ENGINEERING

CORNELL QUARTERLY

25 ANNIVERSARY ISSUE

ENGINEERING
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25

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IN THIS ISSUE

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Below: The new Engineering and Theory Center Building, adjoining Upson Hall at the southeast edge of the engineering quadrangle, is in the center foreground of this aerial photograph showing the Cornell University campus and Cayuga Lake beyond. Cascadilla Gorge, near the bottom of the photograph, marks the southern boundary of the campus.

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ENGINEERING
CORNELL QUARTERLY

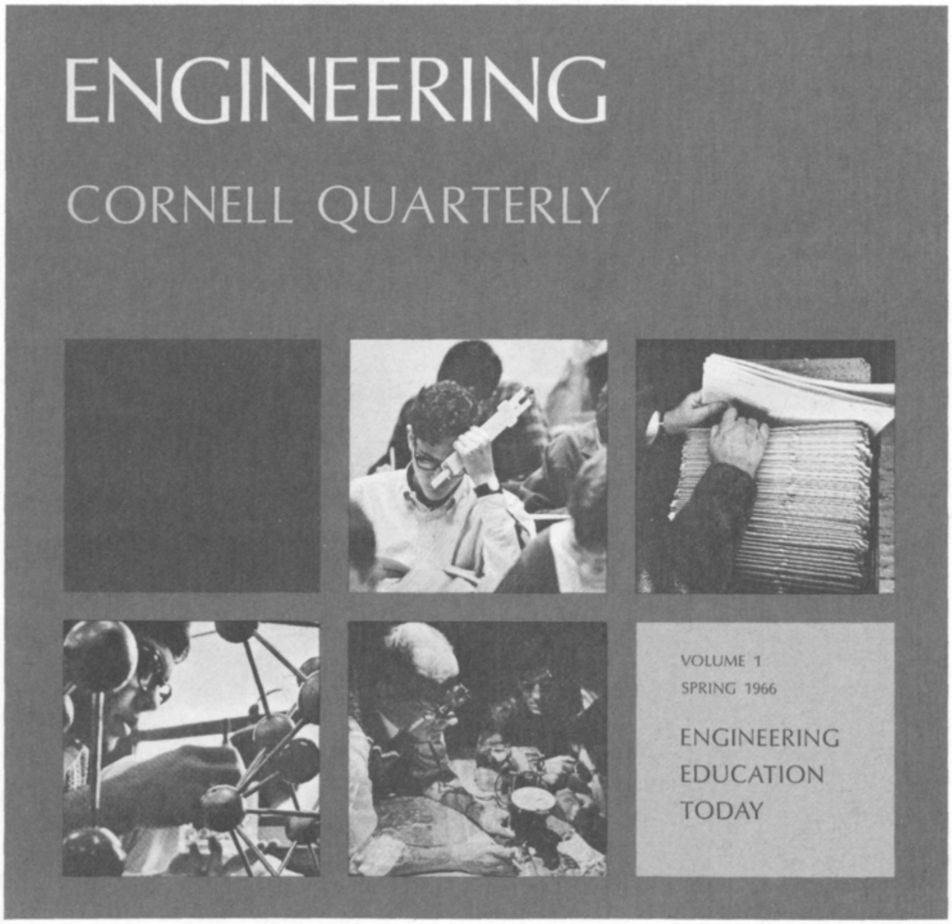
OUR SILVER ANNIVERSARY

When the first issue of this magazine appeared in the spring of 1966, the subject was "Engineering Education Today" and the cover displayed a photo of a student with a slide rule.

A lot has happened since then, to engineering education and to slide rules, not to mention the profession and the Cornell University College of Engineering. Much of what has taken place has been treated in the pages of *Engineering: Cornell Quarterly.* As the initial editorial stated, the intention of the magazine was to "contribute to a better understanding of some of the more interesting and important undertakings in engineering in general and at Cornell in particular." It still is.

There was an additional special motive in starting the magazine, according to its founding editor, Donald F. Berth. "Cornell engineering was then—and pretty much still is—both blessed and cursed by its splendid isolation," he commented in his anniversary message. "Unlike the early polytechnics and

Right: The cover of the first issue of the magazine had a green background, in keeping with the spring season, and black-and-white photographs. As the use of color in photography and computer imagery has increased, the covers have become more varied and colorful.



In the mid-1960s, when *Engineering: Cornell Quarterly* was launched, Cornell Engineering was well on the move. As dean, Dale Corson had brought the perspective of applied science, recognition of the importance of research in the educational process, and the involvement of practitioners. He also raised $4.3 million (in 1961 dollars!) from the Ford Foundation to abet the transformation processes.

His successor, Andy Schultz, presided over that transition and contributed greatly to it through careful faculty recruiting and mentoring. One highly important (and charged) change was the conversion of the five-year undergraduate program to a preprofessional B.S. program; graduates could proceed in either a professional master's degree program (for engineering practice) or M.S./Ph.D. study (for research). The college had previously instituted a basic curriculum for freshmen and sophomores that was essentially the same for all engineering students.

The collective effect of all these changes provided a momentum that offered great opportunity for Cornell Engineering to move to the highest rank once again, but it needed to be "marketed" in an imaginative and sustained manner. This is where I came in, proposing the founding of the *Quarterly* and getting a cautious go-ahead. Thanks to splendid support from Cornell University Publications, we set out on this venture. And what a superb learning experience it proved to be! To provide diverse, representative, and broad coverage of the activities of well over two hundred faculty members required one to learn "a little something about everything".

The faculty, in general, was supportive and helpful, and virtually all who were asked to contribute did so. I especially remember Dale Corson's wise piece "Allocating Resources" (vol. 4, no. 4, 1970); what he said then is still sound reading for today's deans and administrators.

I congratulate Deans Andy Schultz, Ed Cranch, Tom Everhart, and Bill Streett for their sustained commitment to the *Quarterly;* and the editorial staff members who have continued to make the magazine a worthy representative of a world-class engineering college.—*Donald F. Berth*

Above: Donald F. Berth joined the college staff in 1962 as assistant to the dean and became founding editor of the Quarterly in 1966. After a period at Hampshire College in the 1970s, he returned to the Cornell College of Engineering to establish an office for development and corporate relations. Over the years, he also started the college's advising office, handled public relations, co-directed the Co-op Program, became an associate dean, and occasionally taught a course in entrepreneurial engineering.

In 1983 he assumed his current position as vice president for university relations at his alma mater, Worcester Polytechnic Institute. He holds bachelor's and master's degrees in chemical engineering from WPI.

institutes of technology that germinated and flourished in urban environments largely identified with the major U.S. industrial centers, Cornell has flourished largely unto itself," he noted. "This has required, and still requires, Cornell to take its rich and diverse message to the communities that ought to hear it."

And so the *Quarterly* was launched. The basic plan of the magazine, outlined at the beginning and still followed, is to feature a theme or special topic in each issue. Often the theme is an area of research, or particular college programs and policies, or trends and developments in engineering education and practice. News, feature stories, and photo essays appear from time to time. There is a listing of recent faculty publications.

From the beginning, the participation of faculty members, mostly in engineering, has been key to the success of the magazine. Professors do not always find writing for a general (though scientifically or technologically knowledgable) readership an easy task, yet they have almost always agreed to prepare articles when invited to. Sometimes they have suggested themes and made use of the resulting issues. Professors have been the main contributors, along with occasional staff members, alumni, and other people with a Cornell connection.

We like to think that the reputation of the magazine has something to do with this willingness on the part of (unpaid) contributors. The *Quarterly* has won many national prizes, over the years, from the American Alumni Council and its successor, the Council for Advancement and Support of Education (CASE). For example, the *Quarterly*

(continued on page 6)

The photographs on these pages illustrate some of the highlights of the college's history over the past twenty-five years.

Developments and trends that are less photogenic but of fundamental significance are noted in many of the *Reflections* printed in this issue. They include:

- the emergence of research and graduate education as a major part of the program;
- the rise of interdisciplinary and multidisciplinary activity and the establishment of national facilities in such areas as materials science, nanofabrication, research with high-energy x-rays, and supercomputing;
- increasing interaction with industry;
- development of cooperative programs with other institutions in such areas as computer-aided instruction, earthquake engineering research, and educational innovation (for example, through the NSF-sponsored Engineering Education Coalition of eight schools headed by Cornell);
- the impact of computer technology on all aspects of instruction and research;
- increasing attention to environmental and social implications of technology;
- the development of programs to encourage and facilitate the education of women and minorities as engineers.

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1. More than six hundred alumni and faculty and staff members and their guests attended the Engineering Convocation in October 1972 celebrating the centennial of the first commencement of Cornell engineers. A reception and dinner were held in the university's field house. A 100-page historical issue of the Quarterly *was published that fall.*

2. Five deans of the College of Engineering were assembled at the 1980 symposium honoring Andrew Schultz, Jr., at the time of his retirement. Left to right are the late S. C. Hollister, dean 1937–59; Dale R. Corson, dean 1959–63; Schultz, dean 1963–72 and acting dean 1978; Edmund T. Cranch, dean 1972–78; and Thomas E. Everhart, dean 1979-84. Currently, Corson is president, emeritus, of Cornell University; Schultz is the Spencer T. Olin Professor of Engineering, emeritus; Cranch is the Granite State Distinguished Professor, the University System of New Hampshire; Everhart is president of the California Institute of Technology.

3. William B. Streett has been dean of the College of Engineering since 1985.

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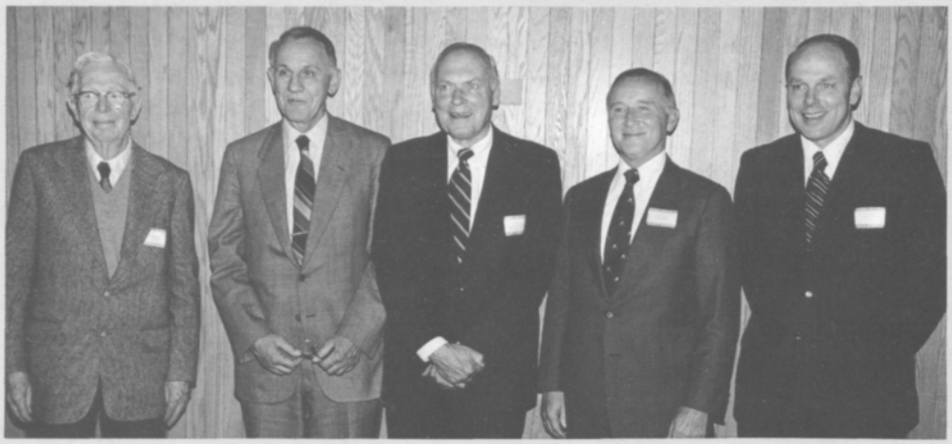

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4. Knight Laboratory was built in 1981 to house the center that is now the National Nanofabrication Facility. The building, attached to Phillips Hall, features clean rooms with air control and vibration-resistant construction. The laboratory was named for major donor Lester B. Knight, Jr., a 1929 alumnus.

5. Snee Hall was built in 1984 for the Department of Geological Sciences (see page 8).

6. In 1980 a high-tech sundial, the most accurate in existence (with an error of less than 30 seconds), became the centerpiece of the newly named Joseph N. Pew, Jr. Engineering Quadrangle. The sundial was designed by former engineering dean and Cornell president Dale R. Corson and mechanical engineering professor Richard M. Phelan, and most of the working parts were made in the Upson machine shop. Passersby can set the dial for the day's date.

7. The college's state-of-the-art Computer-Aided Design Instructional Facility, opened in 1981, is used in courses throughout the college, and specially developed software and equipment are made available to outside school groups.

8. The Engineering and Theory Center Building, dedicated this June, is part of the college's master plan for construction and renovation. So far, project work has been done in Olin and Upson Halls, and undergraduate laboratories throughout the college are being upgraded.

Right: Current members of the Quarterly staff, which is also the staff of the Office of Engineering Publications, are Gladys McConkey (at center), who has been editor of the magazine and director of the office since 1972; David Price, an editor since 1982; and Lindy Costello, assistant editor since 1985.

A variety of backgrounds is represented. McConkey holds degrees in chemistry and biochemistry and has worked in areas of scientific research and journalism. Price, a Ph.D. in anthropology, practiced that profession before becoming an editor. Costello, a Cornell graduate, studied animal science as well as industrial and labor relations.

has been selected several times as one of the top ten university magazines in the nation. Articles are often reprinted in other publications, such as engineering society journals. Sometimes word gets around about an issue on a timely subject and requests for copies are received. A few issues have been used as material for university courses.

The magazine's circulation is around 7,000; recipients include alumni (members of the Cornell Society of Engineers), educational institutions and departments, high schools, libraries, professional societies, foundations, publications, and people in industry, academia, and the media. Often a particular issue is useful to a department or program, and extra copies are printed.

The initial staff of the *Quarterly* consisted of the editor—Berth—and an editorial assistant, K. Toby Clarey. Six faculty members—Nelson H. Bryant, William H. Erickson, Gordon P. Fisher, John P. Howe, Howard N. McManus, Jr., and Ferdinand Rodriguez—served on the editorial advisory committee (they were later joined by K. Bingham Cady and Richard N. White). The magazine was produced by the Office of University Publications, which was directed by Kelvin J. Arden; Lynda A. Thompson was the designer, and Publications editors provided final and copy editing. The magazine's editorial assistants or associates during the early Berth years were, successively, Susan E. Dillman, Nancy G. Klabunde, and Victoria A. Groninger.

Berth left the university in 1972 and Gladys McConkey, who had been the associate editor since 1970, became the sole editor. In the late 1970s the staff once again expanded; Terrence Holt, then Ann Pollock, and currently David Price have served as associate editor. Lindy Costello joined the publications staff in 1985.

Among the photographers whose work has appeared, David Ruether is the one who has done the most for the longest time, beginning with the second issue and continuing to the present. Francis Russell was the graphic artist for a long time, until the advent of in-house computer technology.

The staff members have never spent all their time putting out the magazine. The Office of Engineering Publications, which is responsible for the *Quarterly*, produces dozens of other publications: newsletters, brochures, fliers, posters, programs, books (including the semiannual 360-plus-page volume on research at the college, and a series of departmental histories), and sundry items, even copy for the course catalog.

Production of the *Quarterly* (and all the other publications put out by the office) has evolved from the days of hot type, galley proofs, and pasted-up dummies to the present era of desktop publishing, in which editing, composition, layout, and illustration are done right on the computers in the Carpenter Hall office. The printer receives camera-ready repros or negatives. In recent years the magazine has been excellently printed by Davis Press.

Now change is in the air again. After this Silver Anniversary issue and the publication of a twenty-five-year index, the *Quarterly* will have a new design, McConkey will retire, and Price will take over as chief editor.

Engineering: Cornell Quarterly has established a place for itself, and we look forward to another fruitful quarter century of publication.—GMcC

REFLECTIONS
by Cornell Engineering Professors

For twenty-five years *Engineering: Cornell Quarterly* has covered developments in research, in the various engineering disciplines, in the profession, and in the academic and extracurricular programs of the Cornell University College of Engineering. Over the years, most of the authors have been members of the faculty.

For this silver anniversary issue, we have called on the faculty once again, for reflections on the past quarter century as they have observed and experienced it academically and professionally. We contacted former deans and those professors, some now emeritus, who have been on the Cornell scene for as long as the *Quarterly* has, and invited them to contribute a commentary.

The charge was not very specific, and perhaps dauntingly comprehensive: we suggested short articles about "changes that have taken place in their fields, or in the profession, or in education, and perhaps a view of the future which might include comment on ramifications such as effects on national and world economies or on people's lives." It is hardly surprising that the result is a heterogeneous collection of essays: reminiscences, personal observations, historical accounts of departments or research ventures, assessments of scientific and technological developments, discussions of specific aspects of the Cornell engineering program, speculations about the future. Some of the authors managed to stay within the recommended length and others found it necessary to have more space. All in all, it is an interesting collection from a remarkable group of Cornell professors.

The essays are arranged alphabetically by author.

Arthur L. Bloom
Geological Sciences

When the Department of Geological Sciences was administratively transferred to the College of Engineering as a bi-collegiate undergraduate department in 1970, I was the only permanent faculty member who carried over from the preceding long tradition of geology in the College of Arts and Sciences. That tradition dated back to the founding of Cornell University in 1868.

The subsequent development of the department to its present leading status, with an almost completely new and enlarged faculty and research staff, is certainly the dominant feature of the last two decades of my life at Cornell. The pace-setting Consortium for Continental Reflection Profiling (COCORP) Project to study the continental lithosphere has influenced every aspect of that area of geology, and in addition it has trained a cadre of graduate students who are now leaders in academic and industrial research.

My own involvement has been with the Andes Project, conducted by a group of congenial and like-minded researchers who almost accidentally found converging interests in Andean studies beginning in the early 1980s. Our independent and joint research efforts, covering a wide range of geologic topics and diverse collaboration with South American colleagues, has progressed through a series of projects funded by NSF, NASA, and other agencies, culminating in our selection for one of twenty-eight NASA EOS (Earth Orbiting System) interdisciplinary projects. Bryan Isacks is the principal investigator of the Cornell EOS group.

We are now launching a decade-long program to study the interaction of tectonics and climate in the shaping of the Andes Mountains, doing geology on a scale hardly possible before the advent of computer-driven image processing and information handling. We approach the next century beginning a major research program in which the graduate students are currently in junior high school.

The Department of Geological Sciences moved into its new building, Snee Hall, in 1984. The atrium with its display cases provides an architectural center for the four-story building.

Arthur L. Bloom, a professor of geological sciences, joined the Cornell faculty in 1960 after completing doctoral studies at Yale University and teaching there for a year.

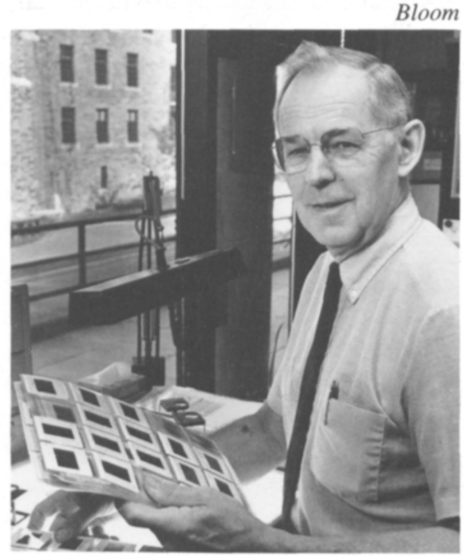
Before starting graduate school, Bloom earned a bachelor's degree at Miami University and a master's at Victoria University in New Zealand, and served in the amphibious forces of the Pacific Fleet.

"We are now . . . doing geology on a scale hardly possible before the advent of computer-driven image processing and information handling."

Bloom has spent leaves as a visiting lecturer at Yale; as a senior Fulbright scholar at James Cook University of North Queensland and at the Australian National University; and as a research fellow at Kobe University, Japan. He has lectured in Korea and China and collaborated in research projects with scientists in those countries. In recent years, most of his research has been in collaboration with Argentine scientists.

Bloom is a fellow of the American Association for the Advancement of Science and the Geological Society of America. He is an editor of several professional journals.

Bloom



Ralph Bolgiano, Jr.
Electrical Engineering

"It is now possible to detect and measure air motions—both their speed and their direction—even in the absence of precipitation or other airborne tracers."

In the aftermath of World War II, throughout the 1950s, the meteorological community learned to make extensive use of radar in the detection and analysis of weather systems, especially in the study of severe storms. By the mid-1960s, radars—usually large, land-based systems with relatively coarse resolution—were regularly being used to collect substantial amounts of meteorological data. These data were, in turn, fed into weather-prediction systems on national and international scales.

In the two and one-half decades since then, significant improvements in sensitivity, resolution, and on-line information-processing capability, as well as the advent of highly miniaturized equipment (all of which can be traced, directly or indirectly, to developments in solid-state electronics), have extended greatly the role that radar now plays in the field of meteorology. The wide use of Doppler radar for windfield analysis and clear-air-turbulence studies is a case in point.

It is now possible to detect and measure air motions—both their speed and their direction—even in the absence of precipitation or other airborne tracers. Instances of intense wind shear or turbulence, which may pose great danger to aircraft and their passengers, can be observed and suitable warnings issued. The structure of the windfield in severe storms (frontal systems, hurricanes, and tornadoes) can be mapped and analyzed remotely, in great detail—a capability of paramount significance to the atmospheric scientist attempting to gain a better understanding of these often catastrophic natural phenomena.

We shall, of course, never be able to do much more than talk about the weather. Now, however, our conversation can at least address with some precision the degree of vorticity present in that "howler" to which we were subjected last night.

When Ralph Bolgiano, Jr., became an emeritus professor of electrical engineering in the spring of 1990, he had reached the golden anniversary of his arrival at Cornell. He received the B.S. degree in 1944, the B.E.E. in 1947 (after service in the Army Signal Corps during World War II), and the M.E.E. in 1949 (having been an instructor as well as a graduate student). After five years at the General Electric Company, he returned to Cornell for graduate study in electrical engineering, received the Ph.D. in 1958, and rejoined the faculty.

As his remarks here suggest, Bolgiano's speciality is tropospheric radiophysics. At Cornell he was associated with the Center for Radiophysics and Space Research as well as the School of Electrical Engineering.

He has been a Guggenheim scholar at the Université de Provence, France, a visiting scientist at the Appleton Laboratory, United Kingdom, and a visiting senior associate at the University of Colorado.

He is a senior member of the Institute of Electrical and Electronics Engineers and a fellow of the American Association for the Advancement of Science.

Bolgiano

David D. Clark

Nuclear Science and Engineering

By 1966 nuclear engineering had become a well established field at many universities. At Cornell it had grown from one course taught in 1952 by Trevor R. Cuykendall to eleven courses and a faculty of six in Engineering Physics; fourteen M.S. and eighteen Ph.D. degrees had been awarded. In 1961 it had moved into its own building (named in 1968 for J. Carleton Ward, Jr.) housing a TRIGA reactor, a zero-power reactor, and a gamma irradiation cell.

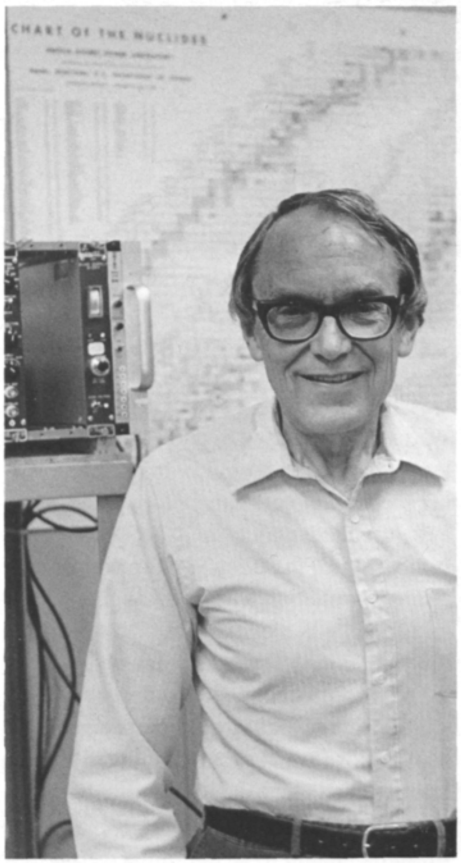
The intervening twenty-five years did not witness the rosy future for nuclear power foreseen in 1966. Although many nuclear plants were successful projects, it was the few failures that caught public attention. Although the atmospheric-test-ban treaty reduced the public's radiation exposure, people still associate nuclear power with weapons. Nuclear radiation is viewed by the media and the public as little understood and fearsome. The drumbeat of opposition increased with Three Mile Island and Chernobyl. Official reassurances are distrusted, in part because of the government's denials until recently that its own weapons program, conducted in urgency and secrecy, exposed many people and left a legacy of ill-stored wastes. Along with other universities, Cornell has not been immune to public reaction. Enrollments have decreased and professors in key areas who retired or moved have not been replaced.

Nonetheless, nuclear energy has a place in 1991 and beyond. Controlled thermonuclear fusion is on the verge of realization. Non-power reactors are necessary for beneficial uses in medicine and biology and for

Right: The TRIGA reactor, a source of neutron and gamma rays, has been in use since 1961.

"Many observers expect nuclear power to return as an important component of an overall energy program for the United States and the world."

