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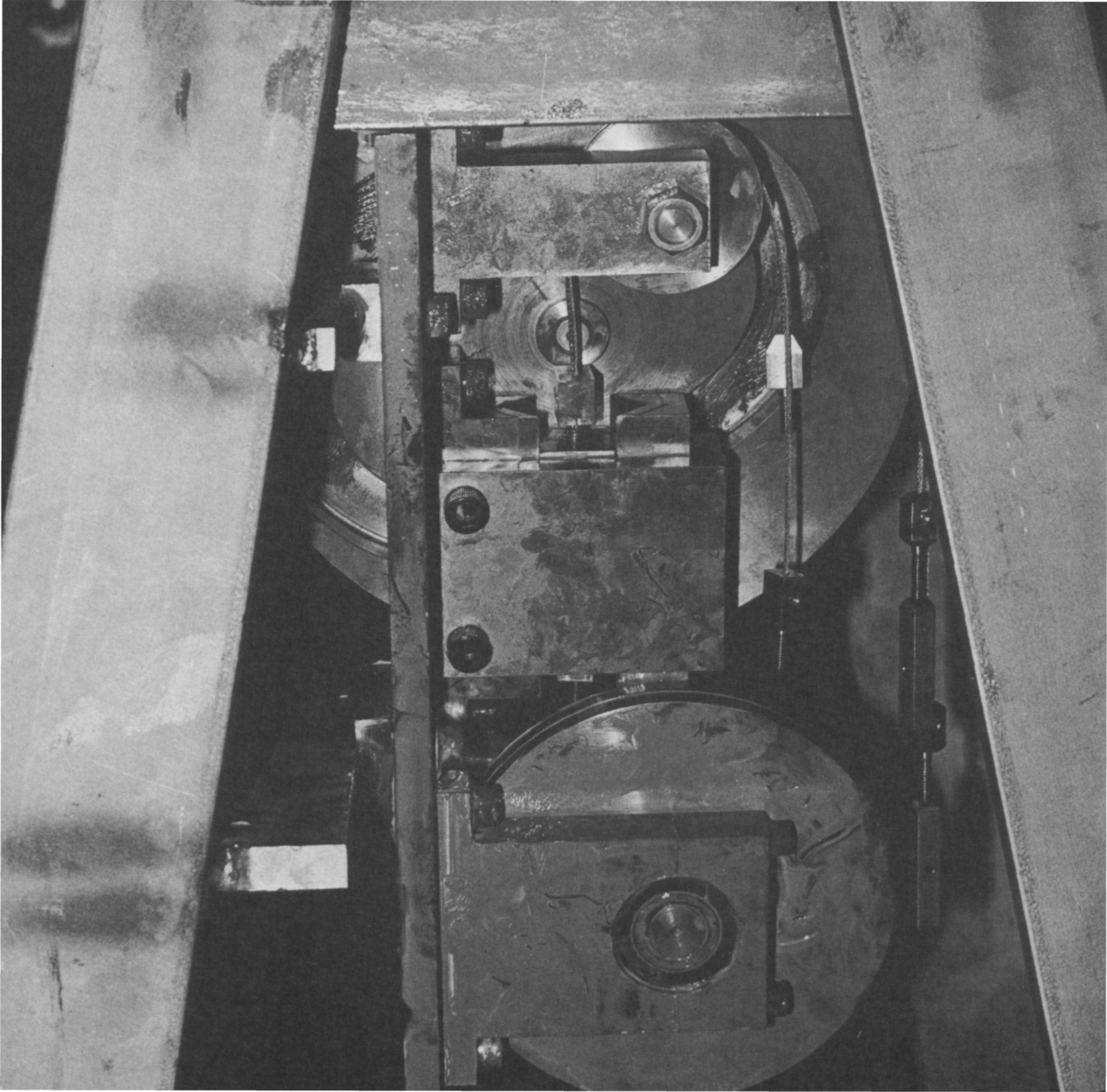
SOCIAL ISSUES AND THE ENGINEER



IN THIS ISSUE

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Opposite: Part of the internal mechanism of the new sundial. The cam with its precisely machined groove provides the adjustment needed for accuracy.

ENVIRONMENTAL LAW IN THE EIGHTIES

by Neil Orloff

Environmental law, which took root and burgeoned during the 1970s, is likely to undergo major revision in the 1980s. While no one expects a wholesale abandonment of the nation's environmental goals, virtually all observers anticipate a period of reassessment and change.

The field of environmental law has had a remarkably short history. It hardly existed a dozen years ago. Most of our current environmental problems became widely perceived only in the late 1960s and early 1970s; and, in response to the problems, a conglomerate of statutes—federal, state, and local—emerged in areas of activity that had never before been regulated. During the course of the past decade, the statutes rapidly expanded in reach, stringency, and complexity.

Now the time has come when the provisions of environmental law will be assessed in the context of other national priorities. This is also the time to examine the large body of law to see how well it is organized and constructed, how well it is functioning, and how it should be modified.

ENERGY, ENVIRONMENT, ECONOMY: MULTIPLE NEEDS

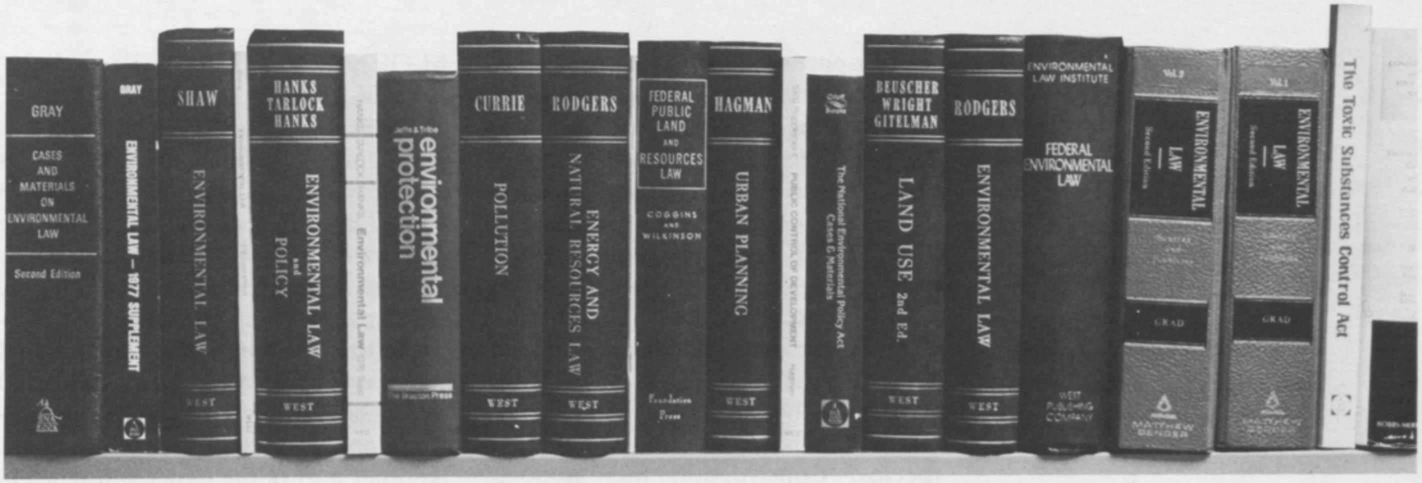
Much of the gathering debate will revolve around the competing concerns of energy, the environment, and the economy. The nation could, for example, dramatically reduce its dependence on foreign oil if it shifted existing electric power plants to the use of coal; however, this would require either a massive investment of capital in pollution-control equipment or a substantial relaxation of environmental requirements. Federal holdings in Alaska and in coastal waters could be opened further to development of oil and gas reserves—provided that impairment of wilderness areas and intermittent oil spills were deemed acceptable. Abandoned waste-disposal sites containing hazardous substances could be cleaned up and ground waters protected—at a cost to the government of billions of tax dollars.

Issues like these are not debated in the abstract, but rather in connection with the search for solutions to specific problems; the various interest groups come into conflict with each other only when specific actions are proposed. Accordingly, most of the debate over reforming the nation's environmental laws has centered on how to achieve the proper balance in connection with specific measures that affect energy supply, environmental quality, and the national economy.

The need for reform goes deeper, however. While particular problems will be resolved, in due course, such solutions will affect only the *content*, and not the *form* of the laws. Yet the current laws are:

(1) too complex for small businesses, large corporations, and government officials alike to cope with;
(2) too inflexible to deal with the wide variety of activities in the society; and
(3) currently constructed so as to create a procedural morass.

Their basic design is defective. Unless the *approach* to protection of the environment changes, these fundamental problems will remain—even after new compromises are reached in the three-way struggle on behalf of energy supply, the environment, and the economy.



MUDDLING THROUGH THE COMPLEX REGULATIONS

The major environmental programs defy the best attempts to understand and stay abreast of them. The complexities are mind-boggling. The Clean Air Act runs 185 pages, and the regulations established by the Environmental Protection Agency (EPA) to carry out the statute are over 2,500 pages long. The Clean Water Act exceeds 125 pages, and its regulations are over 1,200 pages long. The regulations issued by the EPA last May to implement several sections of its new hazardous-wastes program consumed more than 500 pages of the *Federal Register*.

When one asks an EPA official who is an expert on one part of a statute about a related but different part of that statute, the answer is frequently, "I don't know—ask Joe." When one asks Joe, the question may be answered—unless it touches on still another part of the statute, in which case one is referred to Tom. No one at EPA headquarters fully understands even a single program, such as the one that addresses air pollution or the one on water pollution. How then are people around the country supposed to comply with its regulations?

And how can a company comply with not just one law, but a whole collection of programs? For environmental law is not a comprehensive and coherent set of rules, like the tax code, but a group of dozens of independent statutes. The federal patchwork of programs is implemented by some ten agencies administering over ten thousand pages of regulations. In addition, each of the fifty states has its own programs, partially coupled to the federal ones, each with its own set of requirements.

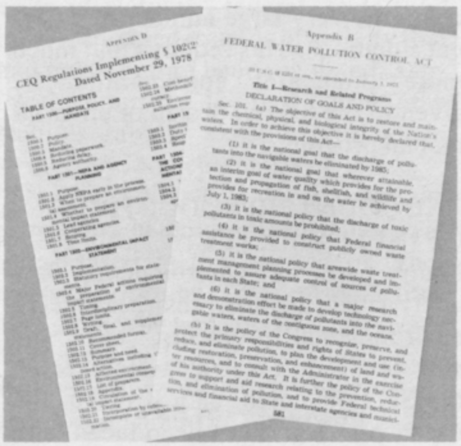
What happens in practice, of course, is that people just "muddle through." The complexity has not led to a laying out of clear rules for compliance, but has had just the opposite effect. It has reduced the predictability of what the law requires and, in the process, has given agencies enormous discretion. It has also provoked substantial litigation, increased the cost of lawyers and consultants, and, more importantly for the long run, undermined good-faith attempts to comply with the law.

The diversity of environmental problems does not require this complexity. The diversity provides an explanation — but not a justification. And the explanation is weak, since what lies behind it is the assumption that a sufficiently large bureaucracy in Washington can develop a detailed plan for controlling the full range of situations encountered throughout the United States. What is needed is a set of new approaches that, like the marketplace, automatically take into account the very large number of different situations. This requires that much more thoughtful consideration be given to the overall design of environmental programs.

THE COUNTERPRODUCTIVITY OF INFLEXIBILITY

Many parts of environmental law apply a meat ax rather than a scalpel to environmental problems. Take the case of Union Electric, which serves the St. Louis area: as a result of the Clean Air Act, it has been faced with the prospect of shutting down its coal-fired power plants. In response to its plea that the standards are economically and technologically infeasible, the Supreme Court has declared that the statute contains no provision for flexibility in dealing with such situations. Other examples abound. Work on the Tellico Dam was halted by the threat to the snail darter, a three-inch fish that was discovered in 1973 upstream of the project and was subsequently listed as an endangered species. Construction was stopped even though, by government estimate, several hundred thousand species of plants and animals will become extinct between now and the year 2000, and even though the dam was already 80 percent completed and no demonstrable harm to the environment would have resulted. Substances that may cause cancer in laboratory test animals are banned from foods regardless of the degree of risk to humans or whether the benefits (such as the provision of an artificial sweetener for diabetics or the preservation of foods) clearly outweigh the costs. Industries that discharge effluents into the ocean must employ the best available control technology, even when the discharge causes no demonstrable environmental harm.

In short, the statutes are too rigid. They do not distinguish among situations that are clearly very different in their consequences. The result is an inefficient use of the resources of society. Projects are halted and costs imposed, even when the benefits are marginal or nonexistent. A more selective approach to protection of the environment is required.



FLOUNDERING IN A PROCEDURAL MORASS

There is an old adage in the law that procedure is substance, and this is certainly true in the field of environmental law. Part of the reason for the elaborate procedural requirements is that the objectives being sought by the law are frequently unclear. An example is the question, already cited, about whether federal lands in Alaska should be opened up for oil and gas exploration or preserved as wilderness. Another part of the explanation lies in our poor understanding of the biological or ecological basis of an environmental issue. For example, it has been established that asbestos, when inhaled, can cause cancer; but can it also lead to cancer when it is ingested? The answer is crucial to a determination of whether Reserve Mining's discharge into Lake Superior of taconite tailings, with their asbestos-like fibers, is harmful to the residents of Duluth, Minnesota, whose drinking water is supplied through a nearby intake pipe. (In the litigation, Reserve Mining was finally ordered to either cease discharging the tailings or shut down, but the effect of the discharge on drinking water is still unknown.) In some cases, legislatures have been unable to specify not only the results, but even the criteria to be weighed by a regulatory agency, and instead have created procedural requirements, including multiple permits. A company frequently must secure ten permits, twenty permits, or more, before it has gained the necessary approvals for construction of a plant.

While this is cumbersome enough, an even greater difficulty is the delay in

"Many parts of environmental law apply a meat ax rather than a scalpel to environmental problems."

acquiring permits. Most statutes specify time limits for filing permit applications, but do not limit the time the agency can take to reach a decision. Projects are often stalled, not because of negative decisions, but because of no decisions. In 1979, for example, Standard Oil of Ohio abandoned efforts to build an oil pipeline in California to handle crude oil from Alaska. After four years of effort and the expenditure of $58 million on engineering and permitting, the company still had not secured all the necessary permits, and concluded that by the time the pipeline was likely to become operational, the crude from Alaska would not be available long enough to justify the project.

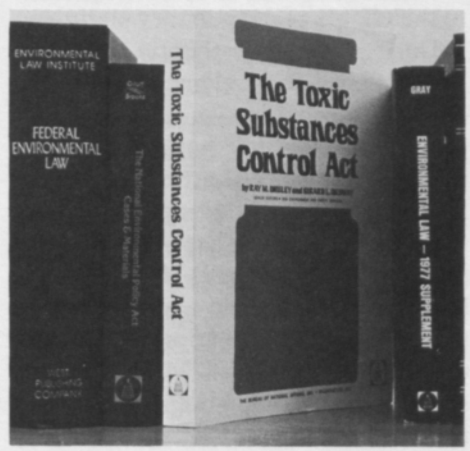
The procedural morass is made worse by the changing nature of the rules. EPA's regulations are continuously in flux. A new vocabulary has been spawned to describe them: "rough draft," "preliminary draft," "proposed," "interim final," "final," and "final-final." But while the terms aptly capture the characteristics of the requirements, they must not be viewed too literally. A few months ago, for instance, EPA issued "final-final" regulations to implement a portion of its hazardous-wastes program, and *on the same day* issued "proposed" changes. Many of the agency's substantive requirements have become a constantly moving target.

