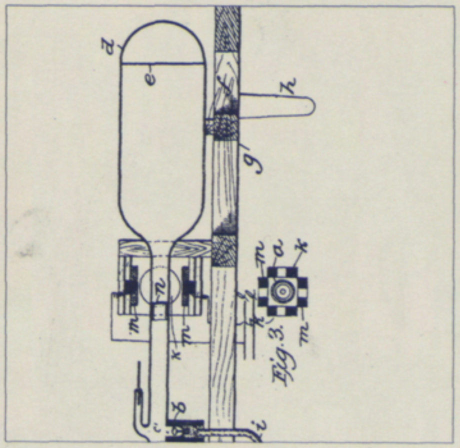
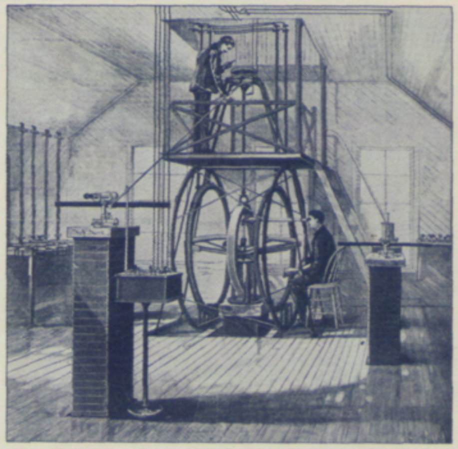
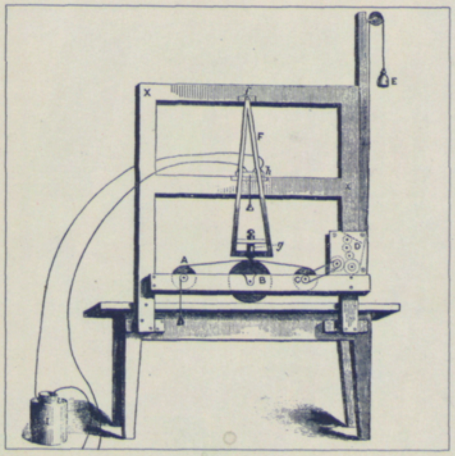
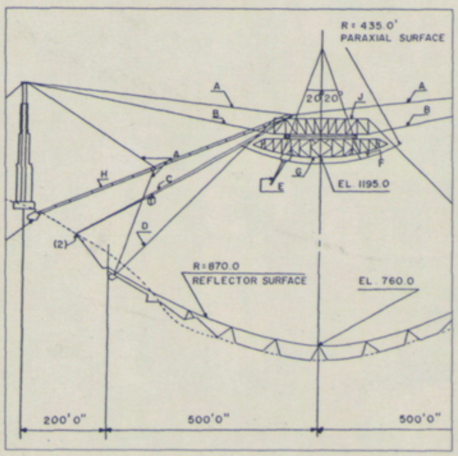
ENGINEERING

CORNELL QUARTERLY









VOLUME 11
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SUMMER 1976

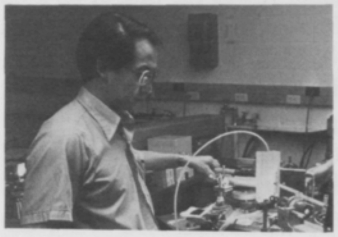
A CENTURY OF ELECTRICAL ENGINEERING

IN THIS ISSUE

In the spirit of centenary (if not bicentennial) celebration, the College of Engineering focuses on Cornell's part in the growth of electrical engineering from its beginnings to the huge, complex, and immensely important technology it is today. Donald F. Berth, director of special projects, and Howard G. Smith, professor of electrical engineering, emeritus, collaborated on the research and writing for this historical survey.

Where the history has led is assessed by G. Conrad Dalman, director of the School of Electrical Engineering, in a survey of the scope and significance of the educational and research functions of the College's largest unit.

An example of current Cornell electrical engineering research is provided by Professor C. L. Tang, who explains why he believes optics technology is at the threshold of a revolutionary development.