Clark



analytical uses in fields from archeology to textiles. Furthermore, many power reactors *have* been built on schedule within budget and *have* run safely. Nuclear power *can* be efficient and safe, with environmental advantages over the use of fossil fuels. Techniques for safely segregating wastes from the biosphere *are* available. It is therefore conceivable that public suspicion can be allayed, with time, through education. Many observers expect nuclear power to return as an important component of an overall energy program for the United States and the world.

In anticipation of this resurgence, Cornell is continuing its graduate programs and introductory undergraduate courses, teaching nuclear science and engineering, and conducting research in power reactor design, plasma physics and controlled fusion, underlying atomic and nuclear sciences, and non-power applications of nuclear energy.

David D. Clark is a professor of nuclear science and engineering and of applied and engineering physics and the director of the J. Carlton Ward, Jr. Laboratory of Nuclear Engineering. He also heads the academic Program in Nuclear Science and Engineering. He is a specialist in nuclear physics, activation and prompt gamma analysis, and radiation measurement.

Clark came to Cornell in 1955 after earning B.S. and Ph.D. degrees at the University of California at Berkeley and serving as a research associate in physics at Brookhaven National Laboratory for two years.

He was a Euratom fellow at Ispra, Italy, in 1962, a Guggenheim fellow at the Niels Bohr Institute in Copenhagen in 1968–69, a visiting professor at the Technical University in Munich in 1976, a visiting scientist at Brookhaven in 1982 and during numerous summers, and a guest scientist at the Center for Analytical Chemistry of the National Institute of Standards and Technology in 1990.

Bart Conta

Mechanical and Aerospace Engineering

When the *Quarterly* was born, the country was engaged in a hot war in Southeast Asia and a cold war with the U.S.S.R. Engineers in industry, government, and the universities were largely concerned with the fascinating and challenging problems of sophisticated technology presented by the military and space industries and agencies. Although a few voices were raised to point out the industrial and social problems that were suffering from neglect in this hubristic era, the warnings fell mostly on deaf ears.

Now it is much more generally recognized that the country is in deep trouble. A crippling national debt continues to grow, a trade deficit seems to be permanent, and we have lost much of our conventional industrial base to countries in Europe and Asia. We are faced with overwhelming problems of air, water, and land pollution; acid rain and ozone depletion; decay of the infrastructure of our cities and transportation systems; storage of hazardous chemical and nuclear waste; crime; drugs; and poverty. Compared with other industrialized nations, we rank quite low in education, health care, infant mortality, equitable distribution of both income and wealth, and even in GNP per capita.

The present era is a crucial one. To even begin to solve these mundane but vital industrial, economic, and social problems will

"Perhaps our universities offer the best hope of charting the way to solve these long-neglected problems."

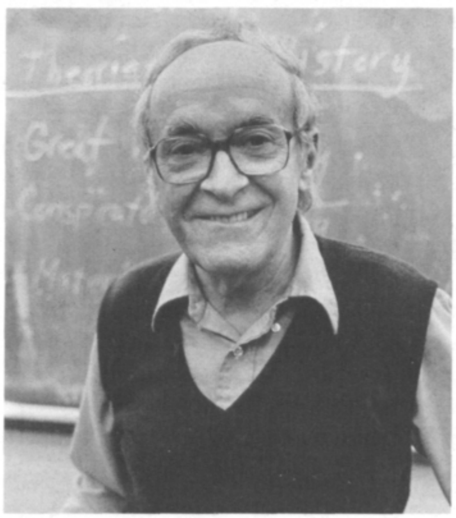
require drastic changes. In national politics it will require a near-revolutionary change. One cannot expect leadership to come from a free-enterprise industrial structure with its emphasis on the bottom line. Perhaps our universities offer the best hope of charting the way to solve these long-neglected problems.

Bart Conta became an emeritus professor in 1984, but has taught some courses since that time. His special interests include the history of science and technology and their social impacts, and intermediate technologies.

He studied mechanical engineering at the University of Rochester, earned a master's degree at Cornell, and joined the faculty in 1937. Except for a year at the Texaco Corporation and four years on the Syracuse University faculty, he spent his career at Cornell. He is registered as a professional engineer in New York and has served as an industrial consultant.

During leaves, Conta was a Ford Foundation visiting professor in Colombia, a National Science Foundation fellow at the University of California at Berkeley, and a researcher on the history of technology at the British Museum and the Science Musuem in London.

Conta



Dale R. Corson
Dean, 1959–1963

"Cornell moved rapidly to the front in graduate study and research in many areas."

On July 1, 1959 I became dean of the College of Engineering, following a remarkable twenty-two-year period of building and rebuilding under the leadership of Dean S. C. Hollister. "Holly" moved Engineering from the north end of the campus to the south end. He created the five-year undergraduate program. He established the Graduate School of Aeronautical Engineering and the Department of Engineering Physics. He recruited some outstanding faculty members. These were remarkable achievements.

In 1959 Cornell had a high-quality, predominantly undergraduate engineering school. I believed that we had to change the emphasis to add quality graduate education. I saw our society and our economy moving rapidly to ever higher and more complex technology and we had to educate people who could understand, work with, and develop that technology. Not only were we moving toward more complex (what we now call "high tech") machines and processes, we were creating a whole new set of problems for ourselves—pollution, toxic waste, and radiation hazards. I even gave talks about global warming and the "greenhouse effect". I did not believe that engineers educated only at the undergraduate level could cope with these problems.

The primary mission of the university is education. We teach undergraduates to understand our common heritage of learning left by those who have gone before. We teach young people to think clearly and to reason logically. We give them the perspectives and the fundamental tools to sustain them in their mature lives.

At the graduate level we teach students to solve difficult, novel problems. We do that by apprenticing them to teachers who are themselves solving difficult, novel problems and who, in the process, are creating the new insights and understanding on which we will build our technical future. These teachers constitute the research faculty.

I remained as dean only four years, but those years came at a good time. We could command support if we had good ideas. We set about restructuring the college in a number of ways. I say "we" advisedly. Everything that happened in those years was a cooperative effort with the faculty. We established the Division of Basic Studies so that students could explore engineering for a couple of years before deciding on a specialized major field—a plan that is basically still in effect—with a consequent retention rate that was much higher than it had been. We were able to obtain a multimillion-dollar grant from the Ford Foundation to help us on the road to the graduate and research program we sought.

The Ford grant, plus matching gifts from industry and alumni, along with a commitment from the university central administration, enabled us to appoint a dozen new

Three Cornell engineering deans were photographed at the 1971 convocation marking the first century of engineering at Cornell. Dale R. Corson is at left; his predecessor, the late S. C. Hollister, is at center; and Andrew Schultz, Jr., his successor, is at right. Schultz was dean at the time.

and distinguished faculty members in the fields where we saw the greatest need. Cornell moved rapidly to the front in graduate study and research in many areas. The college and its program have been well documented in *Engineering: Cornell Quarterly*, a great journal established by my successor, Dean Andrew Schultz, Jr.

The college now has ninety more faculty members than it had thirty years ago, and the additions are people at the front of their disciplines. We now have many graduate study and research fields that are among the best in the country. Our faculty members are winning major national awards. We get our share of the best students. The future is bright.

I salute those who are making it all happen.

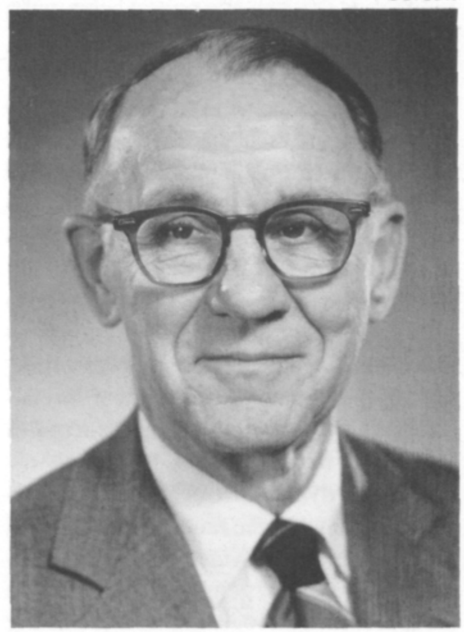
Dale R. Corson is president, emeritus, of Cornell University. He became Cornell's eighth president in 1969, after six years as provost. Before that, he spent four years as dean of the College of Engineering. In 1977–78 and 1978–79 he served as chancellor of the university.

Corson was educated at the College of Emporia in Kansas, the University of Kansas, and (for his doctorate in physics) the University of California at Berkeley. Before joining the Cornell physics department in 1946, he participated in the design and construction of a cyclotron at Berkeley, was a staff member of the Massachusetts Institute of Technology Radiation Laboratory (1941–43), served as a technical adviser on radar to the Air Force during World War II, and worked at the Los Alamos Scientific Laboratory, where he had primary responsibility for organizing Sandia Laboratory.

Corson has served on numerous national and New York State committees, panels, and commissions concerned with such topics as higher education, international technical cooperation and assistance, industrial research and development, satellite power systems, and scientific communication and national security. He has been a consultant to the Ford Foundation and a director of several corporations. Among his publications are two books on electromagnetism.

He is a fellow of the American Academy of Arts and Sciences and the American Physical Society and a member of the National Academy of Engineering. His honors include six honorary doctoral degrees.

Corson



Edmund T. Cranch
Dean, 1972–1978

". . . Cornell's M.Eng. program [is] in a position of leadership for the next turning point in engineering education."

Engineering education in the United States and the educational challenge facing the profession are at an evolutionary turning point. A new interpretation of the curriculum and degree structure is imperative.

The achievements in engineering education since World War II have been impressive. They include a strengthening of the scientific and mathematical content of the curriculum; increases in the course work in the humanities, social sciences, and other subjects; the introduction of new disciplines and subdisciplines associated with new or advanced technologies; incorporation of the computer as an essential and integral tool in teaching engineering analysis and design; and the building of a system of Ph.D. education and sponsored research.

One result, however, has been severe curricular compression at the undergraduate level—a kind of gridlock exists within the framework of the usual four-year program. Yet academic, industrial, and business constituencies cite the need for still more curricular depth and breadth. Among the changes that are called for are improved development of communication skills; more design, manufacturing, and processing content and hands-on experience; enhanced content in the humanities, social sciences, and languages to make engineers better able to function in an international context; courses to develop management skills; and greater depth of specialization. Obviously, the challenge requires much more than a quick fix.

An underlying cause of the need for educational change is the fundamental changes that are taking place in the engineering workplace. Increasingly, engineering problems are approached through synthesis of existing knowledge and through simulation. The engineering handbooks of the past have become computer programs, and the "bread board" prototypes have become simulation models. A design iteration that once took six months may now take six days or even six hours. And the geographical proximity once required for technology transfer has been eliminated.

An accompanying change is the expanding range and complexity of careers in engineering. Many new opportunities arise from the role and interaction of technology in addressing urgent societal and economic problems—medical, environmental, and economic on a global scale—as well as technical. Interdisciplinary or multidisciplinary collaboration is increasingly needed.

Currently, engineering education, from the baccalaureate to the doctoral level, is ill-structured to respond to the new dimensions of professionalism. Obsolescence, an issue that haunts engineering, continues to be a major problem; considering its importance, it is surprising that engineering education has given essentially no attention to this topic.

After studying the growing problems confronting engineering education, I have reached the conclusion that properly structured master's degree programs can respond to the imperatives of the saturated undergraduate curriculum and can extend the productive period of practicing engineers.

Cornell pioneered in establishing its Master of Engineering program in 1966. Indeed, this may be its most significant contribution to engineering education in the last fifty years. Subsequent advances in technology and developments in engineering education have placed Cornell's M.Eng. program in a position of leadership for the next turning point in engineering education.

Key features in programs that can meet the needs of the profession now and in the foreseeable future are:

- *Articulation between the bachelor's and master's degree programs.* Cornell has been a leader in developing ways of doing this; they include the possibility of early admission to master's degree courses, and flexibility in arranging individual curricula. There is opportunity for additional creative approaches. Currently, a national study along these lines is being conducted by the Council of Graduate Schools.
- *Development of increased technical proficiency.* A well planned master's degree program can accomplish this along with the development of a broad-based and critical approach to advances in a particular field or an area—such as manfacturing, an option in Cornell's M.Eng. program—that does not easily fit within traditional departmental

boundaries. The development of such programs is one of the main recommendations of the 1988 ASEE report "A National Action Agenda for Engineering Education".

- *Interdisciplinary opportunities.* To be effective, engineers must be well grounded not only in their specialty, but in associated disciplines. To meet this need, flexible, joint master's degree programs can be structured; Cornell's joint M.Eng.–M.B.A. program is an example.
- *Interaction with practicing professionals.* The required design project and the opportunity for industrial internship that are part of Cornell's M.Eng. program provide this dimension. Telecommunications technology also has immense potential to enhance the interaction between the educational institution and industry.

If engineering education is to move beyond its present constraints and strengthen the educational base of the profession consistent with the demands of technological change, its structure must include a coherent program extending through the master's degree level. Cornell's Master of Engineering program provides such a base and its graduates are educated for positions of professional leadership.

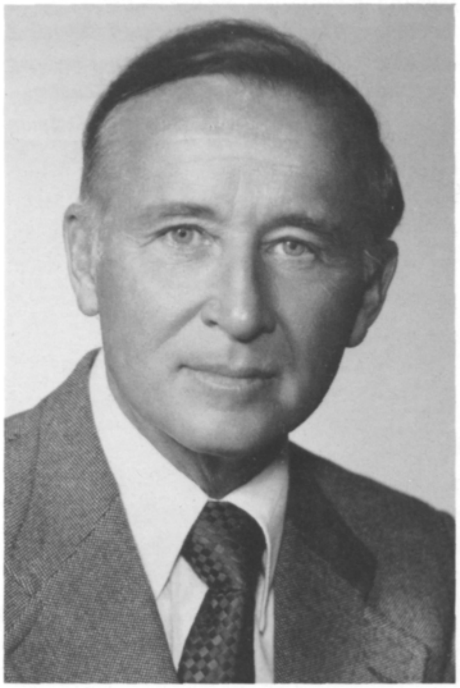
Edmund T. Cranch has been associated with the Cornell College of Engineering for many years—as a student (B.M.E. 1945, Ph.D. 1951), faculty member in theoretical and applied mechanics (1951–78), chairman of the department (1956–68), associate dean for research and graduate study (1967–72), and dean (1972–78). Currently, he serves on the advisory councils for the School of Electrical Engineering and the Sibley School of Mechanical and Aerospace Engineering.

In 1978 Cranch became president of Worcester Polytechnic Institute, and between 1985 and 1987 he was president of the Wang Institute of Graduate Studies. Since then he has been the Granite State Distinguished Professor at the University System of New Hampshire.

Throughout his career, Cranch has served as an industrial consultant and as a director of numerous industrial and educational organizations. Especially in recent years, he has been active nationally and internationally in areas of educational policy. In the late 1980s these activities included some that are relevant to the subject of his commentary printed here: he was a member of the American Society for Engineering Education's Task Force on a National Action Agenda for Engineering Education, and he served as chairman of the National Research Council's Panel on Engineering Undergraduate Education. He is now working on a national study of master's degrees that is sponsored by the Council of Graduate Schools.

Cranch is a fellow of the American Society of Mechanical Engineers and has served as president of the American Society for Engineering Education.

Cranch



G. Conrad Dalman
Electrical Engineering

At this time, as the *Quarterly* completes twenty-five years of publication, I would like to take a twenty-five-year "back to the future" look at the School of Electrical Engineering.

Of the many changes that have occurred in my own field of microwave electronics, one of the most significant is the rapid evolution from high-vacuum, discrete devices toward complete microwave and millimeter-wave systems on a chip. Today, for example, complete satellite communications receivers have already been integrated on a single chip. In the near future, with the further development of millimeter-wave technology, receiver dishes can be expected to shrink from the huge size now in use to as small as a foot in diameter. These developments are largely due to the many recent advances in solid-state technology and computer-aided testing and design.

Students graduating in this area are finding more interesting, stimulating, and challenging careers than the graduates of twenty-five years ago did. Many are finding, however, that they must aggressively seek out job opportunities rather than select from as many as three or four or more, as some of the earlier graduates were able to do.

Over the past twenty-five years, the size of the electrical engineering faculty has increased about 10 percent, and the ratio between the number of theses supervised and the number of faculty members has remained about the same. The faculty has continued to be very active in acquiring research grants and contracts to support graduate students and to help build up the research facilities.

Although proposal writing continues to be an effective way for faculty members to

". . . research problems are more interesting and challenging, laboratory facilities are vastly superior, computing facilities are abundant, and—most importantly—the quality of electrical engineering students continues to be excellent."

clearly define new programs of research, funding has become more difficult to obtain because of an erosion in research dollars for individual investigators. Twenty-five years ago, the probability that proposals would be accepted was very good, both because there was less competition and because money was relatively plentiful—the country was just entering what has come to be considered the "golden age" of research funding. Currently there is a concerted effort, led by NSF and other agencies, to restore university research to the important place it held in the 1960s.

Despite concern about funding for research, electrical engineering at Cornell is in far better condition today than it was twenty-five years ago: research problems are more interesting and challenging, laboratory facilities are vastly superior, computing facilities are abundant, and—most importantly—the quality of electrical engineering students continues to be excellent. We are optimistic that with perseverance and diligence, today's problems can be resolved.

G. Conrad Dalman, an emeritus professor of electrical engineering, joined the faculty in 1956. He had earned the B.E.E. from the City College of New York, and the M.E.E. and D.E.E. from the Polytechnic Institute of Brooklyn, and had had fourteen years of industrial experience at RCA, Bell Laboratories, and Sperry Gyroscope.

At Cornell he served as acting director and as director of the School of Electrical Engineering. He is a recipient of the school's Excellence in Teaching Award.

Dalman spent sabbatical leaves at Chiao Tung University, Hsinchu, Taiwan, where he served as International Telecommunications Union/United Nations Manager of the China Project (1962–63), and at TRW (1980–81). He has served as a microwave consultant to six major industrial firms. He has been awarded four U.S. patents and one is pending.

He is a fellow of the Institute of Electrical and Electronics Engineers and the American Association for the Advancement of Science.

Dalman

P. C. Tobias de Boer
Mechanical and Aerospace Engineering

When the first issue of *Engineering: Cornell Quarterly* appeared, I had been at Cornell's Graduate School of Aerospace Engineering for just two years.

I had visited Cornell for the first time in 1958, when I was working and studying at the University of Maryland. Ed Resler* had been on the faculty there, and I had taken over some of his experiments. Ed had recently moved to Cornell, and there was a need to discuss some recent results. I recall that my wife and I stayed at Willard Straight Hall. We found the guest rooms there pleasant and comfortable, although they generally were considered out-of-date because they did not have private bathrooms; but having arrived from Europe only one year before, we did not consider this unusual. Ed was in the Aero School, which at that time was housed in a "temporary" building near Beebe Lake. It was an old wooden building, filled with fascinating experiments and people. I still have a number of photographs of the campus taken during that visit. Student dress was quite formal: jackets for the men, dresses for the women. Books were carried without briefcase or backpack—an impressively large stack of books could be arranged so that it could be carried under one arm.

One of the outstanding problems in aerospace engineering during the 1960s was the "reentry problem". Reentering spacecraft create a bow shock in front of them, causing a very large increase in temperature. The resulting problem has two aspects: how to avoid serious damage to the vehicle, and how to overcome the temporary loss of radio

*See the commentary by Edwin L. Resler, Jr., beginning on page 31.

contact that is caused by high levels of ionization in the gas behind the bow shock. Faculty and students in the Aero School worked on both of these aspects.

A principal idea for limiting damage due to high heat was to use magnetic fields to keep the hot, ionized gases away from the reentering vehicle. This gave rise to a new discipline, *magneto-fluid dynamics* (MFD), in which Bill Sears, Ed Resler, and their students were pioneers. One of the interesting experiments consisted of shooting a bullet through a plasma in the presence of a magnetic field in order to record the wave system around the bullet. MFD was never applied to the reentry problem, however. A much simpler solution was found: the use of ablating heat shields, in which the heat of ablation keeps the spacecraft cool. (Another solution, applicable to manned spacecraft, is to make the reentry gradual and thereby limit the rate at which heat is generated. This allows the use of ceramic tiles, which can withstand the high temperatures without disintegrating.)

Problems related to the temporary loss of radio contact between ground and spacecraft were studied with shock-tube techniques that had been developed at the Aero School by Arthur Kantrowitz and his students Ed Resler and S. C. Lin (now a professor at the University of California at San Diego). At high temperatures, shock tubes can generate phenomena similar to those experienced by reentering spacecraft, and the rate of ionization—an important parameter—can be obtained as a function of temperature. Since the ionized species is NO (nitric oxide), the problem is related to one that is being studied very actively at the present time: the generation of NO in combustion processes.

Another major problem studied extensively in the 1960s was that of sonic boom, and a number of people in the Aero School worked on that. It is caused by wave steepening, which results in an *N-wave* for pressure recorded on the ground as a function of time. There were lengthy discussions about whether the N-wave could be avoided through airplane design, but eventually it was accepted as unavoidable for practical aircraft; part of the "solution" is to require supersonic planes such as the Concorde to fly subsonically over land.

"Problems related to the temporary loss of radio contact between ground and spacecraft were studied with shock-tube techniques that had been developed at the Aero School. . . ."

Over the past twenty-five years, many physical changes have taken place on campus—for instance, the Engineering and Theory Center Building now stands where there used to be a lawn in front of Grumman Hall—and so have a few ways of doing things. We used to have Saturday morning classes, which at the Aero School were pleasantly combined with Saturday-morning coffee arranged by the school's secretary, Toni Anthony. Toni's title has changed over the years—she is now the administrative associate in the Sibley School of Mechanical and Aerospace Engineering—but she still takes care of many matters, and in fact, still provides coffee to students and faculty on many Saturday mornings.

P. C. Tobias de Boer, a professor in the Sibley School of Mechanical and Aerospace Engineering, is a specialist in high-temperature gasdynamics, fluid dynamics, and transonic flow.

Before he came to Cornell in 1964 as a member of the aerospace engineering faculty, he had earned the degree of Ingenieur at the Technological University in Delft, The Netherlands, and the Ph.D. at the University of Maryland, and had spent seven years at the Institute for Fluid Dynamics and Applied Mathematics at the University of Maryland.

He has been a visiting professor at the von Kármán Institute for Fluid Dynamics in Belgium (1968), the Cornell Aeronautical Laboratory (1969), and the Technological University in Delft (1985–86). During the 1960s, he spent several summers at the Aerospace Corporation, and he has spent sabbatical leaves at the Ford Motor Company and the Gas Turbine Division of General Electric.

He is the North American associate editor of Applied Scientific Research.

de Boer

Leonard B. Dworsky
Civil and Environmental Engineering

Since I have spent my entire career in environmental engineering, my contribution to this issue of the *Quarterly* is an assessment of developments in the area of public health and the environment that have occurred over the past twenty-five years.

No realistic understanding of the changes that have taken place is possible without knowledge of some significant events that shaped those years.

In the last quarter of the nineteenth century, Pasteur's germ theory led to a new understanding of how to protect against epidemic disease. This information was examined in the United States by the Hygienic Institute of the United States Public Health Service (USPHS) and the Lawrence Experiment Station in Massachusetts, where health-related research on water and waste water was initiated. By 1914 the USPHS had promulgated the first drinking-water standards, and by 1915 thirty states had established sanitary (environmental) engineering units (although half of these consisted of only one person).

". . . answers to questions of priorities, degrees of risk, costs, and the balance between development and the environment will be increasingly sought."

Although more than one hundred water-pollution-control bills had been introduced into Congress since 1900, no legislation was enacted until 1948, when the first federal Water Pollution Control Act was passed. This act established new policies for federal financial aid and provided for enforcement, and although implementation of these policies was weak, they broke a half-century-long log jam that had pitted American industry and many state and local governments against further federal responsibility.

That same year there was an air-pollution disaster in Donora, Pennsylvania, in which twenty persons died and six thousand were made ill. The public concern that was triggered by this tragedy resulted in 1955 in legislation that laid the foundation for the current national air-pollution-control program. By the mid-1960s Congress recognized that the people were willing to proceed toward a stronger environmental-management program. Amended and strengthened water- and air-pollution acts emerged as part of President Johnson's Great Society program, and good, but not final, achievements were made in the 1970s and 1980s.

