean loading in the New Hebrides arc. *Bulletin of the Seismological Society of America* 70:283–92.

Moore, J. C.; Watkins, J. S.; *Bachman, S. B.; et al.* (1979). Progressive Accretion and Imbricate Thrusting, Middle America Trench, Southern Mexico: Results from Leg 66 DSDP. Paper read at Annual Meeting of Geological Society of America, 5–8 November 1979, in San Diego, Calif.

Oliver, J. 1980. Seismic exploration of the continental basement: trends for the 1980's. In *Continental tectonics*, pp. 117–126. Washington, D.C.: National Academy of Sciences.

Peltier, W. R.; Farrell, W. E.; and *Clark, J. A.* 1980. Glacial isostasy and relative sea level: a global finite element model. In *Developments in geotectonics*, vol. 14: *Ocean ridges and arcs*, ed. M. N. Toksoz, *et al.*, pp. 1–30. Amsterdam: Elsevier.

Sheu, J. P.; Torrance, K. E.; and *Turcotte, D. L.* 1979. On the Structure of two-phase hydrothermal flows in permeable media. *Journal of Geophysical Research* 84:7524–32.

Thomas, P.; *Veverka, J.; Bloom, A.;* and *Duxbury, T.* 1979. Grooves on Phobos: their distribution, morphology, and possible origin. *Journal of Geophysical Research* 84:8457–77.

Turcotte, D. L.; Cook, F. A.; and *Willeman, R. J.* 1979. Parametrized convection within the moon and the terrestrial planets. In *Proceedings of 10th lunar and planetary science conference*, pp. 2375–92. New York: Pergamon.

Turcotte, D. L.; McAdoo, D. C.; and *Caldwell, J. G.* 1980. An elastic–perfectly plastic analysis of the bending of the lithosphere. In *Developments in geotectonics, vol. 14: Ocean ridges and arcs*, ed. M. N. Toksoz, *et al.*, pp. 311–23. Amsterdam: Elsevier.

Weathers, M. S.; Bird, J. M.; Cooper, R. F.; and *Kohlstedt, D. L.* 1979. Differential stress determined from deformation-induced microstructures of the Moine thrust zone. *Journal of Geophysical Research* 84:7495–509.

■ MATERIALS SCIENCE AND ENGINEERING

Ast, D. G. 1979. TEM, EBIC and SIM's Studies of EFG and RTR Silicon. Paper read at 14th Low-Cost Solar Array Project Integration Meeting, 5–6 December 1979, at California Institute of Technology, Pasadena, Calif.

Ast, D. G., and *Brodsky, M. H.* 1980. Thickness dependent conductivity of n-type hydrogenated amorphous silicon. *Journal of Non-Crystalline Solids* 36:611–6.

Budai, J.; Gaudig, W.; and *Sass, S. L.* 1979. The measurement of grain boundary thickness using x-ray diffraction techniques. *Philosophical Magazine A* 40:757–67.

Föll, H., and *Carter, C. B.* (1979). Direct TEM determination of intrinsic and extrinsic stacking-fault energies in silicon. *Philosophical Magazine A* 40:497–510.

Gösele, U., and *Strunk, H.* 1979. High-temperature diffusion of phosphorus and boron in silicon via vacancies or self-interstitials? *Applied Physics* 20:265–73.

Gupta, M. C., and *Ruoff, A. L.* 1980. Static compression of silicon in the [100] and in the [111] directions. *Journal of Applied Physics* 51:1072–5.

Kumnick, A. J., and *Johnson, H. H.* 1980. Deep trapping states for hydrogen in deformed iron. *Acta Metallurgica* 28:33–9.

Raizman, A.; Suss, J. T.; *Seidman, D. N.;* Shaltiel, D.; Zevin, V.; and Orbach, R. (1979). Electron-paramagnetic resonance (EPR) study of cold-worked dilute gold-erbium alloys. *Journal of Applied Physics* 50:735–7.

Sullivan, T., and *Ast, D. G.* 1980. *Preparation of Schottky diodes for passivation studies of polycrystalline EFG silicon.* Jet Propulsion Laboratory/Department of Energy report no. JPL–954977–3.

Strunk, H., and Kolbesen, B. O. 1979. Den Ausfallursachen integrierter Schaltungen auf der Spur. *Funkschau* 25:1445–9.

Strunk, H.; Gösele, U.; and Kolbesen, B. O. 1980. Interstitial supersaturation and climb of misfit dislocations in phosphorus-diffused silicon. *Journal of Microscopy* 118:35–9.