An anniversary is noted with publication of an index of Volumes 1 through 10.

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Opposite: The main attraction at the Centennial Exhibition in Philadelphia was the huge Corliss steam engine, part of which was later brought to Cornell and used for many years in the mechanical engineering laboratory.

Outside: Drawings from the history of electrical engineering at Cornell. Top row: from the patent drawing for a cathode ray tube modification patented by Harris J. Ryan in 1906; the tangent galvonometer built at Cornell in the 1880s. Bottom row: the first telegraph instrument, as sketched in a publication of Samuel F. B. Morse; diagram of part of the Cornell-operated radio-radar telescope facility built in 1963 near Arecibo, Puerto Rico.

WHEN THE SPARKS BEGAN TO FLY

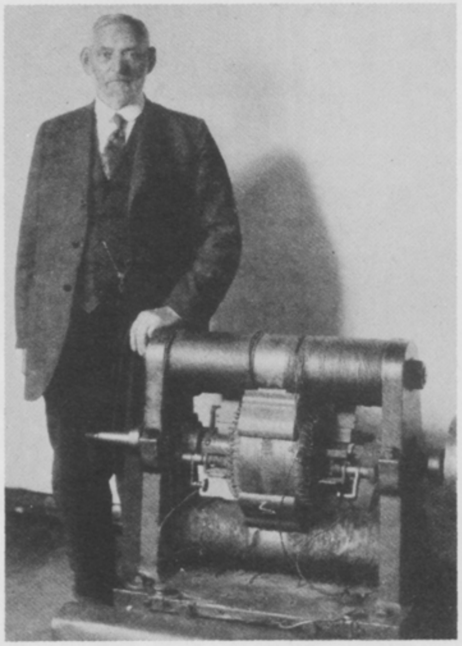
A Century of Electrical Engineering at Cornell

by Donald F. Berth and Howard G. Smith

1876 . . . The Centennial Exhibition in Philadelphia.

One piece of hardware at that grand exhibition that featured the achievements of American invention and technology was a dynamo. It was the first of its kind ever built in the United States—and it had been done at Cornell. In a physical sense, it represented the beginnings of electrical engineering at the University.

The Cornell machine had been copied from the French Grammé dynamo, but several design modifications worked out in the Sibley Hall shops had made it unique. It was historic also because it made possible the first outdoor lighting system in America: after its return from the Philadelphia exhibition, the dynamo was installed in the basement of Morrill Hall (the nation's first electrical laboratory for educational purposes) and used to provide electricity for two carbon-arc lights on the campus. In tandem with a four-horsepower petroleum engine, the dynamo also supplied electricity to the Physical Lecture Room in adjacent McGraw Hall. The construction of this dynamo helped to focus academic attention on the development of a new technology; electrical engineering programs at both Cornell and the Massachusetts Institute of Technology produced their first graduates less than a decade later, in 1885.



George S. Moler, one of the builders of the early Cornell dynamo, is shown with the historic machine. This is the dynamo exhibited at the Centennial Exhibition in Philadelphia in 1876 and later returned to Cornell to supply electricity for the nation's first outdoor lighting system. Moler, an 1874 engineering graduate, was the chief assistant to Professor William A. Anthony in building the machine.

Interest in matters electrical had begun much earlier, of course. Ben Franklin's primitive experiments with electricity and Michael Faraday's and Joseph Henry's efforts to develop the principles of modern electrical science had attracted the interest of America's early tinkerers and inventors.

One of these was Samuel F. B. Morse, who dabbled in electrical experiments while pursuing his career as an artist (he was known as one of the great portrait painters of the pre-Civil War era). While he was an art professor at New York University in the mid-1830s, Morse was able to find some time to work on "the instantaneous transmission of intelligence by means of electricity." Judge Stephen Vail, who owned the Speedwell Iron Works in nearby Morristown, New Jersey, was the first person persuaded to invest money in Morse's telegraph. He also provided machine shop facilities, and his son Alfred made the instruments. Later, in 1843, President John Tyler signed a bill to provide $30,000 for a demonstration project. That famous demonstration—the first practical application of electricity in the field of communications—occurred on May 24, 1844: the message, "What Hath God Wrought!" was tapped out in Washington, D.C. by Morse and received by Alfred Vail in Baltimore.