It is against this background that the advances of the past twenty-five years took place. Conservation education stimulated by the Office of Education and non-governmental agencies also contributed, and writings such as Rachel Carson's *Silent Spring* played a role. There developed a growing concern for nature and beauty, animal life and genetic diversity, Amazon forests, and an ecosystem approach to the management of our planet.

In addition, two technological developments contributed to public attitudes toward environmental issues. These were the use of animal experimentation by the federal Food and Drug Administration and the development of instrumentation to measure the presence of substances in parts per billion or less. A result was that people became aware that certain chemicals, many in common use, can produce cancers, and this was the major impetus for an immense public concern about environmental public-health issues. Subsequently, societies everywhere, led importantly by the United Nations, have developed a new consciousness of environmental issues.

In thinking about what may transpire in the next twenty-five years, I find that society is in the middle of a learning curve. An understanding of the new threats to human and all other life is perceived. Resources necessary to seek solutions to both national and planetary problems are becoming increasingly available. Answers are awaited to the critical problem of how to balance the vital needs of environmental management with the potential uses of scientific discovery, with technical advances, and with the industrial and economic development that is needed to maintain and improve living conditions.

The 1992 United Nations Conference on Environment and Sustained Development should help set the stage for this next quarter century, when answers to questions of priorities, degrees of risk, costs, and the balance between development and the environment will be increasingly sought. Universities such as Cornell will be crucially involved in confronting these issues, and face real challenges in the years to come.

Leonard B. Dworsky, an emeritus Cornell professor of civil and environmental engineering since 1985, spent twenty-eight years as an environmental engineer in local, state, military, and federal organizations before joining the university faculty in 1964.

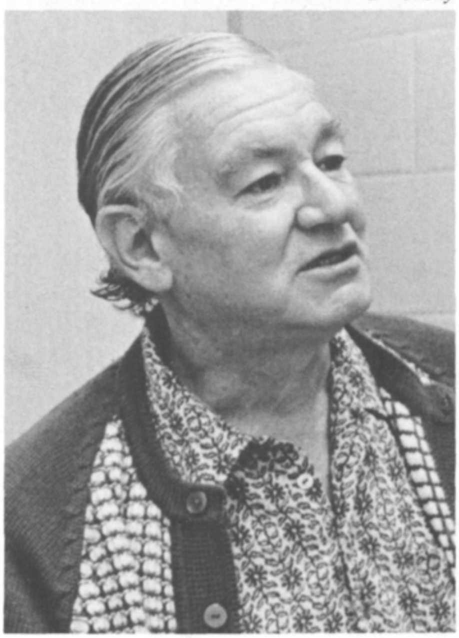
This experience included eighteen years with the United States Public Health Service, during *which he participated in the formulation and administration of the national environmental programs initiated between 1948 and 1965.*

More recently he has been concerned with problems of water-resources management at the nation's boundaries. He sat on the Science Advisory Board of the International Joint Commission (United States and Canada) and was an adviser on water resources to President Lyndon Johnson. He was a principal organizer of a United States–Mexico–Canada conference on boundary issues that was held in April in Florida under the sponsorship of the International Transboundary Resources Center of the University of New Mexico School of Law. Dworsky is a senior associate of that center.

Dworsky graduated from the University of Michigan in 1936 and received a M.A. degree from American University in 1955.

At Cornell he directed the Water Resources and Marine Sciences Center from 1964 through 1974. He has served on the national water and energy-policy committees of the American Society of Civil Engineers and is a diplomate of the American Academy of Environmental Engineers.

Dworsky



Peter Gergely
Structural Engineering

Some important facets of academic life in engineering at Cornell have not changed much in the past quarter century, but others have fundamentally altered the way we do our teaching, research, and professional activities. The quality of students has remained very high, and for me that has been one of the most satisfying aspects of working at Cornell. Most other things have changed to various degrees since I came here in 1963.

Cornell has become much bigger in every sense. The administration has grown and controls more of our operations, both as perceived and in reality. There are more rules, more offices, and more red tape. There is much more diversity all around, especially in the student population, which had been rather homogeneous until the end of the 1960s. Now we have many more female, minority, and foreign students.

The Master of Engineering program, which resulted from the demise of the five-year curriculum, has become very successful and solid. We in structural engineering are especially pleased with our interaction with eminent practicing engineers who help our M.Eng. (Civil) class.

Undoubtedly, the introduction of computers has had the greatest impact on our teaching and research. Pioneering developments in the use of computer graphics in powerful analysis programs has immeasurably improved our teaching in structural engineering. Instead of assigning one trivial problem as homework, we can ask students to analyze numerous complex structures and study the results. Furthermore, we can display the analytical procedures in ways that were impossible on paper or on the blackboard.

"Pioneering developments in the use of computer graphics in powerful analysis programs has immeasurably improved our teaching in structural engineering."

The volume of research has increased exponentially. The obvious benefits are funding for graduate students, broadening of the horizons of students and faculty, financing of lab equipment, and increase in stature for the college. However, there are negative aspects as well, which have become apparent only in recent years. The tremendous amount of work associated with sponsored research (proposal writing, reporting, conferences, other meetings, budgeting) has strained the faculty and others. Successful research also leads to other commitments, including consulting. As a result, we are much busier and more hurried than we were a quarter century ago. I used to attend classes in the arts college and get to know several faculty members there—that was a long time ago. Is it possible to compromise and reduce the exciting research and associated activities? I doubt it, because one has learned to go after funding incessantly and has not learned to say no to opportunities.

Much of our recent research has been concerned with earthquake engineering. In addition to its national importance and technical challenges, this field of research is especially exciting for most of us in structural engineering because of the cooperative

An intensive between-terms design session in which industrial consultants work with the students has long been a feature of the M.Eng. (Civil) program. In 1976, for example, Richard Christie of Hardesty and Hanover helped students work on a bridge design; the actual Hardesty and Hanover design was used in a bridge constructed in New England.

Above: This shake table in the George Winter Structural Engineering Laboratory in Thurston Hall is used in earthquake engineering research. The structure undergoing testing is a model of a three-story concrete building with design details that are typical in the eastern United States.

nature of projects undertaken through the National Center for Earthquake Engineering Research. Cornell is one of several universities in the New York State region that are participants in the center, which was established in 1986.

The variety of research, both within structural engineering and across the college, makes this place an inspiring and stimulating environment, and we continually try to infuse this excitement into the classroom. These efforts keep our faculty active and vigorous, as many visitors have observed. The college's current renewed emphasis on teaching is welcome and will require masterful balancing of the opportunities and responsibilities.

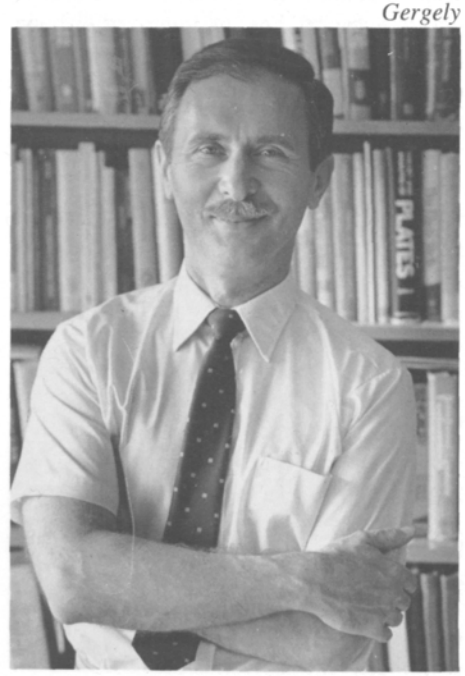
Peter Gergely is a professor in the structural engineering group of the School of Civil and Environmental Engineering. He has served as director of the school and is currently manager of the Cornell program of the National Center for Earthquake Engineering Research and one of the center's principal investigators.

He began his university education in Budapest and completed a bachelor's degree in engineering at McGill University in Montreal. He did his graduate work at the University of Illinois and joined the Cornell faculty after receiving his Ph.D. in 1963.

He has spent sabbatical leaves with the Pittsburgh–Des Moines Steel Company (1969), at the Hungarian Academy of Sciences and the University of Toronto (1976), and at the Lawrence Livermore National Laboratory and the University of California at Berkeley (1983).

Gergely is a fellow of the American Society of Civil Engineers (ASCE) and the American Concrete Institute (ACI) and has served on the board of directors of the ACI. He has received four national awards, including the ACI's 1982 Distinguished Service Award.

Gergely



David Gries
Computer Science

Some twenty-five years ago, in 1965 to be exact, the Cornell Department of Computer Science was formed. It was one of the very first computer science departments—the academic field was in its infancy. The initial mission of the department was to produce Ph.D.s—the researchers and the educators of the many students who were expected to become interested in computer science.

With a faculty of five, the department occupied the north side of the fourth floor of Upson Hall. The south side still consisted of large rooms filled with drafting tables, where freshman engineers learned a skill that computer science was soon to help obviate. There was no women's bathroom on the fourth floor, for few women studied engineering in the 1950s, when Upson Hall was built for mechanical engineering. The elevator in Upson had a sign on it: "For Faculty Only".

In contrast to our small beginning, the department now has twenty-five faculty members and produces some fifteen Ph.D.s, thirty Masters, and seventy Bachelors per year; a total of 150 Ph.D.s in computer science have been granted by Cornell. An undergraduate degree in computer science was not available at Cornell until 1978.

The field of computer science as a whole has also mushroomed. Currently, the nation's approximately 135 institutions that grant doctorates in computer science produce more than 700 Ph.D.s per year, which is getting close to the number of Ph.D.s in mathematics, and probably about 850 departments produce graduates with master's or bachelor's degrees.

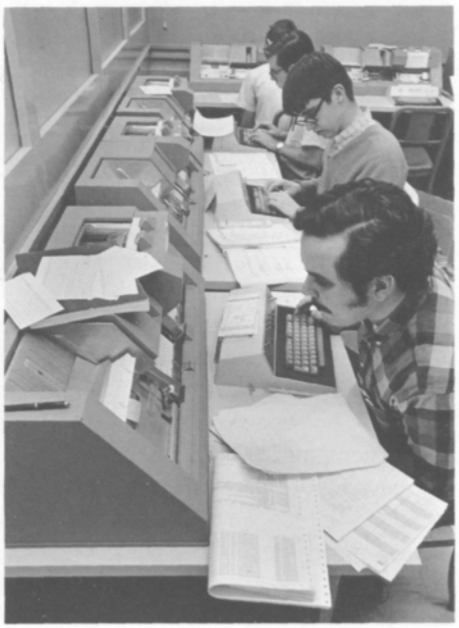
The discipline of computer science was in its infancy in 1965. Research in areas such as the theory of formal languages, automata theory, and programming language semantics had indeed begun, but most of the key broad ideas—for example, NP-completeness, structural complexity, structured programming, parallel programming, axiomatic semantics, denotational semantics, type theory, and relational databases—had not yet been invented. The hot topics of interest were compiler writing, operating systems, algorithm design, formal languages, automata theory, and the new field of computational complexity. Artificial intelligence was pursued at only a few places, most notably M.I.T., Stanford, and Carnegie-Mellon.

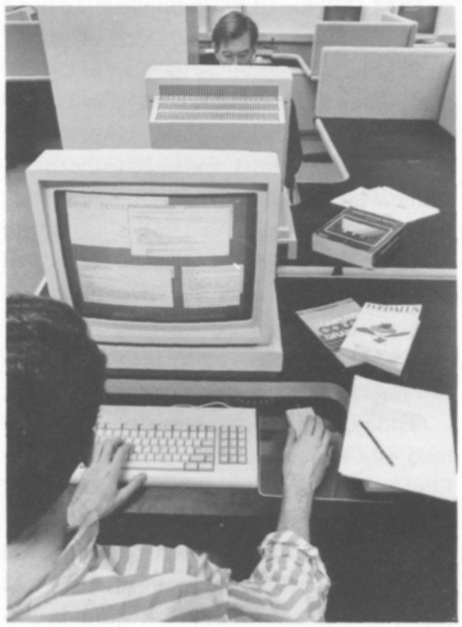
If research was in its infancy in 1965, what did computer scientists teach? At Cornell, there were a few undergraduate courses in programming, machine architecture, assembly language programming, and the like, but the emphasis was on graduate courses and research. Compiler writing, for example, was taught in a graduate course. Most of the material now taught in the senior-level course on compiler writing had not yet been developed. There were few usable textbooks twenty-five years ago. In fact, Cornell's computer science department played a large role in upgrading education by producing textbooks that set the national tone in areas such as the theory of automata and formal languages, algorithms, compiler writing, programming, and information organization and retrieval.

The major high-level languages in use were FORTRAN, PL/I, Algol 60, LISP,

At left: In the days when computing at Cornell relied on one IBM 360, this facility in the basement of Upson Hall was used to punch cards and access the central computer.

At right: Students today have access to individual workstations. The Department of Computer Science has advanced equipment for both instruction and research.





"Historically, one talks of two revolutions that totally changed the world: the agricultural revolution and the industrial revolution. We are now in the midst of a third important revolution: the information revolution."

and COBOL. FORTRAN was taught to engineers initially, and was replaced by PL/C (Cornell's scaled-down version of PL/I), in the early 1970s. Among today's popular programming languages that did not exist at the time are Pascal, C, Ada, Prolog, and Scheme. The UNIX operating system was nonexistent.

For at least its first ten years, the department relied on Cornell's main computer, an IBM 360, for all its computing. To run a program, one brought the deck of punch cards, or IBM cards, as they were called, that contained the program to be run to the basement of Upson Hall, where keypunches, lineprinters, and links to the mainframe were located. The deck of IBM cards was placed in a card reader; the job would be run and the results printed anywhere from ten minutes to a day later. One mistake on an IBM card—a missing semicolon, for example—could mean waiting a few hours or a day to run the program again.

Today, few students know what an IBM card is—or realize that the side of Olin library reminds us oldsters of one. They also don't realize how instant their computer gratification has become, compared to the old days. Computer science was really in its infancy then, with limited computers and frustrating interfaces to them, and with only the beginnings of the theory of the field, few programming languages, and little software. The best thing going for us was that we did not *know* that everything was so backward—we could not read the future.

So what *did* we computer scientists and engineers do at the time? Well, we spent twenty-five years developing, designing, and building the better computers, theory, programming languages, and software that are in use today. The advances have been breathtaking. From a time in which computers were used only by the chosen few, it has taken only twenty-five years to reach the point that computers and computing are ubiquitous and affect the lives of every one of us—to reach the point that there is a respectable, interesting, and deep theory behind the field.

Today is the era of the individual workstation and the desktop computer, which have more horsepower than the single mainframe computer the Cornell community shared twenty-five years ago. We have instant execution, e-mail, instant access to larger computers, windowing systems, editing systems, spread sheets, graphics, laser printers, and on and on: all driven by the research, development, and education that took place in the past twenty-five years.

Computing—by that term I mean computer science and engineering—has joined mathematics as an enabling discipline for almost all other scientific and engineering fields. And simulation by computer has joined theory and experiment as a third paradigm for doing research; today one cannot do, say, physics or mechanical engineering without using computing.

Computer science has developed a new concept, a new idea. While mathematics has concentrated on frameworks for explaining "what is", computing has given us frameworks for explaining "how to" and the machinery—the computer—for carrying out that "how to". The notion of an algorithm, and how we understand it, has become so important that perhaps all educated people should be familiar with it.

Historically, one talks of two revolutions that totally changed the world: the agricultural revolution and the industrial revolution. We are now in the midst of a third important revolution: the information revolution. This information revolution relies heavily on the processing and transmittal of information using computers and, therefore, rests on the intellectual disciplines that focus on the representation, manipulation, storage, and use of information and on the development of computers: computer science and engineering.

This information revolution promises to have just as much effect (both good and bad) on our culture and way of living as did the earlier two revolutions. It has already brought about marvelous products and services and has made the world a smaller place. All means of communications (for example, telephone, FAX, and e-mail), and all means of travel (for example, the shuttle, airplane, and car) rely heavily on computing these days. At the same time, the information revolution has made the world a more complex and fragile place, and it has led to a more frenzied pace of living. We should be aware of both the good and the bad effects of "progress".

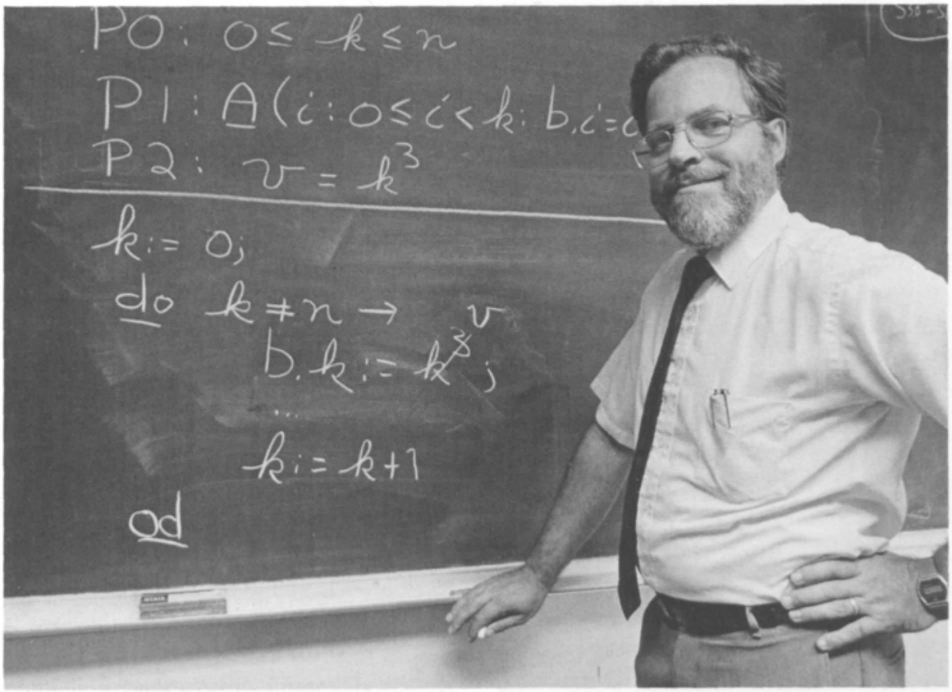
It is hard to predict the future changes that will be caused by the intellectual development of computer science and engineering and the transmittal of the results into products and services. But we do expect the next twenty-five years to be as momentous and exciting as the past twenty-five have been.

David Gries, a professor of computer science at Cornell, is a specialist in programming methodology, programmming languages, and compiler construction, and is author or coauthor of three books on these subjects. Currently he is working on a new programming language and a new undergraduate text on programming and discrete mathematics.

Gries was educated at Queens College (B.S. 1960), the University of Illinois (M.S. 1963), and the Munich Institute of Technology (Dr.rer.nat. 1966). Before joining the Cornell faculty in 1969, he was a mathematician-programmer in Kahlgren, Virginia, and taught at Stanford University. He has spent sabbatical leaves at the Munich Technical University, as a Guggenheim fellow at Oxford University, and at the University of Texas in Austin.

In 1986 he received the Education Award of the American Federation of Information Processing Societies (AFIPS). In 1990 he received the annual award for contributions to computer science education from the Association for Computing Machinery. Also last year he was elected a fellow of the American Association for the Advancement of Science.

Gries



Paul L. Hartman
Applied and Engineering Physics

A quarter of a century is time enough for the world to become almost unrecognizable. This is true of science and technology no less than of society and geopolitics.

In the School of Applied and Engineering Physics, the undergraduate curriculum, which stresses the physics needed in engineering, along with mathematics, has not changed greatly. Engineers do not yet need to know quark and high-energy physics, although quantum mechanics has entered their world. But the technology part of our curriculum—applied physics—has indeed broadened widely.

This has occurred in perhaps no field more than in optics, which is still pretty much wave optics but at a level of sophistication well beyond that of 1966. Today it plays a large role in much of engineering—in communications (where copper wire is rapidly being replaced by optical fibers), engineering holography, data (and music) storage, and mensuration. And research in nonlinear optics is finding numerous applications.

Leaning on quantum ideas, we have tunneling phenomena in superconducting junctions, leading to extremely sensitive magnetic field detection; we have the tunneling microscope, providing surface topography on an atomic scale; and, while not yet fully understood, we have high-temperature superconductors with computer and machinery applications not yet dreamed of.

Chaos has entered our vocabulary through phenomena such as turbulence and dynamic instabilities, but while there are some pretty and fascinating experiments, chaos is still largely in the domain of mathematics.

By 1966 the transistor and the laser were

". . . roughly twenty-five years ago, almost overnight, [the use of integrated circuitry] in computers and calculators made antiques of the engineer's slide rule and gear-driven calculator."

on the scene, but since then applications have proliferated. Transistor integrated circuitry is everywhere in today's world; roughly twenty-five years ago, almost overnight, its use in computers and calculators made antiques of the engineer's slide rule and gear-driven calculator. Laser applications have been manifold in science, and though perhaps less so in society at large, we cannot fail to note the use of the solid-state laser in generating the carrier in fiber-optic communications and its presence in every CD phonograph (while dismissing the use of high-power lasers in laser extravagazas, part of many a rock "concert"). The laser has revolutionized surveying and precision spectroscopy, is used in meteorology and seismology and for cooling atomic beams to unprecedented low temperatures, and provides an ingenious way of trapping even single atoms, opening the way for clocks that will be stable to a part in 10^{14} or better.

Electron optics, which has advanced during the past quarter century to the point where imaging down to a few angstroms is becoming routine, has made possible the lithography of computer chips with ultrasmall components.

Materials research has benefitted greatly from the use of x-rays that are now generated as a byproduct in the operation of high-energy electron sychrontrons and storage rings. The Cornell High Energy Synchrotron Source (CHESS) is one of the best machines of this kind in the world.

Problems of energy supply have become increasingly pressing over the past quarter century. Plasma researchers have made progress in the development of hydrogen fusion machines for power production, although reaching that goal is still ahead of us. The use of fission reactors for power production, so promising at the beginning of this period, is today in abeyance and decline, but it cannot remain so; safer designs are in the works and a resurgence will come. Fossil fuels have their disadvantages, global warming among them. Not that nuclear fuel is all that benign: the problem of waste-product disposal is still with us, as it was in 1966.

Would we today recognize technology as it will be in the year 2016? Can we anticipate what the world will be like? Probably not, but we can say that whatever changes take place, engineering as applied physics will have had a hand in shaping that world.

Paul L. Hartman, an emeritus professor of physics and of applied and engineering physics, first arrived at Cornell in 1934 after graduating from the University of Nevada with a degree in electrical engineering. After earning a Ph.D. in physics in 1938, he was an instructor for a year, worked for seven years at Bell Telephone Laboratories, and then returned to Cornell in 1946 as a member of the physics faculty.

At Cornell he helped establish the engineering physics program and when a new department in that area was formed, he became a member of it as well as of the physics faculty. He participated in the development of the experimental facilities at the Cornell High Energy Synchrotron Source (CHESS) and the program of the Laboratory of Atomic and Solid State Physics. Since his retirement in 1983, he has continued to be active in these areas and in writing histories of physics and of applied and engineering physics at Cornell.

He has served as a consultant to the Hughes Aircraft Company and the Los Alamos Scientific Laboratory, and spent leaves and summers at those facilities. He has been an editor of the Review of Scientific Instruments.

Richard H. Lance
Theoretical and Applied Mechanics

"We now talk less of beams and plates and Timoshenko, and spend more time exploring the subtleties of Poincaré's theories. . . ."

When reflecting on the changes that have taken place in mechanics in the twenty-five years since the founding of this magazine, I am tempted to say: nothing. Yet on further reflection, it sometimes seems that everything has changed.

Mechanics still plays a major role as interpreter to the traditional engineering disciplines of the newest developments in the "purer" studies of, for example, physics and mathematics. We continue to focus our energies and intellects on the general rather than the specific character of the mechanical behavior of materials, mechanisms, and structures. Our undergraduate and graduate students, as in the past, help us build experiments that provide answers to basic questions; they contribute, through their facility with classical methods of applied mathematics, as well as modern computers and software, to our understanding of the details of the thermal/chemical/electrical/mechanical behavior of models of materials and structures.

Many of the subjects of study have changed in twenty-five years, however. Such contemporary topics as advanced composite materials, chaos, materials for electronic packages, nonlinear dynamical systems and "strange attractors", and applications of the theory of neural networks to nondestructive testing are frequently discussed over coffee in the lounge and during the traditional Friday faculty lunch in Collegetown. We now talk less of beams and plates and Timoshenko, and spend more time exploring the subtleties of Poincaré's theories, it seems.