TOWARD BETTER PROTECTION OF OUR ENVIRONMENT

Are all these problems unavoidable? The answer is clearly no.

EPA has experimented with several changes and has had some modest success. It recently consolidated several of its permit programs, and it has sought to give manufacturing plants, through its "bubble concept," more flexibility in meeting clean-air requirements. These are steps in the right direction. Some states have experimented with a mandate that if a permit is not denied within a specified period of time, it is deemed granted. The federal government should follow the states' lead in this area.

More fundamentally, there needs to be greater attention at the time the laws



"The diversity of environmental problems does not require this complexity."

are drafted to the implementation of the requirements. In the heat of the negotiations involving compromises on competing issues and interests, practical matters such as how and whether a result can be achieved have tended to be neglected.

Recourses other than the law also need to be considered. There has been overuse of the law, with attempts to impose a legal regime in situations that would be better handled through education, mediation, or some other social institution. In some cases, the results of no action at all would be preferable to the effects of a regulatory statute.

During the rapid, chaotic growth of environmental law, elements critical to any good program—a set of guiding principles, clarity, straightforwardness, consistency, knowledge of the intrinsic limits of legislation, and a solid informational base—have been neglected or underdeveloped. They have been lost in the shuffle. During the 1980s, as the nation revises its environmental laws, these elements should be added back as indispensable ingredients.

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Before coming to Cornell in 1975, Orloff spent four years in Washington as a senior staff member with the Environmental Protection Agency and as legal counsel to the President's Council for Environmental Quality. Prior to that, he worked with the World Bank on the establishment of development banks in Africa. His experience also includes summer employment during his undergraduate and graduate years with the International Business Machines Corporation, Fry Consultants, and the law firm of Sidley and Austin.

He has written and lectured on such subjects as the environmental impact statement process, air-pollution regulation, and the need for business initiative in environmental matters.

TECHNOLOGY ASSESSMENT

An Added Responsibility for Engineers

by Alfred M. Lee and Arnim H. Meyburg

With increasing frequency since World War II, technological "progress" has been perceived as bringing adverse and unexpected consequences as well as remarkable and much-desired benefits. Questions are being raised about who should control and guide technological developments, and how the best solutions to the resulting problems can be implemented. Citizens are taking a more active part in formulating and influencing policy. Decision-makers must consider complexities previously disregarded. And engineers are discovering new professional duties and responsibilities.

Several factors contribute to the increased concern over possible harmful effects of technology. Many changes occur on such a huge scale that the consequent impacts are effectively irreversible and commonly have environmental, economic, social, political, and legal dimensions in addition to the technical ones. Costs both for implementing large-scale developments and for managing unwanted impacts have greatly increased. The use of resources has accelerated, and their management on a national or global basis has emerged as a crucial issue. The public has become sensitive to issues of health, safety, and environmental quality.

These pressures have promoted increased scrutiny of decisions that were formerly considered to be solely technical in nature. The public debate now concerns large-scale developments such as the use of nuclear power, as well as less complex technologies such as the fluoridation of municipal water supplies. In virtually every instance, the interested public has entered the domain of technological decision-making. As a consequence, the public needs more and better information; in order to understand and judge the efficacy of technological proposals, citizens, as well as regulatory officials, require information about the full range of potential consequences.

A response to this need has been the growth of a new activity, *technology assessment*, which provides a method for studying and directing the design, development, and implementation of technological innovations, both large-scale and less complex, with a high degree of concern for the social context in which they will operate. By anticipating possible negative consequences of a new development, and incorporating technical modifications or legal safeguards in advance of deployment, incipient problems may be avoided; by promoting desirable possibilities beyond the primary design purpose, technologies may be modified so as to offer greater social value. In short, technology assessment can help make technological developments more responsive to human needs.

WHAT HAS BEEN DONE IN TECHNOLOGY ASSESSMENT

Technology assessment activities are being conducted both in the private and in the public sector. It is fair to say, however, that the federal government has taken the lead in promoting both specific studies and the development of technology-assessment methods. The National Science Foundation has sponsored a considerable number of projects, including substantive assessments of particular technologies,

Table I. **TECHNOLOGY ASSESSMENTS SPONSORED BY THE NATIONAL SCIENCE FOUNDATION**

The subjects of representative projects funded through 1979

Composite Materials	Alternative Work Schedules
Guayula—a Domestic Rubber Source	Transition to Advanced Automotive Propulsion Systems
Solar Generation of Electricity	No-Fault Automobile Insurance
Electronic Funds Transfer	Controlled-Environment Agricultural Technology
Information Networking Technology	Remote Sensing
Electricity Rate Structures	Metric Transition in the United States
Alternative Strategies for Conserving Energy	Terrestrial Biomass Systems
Personal Transportation Modes (Use, Choice, and Future Preferences)	Earthquake Prediction
Regulation of the Environmental Impact of Automobiles	Outer Continental Shelf Oil and Gas Operations
Communications for a Mobile Society	Cable Television
Electronic Message Transfer	Personal Computers
The Video Telephone	The Hydrogen Economy
Robotics	Telecommunication-Transportation Interactions
Vegetable Substitutes for Animal Protein in Human Food	Fluorocarbons and the Environment
Life-Extending Technologies	Human Rehabilitation Techniques
Geothermal Energy Resources	Technology Assessment for the Citizen
Large Cargo Aircraft	Structural Modeling in Technology Assessment
Urban Solid-Waste Management	

studies of how technology assessment can be utilized by various groups, and the development of methodologies (see Table I). The Congressional Office of Technology Assessment, which was established in 1973, sponsors studies of technologies ranging from the manufacture of simple devices such as fluorocarbon sprays to large-scale systems such as transit systems (see Table II). The areas that have been examined under the auspices of these two groups have included both hardware, such as solar equipment, and social technologies, such as human rehabilitation techniques.

These studies have brought about a variety of results. In general, technology-assessment activities can produce one or more of the following actions:

- Modifying the project or technology in order to reduce undesired results or increase benefits to certain groups or social sectors
- Defining a monitoring or surveillance program that allows policies to be modified on the basis of what happens as the technology develops
- Stimulating efforts to define risks, forestall anticipated negative effects, further identify alternative methods (which may or may not be technological) of achieving the desired goals, and identify feasible corrective measures
- Assessing the need for regulation or other control, and the means of implementation
- Encouraging the development of the technology into new areas, to exploit benefits previously unanticipated
- Recommending changes or innovations in institutional practices
- Providing information to all interested parties, and stimulating public debate on policy issues and public participation in their resolution
- Preventing a technology from developing (probably an unusual, though not impossible, outcome)
- Delaying the development of the technology until some of the discerned needs can be attended to
- Partially implementing the technology, thereby deferring decisions about the scale of operations until data can be gathered and tests made

Table II. **PRIORITIES FOR TECHNOLOGY ASSESSMENT**

Listed in order, as evaluated in 1979 by the Office of Technology Assessment

Impact of Technology on National Water Supply and Demand
Alternative Global Food Futures
Health Promotion and Disease Prevention Technologies
Technology and World Population
Technology and Land Productivity
Impacts of Technology on Productivity, Inflation, and Employment
Technology and the Developing World — Meeting Basic Human Needs
Peace Technology
Impact of Microprocessing on Society
Applications of Technology in Space
Designing for Conservation of Materials
Future of Military Equipment
Technology and Movement of Goods
Weather and Climate Technology
Allocating the Electromagnetic Spectrum Globally
Implications of Increased Longevity
Controlled Thermonuclear Fusion
Technology and Mental Health
Technology and Education
Prescription Drug Use
Forest Resource Technologies
Health Technologies and Third-World Diseases
Electric Vehicles
R & D Priorities for U.S. Food Production
Alternative Materials Technologies
Deep Ocean Minerals Development
Energy Efficiency in Industry
Role of Technology in Meeting Housing Needs
Ocean Waste Disposal
Technology and the Handicapped

As these results indicate, the process of technology assessment suggests actions that can either accelerate or delay developments, and either stimulate or mitigate the impacts. Furthermore, the process can provide a basis for ongoing assessment.

THE SCOPE AND LIMITS OF TECHNOLOGY ASSESSMENT

Of course, technology assessments differ according to their scope and level of effort. A "macro" assessment, the most comprehensive kind, takes about two years to perform and costs (in 1977 dollars) between \$300,000 and \$600,000. A "mini" assessment, which is more limited in either breadth or depth of analysis (selectively focusing on an impact area, an affected party, or a specific technological configuration), is an order of magnitude less expensive. A "micro" assessment, largely speculation about a particular problem area, is yet another order of magnitude less expensive.

Whatever the level of effort, the assessment involves an analysis of factors beyond technical and economic feasibility. The concerns include economic considerations, such as labor displacement or trade issues, and legal factors, such as the ability of the legal system to resolve new situations of conflict. In addition, there are often political or social ramifications to be examined. Technical options and policy initiatives are formulated to deal with these various contingencies. Analyses must be delivered in a form that can be utilized by both decision-makers and interested citizens.

Since technology-assessment activities typically involve the study of a

". . . a carefully selected interdisciplinary team is a virtual necessity."

Right: Mobile communications equipment is already serving such users as police departments and taxi companies. Advances in the technology will permit the expansion of mobile telephony services to a much larger group of users. Such services could, for example, increase the operational efficiency of a business, or enable individuals to communicate with each other anywhere, at any time.

wide range of impacts, the assembly of a carefully selected interdisciplinary team is a virtual necessity. Team members usually include engineers, economists, planners, policy analysts, political scientists, lawyers, sociologists, and interested private citizens. The team approach permits the introduction of disciplinary interests and expertise and promotes an integration of disciplinary perspectives.

Experience has shown that the organization of an assessment project and the techniques that are used vary according to the particular task. Most assessment teams use a methodological framework similar to the one outlined in Table III. The techniques are derived from various engineering disciplines, the social sciences, and decision theory and forecasting.

While technology assessment has great promise, it is not free of problems and pitfalls. For instance, it is difficult to know whether the potential impacts chosen for analysis are, in fact, the most important concerns of the general public. There are problems in achieving an appropriate balance of depth and breadth in impact analysis. The uncertainty associated with future technological developments and social conditions limits the reliance that can be placed on firm quantitative techniques for modeling alternative futures. And assessment teams often experience difficulty in coping with the dynamics of interdisciplinary research. These problems are being addressed by university researchers and by the institutions in both government and industry that support technology-assessment activities.

Table III.

AN ASSESSMENT PROCEDURE

Seven steps for carrying out a technology assessment, as outlined by the Mitre Corporation

1. Define the assessment task.
2. Describe relevant technologies.
3. Develop state-of-society assumptions.
4. Identify impact areas.
5. Make preliminary impact analysis.
6. Identify possible action options.
7. Complete impact analysis.

TECHNOLOGY ASSESSMENT ACTIVITIES AT CORNELL

Cornell University has been involved in technology-assessment activities for more than a decade. The School of Civil and Environmental Engineering has offered a seminar in the subject since 1970, and several research projects have been undertaken. These studies have included analyses of the implications of emerging developments in telecommunications and electronics: microwave solid-state devices, video telephones, and mobile communications. A current project involves a study of the implications of the development of electronic message transfer. The last three of these assessments represent large studies, involving faculty members and students from several colleges, including the College of Engineering.

The videotelephone study explored the probable modes of development of video telephony and the anticipated impacts in ten selected areas. Included were studies of the potential usefulness of video technology for energy and transportation needs, in educational and medical situations, and for the needs of the deaf. The study also examined various economic, legal, regulatory, and trade issues.

The mobile communications project included studies of the historical, technical, and economic factors that would influence technological development. Contemporary patterns of use within particular sectors of the economy were examined, and changes in those patterns that might accompany the deployment of new technology were suggested. General implications of the technology's evolution—effects

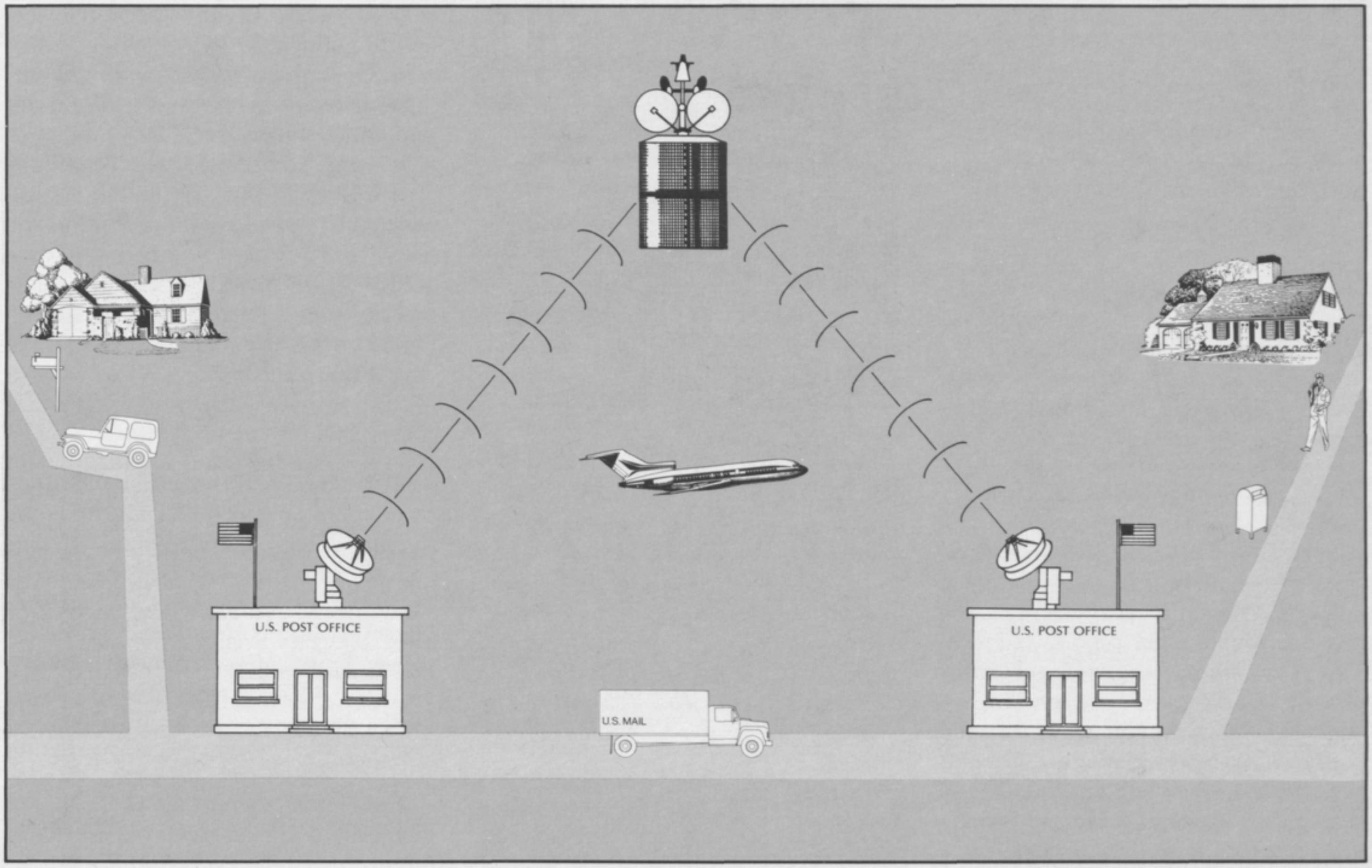


Figure 1. A hybrid system for message transfer. Currently, first-class mail travels between post offices by airplane or truck; such mail could be transferred electronically via satellite. A hybrid system combining capabilities of electronic message transfer (EMT) and conventional mail collection and delivery could provide rapid, low-cost service to the general public. EMT systems could also offer high-speed, direct communication.