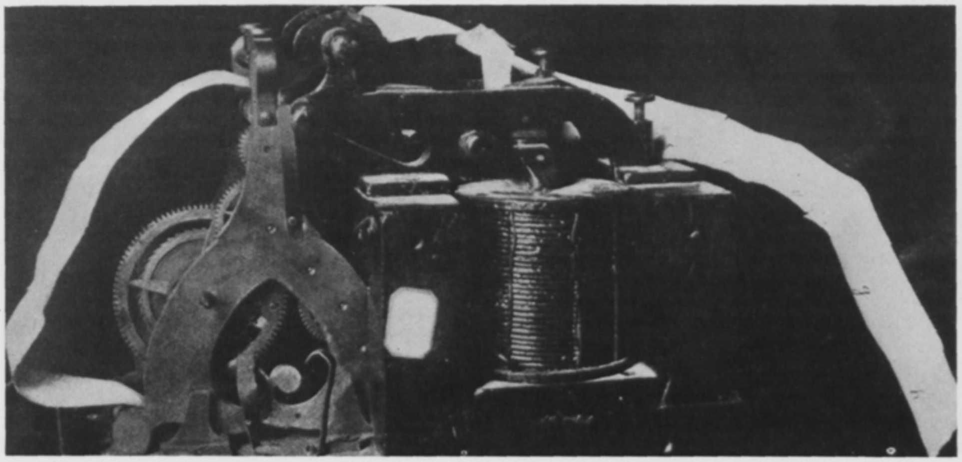
THE TELEGRAPH AND ITS ROLE IN THE UNIVERSITY FOUNDING

Ezra Cornell, founder of the University, had supervised the development of a special plow to lay Morse's first telegraph line, along the right-of-way of the Baltimore and Ohio Railroad. Because of poor insulation technology, however, he had to abandon the underground method and instead string wires from trees, poles, and buildings. Cornell later served as superintendent for the construction of several additional transmission lines (those connecting New York to Philadelphia, New York to Albany, and Troy to Montreal).

In April, 1856, several small, competing lines were formed into the Western Union Telegraph Company, a name suggested by Ezra Cornell. The enterprise was backed by a group of Rochester-based businessmen, including Hiram Sibley, who later supported the development of the Cornell University unit that has become the present Sibley School of Mechanical and Aerospace Engineering. Largely through the fortune he acquired in this, the nation's first major commercial electrical engineering business, Ezra Cornell was able to provide the capital to establish his university.

CORNELL IN THE VANGUARD OF NEW DEVELOPMENTS

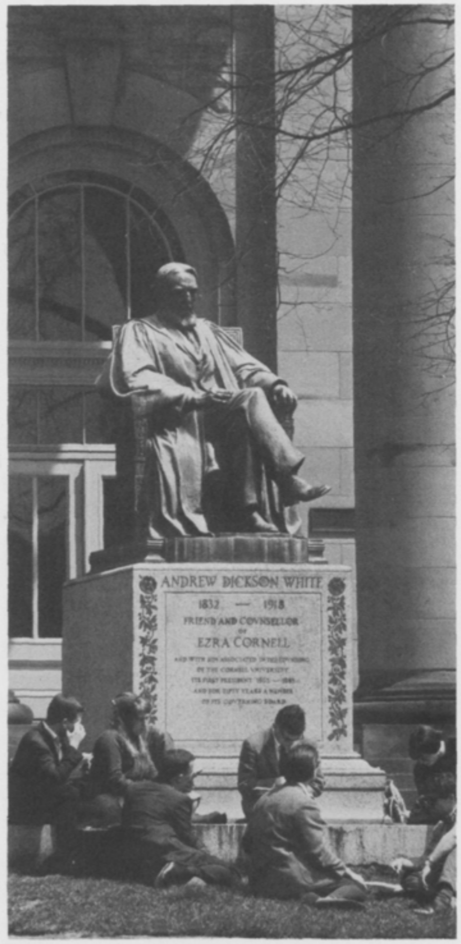
The harnessing of electricity for practical uses was advanced further when, a century ago in 1876, Alexander Graham Bell formed his telephone company in Boston. And by 1883, the year in which Cornell University formally announced a curriculum in electrical engineering, the Pearl Street Generating Station in Brooklyn was