Thus, mechanics, with one foot firmly planted in the sciences and the other on the "red clay" of real engineering, is as exciting intellectually as it always has been. The challenges of developing a clear and accurate "engineering description" of the fundamentals of the behavior of the world around us are unabated.

Richard H. Lance has been a member of the Department of Theoretical and Applied Mechanics since 1962.

He has served as acting chairman of the department twice, and he was the college's associate dean for external affairs (1974–1980) and associate dean for undergraduate programs (1981–1986).

Lance earned a bachelor's degree in mechanical engineering at the University of Illinois at Urbana-Champaign, an M.S. at the Illinois Institute of Technology, and a Ph.D., granted in 1962, at Brown University. Between periods of study, he worked as an engineer at the Minneapolis Honeywell Company and at the Ingersoll Milling Machine Company, and served in the armed forces.

While on sabbatical leaves, Lance has been a visiting professor at the University of Edinburgh, and a senior scientist at Hughes Aircraft Company. He has been a consultant to the IBM Corporation.

Lance

Simpson Linke
Electrical Engineering

"During the twenty-five years that have passed since the Blackout, this interconnected-network mode of operation has become the mainstay of bulk electric-power transmission in the United States."

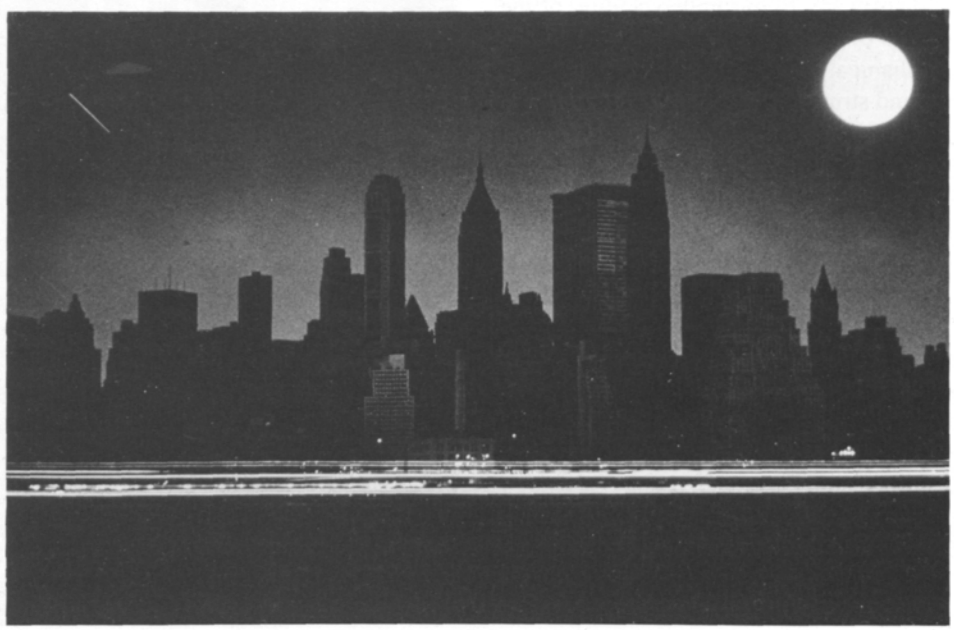
The Great Northeast Blackout of November 9, 1965, and its aftermath precipitated an unprecedented examination of the nation's electric-energy supply facilities. Consumers lost their faith that electric power would always be available at the flick of a switch. The energy crisis of the early 1970s and the lack of new generating capacity as a result of unanticipated difficulties with planned nuclear power stations were additional factors that moved the electric-utility industry to correct deficiencies in its system operations.

An effective and relatively quick solution to the problem of potential reductions in power-system reliability was to construct very-high-voltage (345 to 765 kV) transmission lines to serve as solid ties between major power systems. During the twenty-five years that have passed since the Blackout, this interconnected-network mode of operation has become the mainstay of bulk electric-power transmission in the United States.

System engineers soon found that the resultant stiff grid was not only useful in helping to prevent large-scale outages during emergencies, it also could allow bulk power to be "wheeled"—that is, transferred from point to point within a system and from one system to another—to meet demand requirements. When coupled with modern computerized control facilities, the expanded grid has been able to offset the lack of new generation by taking advantage of regional differences in demand. Consequently, the interconnected networks could become an "interstate transmission highway" where, in principle, all connected loads could be supplied by the network, which, in turn, would draw power from discrete input points. This potential capability is of particular interest to so-called "co-generation" facilities, where excess capacity from local non-utility generators is available for sale either to the utility or to specific customers. Thus far, operational problems and regulatory disputes have limited the general adoption of this open-market concept.

Since technological and economic factors limit the feasible lengths of ac transmission lines to between one hundred fifty and three hundred miles, long-distance high-voltage direct-current (HVDC) lines have become accepted as useful alternatives. HVDC lines can be a thousand or more miles long, and can act as stabilizers for ac systems. They also permit power transfer between the western and eastern networks that, because of the Rocky Mountain barrier, cannot otherwise be interconnected. Additional modifications to transmission capability will result eventually from current research on underground superconducting and gas-insulated

The 1965 Great Northeast Blackout. (©1990 New York News Inc. *Reprinted with permission.)*



cables in both ac and dc modes, expansion to ultra-high ac and dc voltages (1,000 to 2,500 kV), and perhaps power transmission at microwave frequencies.

Simpson Linke, a professor of electrical engineering, emeritus, came to Cornell as a graduate student in 1946, after earning a bachelor's degree at the University of Tennessee, working with the electric utilities board in Knoxville, and serving in the Army Signal Corps during World War II. He received the M.E.E. degree in 1949 and joined the faculty at that time.

At Cornell he supervised the Power Network Calculator Facility until 1960, and later served as assistant director of the Laboratory of Plasma Studies. He collaborated in the establishment of a program in power systems engineering at the School of Electrical Engineering in 1983. He retired in 1986.

During the 1970s, Linke chaired the International Symposium on the Hydrogen Economy, held at Cornell, and a joint Cornell–Los Alamos Scientific Laboratory Seminar on Superconducting Magnetic Energy Storage. He edited a series of proceedings of symposia held in connection with the 1985 centennial celebration of electrical engineering at Cornell.

Linke

Daniel P. Loucks
Civil and Environmental Engineering

More than twenty-five years ago, I came to Cornell as a graduate student on the advice of the current dean of the university faculty (Walter R. Lynn, a professor of civil and environmental engineering), who persuaded me to work in a new—at least to civil engineering—subject area called *systems analysis* and its application to environmental and water resources management. I was told that systems analysis involved mathematical models and computers, and was a way to integrate economics into engineering management and decision-making. It was an approach to simulating and finding optimal solutions to problems involving the design and operation of large complex multivariate systems (whatever *they* were). All I had to do was to learn some mathematics, economics, computer programming, and environmental and water resources engineering. Twenty-five years ago I thought I could.

So what has happened over these past twenty-five years? With the help of our colleagues and students, those of us in this field have managed to learn enough to be able to introduce systems analysis to every undergraduate who studies civil engineering at Cornell. At most major universities throughout the world, systems analysis has become a subject area studied by everyone interested in environmental and water resources management.

But we have learned that there is much more than economics and technology that influences engineering management decisions. We have learned that it is impossible to identify optimal solutions to real problems involving real people with differing interests, values, or goals. Nevertheless, management agencies are increasingly asking for information related to decisions they must make and the impacts that may result from those decisions. They want to know what will happen if they do A or B and who will care. Those questions are getting more comprehensive, are involving more disciplines, and hence are becoming much harder to answer. This is what drives our continuing research.

"[Management agencies] want to know what will happen if they do A or B and who will care. Those questions are getting more comprehensive, are involving more disciplines, and hence are becoming much harder to answer. This is what drives our continuing research."

In the past twenty-five years we have seen enormous improvements in the mathematical and computational resources that we can apply to our work. We have come a long way from the days of punching out our computer programs on cards or paper tape.

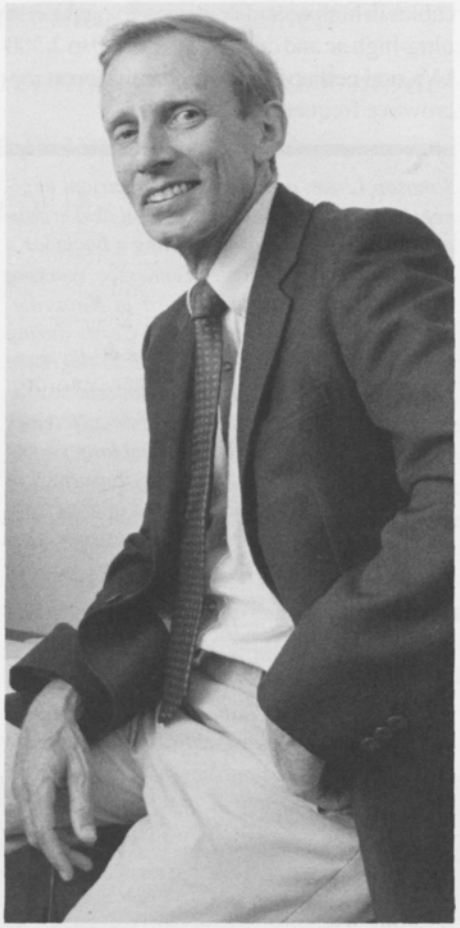
But the complexity of our problems seems to have increased accordingly, and it will take more than supercomputers and sophisticated algorithms to solve many of them.

For example, while we have generally mastered the management or control of oxygen and oxygen-demanding wastes in rivers or lakes, we know little about how to manage the amounts of water, nutrients, and toxic substances entering wetlands and their impacts on deer and wading birds. (This is currently an issue in a major lawsuit in southern Florida.) Understanding and modeling the interactions between the ground and surface waters and all the substances in those waters in the detailed time and space scales required is difficult enough. Add to that the even more difficult task of modeling and predicting the complex ecology of those interdependent subsystems. This is only one example of the challenges our current graduates are being asked to meet.

Today in many countries water management is a major component of the national economy. For example, among other events taking place in the Middle East, construction projects costing billions of dollars are underway to pump, transport, and use the "fossil" water found in very deep aquifers. The water to be obtained will be somewhat like oil, in that it will be very expensive and once it is gone, cannot be replenished. The conflict between Israel and Jordan over the West Bank is not just about who is to occupy the land; it is also over who is to control the underlying aquifers, currently a major source of Israel's fresh water. And, of course, we observe (as I write this) the critical drought situation in southern California, where some residents of Santa Barbara have been photographed painting their dead grass green. (Water management issues can really be serious!)

If our young engineers are going to play a leadership role in helping to build a better society, it seems to me they will need a broader education than they now receive in a four-year program. Some twenty-five years ago, Cornell had to drop its five-year undergraduate engineering degree program. Today I believe Cornell should be joining other major engineering universities to work toward establishing engineering throughout the country as a graduate program.

Engineering, like business, law, and medicine, should be a profession requiring postgraduate education. This would allow our undergraduates more time to explore the liberal arts as well as the physical, biological, social, and engineering sciences. It would allow graduate students more time to learn the multidisciplinary art as well as the science of engineering, and to consider what we as engineers can do to improve our society and our natural environment. I believe our engineering graduates will increasingly need this additional liberal as well as professional training and knowledge if they are to be among those who lead us in defining the direction of our future development and in implementing that development over the next twenty-five years.



Daniel P. Loucks, a Cornell Ph.D. and professor of civil and environmental engineering, joined the faculty here in 1965 after completing his doctoral studies. He earned his B.S. degree at Pennsylvania State University and an M.S. degree at Yale University.

A specialist in environmental systems engineering, including water resource planning and environmental control, Loucks has worked with the World Bank, the International Institute for Hydraulic and Environmental Engineering, and the International Institute for Applied Systems Analysis, and he has been a consultant to a number of government and international organizations concerned with resource development and management. He is currently advising the International Institute for Applied Systems Analysis, the United Nations, and the North Atlantic Treaty Organization on several projects in Africa and Europe.

At Cornell he has served as associate dean for research and graduate education at the College of Engineering, and as chairman of the environmental engineering department (now integrated into the School of Civil and Environmental Engineering).

Loucks is a recipient of the Walter L. Huber and the Julian Hinds awards of the American Society of Civil Engineers. He is a member of the National Academy of Engineering.

William L. Maxwell
Operations Research and Industrial Engineering

Reflections from twenty-five years ago:

■ Industrial Engineering and Operations Research (IE&OR) had recently (in 1963) broken off from Mechanical Engineering to form a separate department, and already a new Department of Computer Science was in the making, growing out of IE&OR. Don Iglehart was soon to depart for Stanford, which was to become our arch rival in operations research.

■ In 1967 IE&OR became a school, with Byron Saunders, who had chaired the department, as director. Bob Bechhofer headed the newly formed Department of Operations Research and nurtured its growth to preeminence. (In 1975 the school was reorganized under its present designation of OR&IE.)

■ The school's undergraduate program attracted large numbers of students—I recall teaching a class of one hundred seniors in 1967. The M.Eng. program was much stronger than it is now, with ample support for students. There was federal support for U.S. students at the Ph.D. level, and we were able to attract the very best; some of these are now leaders in our field.

"The Burroughs 220 and the CDC 1604 were our computing engines for the entire campus; they were something like a fast PC in horsepower."

Today's OR&IE undergraduates work on projects in the new microcomputing laboratory.

■ Dick Conway (then of the computer science faculty and now of Cornell's Johnson Graduate School of Management) and I were finishing the work on our book, *The Theory of Scheduling,* which is a classic; it is out of print, yet still relevant.

■ The Burroughs 220 and the CDC 1604 were our computing engines for the entire campus; they were something like a fast PC in horsepower.

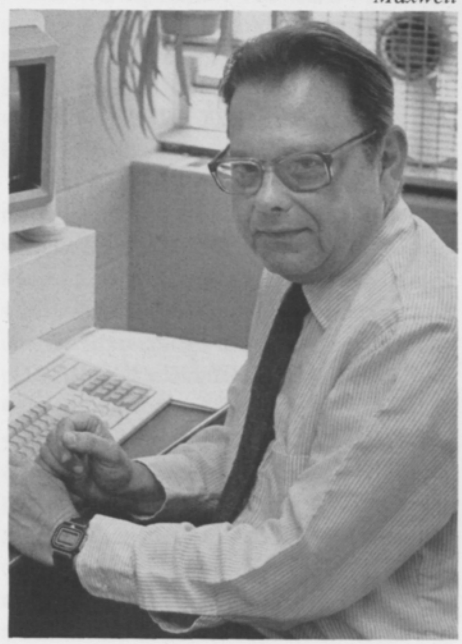
■ Dick Conway, Bob Walker (of the mathematics faculty) and I embarked upon CUPL, the predecessor of PL/C and current instructional computing languages.

William L. Maxwell, the Andrew Schultz, Jr. Professor of Industrial Engineering, is currently associate director for graduate education in the School of Operations Research and Industrial Engineering.

He was educated at Cornell, earning the B.M.E. degree in 1957 and the Ph.D. in 1961, and has been on the faculty since 1960. He has been a recipient of the Excellence in Teaching Award at the College of Engineering.

During leaves, Maxwell has been a consultant in residence at the RAND Corporation, General Motors Manufacturing Development, and SI Handling Systems, and he is currently a consultant to several companies. He has held visiting professorships at the University of Michigan, the Wharton School of the University of Pennsylvania, and Stanford University.

Maxwell



Gerald E. Rehkugler
Agricultural and Biological Engineering

In August 1966, when I returned to Cornell with a fresh Ph.D. after a two-year hiatus at Iowa State University, a new era in teaching had begun. I had previously taught several courses in agricultural engineering, and in some even taught the use of the slide rule. But in 1966 I had access to the computational power of the mainframe computers, albeit accessed via punch card and batch processing. (It was only a few years ago that I threw away the last of those punch cards from my earlier teaching modules.) And now on my desk and on many students' desks we have the computing power that was available only in the mainframes a decade or two ago.

Instrumentation for teaching in the 1960s and early 1970s remained quite primitive. It was always a test of ingenuity to set up a laboratory and obtain useful data within the two and one-half hours allotted. Stability of the signal output of most of our devices was nonexistent. The standard procedure for obtaining each data point was: balance, calibrate, read, and then repeat the process again and again.

An example of the evolution of teaching a lab course is illustrated by an exercise in traction testing that I taught with an agricultural tractor. In the 1960s and 1970s, when we wanted to measure traction versus wheel slip, we used a stopwatch, a hydraulic dynamometer, and a steel measuring tape. Each student had a task and everything was recorded on 10-column data sheets, which we shared by hand-copying at the end of the tests. It took most of the afternoon to get enough data for a few curves; obtaining answers to "What if?" questions was impossible in the time available. Today that same test is conducted with slip sensors, ultrasonic or radar speed measurement, an electronic dynamometer, and a digital data-acquisition system. Output of the results can be obtained in minutes and each student can access an electronic file of the results. "What if?" questions can be explored and answered in minutes rather than hours. We believe that these advances in technology have increased the effectiveness of teaching and learning, as well as research.

All of this has caused me to reflect on the influence of technological and scientific advances on both my teaching and student learning. With the proper use of technology, I now have the capability to condense, present, and interpret information with

Below: Modern equipment for testing farm machinery increases the effectiveness of research and instruction.

"It took most of the afternoon to get enough data for a few curves. . . . [Today] output of the results can be obtained in minutes [and] 'What if?' questions can be explored and answered in minutes rather than hours."

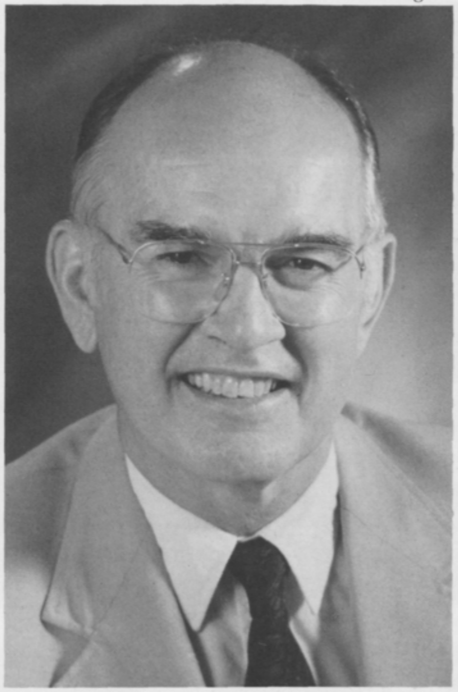
greater ease. However, the sorting process is much more difficult because of the immense glut of information. We have the tools to do things right, but unfortunately, we have a more difficult time being leaders in education by doing the right things. For instance, now we teachers can expect laser-sharp graphs and reports from our students, but neither we nor they may have concentrated on the understanding and the insights that are at the core of education.

In spite of all our technological advances, I believe that the fundamental process of teaching remains the same as when I started in the 1950s: (1) Establish your instructional objectives. (2) Assemble strategies and delivery systems to achieve those objectives. (3) Measure and monitor the progress toward meeting those objectives. (4) Readjust, improve, and modify on the basis of feedback and further insight. The delivery systems have changed, but the process remains.

The other essential factor in the educational process is the student-teacher relationship. Regardless of the times, the technology, or the system, the student and teacher must be mutally motivated and sharing in the learning process. This rapport is a timeless characteristic of education and when you have it, there is long-lasting satisfaction.

Thus I conclude that although I have had the satisfaction of participating in the technological development of fruit and vegetable harvesting equipment that has eliminated back-breaking labor for thousands of people, the most pleasure comes from the encounter with the former student who says, "Yes, I had you in Course xxx. That was a great course and I really found it useful."

Rehkugler



After Gerald E. Rehkugler received B.S. and M.S. degrees in agricultural engineering from Cornell in 1957 and 1958, respectively, he joined the department's faculty. In 1964 he studied at Iowa State University as a National Science Foundation faculty fellow and earned a Ph.D., awarded in 1966, and then returned to Cornell.

His research has covered many applications of engineering to agriculture and food processing. He is the recipient of five awards from the American Society of Agricultural Engineers for outstanding research publications.

Rehkugler has spent sabbatical leaves as a visiting professor of food engineering at Michigan State University and as a researcher at the Cornell Animal Science Teaching and Research Center.

He served as chairman of his department from 1984 to 1990, when he became associate dean for undergraduate programs at the College of Engineering.

Edwin L. Resler, Jr.

Mechanical and Aerospace Engineering

"Aeronautical to Aerospace and Beyond," my subject here, calls for more than the page or so suggested for these *Reflections*, and the account needs to begin earlier than the target date of 1966. I have been granted a little more leeway in my remarks.

My story begins in the fall of 1946, when the Graduate School of Aeronautical Engineering was founded at Cornell. Its first director was William Sears, previously of Northrop Aircraft, where he was chief aerodynamicist. He brought with him John Wild; the two of them had participated in the design and building of the Black Widow fighter and the Flying Wing. They were joined by Arthur Kantrowitz from the NACA (forerunner of NASA) Langley Field Laboratories; Y. H. Kuo, a Cal Tech graduate; and Carlo Riparbelli. Already here was Fred Ocvirk of "short bearing fame". The team was completed by Alice (Toni) Anthony, now administrative associate of the Sibley School of Mechanical and Aerospace Engineering, who was the earliest arrival, after Sears, and still looks after the school's graduates.

The first class to enter that school was made up primarily of World War II veterans who had either flown or maintained aircraft. Most of the chatter among those classmates was about their wartime experiences. The change from soldier to student was accomplished with great difficulty, but outstanding faculty members within and outside the school were on hand. For instance, Sears arranged that Richard Feynman, who was then at Cornell, would teach the students the mathematics they needed. Those early students formed a flying club and somehow managed to acquire a small airplane, and since there were a number of instructors in

1

2

3a

3b

4

1. Toni Anthony and founder William Sears were photographed at one of the early annual picnics of the Graduate School of Aeronautical Engineering, established in 1946. Toni Anthony is currently the administrative associate in the Sibley School of Mechanical and Aerospace Engineering.

2. Most of the members of the initial faculty appear in this photograph (loaned by Toni Anthony). From left to right are David Sears, Y. H. Kuo, John Wild, William Sears, Arthur Kantrowitz, and Carlo Riparbelli. Fred Ocvirk was also a member of the first faculty.

3. William Sears and John Wild helped design the YB-36 Flying Wing—precursor of today's Stealth aircraft—before they came to Cornell. (The picture of the Flying Wing, 3a, is from a glass transparency loaned by Resler. The photograph of the F-117 Stealth, 3b, was provided by Aviation Week and Space Technology.*)*

4. Sears returns to Cornell each year for the distinguished lectureship series that has been established in his honor. In this 1985 photograph he is greeting old friends (including Thomas Gold, at center). Sears piloted his own plane on the trip from his home in Arizona.

"Students in the school very quickly achieved Mach number flows greater than their age, but it took a number of years before they achieved Mach number flows greater than their weight."

the class, a majority of those at the school who were not already pilots learned to fly. This included members of the faculty.

The oldest member of the school in those days was not a faculty member, but a student—he had been a wing commander in the Canadian R.A.F. The youngest, called "Junior", was fresh out of the Navy, where he was the assistant engineering officer at the Miami Opa Locka Naval Air Station: the author of this piece.

The aircraft in those days were all propeller-driven. The students usually arrived at Cornell via the Lehigh Valley Railroad, but if they came by air it was via a twin-engined Beechcraft on Robinson Airlines. (Robinson Airlines later became Mohawk, then Allegheny, and is now U.S. Air.) The school had acquired a Link trainer for the DC-3, as well as one of the first jet fighters, "Smokey Stover", and also a partially completed P-49. The Link trainer was popular at parties. It was finally given to Mohawk so they could train their pilots to fly the DC-3s they had acquired.

The students were enrolled in a two-year master's degree program. Their theses were on automatic controls, boundary-layer control, combustion, shock tube studies, and wave engines. The first graduating class went out and participated in the design of the DC-8 and the Boeing 707, the first jets used in commercial service.