Right: An end-to-end home electronic information system would provide for keyboard input and display of selected information.

Electronic Message Transfer: A Technology Assessment

Sometime before the year 1990, instead of posting an order by mail or telephoning a client in another city, you may be entering a written message into an electronic instrument or recording an oral message for electronic transfer. Is electronic message transfer economically and technically feasible? Will people like it? What effects would it have on existing facilities such as the postal service and the telephone companies? On employment? On trade? On energy and other resources? On issues of privacy? On everyday life in the society?

Electronic message transfer (EMT) is an example of an emerging technology that is a prime candidate for scrutiny by the relatively new technique of technology assessment. It has the potential for bringing about changes that extend far beyond the technical considerations. It is a technology that requires broad study in advance of widespread implementation, to reveal its benefits and costs—economic, social, political, legal—and to provide a basis for planning and direction.

At Cornell a technology assessment of EMT is being conducted in a project sponsored by the Program on Science, Technology and Society, and the Department of Environmental Engineering. The researchers are Alfred M. Lee and Arnim H. Meyburg, authors of the article published here, and Richard E. Schuler of the environmental engineering faculty. The findings are based on detailed investigation and analysis in each area of inquiry.

Technology assessment, though it uses quantitative techniques, cannot be exact; there are too many alternatives and unpredictable factors. While it is difficult to say whether the benefits of EMT will outweigh the costs, it is fair to conclude that the benefits that could result are not trivial and that the social costs can be mitigated. The general conclusions of the Cornell study are:

- The technology for electronic message-transfer (EMT) systems already exists. New technological developments will reduce costs and the market potential will continue to increase.

- Because of relatively high costs for terminals and telecommunication linkages, end-to-end service will be justifiable in the near future only for heavy users; the general public can be expected to begin with hybrid systems that utilize both conventional and electronic technology. Over the long term, after terminal and linkage costs fall, hybrid-service users may switch to end-to-end services.

- The development of widely used end-to-end EMT is feasible only if terminal equipment is acquired by the general public. Personal decisions about whether a terminal should be purchased will depend not only on cost, but also on the possibilities for multiple use. Potential applications of home EMT systems include paying accounts and bookkeeping; retaining records such as recipes or an index of family birthdays; computing; text editing; gathering, sorting, and retrieving information such as news or stock prices; and purchasing goods.

- Many communications now carried by conventional means can be diverted to electronic systems. Without special government incentives to develop a mass market, however, electronic services will probably be limited initially to use by businesses and for priority messages. This is a pattern similar to that of the early diffusion of telephone service.

- EMT can combine features of the telephone and mail services. Like telephone systems, EMT systems can be interactive and have rapid-transfer capability; and like the mail, they can provide written records of communications. (In fact, the development of a mass market for EMT may depend upon the general level of keyboard skills, unless low-cost facsimile services emerge.)

- The national monopoly on "conventional letter" postal service should not be extended to EMT, for competition can be expected to spur the development and adoption of innovations, as well as to lower costs to consumers.

Sole-service providers might be justified, however, in specific regional markets in which the demand is limited; the issue of market structure should be reexamined when cost data become available. On the other hand, the United States Postal Service should not be excluded from EMT developments. Early government involvement might stimulate industrial activity and inspire public confidence in the new service. Furthermore, government involvement could ensure the development of services for more than just the most lucrative markets.

• Joint ventures between the Postal Service and private firms might be desirable. The resources and infrastructure of the Postal Service, combined with the expertise available in the private sector, would be particularly helpful in making hybrid EMT systems successful.

• It may be desirable, for reasons of national security and consumer response, to maintain two alternatives for the transfer of written messages. Public opinion, at least at first, will demand that electronic services exist in conjunction with conventional services, and even in the long run, people may continue to prefer conventional means for the delivery of communications such as greeting cards or letters on special stationery. A situation may evolve in which electronic services are used for rapid communication and conventional mail services are used to transfer more personal, intrinsically valued items.

• In order to participate in widely used EMT service, the United States Postal Service will have to change the nature of its operations, alter its capital-labor mix, and attract more technically trained personnel. It will also have to develop a new public image and promote different patterns of customer usage. In fact, popularity of EMT services could stimulate the post office to begin to cope with longstanding operational and deficit problems. If it is prohibited from offering EMT, its viability may be at stake.

• The development of EMT will have an impact on postal and office labor. Levels of employee skills may be changed. Projected increases in labor productivity may be accompanied by a reduction in the number of entry-level positions (such as those requiring only secondary education). Some job dislocations are possible. On the other hand, EMT development could enhance working conditions and employee opportunities if they are implemented properly, and cooperative programs by government and industry could augment these possibilities.

• The use of EMT services may promote the conservation of resources, particularly energy, paper, and vehicles required for postal operations. End-to-end services, of course, offer a greater potential for savings than hybrid services.

• Developments in EMT offer new trade opportunities and may contribute to efforts to reduce the national trade deficit, but the United States will have to compete with other industrialized nations, notably Japan, West Germany, and the United Kingdom, for a share of the international market.

• The duties and responsibilities of providers of EMT services will not be radically different from those of providers of conventional message-transfer services. Liability situations could increase with the volume of EMT, but current legal provisions could probably cope with them.

• EMT technology may introduce new problems in safeguarding privacy, especially in the transmission of messages and data, and in regard to the intrusiveness of electronic communication devices. The development of public policies may be needed to resolve a conflict between society's (or government's) right to know and an individual's right to privacy. A combination of technical, legal, and social measures would probably be most effective in coping with problems of this kind.

• The introduction of EMT can be expected to affect personal lifestyles. EMT may be viewed by some as a depersonalizing influence, perhaps promoting social alienation. The infusion of rapid communication and information processing into daily life may raise questions about "information overload" and personal autonomy in decision-making. EMT services may change the pace of transactions: users may expect faster responses to messages and creditors may demand prompter payment. Even the nature of human communication may be affected: fast, concise messages lacking subtlety and nuance could increase the chance of mistakes and misunderstandings. Therefore, consumers must learn to use the technology carefully and wisely.

"Engineers must be prepared to participate in the public debate over issues of technological development. . ."

not restricted to particular sectors—were also considered. The future structure of the industry was projected, and speculations were made about the future of land mobile communications and issues associated with public policy and planning.

In the study of electronic-message technology, our research group is examining recent developments in the industry in order to evaluate the economic and technical feasibility of future services. The potential market for electronic message-transfer services is analyzed, along with the various options for the provision of service. This study also investigates how the development of this technology may affect operations of the federal postal service, what the consequences might be for postal and office workers, how development of the technology might influence resource conservation and trade, and how liability and privacy issues might arise.

Actually, it is fairly difficult to generalize the particular results of technology-assessment studies. Specific findings are often contingent upon a set of plausible scenarios and are valid only in the context of the assumptions that are made. Technology assessments often generate a list of questions that should be asked about the impacts of new technology, without necessarily providing all the answers. The value of a well executed assessment is that technologies will be better designed and that undesirable surprises will be minimized.

In selecting technologies for study, the Cornell group has chosen new and emerging technologies that seem likely to develop, rather than those already established. While each of the technologies examined is significant in terms of contemporary policy issues, an additional focus of the Cornell research activities has been the development and testing of assessment methods.

PREPARING ENGINEERS FOR NEW RESPONSIBILITIES

Cornell is one of a number of universities in which researchers are actively involved in technology assessment, both in developing techniques and in carrying out policy-oriented analyses. But there is an equally important responsibility that universities, and particularly engineering schools, must assume: They must ensure that the engineers they educate are prepared to assess and understand the full consequences of the technologies they design. With increasing frequency, engineers are required to do more than design technical solutions or solve implementation problems. Their responsibilities include proposing a variety of viable solutions that weight technological factors against social and human needs, and assisting policy-makers and public-minded citizens in evaluating these alternatives. Engineers must be prepared to participate in the public debate over issues of technological development, and to work with lawyers, economists, and social planners in proposing, selecting, and implementing the best choices.

Engineering education must acquaint future professionals with these new responsibilities and prepare them to meet the challenge. It must compel them, in all their academic work, to look beyond the purely technical factors. It must nurture a sensitivity to the social implications of technology. At Cornell, the development of courses such as the Seminar in Technology Assessment, jointly sponsored by the College of Engineering and the Program on Science, Technology and Society, is intended to foster this kind of professional education.

The growth of technology-assessment activities here and throughout the country is evidence of a general concern about the impact of technology upon society. The changes already introduced have become integral features of our civilization, and technology will continue to be a dominant factor. As industrial and technical developers, decision-makers, and citizens, we must be able to manage our technological progress for the greatest public good.

Alfred M. Lee, a postdoctoral associate, and Arnim H. Meyburg, professor and chairman of the Department of Environmental Engineering, are both members of Cornell's Program on Science, Technology and Society. They have collaborated on several technology assessments.

Lee came to Cornell for graduate study in 1973, after graduating from the University of Illinois with a B.S. degree in electrical engineering. He received the M.S. in environmental systems engineering in 1975 and the Ph.D. in civil engineering and public policy earlier this year. His publications include journal articles on technology assessment, telecommunications planning, and the interaction between transportation and communication.

Meyburg, a specialist in urban transportation planning and engineering, has been at Cornell since 1969. He earned a degree in linguistics at the Free University of Berlin and took his graduate work at Northwestern University, earning the M.S. degree in quantitative geography and the Ph.D. in civil engineering. He has been a consultant on transportation projects for a number of United States and foreign agencies, governments, and firms, and has co-chaired international conferences on behavioral travel-demand modeling. His publications include books on transportation modeling, planning, and systems evaluation, and on survey sampling and multivariate statistics. He also was co-editor of two books on behavioral travel modeling.

Lee

Meyburg

COMMENTARY

by Stuart M. Brown and Walter R. Lynn

Engineering, like law and medicine, is a profession in which specialization plays a dominant and increasingly preemptive role. In fact, professionalism is increasingly thought to be identical with specialization: what is not specialized, it is supposed, is neither professional, worthwhile, nor well-paid.

In order to make primary-care physicians professionally respectable, the American Medical Association recently added this area of medical expertise to its list of official specialties. Yet primary-care physicians are actually the generalists of the profession. They are what we used to call general practitioners. Their field of expertise is health, generally. It is their business to know something, but not everything, about most of the commonly encountered medical problems. They are badly needed experts, in short supply in our society; specialists, they are not. The effort to classify this practice as a specialty, and thereby dignify it, reveals the powerful inclination to identify professionalism with specialization. It also gives the game away: in our society, at least—and, we think, in any conceivable society—general medical practice has a place among and alongside of the specialties; and in order to serve the society, the medical profession must recognize this and provide for it.

So professionalism and specialization are not the same. The professions, in order to be socially responsive and responsible, must recognize and provide both specialists and generalists, of the kind and mix determined by particular social needs.

Such recognition and provision must be made primarily in the professional schools. Faculty attitudes not only determine what and how the students are taught, but strongly influence the students' view of their profession, including their attitudes toward the place and value of generalists and specialists; and these attitudes determine what the profession will be like tomorrow and the day after, and how well it will serve society. Indeed, the state of any profession depends very largely upon faculty decisions about the curriculum and faculty attitudes in the classroom.

SPECIALIZATION VERSUS BASIC STUDIES

Since shortly after World War II, American universities have provided an environment in which specialization flourishes and professionalism is demeaned. This has occurred in all fields, including both the humanities and the sciences, and in liberal arts colleges, scientific institutes, and professional schools. Disciplines have been divided into subdisciplines and then divided again and again as expertise and knowledge expanded into more and more restricted and esoteric areas of study. In engineering, evidence of this can be found in any series of engineering college catalogs, beginning in the early 1960s. At the Cornell College of Engineering, it has surfaced in efforts to devise and revise the core curriculum of the Division of Basic Studies.

What we have to say here about professionalism and specialization has applications, we believe, to professional education generally. But we shall restrict our discussion rather narrowly to engineering education.

. . . on professionalism and specialization in engineering education

After faculty study for some months, revisions in Cornell's undergraduate program in engineering are to be instituted in the fall of 1981. The main features of the revised curricula will be outlined in the Summer issue of this magazine, along with a Commentary *by Malcolm S. Burton, associate dean for undergraduate education.*

Comments from other readers on the issues raised here are invited as letters to the magazine.

The idea underlying a program of basic studies is simple and sound. It is the idea that professional expertise, both specialized and general, is founded upon and developed out of bodies of theory and knowledge that have great generality and wide application. For professional education in both medicine and engineering, the subjects of mathematics, physics, and chemistry are basic; and for medicine, biology as well. These basic studies are necessary for developing both competence and adaptability. They are necessary for competence because they dispose practitioners to seek theoretically sound solutions to professional problems, rather than to arrive at them through tinkering and folklore. They are necessary for adaptability because they provide the theoretical base common to the various specialties of the profession and so enable practitioners to meet the changing needs of the society and to pursue their own changing interests. The social and individual pay-off of competence and adaptability is very high. Any profession that ignores basic studies or permits the quality of instruction in them to deteriorate is in trouble, and so is the society the profession serves.

The problems arise in constructing specific curricula. Although everyone agrees that mathematics, physics, and chemistry are basic subjects, there may well be some disagreement about what parts of them should be taught, and how—disagreements that reflect different views of the place of specialization within the profession. There are further differences of opinion about what other subjects should be included in a basic program. Cornell's experience with its basic engineering curriculum is a case in point. In 1963, when the faculty adopted the curriculum for the new Division of Basic Studies, it added four core courses in engineering science (such as mechanics or electrical science) and four liberal studies courses to the basic subject requirements in mathematics, physics, and chemistry. The engineering core courses could be selected from a set of six, and the liberal studies courses could be chosen without substantial restriction. The rationale for the engineering science courses was that they provide a bridge between the three basic sciences and the various specialized fields of engineering and provide students with some overall understanding of the breadth of engineering as a profession. In 1980, the liberal studies requirement remained in place, substantially unmodified. The engineering science courses, however, were to be chosen from a list of nineteen, loosely classified into four categories. The student selected one course from each category in the

"The engineering college faculties must regard themselves seriously as professionals engaged in a social and moral enterprise."

list—a Chinese menu, which on the face of it makes no sense. Are there nineteen engineering core science courses or only four? If only four, why were they offered in nineteen flavors? If nineteen, how could a student afford to study only four? (This system will change beginning this fall.)