The world's first telegraph message was received by this instrument, later given to the Sibley College at Cornell by Hiram Sibley and still in the possession of the College of Engineering. This photograph appeared in the Sibley Journal of Engineering *in 1898, at the time of the presentation.*

The first leaders of Cornell University placed a high value on technical education and were largely responsible for the early development of electrical engineering here. Statues of Ezra Cornell, the founder, and Andrew D. White, the first president, face each other across the original quadrangle, now the arts and sciences campus, where engineering was first housed. (A campus legend is that the two men visit from time to time, as evidenced by the appearance of footprints between the statues.) Ezra Cornell supervised the construction of the first telegraph transmission lines and subsequently acquired capital used to establish the University through his interest in the Western Union Telegraph Company. The statue depicts him with a hand resting on a replica of the Morse telegraph instrument (see the photograph on the inside back cover).

Below: The campus in the late 1870s before the construction of Franklin Hall (at the far end of the quadrangle).



supplying the first commercially generated and distributed electrical power in America.

Interest in technical education was found at the highest levels of Cornell University, first in Ezra Cornell himself and then in Andrew D. White, the first president. Writing in his autobiography, White, a Yale-educated historian reminisced:

> I had been interested, even in my boyhood (in Homer, New York, near Ithaca) in all scientific questions, both at school and in college. During my professorship at the University of Michigan, as early as 1857, while frequently visiting the laboratories of that institution, I began to realize that we were at the beginning of a new epoch, as regarded instruction in the sciences . . . both pure and applied. When I (later) took my seat in the Senate of the State of New York, I exerted myself to the full extent of my power, preaching, early and late, the necessity of more and higher technical education.

In hiring the University's first professor of physics and industrial mechanics in 1872 (at the magnificent sum of $2,250 a year), President White attracted the services of an unusual man, William A. Anthony. For many years Anthony constituted the Cornell faculty in physics, and it was he who supervised the construction of the famous dynamo in the Sibley shops. (His chief assistant was George S. Moler, a mechanic arts graduate of 1874. Another helper was a young man from nearby Cortland, New York, who was attracted by the shop activity; he was Elmer Sperry, who later developed one of the nation's large industrial combines.)

Anthony

Anthony's major achievement at Cornell—a university of less than one thousand students in the mid-1870s—was to draw attention to the practical harnessing and utilization of electricity. His interest in technological innovation and experimentation was not lost on President White. White, who travelled extensively on the Continent and in England, had observed at first hand the flowering of mechanical and the beginnings of electrical technology in Europe, and he encouraged Anthony to organize a course of instruction in electrical engineering at Cornell. Anthony presented a detailed plan at a meeting of the University's Trustee Executive Committee on March 22, 1883, and four days later the committee passed the following:

> Resolved, that the Faculty be authorized to announce a course of study in electrical engineering, leading to a degree, provided such course occasions no additional expense.

President White is known to have agreed to underwrite, with his own funds, any "additional expense."

"It was I who, as Professor Anthony will testify, suggested the establishment at Cornell of the first Department of Electrical Engineering ever erected in the United States, indeed, ever created anywhere, as far as I know . . ."

—from an 1893 letter by Andrew D. White

THE

CORNELL UNIVERSITY

REGISTER

1883-84

ITHACA, N. Y.

CORNELL UNIVERSITY.