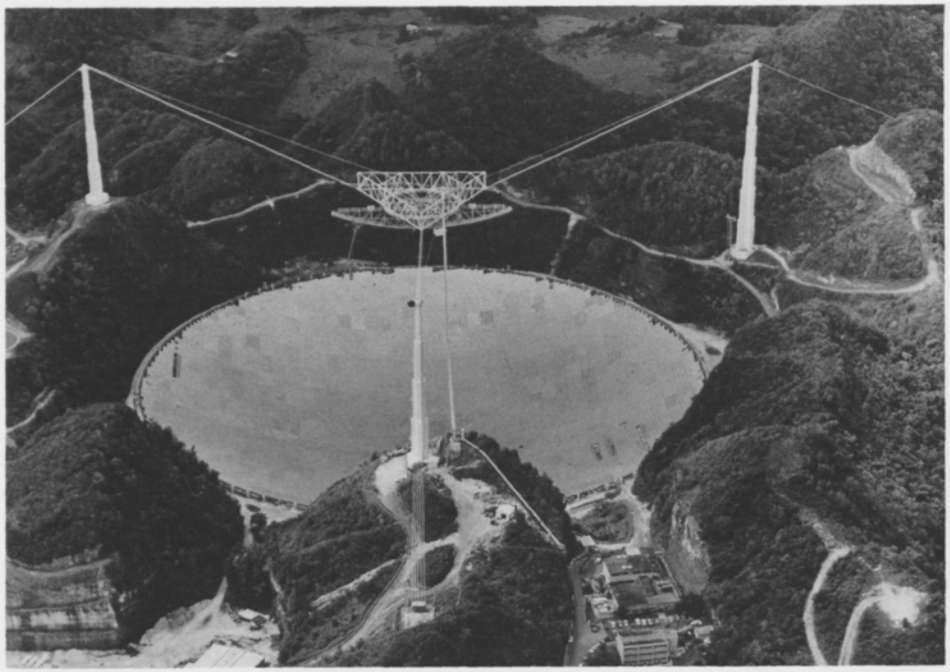
In the ensuing years the interests of the school became more wide-ranging. John Wild participated in the design of the Air Force's Arnold Engineering Test Center (he subcontracted much of the work to the students so they could earn extra funds); he became the Center's first Chief Engineer and so became the first faculty member to leave the Cornell school.

The shock tube technology developed by Kantrowitz and his students was used to help solve the reentry problem for ballistic missiles. (Missile ranges in the early 1950s were around 150 miles, not the 6,000 miles of those in the silos today.) Kantrowitz left Cornell to found the AVCO Everett Research Laboratories; the majority of the employees were Cornellians. The lab designed, and AVCO built, and still does, reentry nose cones for the long-range missiles. Other Cornell graduates of the school were engaged in similar studies at the General Electric Space Laboratory in Valley Forge, Pennsylvania, and the Cornell Aeronautical Laboratory in Buffalo, New York, which was then owned and operated by Cornell (it later became Calspan, Inc.). In those days "High Mach Number" was the buzzword. Students in the school very quickly achieved Mach number flows greater than their age, but it took a number of years before they achieved Mach number flows greater than their weight. When Kantrowitz left Cornell in 1956, I returned, this time from the Institute for Fluid Dynamics and Applied Mathematics at the University of Maryland.

It was an exciting time at Cornell. Bill Gordon and Henry Booker were designing the huge radio-radar telescope that was subsequently built near Arecibo, Puerto Rico, in the early 1960s. It was thought that the ionosphere surrounding the earth might emit waves or "jiggle" if an enemy long-range missile were to pierce it, and Sears and I were involved in the project to estimate such an effect. It turned out that the "jiggle" was not detectable, and the telescope was then free for radio astonomers to use to study quasars and other far-off heavenly bodies, and also to map out the contours of the moon in preparation for moon landings. At about this time, Tommy Gold, an old friend of the school, joined Cornell officially; later he founded the university's space center.

The field of magnetohydrodynamics became popular and was pursued by many graduates of the school. Various magnetohydrodynamic generators and pumps were designed and built with varying degrees of success. This work at Cornell led to the establishment in 1967 of the Laboratory of Plasma Studies, a cooperative venture of the university and the Naval Research Laboratory. The first director was Peter Auer of the aerospace engineering faculty. New projects at the lab resulted in new personnel in astronomy, electrical engineering, and engineering physics, as well as in the Graduate School of Aerospace Engineering, as it was then called in accord with the growing interest in aerospace technology.

The shock tube techniques that were developed to study the reentry problem were adopted, refined, and improved by members of the chemistry department, chiefly Simon Bauer. (The cooperation extends to this date, although Bauer officially retired a number of



The huge radio-radar telescope near Arecibo, Puerto Rico, was designed at Cornell and built in the early 1960s, and has been upgraded since then. It is now operated by Cornell under an agreement with the National Science Foundation.

years ago.) Work done at Cornell aided the development of the high-powered laser, the "death ray" of early "star wars" developments. The patent for the gasdynamic CO_2 high-powered laser is held by four persons, three of them veterans of the Aero School.

One of the first artificial heart pumps was built in the shop of the Aero School. It was designed by Kantrowitz and used in animals by his brother, who was on the staff of a New York hospital. Much was learned from the early experiments, and the work continued at the AVCO research laboratory in cooperation with Massachusetts General Hospital in Boston. Heart pumps and artificial hearts, now routinely used, and also other medical devices, are being designed and manufactured by graduates of the Aero School.

The faculty of the school participated in the formation and growth of the Department of Engineering Physics (now the School of Applied and Engineering Physics). And in 1963 Sears founded and became involved in the Center for Applied Mathematics at Cornell; while remaining on the Aero School faculty, he turned the directorship over to me. Later Sears joined the faculty of the University of Arizona.

At about that time, research at the school included work on the design of the United States supersonic transport, especially the sonic-boom aspects of the program. While on sabbatical, I worked on exotic propulsion schemes for submarines (such as portrayed in *The Hunt for Red October*) and began the early development of ferro-fluids, which are now produced by Ferrofluidics Corporation and play a role in audio equipment, computers, farm machinery, vacuum seals, etc.

Some members of the faculty became interested in the flow of fluids in the interior of the earth and one—Donald Turcotte—joined the Department of Geological Sciences and later served as its director. (A standing joke in that department, he has said, is that he is the only member who never studied geology.)

Nicholas Rott participated in propulsion studies sponsored by Ramo-Wooldridge; the schemes involved plasma propulsion, magnetohydrodynamic propulsion, and the use of liquid hydrogen. Also participating in this project was the present mayor of Ithaca, Emeritus Professor Ben Nichols. Rott left Cornell and ultimately became director of the Institut für Aerodynamik in Zürich. Another member of this group, Richard Seebass, followed Sears to Arizona; he is now dean of engineering at the University of Colorado.

In 1972, at a time when the novelty of space was wearing off, the Aero School and the Sibley School of Mechanical Engineering were merged to form the Sibley School of Mechanical and Aerospace Engineering. I became the first director, Al George became the second, and the incumbent, Frank Moon, is the third. Moon works in aerospace structures and the new field of chaos; Tob de Boer, the present associate director, is working on plasma ignition of jet engines for restart at high altitudes.

Another Sibley School professor who was a member of the Aero School faculty is Shan-Fu Shen, a member of both the Academy of Sciences of China and the National Academy of Engineering of the United States. Shen did extensive work in the field of the aerodynamics of rarefied gases and has continued to develop the theory of boundary-layer separation, a phenomenon to be avoided by any worthy aircraft. He participated also in the Cornell Injection Molding Program at the Sibley School, applying his expertise in viscous flow to the flow of molten plastic on its way to being formed into useful products.

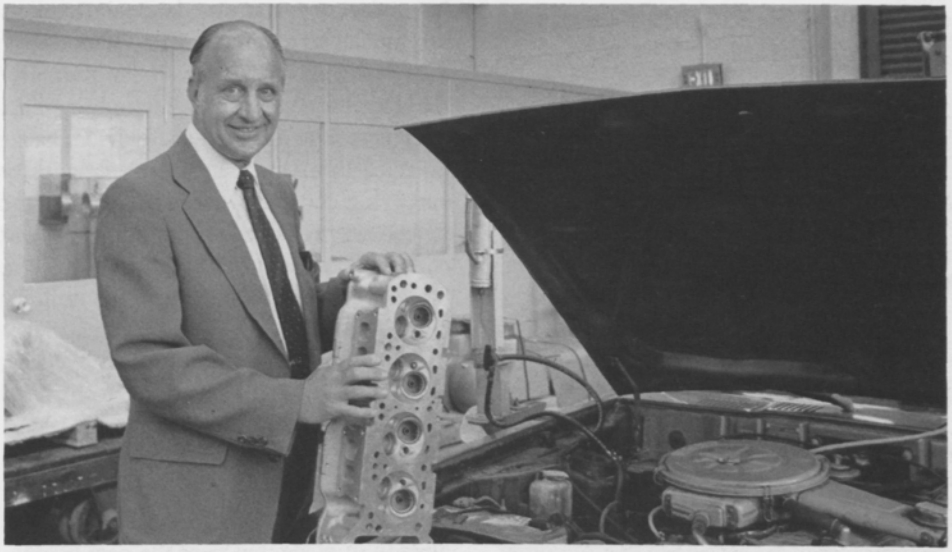
I have mentioned only some of the projects worked on over the years by a few of the faculty members who were associated with the old Aero School. Another story worth telling would be that of the school's graduates, who have become leaders in their field throughout the world. An early graduate, Frank Moore, went to the Cornell Aeronautical Laboratory and became the director of the Aerosciences Division there before returning to Cornell as a faculty member in 1965 (he is now the Joseph C. Ford Professor of Mechanical Engineering). Another graduate, Lewis Crabtree, served as president of the Royal Aeronautical Society; and Gerald Marsters is now the director of the National Aeronautical Establishment of the National Research Council of Canada. Other graduates are active in China, Japan, Germany, France, England, Canada, Australia—wherever the boundaries of space projects have been extended.

What is on the horizon? With the rapid growth of computer technology, aircraft and spacecraft can be designed more quickly and effectively, requiring much less testing. The aircraft being designed today will fly faster and higher and more safely. The spacecraft will explore further in our solar system, but to do so will require better propulsion units, maybe utilizing plasma dynamic systems and magnetohydrodynamics.

Flying higher and faster has opened new environmental problems—namely, the effect of engine exhaust on the ozone layer and the noise generated by the larger engines around airports. Work in the Sibley School that was directed toward the control of automobile exhaust emissions can be built on to help solve problems of emissions from future jet aircraft.

Since 1947, materials used in engines have improved immensely, as have the methods of using them in jet engines. Present engines utilize single-crystal, aerodynamically cooled blades, but because these blades are not good enough for the engines now being designed, replacing material blades with waves, which neither melt nor break but accomplish the same task, is again being considered. It's back to the wave engine! This time, however, we have thirty years' experience in appropriate aerodynamic theories and the aid of supercomputers.

Since the founding of the Aero School, many of humanity's dreams have been realized. Men have walked on the moon and returned safely, probes have explored the reaches of our solar system and beyond, and jet airports resemble the bus stations of yesteryear. Present projects are concerned with realizing the dreams for the year 2000 and beyond. The fulfillment of these dreams will no doubt be accomplished with the help of people trained by alumni of the old Aero School.



Edwin L. Resler, Jr., came to Cornell in 1947 after graduating from Notre Dame University, and received his Ph.D. in aeronautical engineering in 1951. He taught at Cornell for a year, and after four years at the Institute for Fluid Dynamics and Applied Mathematics of the University of Maryland, he returned to Cornell in 1956. Currently he is the Joseph Newton Pew, Jr. Professor of Engineering.

Resler worked on the early design of wave engines and in the areas of shock-tube research, magnetohydrodynamics, and ferrohydrodynamics. A number of patents resulted from studies pertaining to the control of combustion and the elimination of pollution in automobile engines. He is currently working on jet-propulsion systems for aircraft and space vehicles.

He has spent leaves at the AVCO Corporation, Pratt and Whitney's Advanced Engine Design Group, and NASA's Lewis Research Center. He has been a consultant to many industries.

He is a fellow of the American Institute of Aeronautics and Astronautics. He has served as an editor of various professional journals, as chairman of NASA's Advisory Committee for Fluid Mechanics, and as chairman of the Magnetohydrodynamics Committee of the American Rocket Society.

Ferdinand Rodriguez
Chemical Engineering

One memorable word of advice was whispered to Dustin Hoffman in the 1967 movie *The Graduate*. That word was *plastics*. The advice would have been well worth taking, for the use of plastics, the fastest growing sector of the polymer industry, has indeed boomed in the last quarter century. United States sales went from 10.5 billion pounds in 1965 to 58 billion pounds in 1990.

Of the other polymer-based industrial sectors, synthetic fibers also grew. Whereas in 1965 more cotton was used than all synthetic fibers put together, in 1990 mill usage of polyester *alone* exceeded that of cotton. Uses for coatings, adhesives, and rubber have grown at a slower pace, but even with these, the advances in polymer technology are readily apparent to consumers. Today's radial tires last twice as long as the old bias-ply tires, super glues and silicone adhesives are commonplace, and latex-based coatings have taken over many outdoor paint markets and almost all the indoor paint markets.

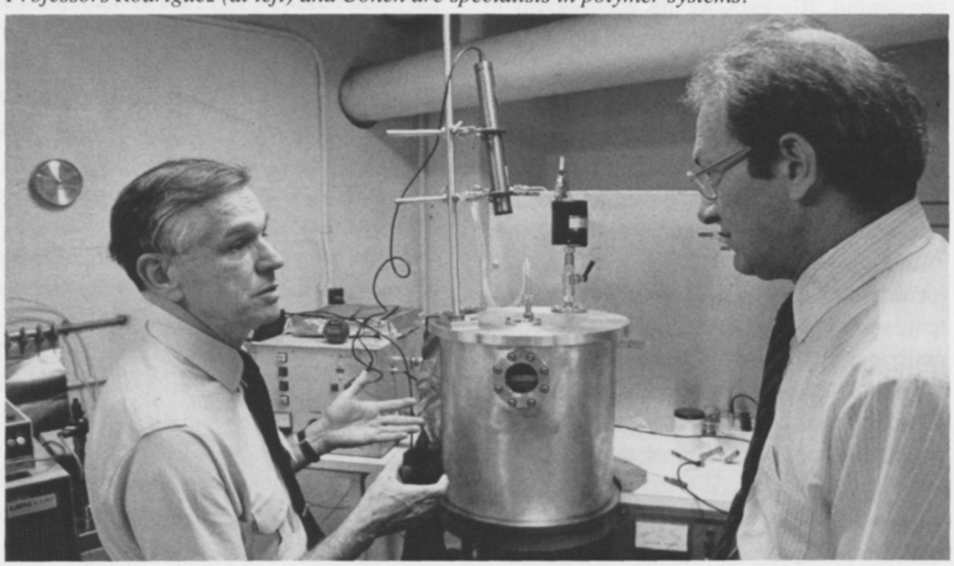
These innovations have been primarily the result of work by chemists and chemical engineers who are the technological backbone of the American chemical industry supplying consumer needs. Except for the development of some exotic composites and certain fibers, very few of the advances in polymers have been driven by military applications.

To keep pace with industrial advances, the number of course offerings in chemical engineering at Cornell has grown. In 1966 a polymer program—including undergraduate and graduate courses that Charles C. Winding had established in the 1940s—was already in place, but over the past twenty-five years there has been considerable growth in both supported research and specialty courses in the areas of polymer physical science (Professor Claude Cohen) and polymers for electronic applications (Professor James R. Engstrom and I). In addition, the importance of synthetic polymers has been recognized by people in other fields of science and engineering at Cornell.

". . . a fresh challenge is apparent in the new industry of recycling, still in its infancy."

With the dramatic growth of plastics in bottles and other forms of disposable packaging, a fresh challenge is apparent in the new industry of recycling, still in its infancy. It would be foolhardy to abandon the safety, economy, and convenience of modern packaging, most obvious in foods and medicines. But reduction of the small yet highly visible fraction of polymers in municipal waste is a realistic goal, and chemical engineers, with their knowledge of the chemistry and physics of polymeric materials, are leading the effort to find ways of achieving it.

Professors Rodriguez (at left) and Cohen are specialists in polymer systems.



Ferdinand Rodriguez, professor of chemical engineering, earned his doctorate at Cornell in 1958 and became a member of the faculty that fall. He had already earned B.S. and M.S. degrees at Case Institute of Technology and worked for four years at the Ferro Corporation. He is a registered professional engineer in Ohio.

He has spent leaves in industry—with Union Carbide, Imperial Chemical Industries, and Eastman Kodak—and (in 1985) at Queen Mary College, University of London.

At Cornell Rodriguez is associated with the National Nanofabrication Facility through his work on advanced lithography.

He is a fellow of the American Institute of Chemical Engineers.

Arthur L. Ruoff

Materials Science and Engineering

It was in 1955—eleven years before the advent of *Engineering: Cornell Quarterly*—that I arrived at the Cornell College of Engineering. What was it like at the college then? The faculty was dedicated to teaching undergraduates; there was little research underway. Usually the parents of the undergraduates paid for most of the students' education. The students understood the source when you quoted from *Hamlet*, cited Seneca or Marcus Aurelius, or referred to classical Greek art or the Renaissance. The administration was capable of providing free parking. At Cornell freedom of speech was practiced and strongly defended and we were free of social engineering.

What is the college like in 1991? We now have a major research effort; there are currently 801 graduate students in M.S./Ph.D. programs in engineering, and 247 in the professional Master of Engineering program. We have new departments, including Materials Science and Engineering, which was established in 1965; in MS&E we now have an undergraduate program (rated first in the nation in the Gourman report) with twenty-five or thirty seniors graduating each year. Our students are bright, but I find they are less knowledgeable in mathematics and liberal arts than students used to be. Parking is inadequate and expensive. The "politically correct" syndrome is prospering at Cornell and is the most serious threat to free speech since the time I arrived on campus.

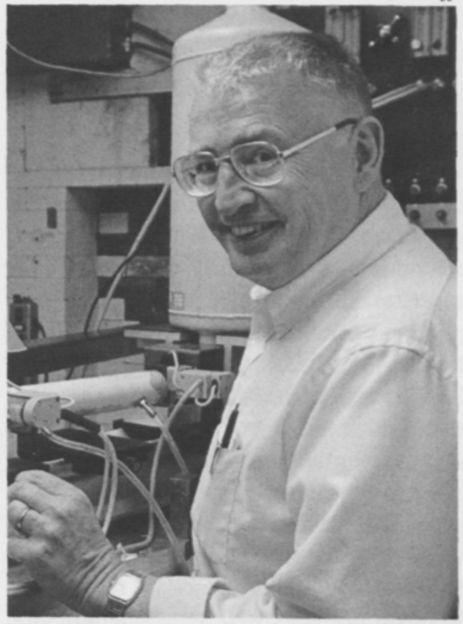
There are now major facilities that make Cornell a mecca for research in materials science. These include the Materials Science Center, the Cornell High Energy Synchrotron Source (a national resource), the National Nanofabrication Facility, and the

"There are now major facilities that make Cornell a mecca for research in materials science."

Cornell Theory Center (which includes a national supercomputer facility). These, and the research performed, are primarily supported by the federal government, but close to 20 percent of our research support now comes from industry, much of it via the Cornell Ceramics Program, the SRC Program on Microscience and Technology (Cornell is a SRC "center of excellence"), and the Industry-Cornell Alliance for Electronic Packaging.

In our department we have expertise in ceramics, metals, polymers, and semiconductors, and on materials for structures large and small: composites for airplanes, for example, or carefully made materials for computer chips. We have achieved static pressures greater than those at the center of the earth, carried out x-ray diffraction on samples as small as 10^{-11} cubic centimeter, and studied polymer interdiffusion with use of Rutherford backscattering. Our research is internationally respected.

Of our more than one hundred Ph.D. students, about 25 to 30 percent are foreign—the best and brightest from their native lands. Since many of these foreign students remain in the United States, this constitutes a giant brain drain—a lend-lease in reverse. If better United States applicants were available, we'd take them. Our criterion is: excellence. A great department, a great college, a great university, and a great country owe their eminence to a relentless drive for excellence.



Arthur L. Ruoff came to Cornell in 1955 as a member of the Department of Mechanics and Materials. He is now the Class of 1912 Professor of Engineering in the Department of Materials Science and Engineering.

At Cornell he has served as director of his department and as chairman of the program committee of the National Nanofabrication Facility. He initiated the Industrial Affiliates Program in Materials Science and Engineering, and also the Cornell Ceramics Program, which he directs.

Ruoff received the B.S. degree from Purdue University in 1952 and the Ph.D. from the University of Utah in 1955. A specialist in ultra-pressure phenomena, he has published two books as well as several hundred papers. His research includes studies on x-ray diffraction at pressures greater than those at the earth's center.

Ruoff has been a visiting professor at the University of Illinois as a National Science Foundation fellow. In 1966–67 the American Society for Engineering Education presented him the Western Electric Fund Award for Excellence in Instruction of Engineering Students. He is a fellow of the American Physical Society.

Andrew Schultz, Jr.

Operations Research and Industrial Engineering; Dean, 1963–72

Twenty-five years ago, when *Engineering: Cornell Quarterly* was started, our immediate objectives at the college seemed obvious and accepted. The goal was to put the Cornell University College of Engineering in a position to play an important role in modern engineering education and in the research and technology essential to it. This required development of new standards for faculty recruitment and tenure decisions, as well as for graduate-student admissions. It also required a curricular structure that made it feasible for the faculties of the various schools and departments to respond to societal needs as well as to scientific and technological developments, and thereby to provide opportunities attractive to excellent undergraduates, wisely selected. Publications, procedures, faculty seminars, committee activities, and administrative structural changes all played a role in these endeavors, which were largely successful.

One change, instituted shortly before the *Quarterly* began publication, was a change from the five-year undergraduate curriculum that had been in place since 1946—a curriculum that led to a bachelor's degree in one of the engineering schools—to a four-year Bachelor of Science program followed by an optional one-year professional Master of Engineering program in a particular field. The idea behind the five-year curriculum was that this length of time was needed to provide students with both an adequate foundation in science and technology and sufficient opportunity to explore social and environmental issues. For many reasons, the five-year curriculum had become less attractive, however, and so the program was restructured: There are two decision points—one after two years of basic study, when the student chooses an undergraduate field in which to concentrate, and another after four years, when the B.S. degree is awarded and the student has the opportunity to select a professional field in which to pursue a year of graduate study concentrated on advanced technology and design and culminating in an M.Eng. degree. This program is educationally sound, offering an opportunity for the student to experience the design process in a realistic environment, and although it has required some time to become widely understood and recognized, it appears to be well accepted now.

What changes in engineering education are needed today? There is no question that the country and therefore the profession face serious challenges in modern economic competition. The problems are complex and intractable, with political as well as technological aspects. The United States is preeminent in scientific and technological advancement, but once the developments are in process or completed, they seem to be adopted much more rapidly in other industrial economies. In the United States the linkages between academia and industry are somehow more limited than they should be, and the nation pays the price for this, not only in the loss of markets, but also in diminished ability to sustain superior technological and scientific development in related areas.

In my time, I was quite familiar with two developments that illustrate this difficulty. In each case, a generation was to pass before the ideas were adopted by a significant number of industries.

One is the concept of *statistical quality control*. This was originally developed within Bell Laboratories and was fully exposed in the late 1920s and early 1930s in various publications, including a book by W. A. Shewhart. By 1946, accelerated without doubt by federal intervention in World War II, a significant number of large industrial firms had become familiar with the technology and were applying it. Unfortunately, many discarded it after the war was over.

The second concept is that of *work simplification*, which was introduced by a Cornellian, the late Allan Mogensen. Again, there was a gap of almost a generation before the idea was adopted and implemented, even though Mogensen developed an educational program to hasten the process. By the 1950s, though, techniques of work simplification were used by a number of large corporate organizations.

These two concepts are the foundation of the Quality Circles so successful in Japan, and they have led to many other changes in management and personnel relations there.

With our ability at Cornell to carry out research and technological development in so many areas, a major challenge is to maximize the importance and the economic im-

"In the United States the linkages between academia and industry are somehow more limited than they should be, and the nation pays the price for this. . . ."

pact of the activities selected. Engineers and scientists in general enjoy the challenge of new problems and the process of solving them; however, selection of the important ones demands knowledge of the problems of industry as well as those of the specific field. Such knowledge is desirable for the classroom as well as for the research laboratory, and a major problem facing both colleges and industries is how to knit the kinds of relationships that produce the essential knowledge on both sides. Integrating their aims and implementing them effectively are important for both industry and education, and ultimately for the well-being of society.