Wilson, K. L.; Baskes, M. I.; and *Seidman, D. N.* 1980. An *in-situ* field-ion microscope study of the recovery behavior of ion-irradiated tungsten and tungsten alloys. *Acta Metallurgica* 28:89–102.

■ MECHANICAL AND AEROSPACE ENGINEERING

Chavez, P. F.; *Dawson, P. R.;* and Schuler, K. W. 1980. *Seabed disposal project: two-dimensional axisymmetric penetrometer simulations.* Department of Energy report SAND–79–1679.

Hieber, C. A., and *Shen, S. -F.* 1980. A finite-element/finite-difference simulation of the injection molding filling process. *Journal of Non-Newtonian Fluid Mechanics* 7:1–32.

Jahanmir, S. 1980. Phase transformation of $\alpha-\beta$ brass caused by friction. *Wear* 58:387–9.

Leibovich, S., 1980. Mixing of upper ocean by Langmuir circulations. In *Ocean modelling*, vol. 29, ed. A. E. Gill, pp. 1–5. Cambridge, England: University of Cambridge.

Leibovich, S., and Randall, J. D. 1979. On soliton amplification. *Physics of Fluids* 22:2289–95.

Levin, R. L. 1980. Osmotic behavior of unperfused tissues. In *Advances in bioengineering*, ed. M. K. Wells, pp. 37–40. New York: American Society of Mechanical Engineers.

Munson, D. E., and *Dawson, P. R.* 1980. *Constitutive model for the low temperature creep of salt (with application to WIPP).* Department of Energy report SAND–79–1853.

Phelan, R. M. 1979. The beautiful simplicity of feedback control. *Engineering: Cornell Quarterly* 14(3):26–35.

Shen, S. -F., and *Kwon, J. H.* (1979). Upwinding Finite-Element Method for Heat Transfer Problems with Large Convection. Paper read at First National Conference on Numerical Methods in Heat Transfer, 24–26 September 1979, at the University of Maryland, College Park, Md.

Taylor, D. L. 1980. Nonlinear stability of car-trailer combinations. In *Recreational vehicle dynamics* (SAE report SP–463), pp. 9–22. Warren, Pa.: Society of Automotive Engineers.

Torrance, K. E. (1979). Natural convection in thermally stratified enclosures with localized heating from below. *Journal of Fluid Mechanics* 95:477–95.

Vu, B. T., and *Gouldin, F. C.* 1980. Flow Measurements in a Model Swirl Combustor. Paper no. 80–0076 read at 18th AIAA Aerospace Sciences Meeting, 14–16 January 1980, in Pasadena, Calif.

Wang, J. C. T., and *Shen, S. -F.* 1980. Rational new approach to the response of an aircraft encountering atmospheric turbulence. *AIAA Journal* 18(2):129–37.

■ OPERATIONS RESEARCH AND INDUSTRIAL ENGINEERING

Nemhauser, G. L., and *Weber, G. M.* 1979. Optimal set partitioning, matchings and Lagrangian duality. *Naval Research Logistics Quarterly* 26:(4):553–63.

Taqqu, M. S. 1979. Convergence of integrated processes of arbitrary hermite rank. *Zeitschrift für Wahrscheinlichkeitstheorie and Verwandte Gebiete* 50:58–83.

Todd, M. J. 1980. Global and local convergence and monotonicity properties for a recent variable-dimension simplicial algorithm. In *Numerical solution of highly nonlinear problems*, ed. W. Forster, pp. 43–70. Amsterdam: North-Holland.

__________. 1979. Hamiltonian triangulations. In *Functional differential equations and approximations of fixed points*, ed. H.-O. Peitgen and H.-O. Walther, pp. 470–83. New York: Springer-Verlag.

Todd, M. J., and Acar, R. C. 1980. A note on optimally dissecting simplices. *Mathematics of Operations Research* 5:63–6.

Weiss, L. (1978). A simple sequential test for Hotelling's T^2 problem. *Sankhyā* 40 (series B, parts 1 and 2):38–42.

■ PLASMA STUDIES

Sudan, R. N., and *Keskinen, M. J.* 1979. Theory of strongly turbulent two-dimensional convection of low-pressure plasma. *Physics of Fluids* 22:2305–14.

■ THEORETICAL AND APPLIED MECHANICS

Holmes, P. J. 1980. Averaging and chaotic motions in forced oscillations. *SIAM Journal on Applied Mathematics* 38(1):65–80.

__________. 1979. Bifurcation in Coupled Nonlinear Oscillators with Applications to Flutter and Divergence. Paper read at ASME Winter Meeting, 3–7 December 1979, in New York, N.Y.