SPECIAL NOTICE.

COURSE IN ELECTRICAL ENGINEERING.

The rapid development of the applications of electricity has created a demand for thoroughly trained engineers conversant with electrical science, especially by companies carrying on telegraphy, electrical lighting, electrical supply and transmission of power, electroplating, the manufacture of electrical machinery and apparatus, etc. Recognizing this demand, at the beginning of the next academic year (Sept. 18, 1883), the trustees of Cornell University will receive students who desire to fit themselves to enter this new and constantly extending field. While the general studies are mainly those of the departments of Civil and Mechanical Engineering, the special studies of the course embrace the theory of electricity, the construction and testing of telegraph lines, cables, and instruments, and of dynamo machines, and the methods of electrical measurement, electrical lighting, and the electrical transmission of power.

The completion of the new chemical and physical laboratories of the University, and the large recent purchases of electrical apparatus from the best makers in England, Germany, France, and the United States, enable the University to present every facility for the pursuit of these studies.

The requirements for admission to this course are the same as for admission to the courses in Science, Science and Letters, Mathematics, Chemistry and Physics, and Analytical Chemistry, as stated on pages 27 and 29 of the University Register.

The details of this course may be had upon application to

ANDREW D. WHITE,
President.

The Cornell Register for 1883 carried an announcement of a new course in electrical engineering, leading to the degree of Bachelor of Science.

The curriculum described in this Register was innovative in that it provided a course of study intermediate between the Cornell mathematics and science programs and the mechanic arts curriculum, which required four hours of shop and drawing daily. The electrical engineering curriculum was arranged in three terms during each of the four years.

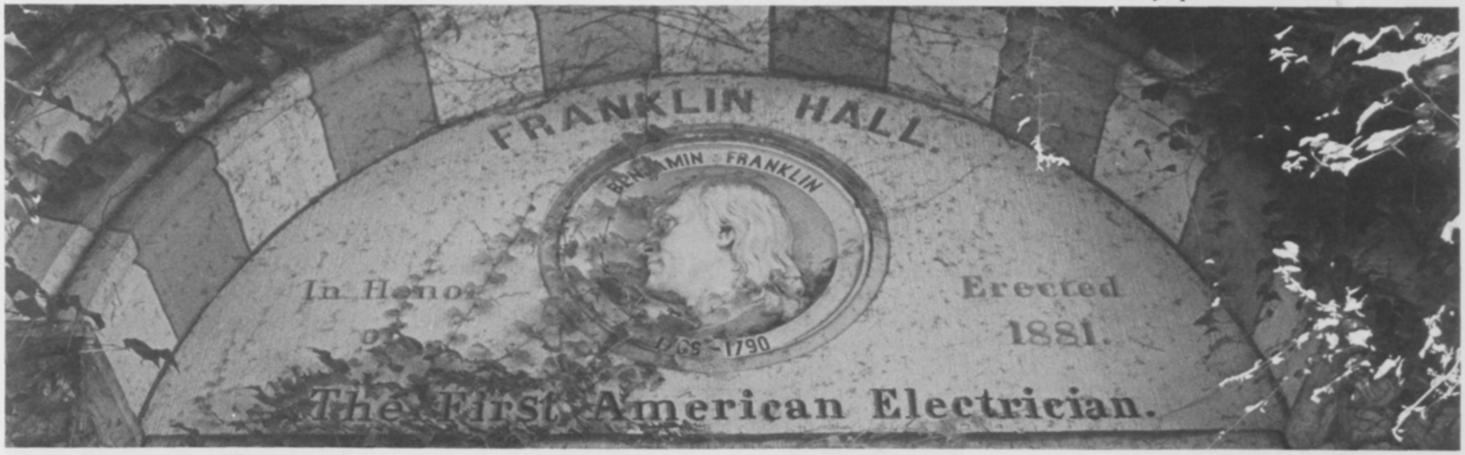
As freshmen, the students took French or German, rhetoric, mathematics (geometry, algebra, and trigonometry), and drawing (freehand, instrumental, and text). They also had military drill and some lectures in hygiene.