In this space it is not possible to elaborate much on the breadth and depth of the industrial-productivity problem that faces the nation. But this problem does present a most serious challenge to us all, and extends beyond the limits of engineering education. Required for its solution are major changes in public policies, relationships between workers and management, and industrial organizational structure as well as financial and accounting systems and measures. These issues must be resolved before the country's abilities in research and technology can be fully realized.

Andrew Schultz, Jr., the Spencer T. Olin Professor of Engineering, emeritus, began his Cornell career as an undergraduate in administrative engineering (class of 1936), earned a doctorate in 1941, joined the faculty after World War II, headed the Department of Industrial Engineering and Administration for twelve years, and served as dean of the College of Engineering from 1963 to 1972 and as acting dean in 1978. Now living in Ithaca, New York, and Ponte Vedra Beach, Florida, he continues to be active in educational and professional affairs.

Schultz helped develop the new field of operations research on the basis of his wartime experience as an officer in the Office of the Chief of Ordnance, as well as a sabbatical leave spent at the Army's Operations Research Office. At Cornell he established the department that is now constituted as the School of Operations Research and Industrial Engineering. As dean he initiated and supported many educational and extracurricular innovations (including the establishment of Engineering: Cornell Quarterly*).*

He has been active also at the national level, particularly as a board member of the Engineers Council for Professional Development; as a member of the Commission on Education for the National Academy of Engineering; and as vice president and director of research for the Logistics Management Institute in Washington, and subsequently, for twelve years, as chairman of the Board of Trustees of that organization. In addition, he has been active as an industrial and educational consultant.

Schultz is a fellow of the American Institute of Industrial Engineers and the American Association for the Advancement of Science.

Schultz

Norman R. Scott

Agricultural and Biological Engineering

Agriculture during the twentieth century has provided a bounty of low-cost, nutritious, and healthful foods for not only the United States, but the world. From the early part of the century, when the focus was on agricultural production, to the present, with its focus on the quality of foods and maintaining the environment, agricultural engineers have played a key role in the workings of a highly efficient food-producing machine.

The era of mechanization led to tremendous improvements in production efficiency during the 1940s and 1950s and into the 1960s. Following and overlapping this era of mechanization, agriculture experienced immense gains through "chemotechnology"—the development of inorganic fertilizers, herbicides, pesticides, and fungicides. Beginning in the late 1950s, but gaining momentum in the early 1980s, agriculture entered the era of biology. The promise of biotechnology to dramatically transform plant and animal agriculture is perceived as almost limitless.

Clearly, agricultural engineers were at the very heart of the era of mechanization, in the development of power units and equipment to create a mechanized agriculture that became the envy of the world. In fact, the tremendous success due to mechanization through advances in engineering research and design has led to a perception that agricultural engineers are "tractor engineers" or "tractor drivers!" Then, and today, agricultural engineers are frequently asked what it is they do. The question provides the agricultural engineer an opportunity to explain his or her role as an engineer applying scientific

"The promise of biotechnology to dramatically transform plant and animal agriculture is perceived as almost limitless."

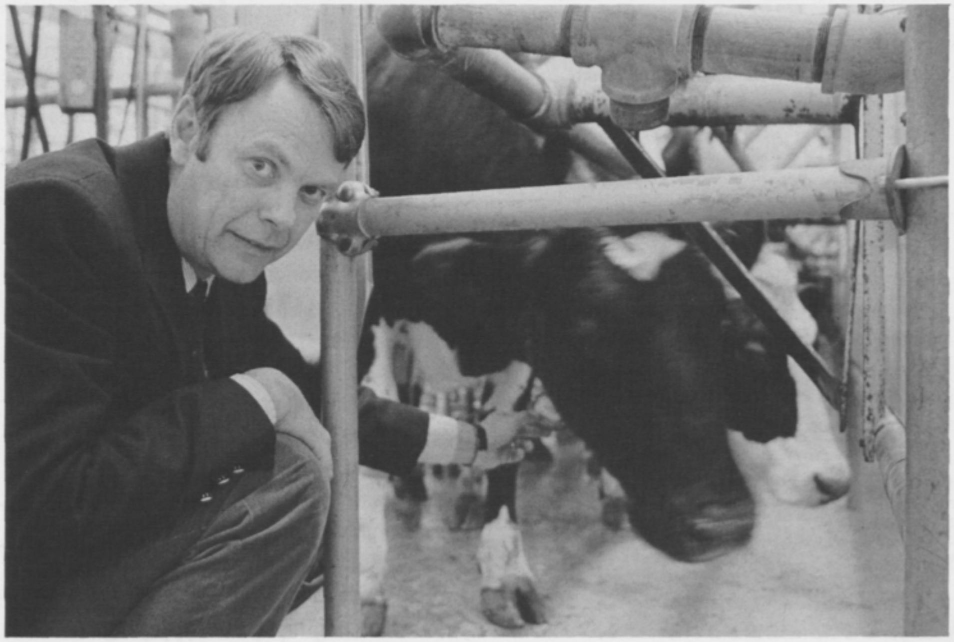
expertise to any and all elements of the production of food, from the seed to the consumer.

Prior to the 1970s, education in agricultural engineering consisted of a broad engineering background with a main focus on physical processes in food production. The curriculum was heavily entrenched in mathematics, physics, and an array of engineering sciences, including thermodynamics, fluid mechanics, materials, and electrical systems; it provided a relatively small number of courses in the biological sciences. Research and design was concerned primarily with physical systems for farm machinery, farm structures, irrigation, drainage, farm electrification, and systems for processing and handling materials.

Today there is a changing focus, as reflected in the recent renaming of the department as Agricultural and Biological Engineering. Where the emphasis used to be on machines for harvesting fruits and vegetables, now it is on the biological properties of these products, and the interaction with mechanical systems. Where the early emphasis was on farm structures, the focus is now on the biological interactions of animals and products housed within those structures. Today's agricultural and biological engineer takes the biological-systems approach to bioprocessing, food engineering, livestock engineering, plant and cell mechanics, preservation and handling of agricultural products, biological waste treatment, alternative energy systems for production and conservation, and environmental protection and management.

John Naisbitt assessed the outlook for agriculture in his book *Megatrends*. "Things aren't going to get better," he wrote. "They are going to get different." Engineering for agriculture in the 1990s and the next century is going to be different because its main concern will be with biological systems for applications in farming, food processing, forestry, and the environment. Agricultural and biological engineers will make a difference.

Scott



Norman R. Scott spends more time these days in Day Hall than in the barn, since he is Cornell's vice president for research and advanced studies as well as professor of agricultural and biological engineering.

Scott was graduated from Washington State University in 1958 and joined the Cornell faculty after completing his doctorate here in 1962. He served as chairman of his department from 1978 to 1984, and then as director of the Agricultural Experiment Station and director for research at the College of Agriculture and Life Sciences until 1989. He has spent leaves at Case Western Reserve University with the biomedical engineering faculty, and at the National Institute for Research in Dairying in England.

He is a fellow of the American Society of Agricultural Engineers and has received four awards for research publications from that organization. In 1990 he was elected to the National Academy of Engineering.

Dennis G. Shepherd
Mechanical Engineering

"In 1966, there were thirty-five or forty mechanical engineering graduate students; today there are just under one hundred."

It is always a good thing to begin at the beginning. So where was the Sibley School of Mechanical and Aerospace Engineering at the birth of the *Quarterly* in 1966?

That was about the time the College of Engineering returned to a four-year undergraduate program after the twenty years of the "noble experiment"—the five-year program. For Sibley, this was symptomatic of a change in emphasis from the undergraduate program to graduate study and research.

The importance of research activity had been recognized for some time, but its growth was leisurely. Some figures tell the story: in 1966, only about 50 percent of the Sibley faculty had the doctoral degree; today there are none without it. In 1966, there were thirty-five or forty mechanical engineering graduate students; today there are just under one hundred. It is this growth that shapes my perspective of major change over the years of the *Quarterly*.

This viewpoint is consistent with the results of an event in 1973 that was of great consequence for two divisions of the college: the amalgamation of the Graduate School of Aerospace Engineering and the Sibley School to form the Sibley School of Mechanical and Aerospace Engineering. The Sibley School faculty increased from sixteen people in mechanical engineering to a total of twenty-three, with the seven new members providing a lively group of researchers in high-tech engineering.

So now in 1991, M&AE has a research standing second to none. But, after twenty-five years, have we thrown the baby out with the bath water? Countrywide, there are screams of anguish regarding the state of education in practically every level and discipline, from day school to college (except for graduate research).

This may suggest a prospect for the future, but I am quite unable to prophesy, except to predict that overall the future will be an electronic one. Or am I behind, and we are already in the quarkic age?

Nevertheless, I still relish a verse of long ago, whose provenance I have forgotten, but whose words I remember:

A decent docent doesn't doze,
He teaches standing on his toes,
His student dassn't doze but does,
And that's all teaching ever wuz.

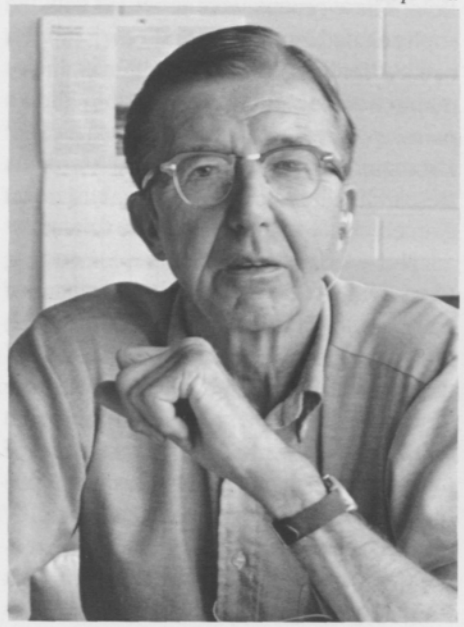
Dennis G. Shepherd, the John Edson Sweet Professor of Engineering, emeritus, has been a member of Cornell's mechanical engineering faculty since 1948.

After studying engineering mathematics and engineering physics at the University of Michigan, he spent fourteen years in industrial research and development in Canada and in his native England, where he participated in early work on turbojet engines and gas turbines. A more recent interest has been wind energy. He is the author of books on fluid mechanics, turbomachinery, and propulsion.

At Cornell he served as head of the Department of Thermal Engineering and later as director of the Sibley School of Mechanical Engineering. He twice received the College of Engineering's annual Excellence in Teaching Award.

Shepherd has held visiting appointments at Imperial College, London, the Technische Hogeschool in Delft, The Netherlands, and the Organization for European Economic Cooperation. He is a fellow of the American Society of Mechanical Engineers and was awarded that society's Worcester Reed Warner Medal. Other honors he has received include a Guggenheim fellowship.

Shepherd



John Silcox

Applied and Engineering Physics

"Once again, concern over materials is high and a renewed federal priority may emerge in the next few years."

From the perspective of 1991, the decade of the 1960s takes on the aura of a "golden age". One result of the U.S. response to the first Sputnik was to identify the development of advanced materials as a priority, and Materials Research Laboratories were established at selected universities across the country to enhance the training of scientists in this field. These centers were provided with the sophisticated equipment and other support needed for carrying out multidisciplinary research of the type conducted in the nation's premier research laboratories, such as Bell Laboratories. One of these new Materials Research Laboratories was established at Cornell as the Materials Science Center.

This was the situation when I arrived at Cornell in 1961 to join the Department of Engineering Physics. Now, thirty years later, I am director of the Materials Science Center, and I am struggling with somewhat the same issues that were prevalent in the decade of the sixties. Once again, concern over materials is high and a renewed federal priority may emerge in the next few years.

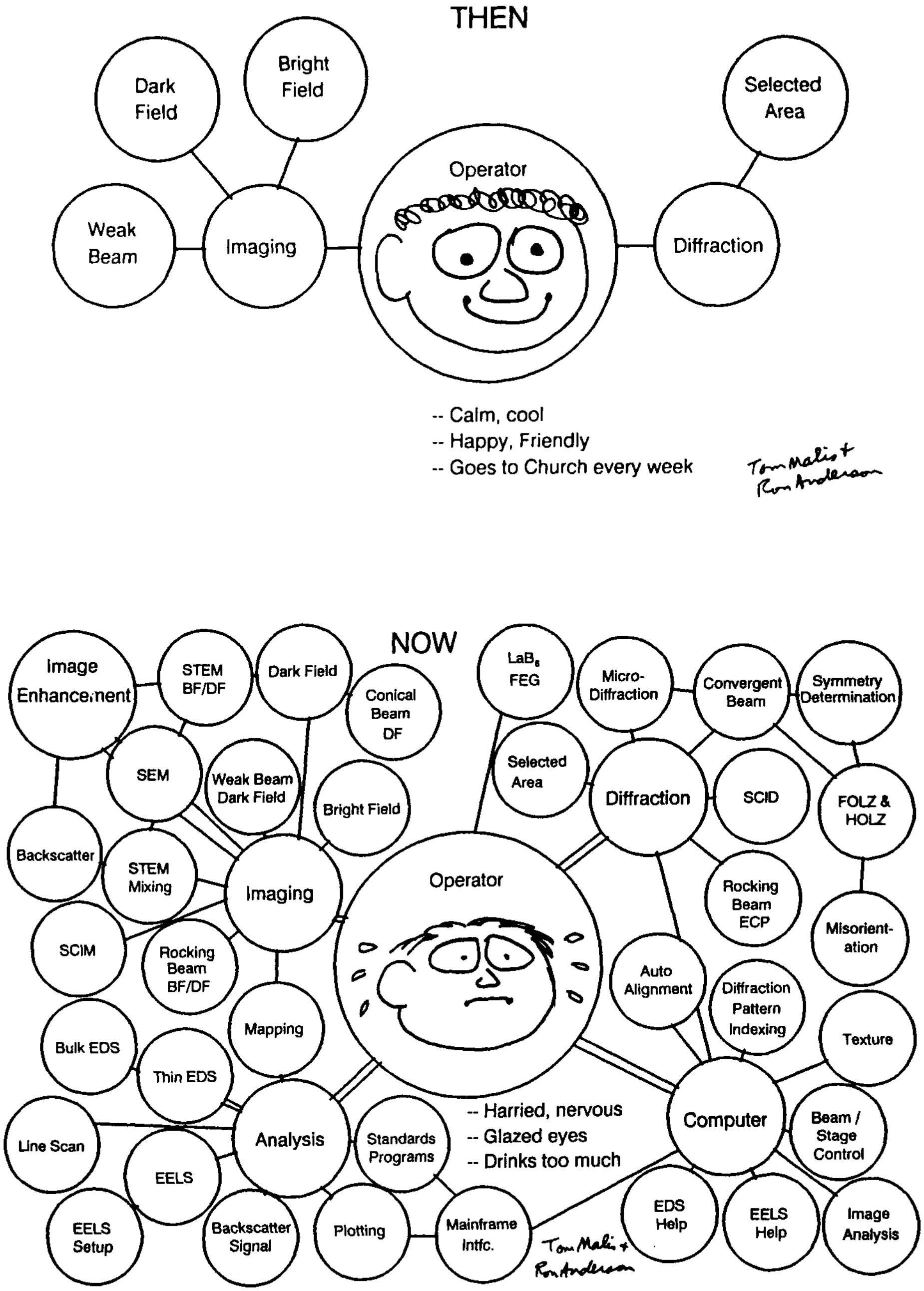
My field of research is electron microscopy of materials. Shortly before I arrived at Cambridge University's Cavendish Laboratory to do Ph.D. thesis work with Peter B. Hirsch, his group had startled the materials world by demonstrating that dislocations in thin metal films could be imaged directly through the use of transmission electron microscopy. This was recognized as immensely important for the study of materials, since such microstructural defects are often critical in determining practical properties of materials. Today electron microscopy is deeply embedded in materials science departments in this country—it is taught even at the undergraduate level—but it is not an active field of research in physics departments, as it is in Britain. Cornell is almost unique in that there is a group in physics (myself and Michael Isaacson in the School of Applied and Engineering Physics) pursuing work that attempts to realize the full potential of this approach.

What else has happened in thirty years? For one thing, the cost of equipment—such as an advanced electron microscope—needed for an advanced materials research center has gone up by a factor of almost forty, from around $40,000 to around $1.5 million. This reflects a growth in complexity, as illustrated in the cartoon on the opposite page, and it represents enormous progress in the field. The level at which we can now ask questions and expect to find a useful answer in studies of the microstructure of materials includes not just atomic arrangements, but also microchemistry and even microelectronic structure.

Other costs, including graduate tuition, have also gone up. Since graduate tuition is paid primarily through fellowships or outside research support, the high cost is not seen by the students themselves, but is a matter of concern to the program directors of the federal agencies and to the faculty members who are directing the graduate research. Even at Cornell, the struggle to provide adequate resources for an active research program is assuming proportions that, at a minimum, carry the potential for significant distortion of the educational process. Maintaining a balance between research and educational activities has become a "hot" issue. Unfortunately, in my view, the debate has taken on a confrontational tone and there seems little effort to resolve the real issues and to reduce the real pressures that are involved.

The past thirty years have also brought changes in the undergraduate program. When I came to Cornell, the notion of an engineering physics undergraduate program was new to me, and appealing; my education had been in physics, but my Ph.D. thesis work was clearly in an applied area. The Cornell program, which provided a physics-based curriculum in an engineering environment, was impressive—strong in mathematics and physics, and equally strong in engineering. The curriculum included course work in electronic circuits, gas-phase dynamics, thermodynamics, statistical mechanics, and solid mechanics, and also in chemistry (including organic chemistry). The program even included a seminar course that provided training in presenting work through written and oral reports and a project. All this was achieved in a five-year curriculum with a solid set of requirements through the fifth year (where a few electives crept in). The program attracted motivated, intellectually strong students who well merited the "intel-

Below: Electron microscopy THEN and NOW, as depicted by Tom Malis and Ron Anderson. This cartoon appeared previously in The Bulletin of the Electron Microscopy Society of America.



lectual supermen" epithet reported in Carl Becker's *History of Cornell.* Alumni, with some pride, have termed the program "an intellectual boot camp".

Over the years, the program has changed from five years to four, and the first two years are now essentially the same for all engineering students, so as to defer the need to choose a major until, usually, the junior year. Students entering engineering physics are not likely to have taken advanced courses in the underclass years, and in addition, we have reduced the upperclass requirements to permit flexibility in electives. (As a conservative old fuddy-duddy, though, it is my view that flexibility in a later career is made possible by using the undergraduate years for achieving a solid basis in the fundamentals rather than for getting an introduction to the latest whiz-bang technology. The latter may get you started, but what happens when the next new technique comes along?) Our students are still very bright and hard-working. We do our best to challenge them and to provide the careful advising they need to navigate the route in the two years we still have left. They seem to succeed, although whether the successes of the students we had in the sixties will be matched is hard to predict.

The education of both undergraduates and graduate students has become much more difficult and challenging, with programs at both educational levels presenting new needs and priorities. A result, not only in my field but all across the engineering disciplines, has been a growing tension between undergraduate and graduate programs in decisions about how those needs and priorities should be met. In my view, simplistic measures for reducing this tension by cutting back on one side or the other are likely to fail, particularly at Cornell, where all our students are taught by the same active, practicing professionals. How effective the faculty is in both aspects of its responsibility depends on how carefully that responsibility is defined. I believe that the continued high reputation of engineering at Cornell depends on a successful resolution of this issue.

John Silcox is the David E. Burr Professor of Engineering in the School of Applied and Engineering Physics, and currently he is the director of Cornell's Materials Science Center. He has twice served as director of his school.

Silcox came to Cornell in 1961 after studies in England for the B.Sc. degree from Bristol University and the Ph.D. from Cambridge. He has spent sabbatical leaves as a Guggenheim fellow in France and England in 1967–68, at Bell Laboratories in 1974–75, and at Arizona State University in 1983.

He is a fellow of the American Physical Society and a member and past president of the Electron Micrsocopy Society of America. He has served on the Solid State Sciences Committee of the National Academy of Sciences/National Research Council, and currently he is a member of the Materials Advisory Committee for the National Science Foundation. He also serves on advisory committees for the Argonne National Laboratory and Arizona State University.

Silcox

Julian C. Smith
Chemical Engineering and Continuing Education

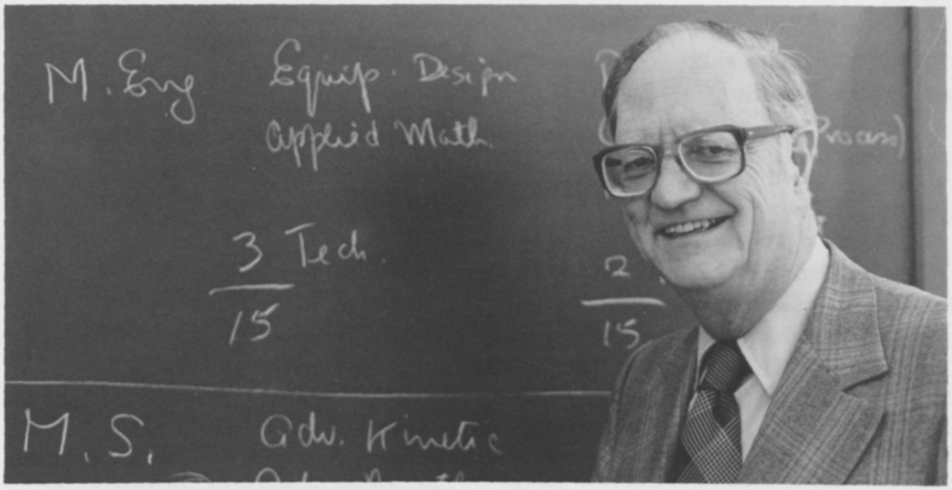
Continuing education—the provision of courses for off-campus students—was a special concern of mine twenty-five years ago. For seven years, beginning in 1965, I organized a variety of programs, mostly noncredit, for engineers in industry. As a land-grant university, Cornell has an obligation to provide extension education, and these programs were offered as part of that effort. They were designed to combat a perceived rapid obsolescence of practicing engineers. "With technology changing so fast," we predicted, "an engineer with no continuing education will be obsolete five years after graduation."

Some programs succeeded very well. Others didn't. The ambitious Guideposts Program would have brought practicing engineers to Cornell for several weeks every year for up to five years to take a series of noncredit courses. This program failed to attract any participants, however. More successful offerings included:

- Modern Engineering Concepts—a full-time, four-week, noncredit course given each fall at IBM's facility in Endicott, New York. The purpose was to provide engineers in middle management with an overview of current concepts in a range of technical subjects. Cornell professors gave lectures summarizing developments in their various fields.
- Blackboard by Wire—courses in metallurgy, given in-house for Sylvania (GTE) at the plant in Towanda, Pennsylvania, and simultaneously to students at Cornell. Two such courses were given by Robert Balluffi, and one by George Smith and Che-Yu Li, all of the Department of Materials Science and Engineering. Most of the off-campus students took these courses for academic credit. The professor talked to the students by telephone while writing on an X–Y plotter at Cornell, sending signals over the telephone lines so that his writing was reproduced on a TV screen at the Sylvania plant. (This was considered high technology at the time.)
- Basics of Chemical Engineering for Chemists—a four-week, noncredit course given in Endicott at IBM's request. Ray Thorpe of the Schoo! of Chemical Engineering was the professor.
- A group of six to eight noncredit courses on various subjects, given on campus for between four and twelve days each summer. The most popular (and lucrative) of these courses was Introduction to Finite Elements, taught by Richard Gallagher of the School of Civil and Environmental Engineering.
- Two major federally funded programs: Modern Technology in the Construction Industry, sponsored by the U.S. Department of Commerce; and a program of technology transfer for industries in the Southern Tier of New York State, sponsored jointly by the federal and state Departments of Commerce. The course on construction technology flourished for several years with good industrial participation. It involved a series of lectures on campus each winter, and periodic visits by Cornell faculty members to construction sites. This program was headed by George Blessis of Civil Engineering and later by Brig. Gen. (Ret.) Richard Jewett. The technology-transfer program was funded under the State Technical Services Act of 1965, part of President Lyndon Johnson's "Great Society" initiative. It was run by Donald Gordon of the college staff. He and I studied the feasibility of giving courses by TV to nearby industries, but concluded it was too expensive.