Kim, B. S., and *Moon, F. C.* (1979). Impact induced stress waves in a laminated composite plate. *AIAA Journal* 17:1126–33.

Kumar, V.; Morjaria, M.; and *Mukherjee, S.* 1980. Numerical integration of some stiff constitutive models of inelastic deformation. *ASME Journal of Engineering Materials and Technology* 102:92–6.

Lenox, T. A., and *Conway, H. D.* 1980. An exact solution for the flexural vibration of circular plates of variable thickness. *Journal of Sound and Vibration* 68(2):231–9.

Moon, F. C. (1979*a*). Buckling of a superconducting ring in a toroidal magnetic field. *Journal of Applied Mechanics* 46:151–5.

————. (1979*b*). Experiments on magnetoelastic buckling in a superconducting torus. *Journal of Applied Mechanics* 46:145–50.

Moon, F. C., and *Holmes, P. J.* (1979). A magnetoelastic strange attractor. *Journal of Sound and Vibration* 65(2):275–96.

Moon, F. C., and *Kim, B. S.* (1979). Buckling of a superconducting energy storage shell. In *Proceedings of 3rd engineering mechanics conference*, pp. 69–73. Austin, Tex: American Society of Civil Engineers.

Morjaria, M., and *Mukherjee, S.* 1980. Improved boundary-integral equation method for time-dependent inelastic deformation in metals. *International Journal for Numerical Methods in Engineering* 15:97–111.

Morjaria, M.; Sarihan, V.; and *Mukherjee, S.* 1980. Comparison of boundary element and finite element methods in two-dimensional inelastic analysis. *Res Mechanica* 1:3–20.

Mukherjee, S.; Harkness, S. D.; and *Li, C. -Y.* 1979. Mechanical analysis of a first wall model by using a state variable approach. *Journal of Nuclear Materials* 85–6:183–7.

Sinclair, T. R., and *Rand, R. H.* 1979. Mathematical analysis of cell CO_2 exchange under high CO_2 concentrations. *Photosynthetica* 13(3):239–44.

Stroshine, R. L.; Cooke, J. R.; Rand, R. H.; Cutler, J. M.; and *Chabot, J. F.* 1979. Mathematical Analysis of Pressure Chamber Efflux Curves. Paper read at Winter Meeting of American Society of Agricultural Engineers, 11–14 December 1979, in New Orleans, La.

Van Arsdale, W. E., and *Burns, J. A.* 1980. Tidal heating of a viscoelastic moon: comparison to the elastic calculation. In *Lunar and planetary science*, vol. 11, pp. 1190–2. Houston, Tex: Lunar and Planetary Institute.

Veverka, J., and *Burns, J. A.* 1980. The moons of Mars. *Annual Review of Earth and Planetary Science* 8:527–58.

Yuan, K.-Y.; Moon, F. C.; and *Abel, J. F.* (1979). Magnetic forces in plates using finite elements. In *Proceedings of 3rd engineering mechanics conference*, pp. 730–733. Austin, Tex.: American Society of Civil Engineers.

LETTERS

Sound and the Science of Listening

Editor: The issue of your magazine devoted to sound is an impressive publication, and I am glad to see pictures of my friends and colleagues and learn of their experiments. Thank you also for the note about my own work at Cornell on page 40. This is certainly ancient history. . . . I do not recall ever studying bats actually over Beebe Lake, but rather a small pond further upstream near Varna. This was where I first studied bats pursuing insects, as described in *Listening in the Dark*. I do not recall that the pond even had a name, but it was near a rifle range and the creek was crossed by a small suspension bridge. . . . I think my old friend Bill Wimsatt could give you the details . . . . My book was reprinted by Dover Publications, New York, in 1974. . . . Since I am pleased to see that anyone at Cornell should still be interested in my activities there thirty-odd years ago, I would like to have your picture as complete and as accurate as possible.

Donald R. Griffin
The Rockefeller University
New York, N.Y.

Editor: I was glad to have Wolfgang Sachse's article in your spring issue to quote in my editorial, "Critical Point," for the August "Testing and Inspection" issue of *Metal Progress*. [It] was very much in line with the message I had in mind. . . . The preamble to [his] article, "Testing Materials by Ultrasound," leaves no question that the application of testing and inspection technology is the responsibility of all engineers and technical managers.

Allen G. Gray
Publisher, *Metal Progress*; Technical Director, American Society for Metals
Metals Park, Ohio.

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Opposite: Is it a bird? Is it a plane? No, it's a dropping egg. See pages 24–27.

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