Although the expanded number of engineering core courses can be explained in part by advances in knowledge, a more plausible explanation lies in the interests of the specialized fields. The members of each specialized field, one suspects, sought to add those courses that would advance the specialized interests of their own students. For example, it could be argued cogently that students in operations research or structural engineering need numerical methods more than chemistry. This kind of argument leads gradually to the erosion of basic studies, and their replacement by thinly disguised specialized offerings. The conflicts between the needs of each specialty and the need for a more general education in theoretical and applied science are, in any case, inevitable, given the limited time in which students must earn their engineering degrees. But the demands for specialization and the temptation to identify specialization with professionalism weight the balance strongly against basic studies. There are, of course, no villains here, only performers acting out roles inspired and supported by the prevailing specialist milieu of our universities.

If all engineers are to be specialists and if the general engineering education provided by basic studies is being gradually eroded away, how shall we provide for the adaptability necessary for all professionals in a rapidly changing society? Does our society need in engineering the equivalent of primary-care physicians? And who is to decide if this is so? We shall return to these questions.

The fact that the liberal-studies requirement remains intact in the Cornell undergraduate engineering curriculum while the engineering-science course requirement seems in danger of being destroyed by fragmentation is an inexplicable anomaly. The eight required but freely elected courses in the humanities and social sciences (the equivalent of one course per term) do not provide the basic theory on which the practice of engineering rests. They are not bridge courses, for they have no special relevance either to any of the specialized fields of engineering or to the social setting and function of engineering as a profession. These courses are free-floating lacunae, to be filled one way or another by humanities or social science. One suspects that the original (and continuing) intent was to produce better-rounded, more broadly educated, and more humane persons, in the expectation that such persons would also turn out to be better engineers. But this rationale confuses two very different educational aims: to graduate more broadly educated persons, and to produce better engineers. And no matter how well intentioned, the requirement advances neither aim. An unstructured requirement cannot, except by accident, achieve anything. Nonetheless, this liberal-studies requirement contains the germ of a viable and valuable goal:

to produce better engineers, in the sense that "better" means "more professional," not "more specialized."

WHAT MAKES ENGINEERING A TRUE PROFESSION?

What we propose here is a reversal in emphasis within engineering education, from specialization to professionalism. While continuing to provide the very best training in the specialized fields of engineering, the engineering colleges should place fundamental emphasis upon attaining the highest possible degree of professionalism.

Not surprisingly, the greatest obstacle to making this shift comes from the engineers themselves—how they think about their careers and place in society. For the most part, engineers have no clear conception of engineering as a profession or of themselves as professionals. They would agree that engineering has a professional aspect, but think of this almost exclusively in terms of membership in professional societies, licensing requirements, and other such appurtenances or trappings of specialized careers. In this respect, of course, engineers as professionals would not differ at all from cosmeticians and dental hygienists.

The four principal criteria of a profession, however, are quite different:

- *Expertise*. This consists of a high degree of expert knowledge and skill that contribute to the well-being of people and of society. It requires the provision of technical training to transmit the knowledge and perfect the skills. It implies a built-in inequality of knowledge and skill between those who have the expertise and those who benefit from it.
- *Autonomy*. The profession is self-regulating and self-policing, as only other professionals have the expert knowledge and skills required for setting and maintaining standards of attainment and performance. Members are, therefore, accountable primarily to others in the profession; some of the principal mechanisms for collegial control are certification, membership in professional societies, and accreditation of curricula.
- *Social function and responsibility*. The profession performs a central and critical social function (in medicine, this is the preservation of health; in law, the interpretation and application of the rules that define and govern the society; in engineering, the design and control of processes). Society protects and subsidizes its professions, each according to its place and social function; the professions, in turn, have overall responsibility to the society to improve and perfect their services.
- *Special professional obligations*. The professions of law and medicine, for example, have special obligations to clients, such as observing confidentiality. The special obligation of engineering is to protect the public welfare, even when work is being performed under contract to private parties or corporations.

Engineering as a profession is to be understood in terms of these criteria, worked out in detail so as to fully expose the internal structure of each and the relations among them.

So understood, the practice of engineering not only has a rich social context; it is, in part, a social and moral enterprise. The four criteria inescapably involve conflicts between professional and social responsibility, between duties to employers and the public welfare, between the need for general competence and the need for specialization. It is virtually impossible to find any engineering problem that does not pose social and moral problems and intrude significantly into areas of social concern. The increasing complexity was discussed by Harvard's Derek Bok in his 1978 presidential report:

> *As knowledge expands and society grows more complex, the urge to specialize increases. At the same time, advancing knowledge constantly uncovers new links connecting seemingly disparate phenomena or illumines known connections in greater specificity and detail. Fluorocarbon sprays are found to destroy the ozone layer which in turn has effects on nutrition and human health. Environmental measures may inhibit capital investment and hence dampen employment and growth which will in turn affect our crime rates, tax revenues, balance of payments and commitments abroad. As such awareness accumulates, it grows harder to consider anything in isolation. Every problem that affects other people involves more factors, more relationships, more ramifications of every kind. Every decision forces us to weigh more and more separate human interests—interests that cannot be measured and compared by any quantitative sleight of hand.*

Whether we like it or not, whether we recognize it or not, our technical decisions have implications and consequences for our society and its values. Engineers as professionals must understand that this is so and ascertain for each decision how and in what degree it is so. They must be aware of their own value judgments, assumptions, commitments, and doubts. They must expose and articulate their perceptions of acceptable risk, and both the social and technical bases of their engineering judgments.

ACHIEVING A SHIFT TOWARD PROFESSIONALISM

The aim of the engineering colleges, we have said, should be to produce better professionals, those who regard themselves as professionals with a social role and function. It remains for us to say something about how this might be done. We can begin by eliminating ways in which it cannot be done.

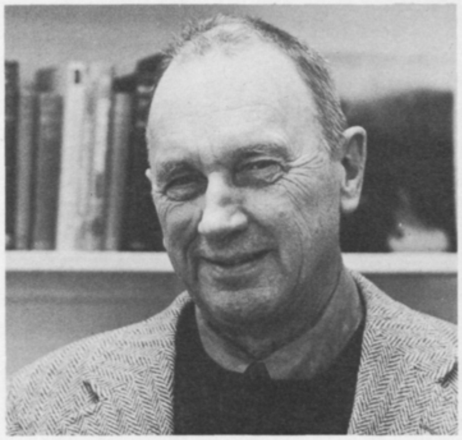
First, it cannot be done by means of any liberal-studies requirement. It is true that values are an integral component of the subject matter of the humanities and the social sciences: one cannot study those subjects without encountering and considering questions of value. But the questions of value that typically arise in humanities and social-science courses are remote from those social situations in which engineers work and make decisions. They seem to be, and to a considerable degree are, in fact, irrelevant. This is not to say that the idea behind a liberal-studies requirement should be abandoned, only that it should be carefully rethought and closely integrated into the professional curriculum. Integration of liberal studies does not mean that an engineering faculty should take upon itself the responsibility for providing liberal-studies courses. What it does mean is that a faculty needs to be concerned about and involved in providing liberal studies in a context in which they pertain to the education of engineers who hope to become professionals.

Another way it cannot be done is by providing for the training of engineering generalists alongside of the various specialists. The underlying idea of proponents of such a plan (see, for example, an article by R. C. Seamans that appeared last year in *Engineering Education*) is that our society has a need and a place for both generalists and specialists and that the profession would better serve its social function if it undertook to provide both. There is validity in this view; as we have pointed out, it is certainly true that our society needs general medical practitioners as well as specialists, and that the society is better served when the medical profession undertakes to provide these. But this solution is not addressed to the problem we have been posing: the problem of training better professionals. There is simply no connection between the better professional, in our sense, and the generalist in medicine or in engineering. Engineering needs to embody within every specialist the qualities of a professional.

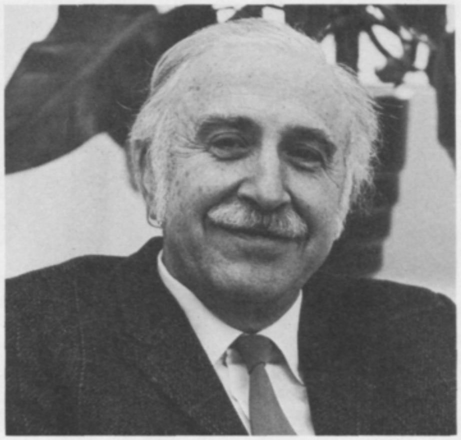
The problem, in our view, requires a very radical solution. It does not require new courses (though two or three new courses, specially designed for this purpose, might prove useful). What is required is a change in the manner of teaching and the outlook of the faculty, in every course and at every academic level. The engineering college faculties must regard themselves seriously as professionals engaged in a social and moral enterprise. They must learn how to discuss moral and social issues seriously and cogently. They must lay out for their students the moral and social consequences of technical decisions. Most of all, they must make clear to their students that this is the proper business of engineers as professionals. It is a matter of paramount concern for every teacher and his students in every classroom. It is part of engineering for generalists and specialists alike. It is not something to be handed off to social scientists and humanists or relegated to formal, systematic treatment in special courses.

It is sometimes thought that engineering is only weakly a profession because it has no clients in the sense in which medicine and law have them. But having clients is not a defining feature of the professions; it is not even an element in the criteria for professions. There are lawyers without clients and physicians without patients, and no one for this reason loses

Brown



Lynn



his position as a professional. Being a professional does not turn upon the conditions of employment or who one's employer is. Even under such a false criterion, however, members of engineering faculties are professionals: they are both engineers and teachers, and as teachers, they have students, who are clients.

It is through these students and the instruction offered them that teachers of engineering maintain the vitality of their profession and determine what it will be in the future. Not only to the students, but to the profession itself, teachers have an obligation to produce better professionals, capable of practicing engineering as a specialty and as a social and moral enterprise.

Stuart M. Brown and Walter R. Lynn, both professors at Cornell, are colleagues in the University's Program on Science, Technology and Society (STS).

Brown, professor of philosophy and associate director of STS, has served the University also as chairman of the Department of Philosophy, dean of the College of Arts and Sciences, and vice president for academic affairs. Except for Army service during World War II and a four-year term in the 1970s as vice president for academic affairs and professor of philosophy at the University of Hawaii, he has been at Cornell—as student, faculty member, and administrator—for almost fifty years. His Cornell degrees are the B.S. in biology, granted in 1937, and the Ph.D. in philosophy, awarded in 1942.

Brown's interest in the interplay between science and the humanities is reflected not only in his work with STS, but in activities such as his participation in an international colloquium in the humanities, science, and technology sponsored by the American Council of Learned Societies. In his major professional field, his special concerns are with moral, political, and legal philosophy, and he has published extensively on these subjects. In the humanities, a special interest is the writings of the Bloomsbury Group in England. Over the years, he has participated in various activities concerned with policy formulation for higher education in general.

Walter Lynn, who is professor of civil and environmental engineering and director of STS, is a specialist in environmental systems analysis, water resources, and public health. Throughout his twenty years at Cornell, he has had a concurrent interest in social issues involving these technical areas and engineering as a profession. At the University he served previously as director of the School of Civil and Environmental Engineering and as director of the Center for Environmental Management. Last fall he was elected by the faculty as one of its four representatives on the University Board of Trustees. He has served also on the Faculty Council of Representatives (as chairman of its Executive Committee and its Committee on Academic Programs and Policies) and on numerous University committees. At the College of Engineering he has served as chairman of the Policy Committee.

Lynn holds a bachelor's degree in civil engineering from the University of Miami, a master's in sanitary engineering from the University of North Carolina, and the Ph.D. in civil engineering and systems analysis from Northwestern University. His experience includes teaching and research at Miami, employment as a civil engineer, and consulting. He is active in a number of professional societies; currently he is serving as chairman of the Committee on Water Supply Reviews of the National Academy of Sciences and the National Academy of Engineering, and as associate editor of the Journal of Environmental Economics and Management.

REPORT FROM CHINA

1. Notes on the Visit of a Cornell Delegation

A renewal of Cornell ties with mainland China, disrupted for three decades, was expedited this past summer during a three-week visit to the People's Republic of China by a delegation of ten Cornell representatives, including three College of Engineering professors. The delegation came home with signed memoranda of understanding for the exchange of personnel and information—including the first such agreement between the Chinese Academy of Sciences and an individual university—and with new or expanded perceptions of the Chinese government and people.

For Thomas E. Everhart, dean of the College of Engineering and professor of electrical engineering, the experience reinforced a belief that direct associations between students and professionals in China and the United States are the best foundation for cooperation between the two nations.

For Walter H. Ku, professor of electrical engineering, the visit was not only an opportunity for a first-hand view of China today, but a return to his native land, seen in the context of his own experiences and those of family members and Chinese associates.

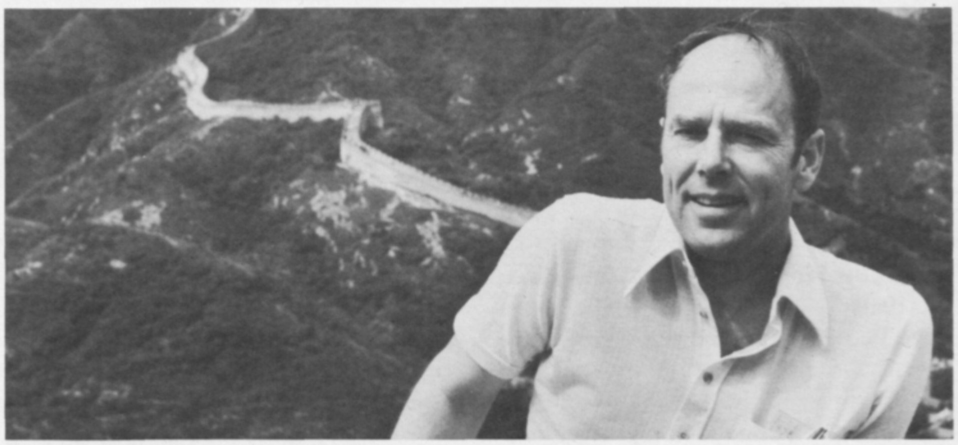
For Frank H. T. Rhodes, president of the University and professor of geological sciences, the overall impression was of a new sense of freedom on campuses, a new openness to the West, and a willingness to explore new fields of study.

After their return from the historic visit, these three members of the engineering college were asked by the *Quarterly* to discuss their views of the proposed exchanges with China, and their impressions of the country.