Later, an off-campus program designed to lead to a Master of Engineering degree

"While Ithaca and Cornell are still 'centrally isolated' geographically from major industrial centers, they are no longer isolated electronically."



was organized (not through my office) by Byron Saunders, a professor in the School of Operations Research and Industrial Engineering, and approved by the Graduate School on an experimental basis. Films were made during regular class sessions of several courses, mostly in engineering mathematics. The classes were held in a specially modified classroom in Phillips Hall and the films were sent to nearby industrial sites for the students to view. The students took the course examinations at their workplace, and their papers were returned to Cornell for grading by the professors. Corning Glass Works provided the bulk of the funding for this venture, as well as most of the students. The initial enrollment was about fifty, but only one or perhaps two of the people ever received a Cornell degree by this means.

All the noncredit programs, except for the summer courses, ended in 1971. The construction and technology-transfer courses lost their funding, and IBM decided that seven years was long enough for their in-house offerings. Overall, the program was only moderately successful, despite a lot of effort. It made no money for the college; in fact, it never quite broke even. The noncredit programs were overwhelmingly more popular than the credit programs; at that time, most practicing engineers in nearby industries evidently did not have the time, the motivation, or sometimes the ability, to meet Cornell's high academic standards.

In spite of this history, however, there may be a place for continuing education in Cornell's future. Requests by industry for in-house programs continue to increase. While Ithaca and Cornell are still "centrally isolated" geographically from major industrial centers, they are no longer isolated electronically. Communication methods are now available that would make possible all kinds of off-campus programs at reasonable cost.

The success of any such programs, however, requires the enthusiastic support of Cornell faculty members who see the effort needed as something they want to do. Given faculty support and that of the Graduate School and the College of Engineering administration, continuing education in the twenty-first century could well become a significant part of the educational mission of the college.

Julian C. Smith has spent not just twenty-five years at the Cornell College of Engineering, but more than fifty. He entered as a freshman in 1937, graduated with the B.Chem. degree in 1941 and the Chem.E. in 1942, and joined the chemical engineering faculty in 1946 after four years with E.I. du Pont de Nemours. He became professor, emeritus, in 1986.

During his tenure, Smith served as director of continuing education for the College of Engineering, and as associate director and then director (from 1975 to 1983) of the School of Chemical Engineering.

He is a co-author of Unit Operations in Chemical Engineering, *now in its fourth edition, and he has published extensively in his specialty fields of mixing, solids handling, and phase equilibria. He also wrote a history of the School of Chemical Engineering, published in 1988. He holds two patents.*

Smith is a licensed professional engineer in New York and has served as a consultant to many government agencies and industrial firms, including du Pont and Rockwell International. He has been a visiting professor in Scotland, a UNESCO consultant in Venezuela, and a visitor to Nigeria and Colombia on behalf of the U.S. Department of State. He is a fellow of the American Institute of Chemical Engineers.

Ravi Sudan

Electrical Engineering and Plasma Studies

I had prepared for a career in the heavy electrical industry that the newly independent India had projected for the future in its Five Year Plans. But delays in the execution of such plans forced me to look elsewhere. Through a combination of fortuitous circumstances, I found myself at Cornell in November 1958, working as a research associate for Sam Linke.

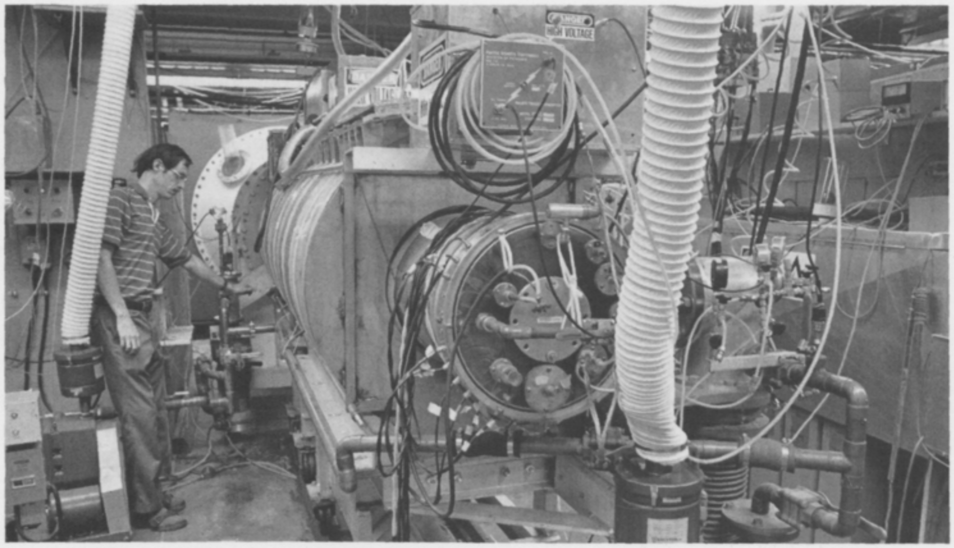
This was an especially opportune time because great changes were imminent in the College of Engineering. After World War II, the federal government became almost the sole architect of the research-funding edifice that has powered the universities and national laboratories for the past forty years or so. The impact of this development was about to be felt in the college through the appointment of Dale Corson as the new dean of engineering in 1959. In the same year, Henry Booker took the helm in electrical engineering as its director. Booker had led the theoretical effort behind British radar development during the war. He possessed both the scientific credentials and the personal qualities needed to radically transform the School of Electrical Engineering into a research-oriented institution.

In the development of radar and other science-based technologies during World War II, it had become very evident that the training of engineers on the basis of detailed study of particular devices was woefully inadequate for dealing with new concepts. To correct this situation, a conscious decision was made to increase the effort devoted to fundamental sciences in engineering education. As a consequence, newly hired faculty members were oriented more toward applied sciences than toward conventional engineering. The electrical engineering curriculum underwent a radical change. Hallowed courses in electrical machinery, illumination design, etc. were dumped without much ceremony or regret. The college also trimmed its five-year bachelor's degree program to four years, in line with the competition. This swift wind of change had a somewhat chilling effect on me: I was obsolescent before I had begun my career at Cornell. It is said that the threat of execution clears the mind instantly and wonderfully. I can testify that it worked for me.

In that period I was tempted by two major scientific currents at Cornell. Bill Gordon of Electrical Engineering had come up with the idea of using a giant radar to probe the ionosphere—a seminal concept that led to the formation of the Center for Radiophysics and Space Research in Phillips Hall and the construction of the Arecibo Radio Telescope in Puerto Rico. Soon Henry Booker, Tommy Gold, Bill Gordon, and Ed Salpeter had set up a world-class enterprise in space science. The other thrust was in Aerospace Engineering under Bill Sears, Ed Resler, and Arthur Kantrowitz. The science of a magnetized conducting fluid (magnetohydrodynamics) was being developed and pioneering work on shock waves in ionized gases was in progress.

Rather than work with these two groups, where my ignorance could easily be unmasked, I chose to study high-temperature collisionless plasma, a regime close to but not covered by the major-league players. By the spring of 1963, I had mustered enough courage to give the first course on the kinetic theory of plasma. I was fortunate to attract a very fine group of graduate students to this class. I have all along suspected that they knew more than I did but were too polite to let on. Don Kerr, now president of EG&G, Mike Roberts of the Department of Energy, and Moshe Lubin, president of Hampshire

Below: The ion ring experiment is carried out in the Laboratory of Plasma Studies facility in the basement of Grumman Hall. The equipment shown is a high-power pulsed generator for producing intense ion beams trapped in a magnetic mirror.



"Both currents—space science and plasma physics—have merged in the present Laboratory of Plasma Studies."

Instruments, were among the members of this class.

The activity in plasma physics flourished and at the urging of Ed Resler it was consolidated by Dean Andy Schultz into the Laboratory of Plasma Studies. Its subsequent growth under Deans Ed Cranch, Tom Everhart, and Bill Streett is chronicled in a special collection of articles from *Engineering: Cornell Quarterly* that was published in 1987 in connection with the laboratory's twentieth anniversary. Both currents—space science and plasma physics—have merged in the present Laboratory of Plasma Studies.

I have also closely observed and participated in the arrival of the Computer Age at Cornell. My first research task in 1958 was to analyze the electrical performance of a power station under disturbed conditions; this was done on the university's IBM 650 computer, in retrospect only a toy machine compared to its descendents. In the early seventies, Geoffrey Chester, Ed Salpeter, Ken Wilson, and I operated a terminal that gave us access to the remote supercomputers at U.S. national laboratories. In the eighties, I was happy to be associated with Ken Wilson in the big push to establish a NSF-supported supercomputer facility on campus in partnership with IBM. There is no doubt that the Cornell Theory Center has altered the scientific and intellectual landscape of the university.

It appears to me that the pendulum of curricular change initiated in the early sixties has reached the full extent of its swing. There is a certain loss of patience with courses on basic sciences; more discussion of devices and design-oriented curricula are sought. Perhaps this is necessary to restore the balance between analysis and synthesis, but we should also keep in mind lessons of the past.

Another debate that has erupted is one that pits teaching versus research. This is unfortunate because, as all of us know, these two synergistic activities are intertwined. Neither survives for long without the other in a great university.

Ravi Sudan, the IBM Professor of Engineering at Cornell, is a faculty member of both the School of Electrical Engineering and the School of Applied and Engineering Physics. He is a member of the Laboratory of Plasma Studies and was its director from 1975 to 1985. He also helped establish the Cornell Theory Center, a national supercomputer facility, and served as its deputy director from 1985 to 1987.

Sudan studied in India and subsequently in England, where he earned a Ph.D. from Imperial College, University of London, in 1955. After working for several years in England and India, he came to Cornell in 1958.

His research has been in the areas of plasma physics, thermonuclear fusion, high-power electron- and ion-beam physics, and space physics. He has had visiting appointments at laboratories in England and Italy, as well as the United States; these include the U.S. Naval Research Laboratory, where he headed the theoretical plasma physics section. He has chaired several international conferences and has given invited lectures in the U.S.S.R., France, and Germany. He is co-editor of two volumes of the Handbook of Plasma Physics *and is on the editorial boards of several journals.*

Sudan is a fellow of the American Physical Society and in 1989 was awarded its James Clerk Maxwell Prize. He is a fellow also of the Institute of Electrical and Electronics Engineers and of the American Association for the Advancement of Science.

Sudan

C. L. Tang
Electrical Engineering

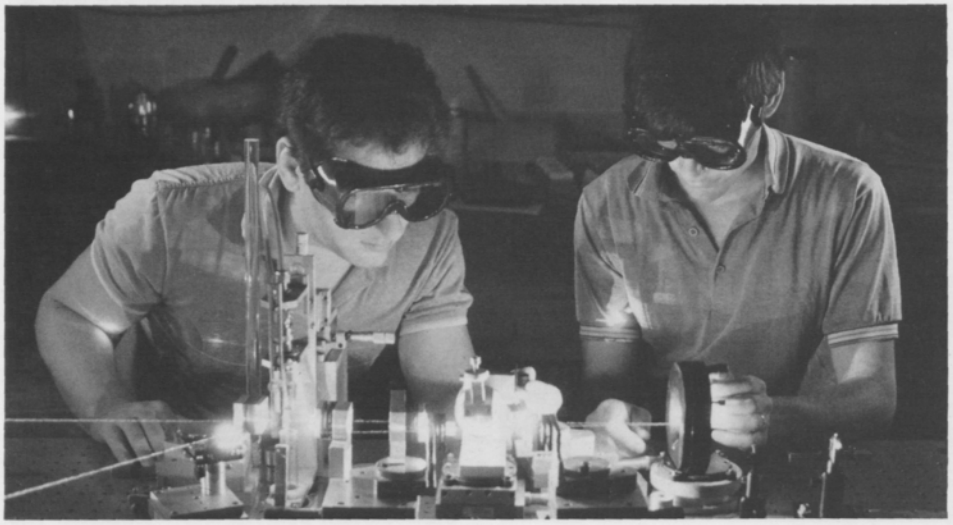
Optoelectronics is today one of the most active and fertile fields of research, with enormous potential for benefits to society.

Its origin goes back to the invention of the laser in the late 1950s and the semiconductor laser in the early 1960s. At first it was by no means clear that these devices were anything more than interesting sources of coherent radiation, useful primarily for scientific research in the esoteric subject of spectroscopy. A joke sometimes heard in those days was that the laser was a solution looking for a problem. Today the question is whether and how to bring fiber optics to every home. What a difference twenty-five years of research and development have made!

In looking ahead to the next quarter century, I would like to add a word of caution. The period beginning in the early sixties was an exciting and rewarding time for university researchers. Americans were stimulated by the launching of the Soviets' artificial satellite Sputnik, and expanding and raising the standards of research and education in high technology became a national goal. Support for research and graduate education was at its peak, and they flourished. So did the undergraduate educational programs. In the research-university community it was understood that the knowledge and the vitality generated in the graduate research program would enrich the undergraduate program as well. The fact that research universities such as Cornell have attracted highly qualified undergraduate students speaks well for policies that promote a strong research program and recognize its value to students, faculty, the institution, and the nation. This is a particularly important consideration in the present era of global economic competition, when there is urgent need to raise the standards of engineering education in order to produce more and better-trained engineers.

We would be wise not to lose sight of the philosophy upon which past successes in research universities are based.

Graduate students participate in optoelectronics research at Cornell.



"A joke sometimes heard in those days was that the laser was a solution looking for a problem. Today the question is whether and how to bring fiber optics to every home."

Tang

C. L. Tang, a specialist in laser physics and technology, is the Spencer T. Olin Professor in the School of Electrical Engineering.

He holds the B.S. degree from the University of Washington at Seattle, the M.S. from the California Institute of Technology, and the Ph.D. from Harvard University. Before coming to Cornell in 1964, he spent a year at the Technical University in Aachen, Germany, and four years as a researcher at the Raytheon Company.

Tang is a member of the National Academy of Engineering and a fellow of the American Physical Society, the American Optical Society, and the Institute of Electrical and Electronics Engineers.

H. C. Torng
Electrical Engineering

In 1956, when I came to Cornell, there was one computer, an IBM 650, for Electrical Engineering, perhaps for the entire university. This machine used a magnetic drum as its memory and the basic machine code programming was the order of the day. Just recently, an instructional computing facility was opened in Phillips Hall with sixteen Mac IIs, nine HP Vector workstations, and seventeen Apollo workstations, each of which is many, many times more powerful than the IBM 650.

Progress in device technology, machine organization, and software development all contributed to this amazing evolution in computing and communications, and Cornell has developed vibrant research programs in all these areas. In device technology, for example, we have made significant contributions in materials, fabrication, and measurements. Currently, the School of Electrical Engineering, with industrial cooperation, is developing a center for research in optoelectronics and photonics.

In the late 1950s the school offered only one course, Switching Circuits, that was related to computer design, and there was one faculty member with even tangential interest in the subject. We now offer some fifteen courses in the design, architecture, implementation, and applications of computers, and there are nine faculty members involved with computer engineering, and a highly regarded Department of Computer Science besides.

Recently, faculty members from Electrical Engineering and Computer Science launched Project 2000, in which we seek to develop, evaluate, and implement the bold, innovative concepts in computer systems design and applications that are needed as we proceed toward the twenty-first century.

"Progress in device technology, machine organization, and software development all contributed to this amazing evolution in computing and communications. . . ."

This instructional computing facility was recently opened at the School of Electrical Engineering. Fifty workstations and computers were provided by Hewlett-Packard and Apple.

H. C. Torng, professor of electrical engineering, is a specialist in computer engineering, telecommunications, and VLSI digital systems. He came to Cornell in 1956 after graduating from National Taiwan University, and he joined the faculty here after earning his Ph.D. in 1960. He is currently the coordinator of graduate studies for the School of Electrical Engineering.

During two sabbatical leaves, Torng served as a member of the technical staff at Bell Laboratories, and he has been a consultant to government and industrial organizations. He is a fellow of the Institute of Electrical and Electronics Engineers (IEEE) and served as a Distinguished Visiting Lecturer of the IEEE Computer Society from 1983 to 1986.

Torng

Robert L. Von Berg
Chemical Engineering

In the period just before 1965 there was considerable activity at Cornell in nuclear energy, and I was heavily involved in it. The Ward Laboratory of Nuclear Engineering was designed and built; it contained a versatile research reactor and perhaps the best facility for using gamma radiation that existed in any university.

At this time I taught courses in nuclear engineering and the applications of chemistry and chemical engineering, and consulted with several national laboratories. I was fortunate to have several students supported by Atomic Energy Commission fellowships, and we used the gamma radiation facility in research on nuclear-fuel processing and radiation chemistry. The development of nuclear power was considered to be important to the future, and there were many graduate students in nuclear science and engineering and in chemical engineering who hoped to work in the field of nuclear engineering.

Looking back, it is amazing to see how quickly all that changed. In large part, the reasons have been political rather than scientific or technological. Now we still have a few students who plan to go into the nuclear-power industry, but the future of that industry is a big question mark.

My teaching and research slowly moved toward chemical process and plant design, but I still have great interest and confidence in nuclear power. I still look forward to the day when nuclear engineering will again be an important field.

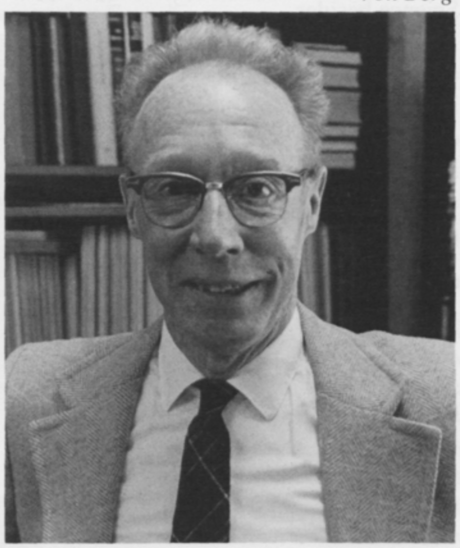
"I still look forward to the day when nuclear engineering will again be an important field."

Robert L. Von Berg, an emeritus professor of chemical engineering, joined the Cornell faculty in 1946 after completing his doctoral studies at the Massachusetts Institute of Technology and working for several years in the engineering department of E. I. du Pont de Nemours and Company. He holds B.S. and M.S. degrees from West Virginia University.

In recent years his research interests centered on the desalination of salt water by a freezing process and in the use of gamma radiation for controlled chemical conversions such as ammonia synthesis.

He spent sabbatical leaves at Dow Chemical (1953–54), as a NATO fellow at the Delft Technical Institute in The Netherlands (1960–61), at the Los Alamos Scientific Laboratory (1967–68), as a visiting professor at the University of Newcastle in Australia (1974–75), and at the University of Canterbury in Christchurch, New Zealand (1982 and 1988). He retired in 1988.

Von Berg



Lionel I. Weiss
Operations Research and Industrial Engineering

As with many other fields, a major force for change in operations research and industrial engineering has been the increasing speed, power, and availability of computers.

First, some background. The name *industrial engineering* goes back much farther than *operations research.* Both fields are concerned with finding efficient ways of carrying out activities, but industrial engineering tends to look at less complicated activities than operations research does. For example, early in its history, "time and motion study" was an important part of industrial engineering. In such a study, the movements of an operator of a machine might be observed to see whether a change in the physical setup could improve the operation in some way, and data would be collected and subjected to statistical analysis of a fairly unsophisticated kind. Operations research looks at much more complicated activities. It developed during World War II, when teams of scientists and mathematicians were asked to help plan industrial and military operations, and over the years its usefulness has increased along with that of the computer.

Several new mathematical techniques have been applied in operations research. Probably the best known is *linear programming*, which is an algorithm for minimizing (or maximizing) a linear function of several variables that must satisfy a set of linear equalities and inequalities. A concrete example is the "feed mix" problem, in which several varieties of grain are available, each variety having its own content of various vitamins, minerals, fiber, and moisture, and each costing a different amount per unit weight. The problem is to create a mixture of

"[An important] effect of the availability of powerful computers is the ability to actually solve problems in which there is a very large number of variables."

these grains weighing, say, one ton, and containing at least a certain specified amount of each vitamin and mineral, and no more than specified amounts of fiber and moisture, at minimum possible cost. The familiar techniques of differential calculus cannot be applied to such a problem because of the inequalities imposed.

There are many other situations in which linear programming problems are encountered; two important ones are fuel-mixing problems (in which different varieties of fuel are to be mixed) and transportation problems (in which the least costly routes must be found to deliver goods from a set of origins to a set of destinations). Some linear-programming problems of practical importance have more than a thousand variables and more than a thousand linear restrictions of these variables.

For many years, the algorithm used to solve linear-programming problems was the *simplex method* developed by G. B. Dantzig. This worked well on many large problems arising in practice; however, it was shown that it was possible to create "worst case" linear programming problems that could not be solved within a reasonable time by the simplex method, even with the most powerful computers then in existence. Thus it created quite a stir when, in 1979, the Russian mathematician Khachian published an algorithm that could do this. The stir was so big, in fact, that it was described in a front-page article in the *New York Times*. Not many developments in mathematics get this sort of attention. It turned out that in most problems arising in practice, the simplex algorithm performed better than Khachian's, but this did not diminish the interest in worst-case comparisons in linear programming problems and also in problems requiring other kinds of algorithms. An important result of the availability of powerful computers is research into just how powerful a computer would have to be in order to solve any mathematical problem of a specified type. This research is often highly mathematical.

A second important, and more obvious, effect of the availability of powerful computers is the ability to actually solve problems in which there is a very large number of variables. This capability has led to large savings in fuel mixing, telephone-call routing, and other operations involving the use of valuable resources.

Computer simulation is a third important technique that is often used in operations research. Here a mathematical model of a complex system is created, and the computer is set to work to find out how the performance of the system would be affected by various changes in the system. The mathematical model is often quite elaborate, and usually must take random occurrences into account. Some sophisticated statistical techniques have been developed to analyze computer output in simulation studies.

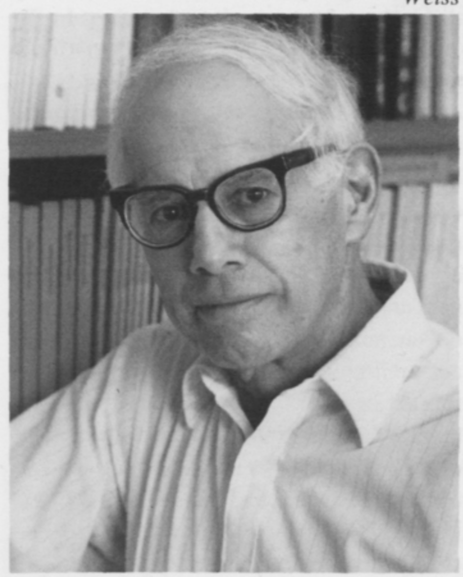
Simulation studies are required when it is not feasible to experiment on an actual system. An example is a study to determine which firefighting facilities in New York City could be closed down without creating dangerous gaps in coverage. This is not the sort of situation in which tinkering with the actual system without prior careful analysis would be desirable. This kind of analysis, for all but the simplest systems, would be impossible without the existence of powerful computers.

Lionel I. Weiss is a professor in Cornell's School of Operations Research and Industrial Engineering. Currently he is serving as associate director for undergraduate education, as well as pursuing research in statistical theory.

Weiss studied at Columbia University for an undergraduate degree in mathematics and economics, and M.A. and Ph.D. degrees in mathematical statistics. After receiving his doctorate in 1953, he taught economics at the University of Virginia and mathematics at the University of Oregon before joining the Cornell faculty in 1957.

He has been a consultant to the General Electric Company and the Exxon Corporation. He is a fellow of the Institute of Mathematical Statistics.

Weiss



Richard N. White
Civil and Environmental Engineering

While I perceive that students seem to be getting younger each year, there has not been any substantial change, over the thirty years I have been at Cornell, in the attitudes, study habits, and overall goals of our undergraduate students in engineering. We continue to be blessed with exceptionally capable young people with essentially unlimited potential.

We now see, however, a much stronger demand for students with graduate degrees, particularly the professionally-oriented Master of Engineering degree. In fact, many of the leading design firms now hire only at the master's level. We also see greatly increased opportunities in civil engineering practice for engineers with Ph.D. degrees—a reflection of the fact that many aspects of practice have become much more sophisticated.