■ Because this summer's visit was his third to the People's Republic of China, it gave Everhart an opportunity to compare today's situation with what could be observed a few years ago. The people he met both formally and casually were noticeably more open and relaxed with Americans than they had been even in 1978, when Everhart was a member of a delegation from the University of California at Berkeley. (His other trip was a week's visit last June with a National Science Foundation group that was working out the protocol for exchanges of personnel and information.) This summer, for instance, when Everhart and Rhodes went jogging in the early morning, people on the streets would wave to them and call greetings. Two years ago, people encountered in public places rarely spoke to foreigners; they tended to act as if they did not notice them.

Though he is "far from an expert" in China affairs, Everhart said it was apparent to him that people in the United States, including Far East specialists, have had many misconceptions about China—ideas formed on the basis of what was learned first-hand twenty or thirty years ago, and what could be inferred from official writings. A visit to a commune during the 1978 trip, for example, revealed that the commune was allowed to accumulate capital, which was then reinvested in the operations. "This amazed the China scholars in our group," Everhart recalled.

We asked him what he felt about the prospects for developing satisfactory exchange between the two countries.



Thomas E. Everhart, dean of the College of Engineering, visited the People's Republic of China as part of a ten-member Cornell University delegation.

A very important requirement for the United States, he said, is to ensure that Americans conduct every transaction honorably—that products are up to the standards advertised, and that promises, whether they are made by government, corporations, or universities, are fulfilled. It was apparent, Everhart said, that the Chinese, who have a great sense of honor and regard one's word as binding, felt that they had frequently been taken advantage of by the Russians during the years in which China looked primarily to the Soviet Union for outside help. Everhart recalled visiting a factory in which the machinery, purchased from Russia as new, was discovered to be obsolete equipment, repainted. "We must be careful not to allow such abuses, or even less overt ones," he said. "It may be advisable for our government to set up some form of safeguard, such as quality control of goods, perhaps through required guarantees. Japan, after World War II, instituted export licensing on goods in an effort to raise international opinion about the quality of Japanese products, and it worked. Perhaps the United States could do something similar."

We asked whether exchanges of the kind negotiated by Cornell would benefit the countries equally. A major objective of the Chinese, he said, is obviously to catch up with the Western world, especially in science and technology, and therefore China will be the greater beneficiary in the near future. The long term, though, is difficult to assess. "The Chinese are extremely smart and diligent," he said, "and because they are coming from behind, they gave great motivation. They can be expected to contribute soon to the world forum of ideas in science and technology." Even now, Everhart pointed out, the West has much to learn. For example, we don't understand the Chinese medical techniques of acupuncture and herbal medication, which "clearly have something to them." They have developed methods of earthquake prediction, based on observations of animal life, that might be valuable supplements to the techniques we are working on. "As we rely more and more on electronic instrumentation," he said, "we tend to forget to rely on our eyes and ears as well." Another area in which the Chinese have made recent progress is agriculture. "They are literally remaking the landscape in some areas," he said. "They are terracing extensively to make full use of the land and are improving the possibilities for irrigation by moving earth to create flat fields at different levels."

A number of Americans are interested in visiting China, at least for relatively short periods of lecturing or consultation, and are sure to find the experience stimulating and valuable, Everhart remarked. Indeed, Cornell faculty members have already received such invitations. In some fields, such as the study of Chinese language or culture, students may be able to learn a great deal by spending a year or so at a Chinese university. But there are problems, of course. In addition to the obvious ones of language and accommodations, there are, especially for undergraduates and particularly in engineering, difficulties because of the great difference between the educational systems in China and the United States.

Beyond the question of who might benefit most, Everhart emphasized, is the opportunity for both countries to profit from a climate of cooperation. "Some people, thinking of Japan's rapid industrial progress after World War II, are apprehensive that China may become an economic threat to the United States," he said, "but for a variety of reasons (the large amount of land, the organization of the country, and its present level of development) I believe such competition would not develop before the year 2000, if then. At any rate, I think we should much prefer an economic to a military threat."

An exchange of students is particularly valuable for good relations, he believes. "This is evident in the attitudes of Chinese people who have been educated in the United States," he said. "They know Americans to be friendly and helpful, and now that they do not have to be quiet about their opinions, they are speaking out in a very pro-American way. These people include some who hold high positions in government."

He pointed out that since China did not and still does not have a system for graduate education, everyone with a graduate degree received it elsewhere. Most of the people the Cornell delegates met in the Chinese universities had studied in the United States before the 1949 civil war. Several generations have been "lost"; many of the scholars at American universities at the present time are in their forties—they did not have a chance at higher education in their youth. "If we do a good job with the Chinese who are now coming to our universities, we will benefit once again in our relations with China."

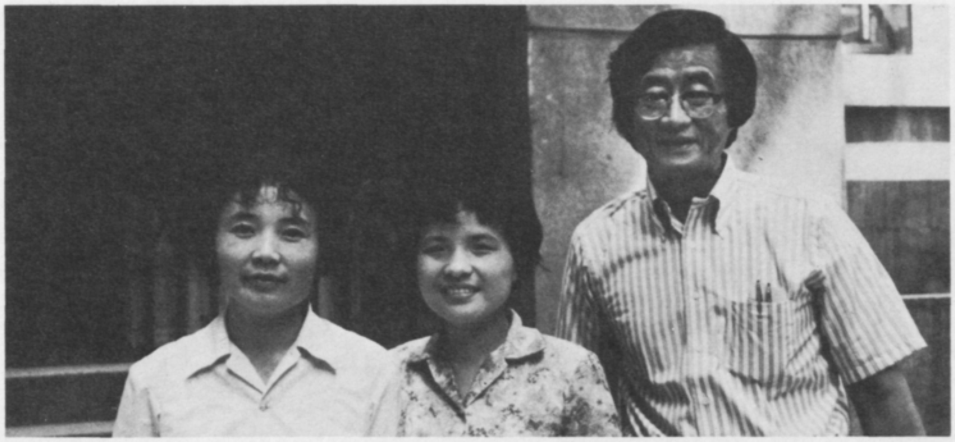
All the Cornell delegates were greatly impressed by the affection shown for Cornell by the fifty-two alumni they met during their visit, Everhart commented. These are all men, typically in their fifties through eighties, who have lived through the Japanese occupation, the civil war, and the devastating "cultural revolution," and have only recently emerged or re-emerged as leaders.

■ Walter Ku knew before he returned to China last summer that scientists there were eager to reestablish connections with their counterparts in the West. Many had already contacted Ku, whom they knew about from his publications in professional journals, and some had already arranged—directly or through the Chinese embassy—to come to Cornell for study and research. Two whom Ku worked with last year at the School of Electrical Engineering were among the first fifty scientists ever to come to the United States from the People's Republic of China. Among the Chinese currently at the College of Engineering are seven in electrical engineering.

The backgrounds of two of the people who have come to Cornell were cited by Ku as examples of the reason for China's great interest in exchange programs. Shih Yen-yang, a research associate at the Institute of Electronics of the Academy of Sciences, and Chi Fu-sheng, a design engineer at the Microwave Equipment Factory in Beijing (Peking), were working with microwave tubes and waveguide and coaxial circuits before they came to Cornell for exposure to the world of gallium arsenide microwave devices, FET field-effect transistors, and microwave integrated circuits.

Ku, who was born in Beijing, came to the United States with his family in 1950. His father, who had been dean at Qinghua University (one of those visited by the Cornell delegation) and president of two other universities, became a professor of electrical engineering at the Massachusetts Institute of Technology, where he had studied for his Ph.D. degree. Walter completed high school in Cambridge and studied at American universities for his baccalaureate and graduate degrees.

The degree of disruption of science and technology caused by the "cultural revolution" is hard to believe, Ku said. "Historically, there is nothing comparable," he pointed out. "The universities were all closed for twelve years, and academic people were sent to prison or to work on farms. Although the majority survived, the ef-



Walter Ku was visited in Beijing by the wives of two Chinese scientists who were then back at Cornell, working with Ku's research group. At left in the photograph is the wife of Chi Fu-sheng, a design engineer at a microwave equipment factory; in the center is the wife of Shih Yen-yang of the Institute of Electronics of the Academy of Sciences.

fects on their lives—and on their professions—were devastating." The experience of one of Ku's uncles, a Cornell Ph.D. from the 1930s, is not atypical: the chief engineer for a large company, he was put in prison for fifteen years. Now restored, he is practicing once again as an engineering consultant. That generation was the hardest hit, Ku said; his two brothers and a sister, all university teachers or administrators, did not suffer as much, although they had no students during the years of closure. (Ku was first reunited with various members of his family in 1979 after a separation of twenty-nine years; Ku and his wife, who was also born in China, were traveling there with an official delegation from the Institute of Electrical & Electronic Engineers.)

Now most of the people in China are looking forward to change, Ku said. "There are great expectations because of the new policies. People are optimistic, and impatient." Generally, the people he has come in contact with are not concerned with political issues—an encouraging sign, Ku feels.

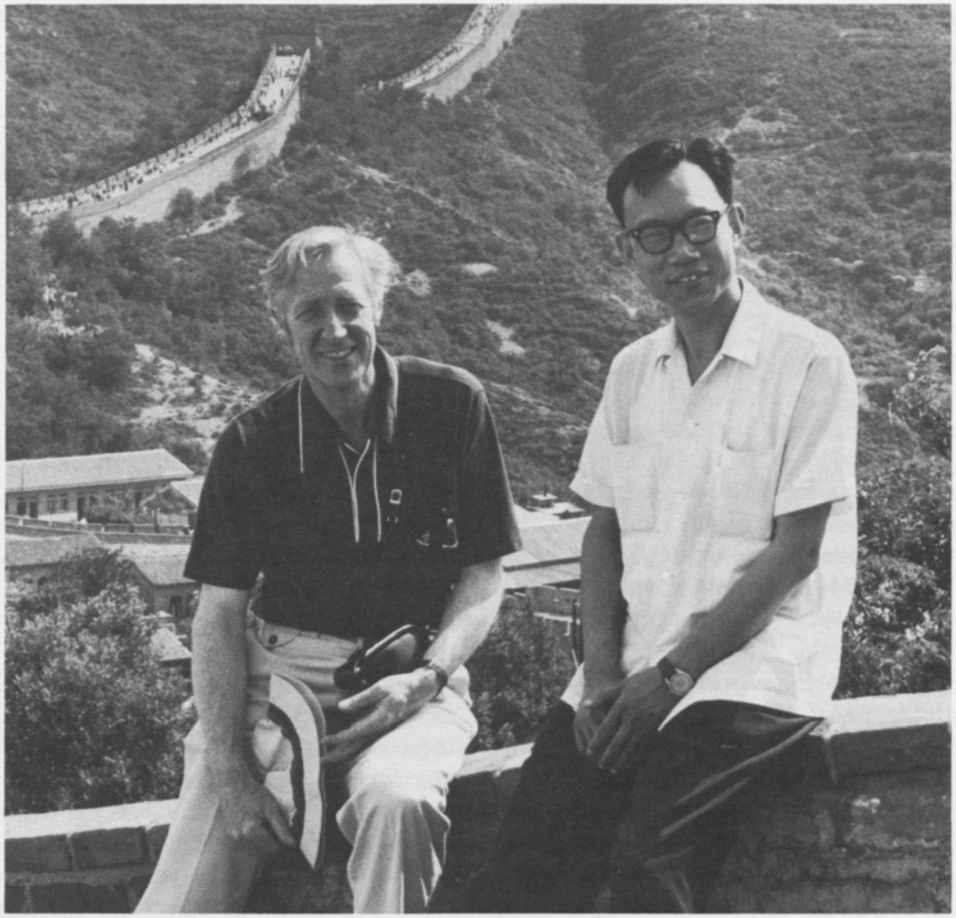
Living conditions are, of course, very different than he remembers them from his youth. "Although things are still tough, there appears to be more food and goods for the people than there were before," he commented. "The most noticeable change is the more even distribution of what wealth there is." As a boy, Ku lived in Shanghai, where the contrast between rich and poor was pronounced. Now large houses such as the one his family lived in are occupied by many families. The crowded living conditions present a difficulty in planning for an exchange of students, Ku noted. The Chinese university officials he talked with during the summer visit mentioned that some special dormitory facilities are planned to accommodate both undergraduate and graduate students from the United States.

There are scientific areas that are likely to be attractive to American students interested in studying in China, Ku said. Although the Chinese are obviously far behind in applied science and technology, there is interesting work being done in areas such as hydrobiology, water resources, agriculture, biochemistry, genetics, and cancer research. Pure science and mathematics are being reinstated in the technical universities. Systematic planning for research and development is nonexistent, however. Management appears to be regarded as a subject with priority.

What especially impressed Ku during his weeks in China was the realization that Cornell engineers hold important leadership positions in the country today. The most prominent bridge designer, for example, is a Cornell civil engineering graduate: Mao Yisheng '17. (He is the uncle of Mao Yu-hai, who is working with Ku at Cornell this year; Mao is an associate professor and head of the signal-processing department at Qinghua University in Beijing.) These people are very loyal to Cornell, Ku found; many hope to send their children and grandchildren here to study now that this is becoming possible once again. To him, the prospect of renewing the previous connection between Cornell and China is important and exciting.

■ Rhodes was impressed with the Chinese interest not only in the high-priority fields of science and technology, but in liberal studies. For example, the place of nontechnical studies in the education of scientists was one of the subjects discussed during a meeting the Cornell delegates had with Vice Premier Fang Yi. "My impression was that the human context of science is a very serious concern of the Chinese leadership," Rhodes said. "It is also an area of central concern to Cornell, which has a long tradition of combining strong programs in many diverse fields." In making the trip to China, one of the aims of the delegation was to open up possibilities for professional exchanges not only in areas of science and engineering, but in the humanities and social sciences.

Of course, Rhodes said, the four major areas of current attention, well defined by the government, are agriculture, industry, national defense, and science and technology, and it is clear that the programs for the universities are closely correlated. The overall national plan is to "modernize" China in these essential areas by the year 2000. In discussions with representatives of the universities visited during the course of the tour, Rhodes found an immediate interest in business management, law, and the social sciences, as well as in technical fields.



President Rhodes posed on the Great Wall with Li Mingde, deputy division head of the Bureau of Foreign Affairs of the Chinese Academy of Sciences.

Rhodes remarked that although China is a firmly communist nation, the attitude toward the West and Western ideas appears to be cooperative and open. Workers on a commune the Cornell group visited now have a limited opportunity to raise and sell produce on an individual basis, he noted, and while this is "not unique to China as a communist country," it is "an interesting variance in the socialist fabric and will be intriguing to watch." He also observed evidence of some religious freedom. Members of the Cornell delegation attending Christian services in Shanghai found the church

crowded; and on one excursion, the Cornell group encountered a number of Buddhist pilgrims traveling to a mountaintop shrine.

Rhodes joined his colleagues in taking special pleasure in meeting Cornell graduates, whom they encountered in virtually every university they visited, as well as at a dinner reunion in Beijing. "We were impressed and touched by their warmth and hospitality," he said, "and I hope that in the years ahead we can foster this response in new generations of Chinese students." — G.McC.

The Cornell delegates lined up with their hosts at the Academy of Sciences in Beijing for the group photograph taken at every meeting.

Cornellians in the front row are: Alain Seznec, dean of the College of Arts and Sciences (second from left); Alison P. Casarett, dean of the Graduate School (third); Frank H. T. Rhodes, president of the University and professor of geological sciences (fifth); W. Keith Kennedy, provost and professor of agronomy (seventh); Thomas E. Everhart, dean of the College of Engineering and professor of electrical engineering (ninth); and Milton J. Esman, director of the Center for International Studies and professor of government (tenth).

Cornell delegates in the back row are: Walter H. Ku, professor of electrical engineering (third from left); Donald F. Holcomb, professor of physics (fourth); Lee C. Lee, associate professor of human development and psychology (fifth); and John McCoy, associate director of the China-Japan Program and professor of linguistics and Chinese literature (sixth).

The chief host, Academy vice president Qian San-quiang, stands between Rhodes and Kennedy.

REPORT FROM CHINA

II. Excerpts from a Delegate's Notebook

Impressions of the visit to China were recorded by Alain Seznec, dean of Cornell's College of Arts and Sciences. The following are excerpts from his China Journal.

▪ Beijing: We sit in deep armchairs covered by antimacassar. There is tea brewing in covered cups. We sit by rank (more or less) with the chairmen side by side and our interpreter next to theirs. . . . We hear about the problems caused by the "Gang of Four," and the hopes for a better life in China. This will be a leitmotif of our visit.

▪ Today our delegation is to be received by Fang Yi, who is not only the president of the Academy of Sciences, but vice premier of the Peoples' Republic of China. . . . Ties, jackets, dresses have suddenly materialized from the bottoms of our suitcases. There is a certain nervousness in the air, all the more that a gift is to be presented (a Steuben bowl). Many strategies are discussed: Give the gift upon arrival? Wait until the end? What about the plaque that is to accompany it? . . . The bus hurtles forward in its usual furious way, but then suddenly dawdles. At last we understand this puzzling behavior. What is at stake is high diplomatic strategy: Our bus must arrive by the gate exactly at the appointed time so that neither host nor guests will have to wait. . . .

On our left a bare, two-tiered platform on which both groups are distributed efficiently by aides. Pause. The camera clicks. . . . Now we are ushered into the actual meeting room, roughly ninety feet long and at least thirty feet high. A huge chandelier hangs from the ceiling. Three magnificent, thick silk rugs cover the whole floor. The central one, a rich blue, is ringed by deep, dark-green plush armchairs separated by lacquered tables. Tea is served, and the inevitable orange soda pop. . . . Fang Yi speaks in a gentle, at times almost inaudible, tone. His whole manner suggests great courtesy, sage reflection, and tranquility. . . . There is banter, some friendly conventional statements; at a certain point he talks about literature and his eyes light up.

■ Walls: Brick fences, stone fences, earth fences, wooden palisades, marble walls, corrugated tin leaning on bamboo poles, all is division and subdivision. Inner courtyards with compounds, compounds within walls, the Forbidden City walls, gates, moats; walls around the cities. The Great Wall of China encompassing this labyrinthian country.

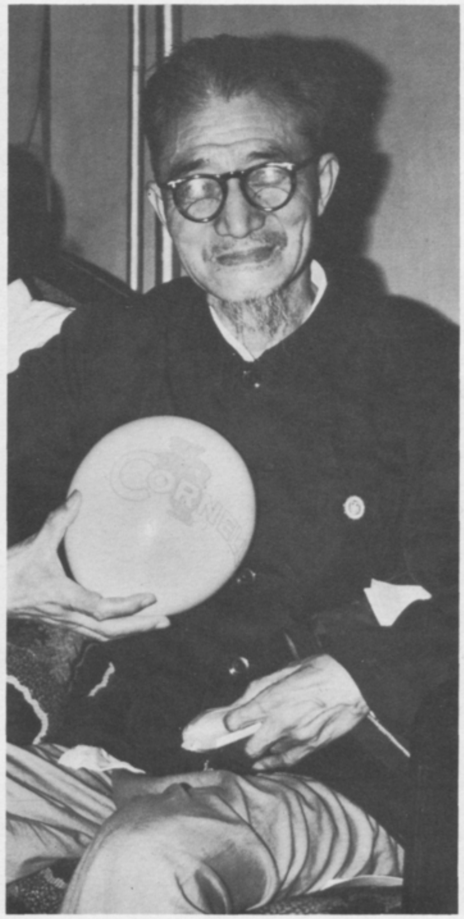
■ "Where," I ask our guide as we drive past Tian An Men square, "is the 'democracy wall' where slogans and posters appear?" No one seems to know. Someone finally points out that the panels erected for this purpose have now been papered with large posters advertising soap and toothpaste.

■ Our alumni are all in the academic world and this means that most are at least in their sixties, of "prewar" vintage. There is a lot of gaiety in the air as we fill them in on the doings of the old campus. We could be in Omaha or Dubuque.

The gentleman next to me is a little fidgety nonetheless and there is something tense about his eyes. He is a scientist, he tells me, but has only recently returned to work, teaching and doing research. I inquire politely about his life since Cornell and he tells me that he taught for a number of years but that when the revolution (the "cultural revolution") came he was put in jail for six years; when finally let out, he discovered that he was the only survivor of five people in his department (one had disappeared, one had died, two more had committed suicide). He himself had a nervous breakdown which prevented him from going back to teaching. But he has been back now for two years. He smiles, I refill his glass with orange pop, offer him a cookie, and we continue to talk pleasantly about our work, as two academics normally do.

■ Our alumni in Beijing have invited us for a banquet in the Winter Palace on the shores of Bei Hai Lake. A charming succession of water-lily ponds, arched bridges, gardens, brightly

Right: Zau-ling Tsoon, who studied at Cornell for a 1926 master's degree in electrical engineering, attended the reunion in Beijing. The delegation from Cornell met a total of fifty-two alumni during the three-week visit.



painted galleries lead us to the Dowager Empress's dining pavilion, now a restaurant.

At the door more than thirty people are waiting. They are alumni, all men, well into their sixties for the most part. . . . We shake hands ceremoniously all around and I notice wonderful scholarly faces, some with very long wispy beards, others with thinning hair brushed back in the "Mao" style, a few bald and looking like Buddhist monks. . . . What they have in common is that they are intellectuals and of a generation that has undergone the Japanese occupation, the civil war, the Russian anti-American years (when they were branded as American spies because of their Cornell connections), and the final indignities of the "cultural revolution." But now, after some forty years of misery, they are back on top and they are not only survivors, but have re-emerged as leaders. Americanism is highly fashionable. Tonight they can afford to be only old grads happily reminiscing about the good days in Ithaca before the war. The clock has come full circle.

As we enjoy exotic delicacies (wooden ear mushrooms, sea cucumbers, beef tendons), the conversation centers on Goldwin Smith Hall, Sibley Dome, the streets in Collegetown. Toasts are drunk, speeches are made (the vice minister of agriculture, Cornell '21 introduces a still older alumnus, Cornell '17), gifts are exchanged (Cornell souvenirs for them, Chinese prints for us). We have brought slides of the campus, and on the dowager's light-green muslin curtains flash the familiar sights of the library tower, Beebe Lake, and Cascadilla Gorge. . . . We are all aware that forty years is a long time to remain separated.

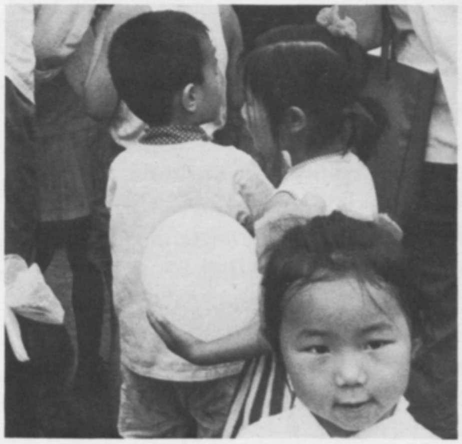
Suddenly one of the oldest alumni intones the alma mater, and in the dowager's dining pavilion, on the edges of the Lily Lake of the Winter Palace, in Beijing, forty-five voices, some frail and reedy, others nasal and fuzzy, at first hesitantly, then with more and more vigor, sing out "High above Cayuga's waters. . . ."

■ At Qinghua University we visit labs where extraordinary ingenuity helps make up for lack of means. Lacquered doors and old-fashioned closets and the antiquated shape of certain basic instruments make me think of the world of Jules Verne. But my scientific friends tell me "it's for real."

■ If class distinction is not always clear, rank distinction is still very much a Chinese preoccupation. Our delegation of ten carries with it a sheet with pictures of all its members and their names and titles, one underneath the other, for easier identification. . . . We find that as we move into the hinterlands this document carries more and more weight with our hosts. The ultimate comes at Southwestern Jiaotong, where every gradation of rank is stressed: at the station there are three cars and a bus waiting for us, and we are each assigned a place according to an exact seating arrangement. The next morning a number of us who had been assigned to cars get into the bus without thinking. After a while, we notice that no vehicle is moving. The chauffeurs cannot accept this chaotic American way of disrupting rankings. Car No. 2 will not drive Person No. 7 of our delegation, any more than the bus (assigned to Persons Nos. 6–10) will accept our No. 2 (the provost), who should be in Car No. 2. Finally we all give in, realizing that our little experiment in democracy has failed.

■ The hosts on either side of a guest are supposed to feed him. Reaching out to the platters in the center of the table, they pick out morsels to put on the guest's plate. As fast as one eats, one's dish will be replenished from the right or from the left, sometimes from both sides at once. The trick is to eat slowly and not leave too many empty places on one's plate. . . . Pacing oneself is part of the art of survival. Between a dozen and fifteen dishes seems about the norm, and it is usually hopeless to decline any of them, whether squid, jellied frogs' legs, hot peppers, or whatever, because one will be served anyhow.

■ Even in large cities there is something composed about Chinese children. They walk hand in hand or one sees them (even the littlest ones) quietly playing by themselves. I have yet to see a temper tantrum or even a child crying. There is a great sense of responsibility among them, too. The serious eight-year-old girl in pigtails and red "pioneer" scarf is helping a four-year-old tie her shoe laces. Later I see the four-year-old solicitously rearranging a white bow on her two-year-old sister's head.



■ In the country everyone works and there are no exceptions. A tiny boy leads (or rather is led) by a truculent black pig on a leash. Here another small child is valiantly struggling to keep a water buffalo from demolishing our bus. Farther along the road another mammoth water buffalo is slowly ambling along the road; on his back, spread-eagled and sound asleep, is a little girl in a pink dress.

■ Southwestern Jiaotong University seemed a place apart. From the first moment (a four-page newspaper entirely devoted to our arrival, Cornell banners flying, children lined up along the streets applauding, speeches and more speeches, an ubiquitous video crew) we felt like a cross between a rock-and-roll group and a posse of Nobel Prize winners.

And who can forget the night we were entertained by the students? The blackboards covered with welcome signs; our president leaping over a bench and launching into a lively Gilbert and Sullivan solo, and their president coerced into singing a Chinese opera show-stopper, both voices being carried outside by loudspeakers and echoing among the surrounding mountainsides; and the great Cornell University Ad Hoc Khorus (Cuahk) belting out "Jingle Bells" in the July night and "High Above Cayuga's Waters" below Mount Emei.

The isolation of the place, and the sense one occasionally had of people in exile (this was a relocated university) and of personal tragedy (there had been recent deaths from an earthquake), made for a more intimate contact with the Chinese world than we were to have anywhere else.

■ Like most Chinese universities, Southwestern Jiaotong is a complete world. It houses its students and its staff, it has day-care centers and all levels of schools. It has its shops and "factories" and, needless to say, raises some of its own food. This makes for a noisy and boisterous atmosphere, with children running around, elderly people sitting by their front stoops, ducks and chickens waddling by the dormitories, bullfrogs croaking in the pond, and the sense of a myriad of orderly activities for young and old so characteristic of Chinese village life. . . . This morning I can hear the cooks chopping food for breakfast and some women are doing their laundry in large tin basins and chattering loudly. There are people doing their exercises and doors are slamming as people go off to work. Below my window I can hear the slapping sound of children's sandals.

Today, as is usual in our first day in a new place, we will have ceremonies and then negotiations. There will be speeches, and tea will be sipped around conference tables. Later we will visit laboratories and we will all solemnly nod as explanations are given about new apparatus.

Right now, however, it is still six o'clock and a rooster is crowing loudly somewhere in the hills.

■ In Sichuan the roads are bounded by lush fields of rice or taro and some corn and beans. Theoretically, there are two lanes; in fact, through shrewd maneuvering and quick reactions, something like an eight- or ten-lane highway is achieved.

The outer lanes are for children, often very young, sitting or playing in the dirt. It is also a space often used to dry rice grains. The next lanes are for pedestrians and animals. The former always seem to carry something, if only a small child, on their backs. Long curved poles are suspended over the shoulder, with heavy buckets or enor-

mous woven baskets hanging from each side. Small boys herd minuscule baby ducks, keeping them in line with fine bamboo poles; young girls pull black sows on leashes. There are water buffalo and cows, some geese, a stray dog or two, an occasional goat.

The next layer is reserved for the bicycles, endlessly flowing in both directions, with passengers, baskets, clusters of live ducks tied to the handlebars, roosters roped to the back seat, bamboo poles, jute sacks, and other paraphernalia.

Finally, in the middle, one finds all the small vehicular traffic: donkey carts carrying huge loads of sand, mule teams, bullocks with chariots, narrow elongated tractors, pushcarts carrying "honey buckets"—small cisterns on platforms over vast rusted wheels.

All of these layers, however, only form what one might call the core material with which to make a traffic pattern. Now comes the final ingredient: from both directions, throw in (going as fast as possible) two converging lines of large green trucks and (this is us) tourist buses and vans. The object of the game is to miss the children, dogs, pigs, etc., scatter the bicycles like so many frightened birds, cower other vehicles by the use of Klaxons of the kind mounted on the largest transcontinental vans in the U.S., and out-Klaxon the hurtling trucks. The near miss is a way of life, all the more that in villages in particular, no one budges until the last possible second.

■ Sichuan: Rows of low mountain ranges with at times almost conic slopes surround both sides of the railroad tracks. Lush forests grow from the summits, but as the eye lowers, one finds terrace after terrace of cultivated land, some at improbable angles, many bolstered by walls of brown rocks. Corn plants sway in long rows high above our heads, leading eventually, in lower regions still, to small villages nestled among bamboos and hugging the contoured hills. Waving fields of rice come next in well delineated rectangles or in kidney shapes or in squares, all ringed in turn by the darker hue of the single rows of beans that outline their borders. Lower still, a

broad dry riverbed of sparkling white stones leads to a shallow onrushing stream of brilliantly transparent water. From time to time a water buffalo can be seen in the distance, while in the foreground small scattered spots of deep blue or yellow reveal farm workers bent over their work, their broad straw hats swaying rhythmically. There are some waterfalls, a few red clay cliffs occasionally interrupt the solid wall of green, and, among the valleys, long trails of vapory clouds stand motionless among the treetops.