Computing permeates our every activity and has drastically changed the way civil engineering is practiced, particularly in my discipline of structural engineering. In the 1950s and early 1960s, we still had "small armies" of people with slide rules and hand calculators doing analysis and design of structures. Thanks to the computer and to well developed analysis and design software, we can now undertake most designs without these tedious hand calculations. The greatly enhanced efficiency of computer-aided design and drafting enables civil engineers to devote much more time to better conceptual and preliminary designs; it also leads to more refined designs of complex structural systems. We have pioneered the development of these methodologies for improving our teaching of structural engineering at Cornell. I think that all of these computer-related changes have been extremely positive.

"Cornell led the way nationally by changing the name of our school from Civil Engineering to Civil and Environmental Engineering."

Another "quiet revolution" that deserves mention is the use of better and higher-strength materials in construction. Concrete design strengths used in practice in the 1990s can be more than four times the typical strengths used thirty years ago. Indeed, all of our construction materials have been improved, and this has led to higher design stresses and smaller structural dimensions and often to less inherent resistance to certain structural actions. Thus, designs must be done more carefully and more thoroughly, with proper attention to durability and to extended service life.

Another point I want to mention is our better appreciation for the environment and the continuing development of technologies to handle serious problems such as hazardous waste. Cornell led the way nationally by changing the name of our school from Civil Engineering to Civil and Environmental Engineering. The challenge for the future is to do even better in how we use, build in, and manage our environment.

Richard N. White, the James A. Friend Family Distinguished Professor of Engineering, has been a Cornell faculty member since 1961. He has served as director of the School of Civil and Environmental Engineering and as associate dean for undergraduate programs at the College of Engineering.

White holds three degrees from the University of Wisconsin; he received his doctorate in 1961. Early in his career, he worked for a firm of consulting engineers in Madison, and served in the U.S. Army Corps of Engineers in Virginia. He has spent sabbatical leaves at the University of California at Berkeley and at Gulf General Atomic.

He is a fellow of the American Concrete Institute and of the American Society of Civil Engineers, and a co-recipient of the ASCE's Collingwood Prize. He is a registered professional engineer in the State of New York.

White is a co-author of five texts on structural engineering.

White

George Wolga

Applied and Engineering Physics and Electrical Engineering

In my view, three significant changes have taken place within the College of Engineering during the three decades I have been teaching here.

The first is a transition from a faculty in great part representing engineering practice, to a faculty promoting engineering science over the broadest spectrum. The two engineering units I have had most experience with are Applied and Engineering Physics and Electrical Engineering. The former was my own school as an undergraduate. With EP, as it was then referred to, establishing engineering science was fundamental; that was the motivation for creating EP in the first place. Within EE, the situation in 1961 was much more in transition. There was a strong group of faculty members active in work on radio waves, and the Arecibo radio-radar telescope was under construction. In the areas of microwaves, control, and systems, faculty members trained in research were starting to build research programs. My own hiring led to the first research with lasers, then an idea looking for significant applications and now almost ubiquitous in research groups throughout the college. Today engineering science is so strong that we are all concerned about ensuring that engineering practice is sufficiently represented in our various curricula.

"The first [of three significant changes] is a transition from a faculty in great part representing engineering practice, to a faculty promoting engineering science over the broadest spectrum."

The second significant change is the growth of centers and interdisciplinary research and teaching. In 1960 the Materials Science Center had been created as a result of the vision of Cornell faculty and the availability of ARPA (now DARPA) funds. This center was the first, and an enduring, example of the interdisciplinary approach to research. Subsequently, many centers were proposed and funded to take advantage of significant research frontiers. The National Astronomy and Ionosphere Center (which operates the Arecibo facility), the National Nanofabrication Facility, the Center for Applied Mathematics, the Cornell Theory Center and its Cornell National Supercomputer Facility, and the Cornell High Energy Synchrotron Source (CHESS) are other examples of the successful melding of faculty expertise in interdisciplinary centers and programs with a common focus.

The third change I wish to mention is the introduction and subsequent proliferation of computers across the college. I remember in the early 1960s when the Hewlett-Packard HP-35 pocket calculator was demonstrated to the EE faculty. At that time slide rules were still in use, some early study of analog computers had begun, and to my best recollection no digital computer was in use in Phillips Hall. Today our students use "calculators" more powerful than some mini-computers of the past. We have the Department of Computer Science and a section of computer engineering within the School of Electrical Engineering, and each engineering undergraduate takes courses in programming and uses computers as an integral part of much classwork. A revolution indeed!

George J. Wolga, a professor in two Cornell engineering schools, lists his specialty fields as lasers, applied spectroscopy, and semiconductor materials and devices.

Wolga earned a bachelor's degree in engineering physics at Cornell in 1953, studied at the Massachusetts Institute of Technology for a Ph.D., awarded in 1957, and taught at M.I.T. before returning to Cornell as a faculty member in electrical engineering in 1961. His joint appointment in applied and engineering physics began in 1964.

That same year he founded the Lansing Research Corporation in Ithaca and currently serves as vice president and consultant to that firm, which specializes in laboratory and electronic equipment. He has been a consultant to a number of other firms and to the Naval Research Laboratory, where he served as head of the Laser Physics Branch in 1969–70.

Wolga

REGISTER


Lee


Nilson

Four faculty members—Charles A. Lee, Arthur H. Nilson, Thor N. Rhodin, and Edward D. Wolf—became professors, emeriti, during 1990–91. Also, Sidney Kaufman, an acting professor, retired from the Department of Geological Sciences.

■ **Charles A. Lee**, a specialist in solid-state physics and devices, joined the faculty of the School of Electrical Engineering in 1967.

He received the B.S.E.E. degree from Rensselaer Polytechnic Institute in 1944, spent three years in military service, and earned the Ph.D. at Columbia University in 1953. After a postdoctoral year at Columbia, he joined Bell Telephone Laboratories, where he invented the first microwave transistors and junction photomultipliers.

At Cornell he continued research on the theory and fabrication of new high-frequency devices. He is a founder of the National Research and Resource Facility for Submicron Structures (now the National Nanofabrication Facility) and originated research there on ion-beam lithography. He holds eighteen patents and has been a consultant for a number of electronics companies.

Lee retired this summer and remains in Ithaca. He and his recently retired colleague G. Conrad Dalman are writing a textbook on microwave science and technology.

■ **Arthur H. Nilson**, who also retired this summer, joined the School of Civil and Environmental Engineering in 1956 after receiving a B.S. degree at Stanford University, working for six years as an engineer, and earning an M.S. degree at Cornell. He earned a doctorate at the University of California at Berkeley in 1967 while on leave.

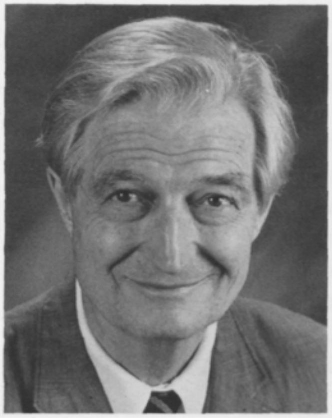
A specialist in structural concrete and concrete materials technology, Nilson is the author of widely used textbooks on reinforced concrete and prestressed concrete. He is a fellow of the American Society of Civil Engineers (ASCE) and of the American Concrete Institute (ACI), and received the ACI's Wason Medal for his research in 1974, 1986, and 1987.

He has held a National Science Foundation Science Faculty Fellowship and a Danforth Teachers Fellowship, both at Berkeley, and he has had visiting appointments at universities in Italy, Switzerland, and England. At Cornell he was chairman of the Department of Structural Engineering for five years and twice served as acting chairman. He is a registered professional engineer in New York, Connecticut, and Maine, where he now makes his home.

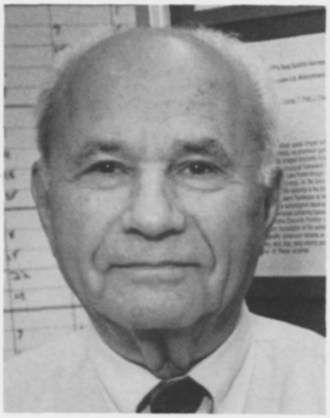
■ **Thor N. Rhodin** had completed thirty-three years at Cornell when he retired from the School of Applied and Engineering Physics this spring. He plans to remain in Ithaca.

Rhodin graduated from Haverford College in 1942, and studied at Princeton University for the A.M. and the Ph.D., awarded in 1946. After postdoctoral study at the University of Chicago Institute for the Study of Metals, he spent seven years with the Engineering Research Laboratory of E. I. du Pont de Nemours and Company, and then joined the Cornell faculty in engineering physics and metallurgical engineering in 1958.

A specialist in the physics and chemistry of solid and liquid surfaces and interfaces, Rhodin's research has focused on the areas of materials science, microelectronics, and condensed-matter physics, primarily in association with the Materials Science Center and the National Nanofabrication Facility at Cornell. He is a fellow of the American Physical Society and a 1986 Humboldt Senior Scientist Award recipient. He has held visiting professorial appointments in Germany, Japan, England, Russia, and France.


Rhodin


Wolf


Kaufman

His publications include a book, *The Nature of the Surface Chemical Bond.* He is working on a graduate-level text on the chemistry and physics of surfaces and interfaces.

At the college, Rhodin has served as associate dean and director of continuing education and as director of the Master of Engineering program. This summer he was named associate director for international science and technology at the Mario Einaudi Center for International Studies at Cornell.

■ **Edward D. Wolf** came to Cornell in 1978 as professor of electrical engineering and initial director of the National Research and Resource Facility for Submicron Structures (now the National Nanofabrication Facility), a directorship he held until 1988. He retired at the end of the fall 1990 term, but remains in Ithaca.

Wolf's degrees are a bachelor's from McPherson College and a 1961 Ph.D. from Iowa State University. Before coming to Cornell, he spent fifteen years in industrial research, first at the Rockwell International Science Center, and then at Hughes Research Laboratories. His research at Hughes included early work in scanning electron-beam microscopy and microfabrication.

In 1986–87 Wolf spent a sabbatical leave as a visitor at three institutions—Trinity College, Cambridge University, England; the Technical University of Vienna; and the Schrödinger Society for Microscience. Recently, he and two colleagues invented a "gene gun" capable of introducing genetic substances into cells and tissues, and founded Biolistics, Inc., which has sold the technology rights to du Pont.

He is a fellow of the Institute of Electrical and Electronics Engineers and of the American Institute of Chemists, and a scientific member of the Böhmische Physical Society.

■ **Sidney Kaufman**, a specialist in seismic reflection profiling for studying deep continental structure, came to Cornell in 1974 after retiring from the Shell Development Company. His work in the Department of Geological Sciences centered on the Consortium for Continental Reflection Profiling (COCORP), for which Cornell is the operating institution. In recent years Kaufman was executive director of the consortium and an acting professor in the department.

Kaufman began at Shell as a geophysicist in 1936. After service in the navy between 1941 and 1946, he returned to Shell, where he became assistant to the vice president for exploration research and development.

Over the years he has been a consultant to the Defense Advanced Research Projects Agency (DARPA), chaired the Geophysics Advisory Panel of the Air Force Office of Scientific Research, served on the Seismology Committee of the National Academy of Sciences, and was an adviser to the U.S.–Japan Cooperative Program in Natural Resources. He received the gold medal of the Society of Exploration Geophysicists in 1983, and the Hollis D. Hedberg Award from the Institute for the Study of Earth and Man at Southern Methodist University in 1990.

Kaufman holds two Cornell degrees in geology—the A.B. (1930) and the Ph.D. (1934). He now lives in Houston.

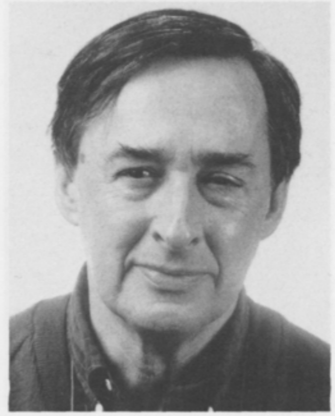
■ An administrative change at the college is the retirement of **Jeanne Thoren** as executive assistant to the dean, and the appointment of **Deborah Janes** to that position.

Thoren retired last summer after twenty-seven years at the college. Over this period, she worked with four deans.

Janes came to Cornell from the University of Arizona, where she was assistant to the head of the Planetary Sciences Department.

Gubbins

Greenberg



Lumley

■ Winner of the 1991 Excellence in Teaching Award at the College of Engineering is **Keith E. Gubbins**, the Thomas R. Briggs Professor in chemical engineering. The award, which is accompanied by a $2,000 prize, is sponsored by the Cornell Society of Engineers and the local chapter of the honorary society Tau Beta Pi. The recipient is chosen on the basis of nominations by students.

Gubbins, a Ph.D. from the University of London, came to Cornell in 1976 from the University of Florida. At Cornell he served as director of the School of Chemical Engineering from 1983 to 1990.

His professional honors include membership in the National Academy of Engineering, a Guggenheim fellowship, and the Alpha Chi Sigma Research Award of the American Institute of Chemical Engineers.

■ Five Dean's Prizes for Excellence and Innovation in Teaching were awarded this spring by Dean William B. Streett. Each prize has a cash value of $1,500.

The four members of the Engineering Communications Program—**Steven Youra**, the director, and **Penny J. Beebe**, **Susan Hubbard**, and **David Adams**—were joint recipients of one of the prizes. In addition to teaching several sections of a course in engineering communications, the program members work with professors throughout the college in integrating writing and speaking experience into upperclass course work.

Another prize was shared by Professors **Anthony R. Ingraffea** (civil and environmental engineering) and **Robert J. Thomas** (electrical engineering), who were leaders in the development of the new National Engineering Education Coalition of eight universities headed by Cornell. The coalition, which will develop and make available innovative courseware and curricular ideas, is sponsored by the National Science Foundation and funded at $30.6 million over five years.

Peter L. Jackson, associate professor of operations research and industrial engineering, was recognized for the development of new materials and teaching methods.

Samuel E. Landsberger, assistant professor of mechanical and aerospace engineering, was awarded a prize for incorporating innovative design work into classes taken by hundreds of undergraduates.

Assistant Professor **J. Richard Shealy** received a prize for introducing individual presentations by students in the junior-year laboratory course in electrical engineering.

■ Recently elected to the National Academy of Engineering are two Cornell professors, **Donald P. Greenberg**, the Jacob Gould Schurman Professor of Computer Graphics, and **John L. Lumley**, the Willis H. Carrier Professor in mechanical and aerospace engineering.

Greenberg was cited for "advances in applications of computer graphics to education and computer-aided design, and for image-synthesis algorithms providing improved realism." He directs Cornell's Program of Computer Graphics, and also the newly established Science and Technology Center for Computer Graphics and Scientific Visualization at Cornell. Earlier, he served as the first director of the Computer Aided Design Instructional Facility at the College of Engineering. He received the 1987 Steven A. Coons Award from SIGGRAPH of the Association for Computing Machinery, and the 1989 Academic Award of the National Computer Graphics Association.

Lumley was cited for "significant contributions to the understanding of turbulent and non-Newtonian flows." Other honors he has received include the 1982 Fluid and Plasma Dynamics Award of the American Institute of Aeronautics and Astronautics and the

1990 Fluid Dynamics Prize of the American Physical Society. He is a fellow of the American Academy of Arts and Sciences.

■ Faculty members who received fellowships and awards in recent months include:

J. Robert Cooke, professor of agricultural and biological engineering: the first Outstanding Teaching Materials Award (for the instructional software program "Stomate Tutor") from the Biological and Agricultural Engineering Division of the American Society for Engineering Education.

David Gries, professor of computer science: a Computing Research Association award for service to the computer science community, and an award from the Association for Computing Machinery for educational contributions.

Dexter Kozen, professor of computer science: a Guggenheim fellowship. Kozen will spend 1991–92 at the University of Arhus in Denmark.

Rishi Raj, professor of materials science and engineering: a Humboldt Senior Scientist Award. Raj will spend 1991–92 at the Max Planck Institute in Stuttgart, Germany.

Christine A. Shoemaker, professor of civil and environmental engineering: the Distinguished Engineering Educator Award of the Society of Women Engineers.

Éva Tardos, assistant professor of operations research and industrial engineering: a David and Lucile Packard Foundation Fellowship ($500,000 in research support over five years) and an Alfred P. Sloan Research Fellowship ($30,000 for research).

Sam Toueg, associate professor of computer science and director of the undergraduate program: an Amoco Foundation award (including a $1,500 prize) for excellence in teaching at the undergraduate level.

FACULTY PUBLICATIONS

Current research activities at the Cornell University College of Engineering are represented by the following publications and conference papers that appeared or were presented during the four-month period October, 1990 through January, 1991. (Earlier entries omitted from previous Quarterly *listings are included here with the year of publication in parentheses.) The names of Cornell personnel are in italics.*

■ AGRICULTURAL AND BIOLOGICAL ENGINEERING

Albright, L. D. 1990*a*. Environmental control for animals and plants. St. Joseph, MI: ASAE.

———. 1990*b*. Production solar greenhouses. In *Solar energy in agriculture*, ed. B. F. Parker, pp. 213–32. Amsterdam, The Netherlands: Elsevier.

Anashanley, D. J., and *C. S. Czarniecki*. 1990. *Complex impedances of cows: Measurements and significance.* ASAE report no. 90–3509, p. 10. St. Joseph, MI: ASAE.

Aneshansley, D. J., R. C. Gorewit, L. Price, and *C. S. Czarniecki*. 1990*a*. *Cow sensitivity to AC current during milking.* ASAE report no. 3505, p. 14. St. Joseph, MI: ASAE.

———. 1990*b*. *Milk production with voltage exposure during entire lactations.* ASAE report no. 90–3502, p. 14. St. Joseph, MI: ASAE.

Bell, J. L., J. S. Selker, T. S. Steenhuis, and *R. J. Glass*. 1990. Rapid moisture measurements of thin sand slabs. Paper read at 1990 International Winter Meeting, American Society of Agricultural Engineers, 18–21 December 1990, in Chicago, IL.

Boll, J., T. S. Steenhuis, J. S. Selker, B. M. Nijssen, and *E. Ochs*. 1990. Fiberglass wicks for sampling water and solutes from the unsaturated zone. Paper read at 1990 International Winter Meeting, American Society of Agricultural Engineers, 18–21 December 1990, in Chicago, IL.

Chandrasekaran, M., R. E. Pitt, J. E. Parks, and *P. L. Steponkus*. 1990. Stochastic behavior of intracellular ice formation in isolated rye protoplasts and mature bovine oocytes. *Cryobiology* 27:676–77.

Derksen, R. C., Z. Sagi, and *J. Sanderson*. 1990. Testing performance of greenhouse sprayers. Paper read at 52nd Annual New York State Pest Management Conference, 12–15 November 1990, in Ithaca, NY.

Derksen, R. C., and *D. Wasson*. 1990. Spray accuracy of orchard tree sprayers. Paper read at 52nd Annual New York State Pest Management Conference, 12–15 November 1990, in Ithaca, NY.

Farmer, G., D. C. Ludington, and *R. Pellerin*. (1989.) Effect of time-of-use rates on New York dairy farms: Load shifting and conservation. Paper read at Agricultural Demand-Side Management Conference, 24–25 October 1989, in Ithaca, NY.

———. 1990. A review of electricity use and the impact of selected demand-side management technologies on dairy farms. Paper no. 903566 read at 1990 International Winter Meeting, American Society of Agricultural Engineers, 18–21 December 1990, in Chicago, IL.

Gorewit, R. C., D. J. Aneshansley, J. Jiang, and *L. Price*. 1990. A method for identifying the vasactive response of isolated perfused arteries. *FASEB Journal (Abstract, pt. III)* 4:A845.

Gorewit, R. C., D. J. Aneshansley, L. R. Price, and *C. S. Czarniecki*. 1990*a*. Effects of long-term (full lactation) exposure to electrical current in dairy cows. *Journal of Dairy Science (Abstract suppl. no. 1)* 73:244.

———. 1990*b*. *Reproductive performance during exposure to voltages: A full lactation study.* ASAE report no. 3503, p. 10. St. Joseph, MI: ASAE.

Haith, D. A. 1990. Mathematical models of nonpoint-source pollution. *Engineering: Cornell Quarterly* 25(1):2–6.

Jewell, W. J. 1990. Removing toxic organics from groundwater: Biological conversion of PCE and TCE. *Engineering: Cornell Quarterly* 25(1):25–29.

King, V. A.-E., R. R. Zall, and *D. C. Ludington.* (1989.) Controlled low-temperature vacuum dehydration: A new approach for low-temperature and low-pressure food drying. *Journal of Food Science* 54:1573–93.

Koelsch, R., D. J. Aneshansley, and *W. R. Butler.* 1990. *Potential approaches for an in-line milk progesterone sensor.* ASAE report no. 90–3551, p. 15. St. Joseph, MI: ASAE.

Lefcourt, A. M., *D. J. Aneshansley,* R. Appleman, *R. C. Gorewit, D. C. Ludinton, R. Pellerin, L. Southwick,* et al. 1990. *Summary of USDA handbook on stray voltage/current.* ASAE report no. 90–3501, p. 19. St. Joseph, MI: ASAE.

Ludington, D. C., D. J. Aneshansley, R. A. Pellerin, and *F. Guo.* 1990. Adjustable speed drive two-vacuum milking system. Paper no. 903556 read at 1990 International Winter Meeting, American Society of Agricultural Engineers, 18–21 December 1990, in Chicago, IL.

Ludington, D. C., R. Pellerin, and *G. Farmer.* (1989.) Vacuum pumps for milking systems "Opportunities for Conservation." Paper read at Agricultural Demand-Side Management Conference, 24–25 October 1989, in Ithaca, NY.

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Pellerin, R. A., F. Guo, D. J. Aneshansley, and *D. C. Ludington.* 1990. *Adjustable speed drive-two vacuum milking system.* ASAE report no. 90–3556, p. 19. St. Joseph, MI: ASAE.

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Pitt, R. E. 1990. The probability of inoculant effectiveness in alfalfa silages. *Transactions of the ASAE* 33:1771–78.

Pitt, R. E., S. P. Myers, T.-T. Lin, and *P. L. Steponkus.* 1990. Subfreezing volumetric behavior and stochastic modeling of intracellular ice formation in *Drosophila melanogaster* embryos. *Cryobiology* 28:72–86.

Richard, T. 1990. Composting and water quality. *Engineering: Cornell Quarterly* 25(1):20–24.

Ruffing, N. A., J. E. Parks, R. E. Pitt, and *P. L. Steponkus.* 1990. Effect of developmental stage on the osmotic properties of bovine oocytes. *Cryobiology* 27:675.

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Steenhuis, T. S., and *L. D. Geohring.* 1990. Preferential flow and solute loss in agricultural tile lines. Paper read at 1990 International Winter Meeting, American Society of Agricultural Engineers, 18–21 December 1990, in Chicago, IL.

Steenhuis, T. S., J. R. Hagerman, S. O. Aburime, N. O. Bailey, J. S. Selker, and *J. Boll.* 1991. In situ vadose zone water quality sampling: Methods for preferential flow conditions. Paper read at American Society for Testing and Materials Symposium, Ground Water and Vadose Zone Investigations: Through the 1980s and into the 1990s, 31 January 1991, in San Diego, CA.

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Steenhuis, T. S., and *J.-Y. Parlange.* 1990. Preferential flow in structured and sandy soils. *Engineering: Cornell Quarterly* 25(1):7–14.

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Lovelace, R. V. E. 1990*a*. Magnetically driven jets and winds. In *Proceedings, Joint Varenna-Abastumani ESA Nagoya-Potsdam Workshop on Plasma Astrophysics,* pp. 201–05. European Space Agency publication ESA SP311. Paris, France: ESA.

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Moeckly, B. H., S. E. Russek, D. K. Lathrop, R. A. Buhrman, J. Li, and *J. W. Mayer.* Growth of $YBa_2Cu_3O_7$ thin films on MgO: The effect of substrate preparation. *Applied Physics Letters* 57:1687–89.

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Chalam, M. K., K. E. Gubbins, E. De Miguel, and L. Rull. 1990. Molecular simulation of a model liquid crystal. Paper read at Annual Meeting, American Institute of Chemical Engineers, 11–16 November 1990, in Chicago, IL.

De Miguel, E., L. F. Rull, *M. K. Chalam,* and *K. E. Gubbins.* 1990. Liquid-vapour coexistence of the Gay-Berne fluid by Biggs ensemble simulation. *Molecular Physics* 71:1223–31.

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