■ We are taken to a commune just outside Shanghai. Our hostess is an attractive young woman with many facts at her fingertips. She handles our questions with ease, although we are not always sure we have gotten to the bottom of things. People do own their own houses, they do have a private plot of land, but for the most part they work as teams or brigades and sell their products to government-run stores in Shanghai. Still, private initiative seems to be encouraged (as are one-child families; you don't pay for school if you have one child, you do pay if you have more than one).

We are then taken to a hospital, a school, and a private home—a small, two-floor compound housing a family of fourteen. At the house we are greeted by the matriarch, a great-grandmother who has lived all her life on this farm. She has had seven children, she tells us, but only one survived (a normal statistic for her generation). She has lived through the period of the war lords, of the Japanese occupation, of the civil war, and now at last feels that life is better. There is no question that this must be true.

■ Above all, I remember the people. So many hidden tragedies, so many faces marked by past terrors and present fatigues. Life is not easy in China. I remember peasants toiling in the mountains to plant corn on impossible peaks, old people bent over in the rice paddies as they slowly moved from row to row, and those millions of bicycle riders who at any hour fill the streets of cities as they go to and from their work along the dusty avenues. I remember, late at night, under street

Author Alain Seznec was assigned to Car Number 2 during the tour of China.

lamps, a few people playing chess, taking refuge from a world that is crowded and hot; and, very early in the morning, solitary figures doing exercises before the working day begins. . . . I remember the smiling young waiter and waitress at our hotel who had been selected to go to an institute for hotel management, and shared their joy with us. And all the people in the stores, curious, friendly, some eager to try their newly acquired English (often learned on their own with the help of the Voice of America).

Above all these scattered memories of people and places, what finally remains, when the heat and the dust and the sense of struggle, of unfinished buildings, of occasionally primitive conditions fade away, is the hospitality we have felt everywhere—a genuine human sense, tinged with good humor and openness. Not for a moment have I felt like an intruder or a hostile presence. On the contrary. Three thousand years of culture have left their mark.

A SUNDIAL FOR THE QUAD

Cornell Design and Workmanship Create a Sculpture That Accurately Tells Time

To create an "engineering statement" was the goal of its designer, Dale R. Corson, president emeritus of the University and former dean of the College of Engineering. And the gleaming stainless-steel sundial in the Joseph N. Pew, Jr. Engineering Quadrangle is exactly that, if judged by its success as a highly accurate scientific instrument for reading time, as a functional and beautiful work of art, and as a fitting monument to Joseph N. Pew, Jr., and the college to which he had been so generous.

The finished work, a six-foot-diameter "bowstring" type of equatorial sundial, is deceptively simple in appearance. All the complicated adjustments for day-to-day astronomical variations are made by the internal mechanism, a marvel of engineering design that makes the Cornell sundial one of the most accurate in existence. (Its error is no more than 30 seconds.) It is also simple to use. All the observer has to do, besides waiting for the sun to shine, is to set a dial for the correct date and read the time directly on a simple scale.

Staff members in the Technical Service Facility in Upson Hall worked with Professor Phelan to machine the sundial parts. In the upper photograph are (left to right) Harry E. Orton, Ralph A. Cochran, Phelan, Donald B. Vandermark, James H. Smith (now deceased), and Lloyd L. Smith. In the lower photograph are Robert S. deBell, assistant manager (at left) and M. L. Tompkins, manager.

Planning, construction, installation, and final alignment of the sundial took place over the eighteen-month period from June, 1979, through November, 1980. The program marking the dedication of the quadrangle on September 20, 1979, included the unveiling of a model of the sundial. But getting from that model to the final instrument was a long, complicated procedure, accompanied by many revisions of design because of esthetic, practical, and technical considerations.

FROM IDEA TO REALITY: A COOPERATIVE VENTURE

The idea for a sundial came from Pew's widow, Alberta, who was consulted about the landscaping plans for the quadrangle that would be dedicated to her husband. "He loved the garden, and a garden suggests a sundial. Also, a sundial is a perfect timepiece for an engineer," Mrs. Pew said.

Corson's involvement in the project came about as a result of his criticism of the sundial design originally proposed by Cornell's Department of Design and Project Management. "I felt that it shouldn't be just a garden ornament," he said. "Precision was one quality it had to have." Corson's knowledge of sundials preceded this project by many years. "I've been interested in astronomy for a long time; at one stage I thought I might like to be an astronomer," he explained. "Then during World War II, I had occasion to learn celestial navigation, which is closely related. It was during that period that I became interested in sundials." In later years, Corson translated his ideas for sundial designs into scale models made of wood and cardboard. So when the opportunity arose to improve upon or, as it turned out, completely redesign the proposed Engineering Quadrangle sundial, he knew exactly what he wanted to accomplish. He also knew how to go about it, obtaining the assistance of friends and associates from his long and varied career at Cornell.

"President Corson never takes no for an answer," explained Richard M. Phelan, professor of mechanical and aerospace engineering, who played an important role in the design and fabrication of the internal mechanism of the sundial. He feels that Corson is the only person who could have accomplished this particular task, involving so much cooperation among individu-

Figure 1

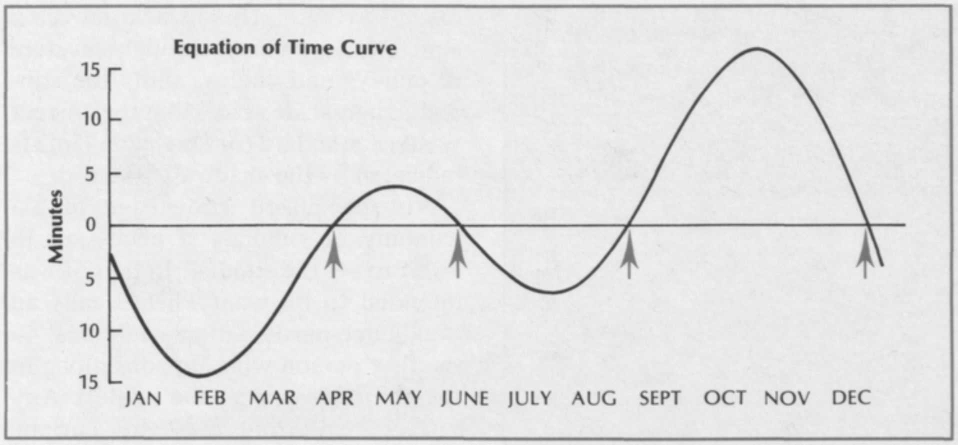
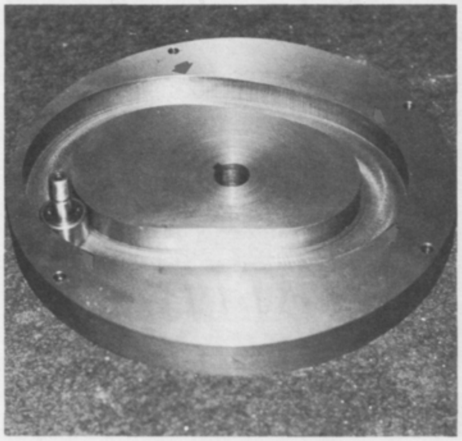


Figure 1. Equation-of-time curve. The difference, in minutes, between clock time and sun time throughout the year is shown in this curve. The number of minutes corresponding to each date is either added to or subtracted from sun time to obtain clock time.

The greatest difference between clock time and sun time occurs on November 3, when the necessary correction is 16.4 minutes. At four times during the year, April 15, June 14, September 1, and December 25 (indicated by green arrows on the curve), the equation of time equals zero, and sun time and clock time are the same.



Left: The approximate position of the cam follower on these same four days is indicated by green arrows superimposed on a photograph of the cam. An equation derived from equation-of-time values was used to program the numerically driven milling machine that cut the cam. The distance of the cam follower from the center of the cam corresponds to the shape of the equation-of-time curve; the follower is furthest from the center of the cam on November 3, the maximum point of the curve. As the cam rotates in a clockwise direction, the movement of the cam follower is transferred to the cables of the pulley system.

als at the University, several departments, and alumni. "The sundial is a monument to the reservoir of goodwill and love for Corson felt by members of the Cornell community who gave of their time, expertise, and labor to carry out the project," Phelan said. Those involved in the project included alumni who helped arrange for materials and manufacture, machinists who made the parts, a Cornell landscape architect who designed the setting, and buildings and grounds personnel who installed the completed sundial.

GETTING THE SUNDIAL TO READ ITHACA TIME

The basic problem Corson confronted was to make the sundial readings correspond to local clock time. Most simple sundials record apparent solar time, which differs in two respects from standard mean time, the time to which we set our clocks and watches and to which we schedule our daily lives.

First, there is a difference between standard time and local time. Eastern Standard Time, for example, refers to time on the 75th meridian, whereas Ithaca is at longitude 76 degrees, 29 minutes west. After it passes the 75th meridian, the sun must always move through one degree, 29 minutes before it passes Ithaca's meridian. (The sun will appear to be due south when it passes the local meridian.) Since the sun moves at 15 degrees per hour, one degree and 29 seconds corresponds to 5 minutes and 56 seconds of time. To take account of this longitudinal correction, the hour scale on the sundial is simply displaced toward the east so that it will record noon, say, 5 minutes and 56 seconds before the sun is actually due south in Ithaca.

The second correction is more complicated. It is required because the sun does not keep uniform time—sometimes the sun is fast (that is, it reaches the standard meridian before a clock indicates noon) and sometimes it is slow. The correction is more than 16 minutes at its maximum; four times a year (April 15, June 14, September 1, and December 25) the sun and the clock agree. The departure of sun time from clock time derives from the ellipticity of the earth's orbit and from the tilt of the earth's axis with respect to the plane of the earth's orbit.

The differences are ordinarily provided in tabular form, one correction for each day of the year, and are referred to as the *equation of time*. Using such an equation-of-time table, Corson derived, through Fourier analysis, an actual equation that gives the correction for any time of year. His equation was programmed into a numerically controlled milling machine used to cut a cam which, together with a system of gears, pulleys, and cables, and in response to a simple manual setting, provides the necessary daily adjustment. The beauty of Corson's design lies in the simplicity of the manual operation needed to effect the complex mechanical adjustments.

How does it work? The visible part of the sundial comprises two semicircular arcs. A "bowstring" arc holds the shadow-casting rod, which is parallel to the earth's axis. A second arc, parallel to the earth's equatorial plane, provides a base for a time scale engraved with lines, each corresponding to one minute, running from 6 a.m. to 6 p.m. Both arcs sit on a granite base with four sides sloping inward at an angle of approximately ten degrees. (Corson, an accomplished amateur photographer, had found the ten-degree slope to be a pleasing one when making frames to exhibit his photographs.) The working parts, including the heart of the mechanism, the cam, are contained within the granite base. When the month and day are set by turning an exterior knob, the cam is made to rotate. This in turn moves a cam follower, which, through a system of pulleys and cables, shifts the sundial's time-scale arc so that the correct Eastern Standard (or Daylight) Time is indicated by the shadow of the rod.

No specialized knowledge of astronomy or sundials is necessary in order to set the sundial. In fact, it was intended to be what Phelan calls an "audience-participation sculpture"—the first person who happens along in the morning sets the date. Any "extra" adjusting done by curious passersby does not hurt and might have the beneficial effect of helping to lubricate the cam mechanism.

CORSON'S EQUATION OF TIME

An actual equation of time was derived by Dale R. Corson from tabulated empirical data that have been known as the equation of time. Corson's expression, derived via Fourier analysis, is:

ET (in minutes) =

$$-7.3412 \sin \frac{360}{365}n \quad + 0.4944 \cos \frac{360}{365}n$$

$$-9.3795 \sin 2\frac{360}{365}n \quad - 3.2568 \cos 2\frac{360}{365}n$$

$$-0.3179 \sin 3\frac{360}{365}n \quad - 0.0774 \cos 3\frac{360}{365}n$$

$$-0.1739 \sin 4\frac{360}{365}n \quad - 0.1283 \cos 4\frac{360}{365}n$$

ET is the correction in minutes and n is the number of the day of the year (January 1 = 1; December 31 = 365).

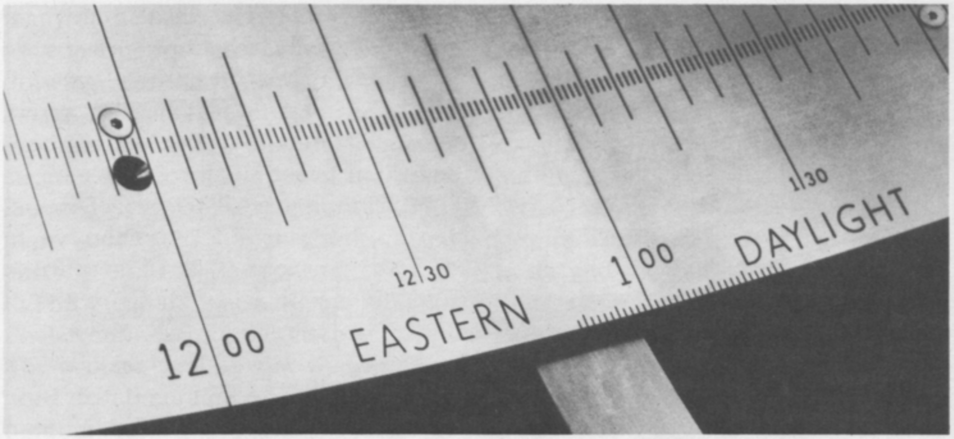
ET is for noon Greenwich Mean Time; to calculate the correction for noon Eastern Standard Time, n is replaced by $(n+0.2)$. Since ET is the average for the leap-year cycle, it can be wrong by possibly 20 seconds during the few months prior to February 29 in a leap year.

WORKING OUT DESIGN AND CONSTRUCTION DETAILS

The location, dimensions, and construction materials of the sundial were arrived at after some experimentation with scale models and after discussion of practical considerations.

The location in the quadrangle was determined not for esthetic reasons, but by the shadows cast throughout the year by the surrounding buildings and trees. Careful calculations were made to find the sunniest spot. To ensure that the sundial would never have to be moved, the site was checked for any buried pipes or cables. Stability of the soil was another consideration; any shifting because of freezing and thawing would reduce the accuracy of the timepiece.

The original plan called for an overall diameter of three feet, but this proved to be too small for the large expanse of open space in which it would be placed. Practical considerations limited the size, however. For



Standard and daylight time scales were engraved on a flat stainless-steel plate, which was later rolled to the correct curvature. A rod on the sundial's "bowstring" arc casts a shadow across the time-scale arc, permitting a reading that is accurate to at least 30 seconds.

example, the time scale could not be so high off the ground that it could not be viewed straight on. An increase in size would also increase the weight of the steel arc to be moved by the pulley system, requiring a larger mechanism in the base. A diameter of six feet proved to be large enough to provide a focus for the quadrangle, to increase the reading accuracy because of a greater distance between minute lines, and yet to keep the sundial compact and light enough for ease of viewing and strength of internal workings. The "bowstring" rod was designed with a diameter of $^{3}/_{16}$ inch, to cast a shadow the width of approximately one minute on the time scale (the center of the shadow marks the correct time).

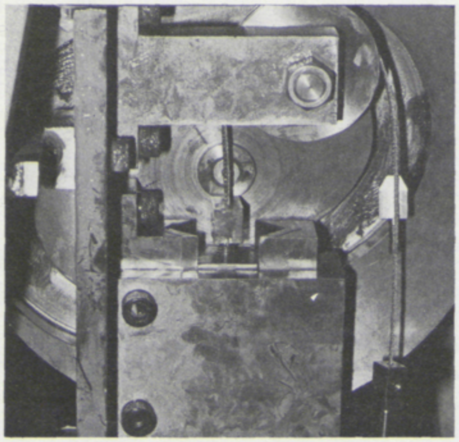
Stainless steel was chosen as the construction material because it seemed suitable for an engineering sculpture and because it is durable and available in plate form. It was used not only for the exposed parts, but for many interior pieces as well: any piece that would come in contact with an exposed part, and many on a level inside that, were fabricated of stainless steel in order to protect against rusting and electrochemical corrosion.

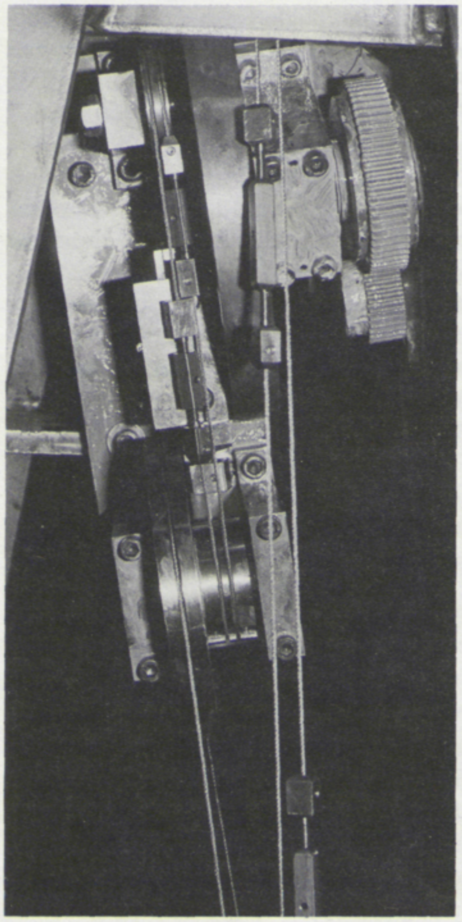
A long-time friend and associate of Corson's, William E. Mullestein, made arrangements for fabricating the large arcs. Mullestein, a 1932 Cornell graduate in civil engineering, is former chief executive officer of Lukens Steel Company in Coatesville, Pennsylvania (a company that does not make stainless steel). He enlisted the help of Robert Buckley, chief executive officer of Allegheny Ludlum Industries and a Cornell Law School graduate, who arranged for a gift of the two-inch-thick steel plate from his company. Mullestein also offered to provide machining of the arcs at Lukens. Leonard Pompa, an engineer who has retired as the international manager for the company, was put in charge of this assignment—one that Corson described as a difficult job well handled. All the measurements had to be extremely precise, and even a difficult two-foot-long hole, ⅞ inch in diameter, through which the cables were to run, was perfectly drilled.

The next step was to have the standard and daylight time scales engraved on a stainless-steel plate 8 inches wide, ⅜ inch thick, and more than 7 feet long. In a memo written before the engraving was done, Corson wrote, "This is a bit tricky, inasmuch as the engraving will be done on a flat plate which will then be rolled to the final curvature, compressing all the distances on the surface in the process. Consequently, the scale as specified must be expanded. I hope the amount of compression on rolling is as advertised." The engraving was done by Thomas Claro, whose shop in Philadelphia is so small that a rearrangement of equipment was necessary before the work could proceed.

PHELAN'S WORK ON THE ADJUSTMENT MECHANISM

Meanwhile, at Cornell, Phelan was working on the design and manufacture of the internal adjustment mechanism. Corson had enlisted his help in translating the movement of the cam into the appropriate movement of the equatorial arc. Phelan made an initial design (see the figure), but because





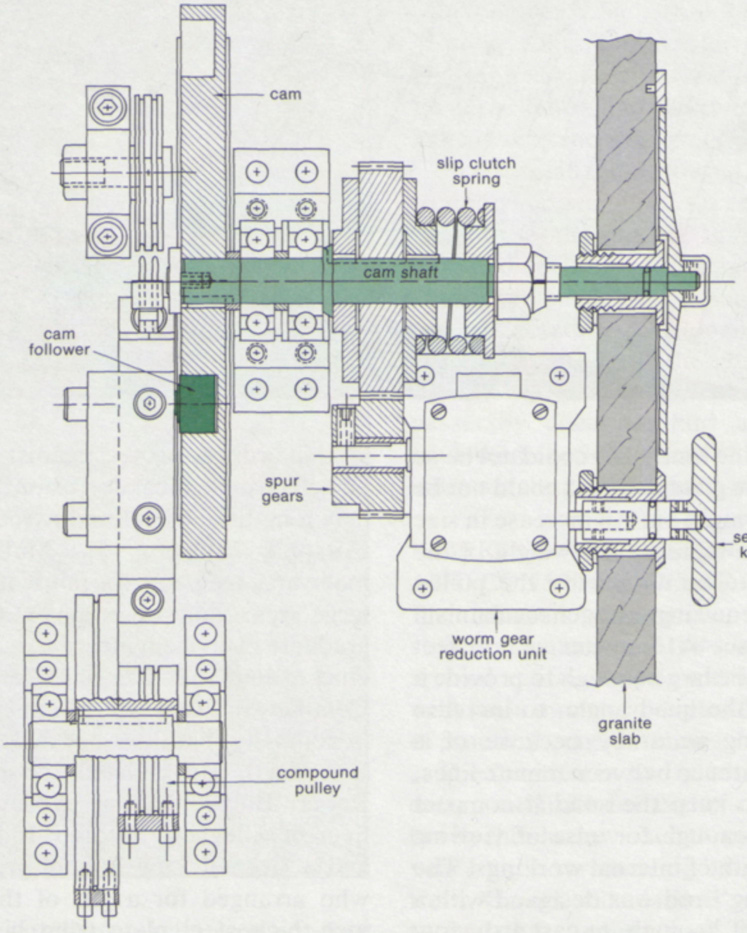


Figure 2. Adjustment mechanism of the sundial (from an early working diagram). The basic mechanical parts are shown in a configuration similar to that of the completed sundial.

In the final version, the movement of the setting knob, far right, is reduced by a 400-to-1 ratio by the worm gears and the spur gears. A slip clutch, located between the gears and the cam shaft, protects the workings from application of excessive force. At the opposite end of the cam shaft from the month-day dial is a positive-drive cam with a curved groove for a radial-roller cam follower. As the cam rotates, the cam follower moves up or down, initiating a movement in the pulley system. Cables from the compound pulley transmit this movement to the equatorial arc for the appropriate adjustment for each day.

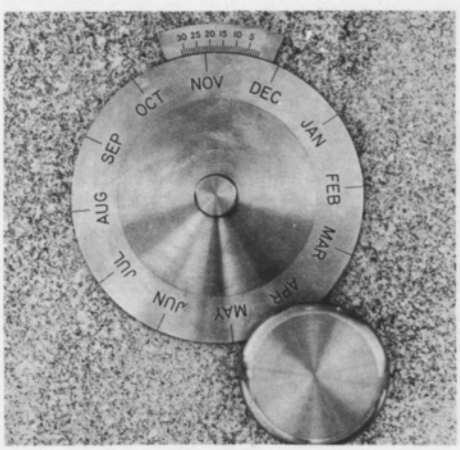
The surrounding photographs (by Corson) show parts of the completed mechanism: the cam, part of the pulley mechanism, and the month-day dial with setting knob.

many of the parts were machined to fit as construction proceeded, no final drawing of the actual mechanism exists. The complicated nature of the mechanism, coupled with the constraints of size and shape of the base, dictated a final configuration with many odd angles and tightly fitted parts.

The engineering challenge is what Phelan enjoyed most about the project. The problem, as he saw it, was "the need for laboratory accuracy in an outdoor setting in Ithaca. I knew it *could* be done, but it would have to proceed step by step, with each piece helping to design the next."

The basic design of the adjustment mechanism consists of a series of gears which transfer the movement of the setting knob into a rotation of the cam, and a system of pulleys and cables which transmit the action of the cam up through a hole in the bowstring arc to the time-scale arc. This is made to move back and forth on a track with rollers.

A worm-gear reduction unit, located just inside the base from the setting knob, has a reduction ratio of 200 to 1. Two spur gears further reduce the movement by a 2-to-1 ratio. To protect the workings against the application of excessive force (for example, if the setting knob is turned while the exterior is covered with ice), a slip clutch is provided in the drive between the gears and the cam shaft. Because the cam shaft is directly connected to the month-day dial, the position of the cam will always correspond to the date shown on the dial.



The positive-drive cam has a diameter of approximately 9½ inches. It has a curved groove, one inch wide, in which the radial-roller cam follower moves up and down as the cam rotates, activating the cable and pulley system. A compound pulley provides the correct multiplication for the appropriate movement of the time scale on the equatorial arc.

All bearings are sealed and lubricated for life, making the sundial relatively maintenance-free. To gain access to the internal workings of the sundial, the granite base would have to be dismantled—an operation that should not be necessary for many years. Noncontacting seals are used between the major moving parts to minimize friction. Water flows along grooves and out drainage holes located so that the drips will not fall on any part of the mechanism.

The cable used to transmit the movement of the cam to the equatorial arc has a breaking strength of 400 pounds, far in excess of the 40 pounds that might be exerted in normal circumstances. The cable is of the type used in aircraft and is made of stainless steel.

LOCAL FABRICATION, ASSEMBLY AND INSTALLATION

Most of the parts of the internal mechanism were fabricated in the machine shop in Upson Hall, the mechanical and aerospace engineering building. "Everything the shop did was superb," Phelan commented.

As each piece was completed, the next was made to fit with it. Dimensions had to be changed according to the availability of materials, as well as the fit of parts. Phelan, whose office is in the same building, was readily available to make the necessary changes from the original design.

It was known almost from the outset, for example, that holes would have to be drilled in the equatorial arc in order to reduce the weight to be moved by the internal mechanism. The size and location of these holes could not be determined, however, until after the hour scale had been screwed down to the equatorial arc: the kind, number, and placement of screws would dictate where the underlying lightening holes could be drilled.

A numerically controlled milling

machine in the Floyd R. Newman Laboratory of Nuclear Studies was used to machine the cam. The computer-driven machine, fed Corson's equation, was able to cut the steel to the necessary shape with an accuracy of one or two thousandths of an inch. According to Corson, this task could have been accomplished with traditional machining methods, but "to have done it with the equipment available in, say, the 1950s, when I last worked in a machine shop, would have been terribly complicated." The precision of this cam was the crucial element in the ultimate accuracy of the sundial.

Assembly of the parts proceeded slowly, as each piece was fit to the next, with modifications made as necessary. "Every part was made so it could be shimmed," Corson said. "We put in small shims to adjust the spacing of the parts so that they worked freely. That all had to be hand-adjusted. We would try it and measure it and take it off and adjust it a little bit and try it again." The last adjustment to be made was machining the grooves on the compound pulley in order to provide the correct multiplication for the movement of the arc.

Above: The first reading of the sundial was a satisfying occasion for Corson.

Below: Joining in the celebration were (left to right) Phelan; Thomas E. Everhart, dean of the College of Engineering; and emeritus Dean S. C. Hollister.

After assembly in Upson Hall, the sundial was lifted by a crane and set in its permanent site, which had been prepared by the laying of a concrete base with a ramp and steps rising to its slightly elevated height. The landscape design was done by Peter Trowbridge, assistant professor of landscape architecture at Cornell.

Proper alignment of the instrument was the next step. Measurements accurate enough for exact placement would have been difficult, so the final alignment was accomplished by setting the sundial to the correct time and then fixing it in the required position, using leveling and rotation-alignment screws in the base.

The ultimate test, for accuracy, took place during the first week of November. The sundial lived up to expectations, with a built-in error of no more than thirty seconds. Corson makes periodic checks to ensure against any changes in accuracy. You can set your watch by it, Phelan points

Left: Engineering students seemed to be proud of the newly installed sundial; many have a proprietary feeling about it as a fitting focal piece for their campus.

out; it keeps better time than Cornell's landmark, the McGraw Tower clock.

AN ENGINEERING STATEMENT: IS IT THE LAST WORD?

Far from exhausting Corson's interest in and enthusiasm for sundials, this project has increased his desire to create the "perfect" solar timepiece. How would he improve on the present design? The next model would be equipped with four cams, rather than one, to accommodate the leap-year cycle. The present cam treats all Februarys as if they had twenty-eight days, which introduces an error, in some months and some years, of as much as 20 seconds (a good portion of the current sundial's 30-second margin of error). "If I were to work on sharpening up the shadow, and changed the cam for each year, I don't see why I couldn't make a sundial accurate to five seconds," he said.

Phelan looks in a different direction for his next engineering challenge, but says he is pleased to have his name associated with this project. Furthermore, the design problems he encountered while working on the sundial were put to academic use. Students in M&AE 325, Mechanical Design and Analysis, taught by Phelan, were assigned problems relating to the design of the gears, slip clutch, cam, and cable attachments; after the students had completed their designs, they were shown the actual parts for comparison. Such an exercise helps relate course work to real engineering problems, Phelan believes.

"The sundial project was a happy operation, involving many people and creating lots of enthusiasm," Corson said. "Everywhere I turned, there were people eager to participate." It is through this cooperative work of Cornell professors, staff members, alumni, and friends that the College of Engineering has a new landmark, a unique engineering statement. —ANN POLLOCK

FACULTY PUBLICATIONS

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

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LETTERS

Professor Streett: With much interest I have come across the Winter 1980-81 *Engineering: Cornell Quarterly* entitled, "The Molecular Level in Chemical Engineering Research." This is a well prepared documentary on this subject that has attracted considerable attention amongst a number of my graduate students interested in this discipline. I wonder if you could arrange to send me six copies of this particular issue that I can distribute to them and also one to keep for myself.

George Thodos, Professor
Chemical Engineering Department
The Technological Institute
Northwestern University
Evanston, Ill.

Professor Gubbins: I read in your article, "Predicting Liquid Properties" (*Engineering: Cornell Quarterly,* Winter 1980-81), about the many-dimensional integrals done by sampling using random numbers. I would appreciate learning the details of the technique. Also I want to learn about the quaternion technique of describing molecular orientations. Would you let me know references for these?

R. Kikuchi, Senior Scientist
Hughes Research Laboratories
Malibu, Calif.

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