In the sophomore year there were classes in experimental mechanics and heat, electricity and magnetism, acoustics and optics, and chemistry. Calculus and shop work were introduced, and instruction was continued in French or German, geometry, mechanical drawing, and military drill.

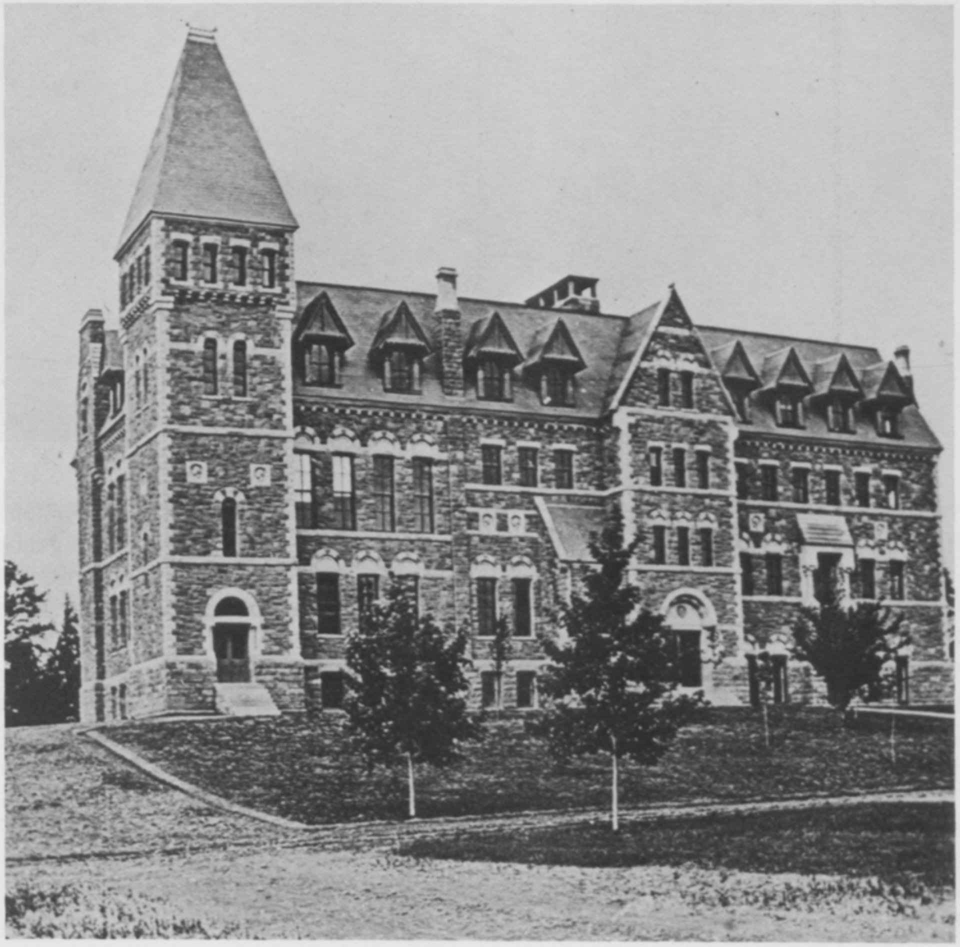
In the junior year, the classes were in calculus; physics with laboratory work in mechanics, measurements, electricity, general experiments, and acoustics and optics; chemistry with laboratory; shop work; mechanics of engineering; mechanism; and mechanical drawing.

The senior-year physics courses included instruction in the specialties Cornell was becoming noted for: photometry and electric lamps; telegraph instruments, lines, and cables; the dynamo machine and electrical motors; and testing of instruments and determination of constants. There were also courses in the mechanics of engineering, the steam engine, hydraulics, mechanical drawing, and military science, and the curriculum included the preparation of a thesis.

Tympanum over Main Entrance



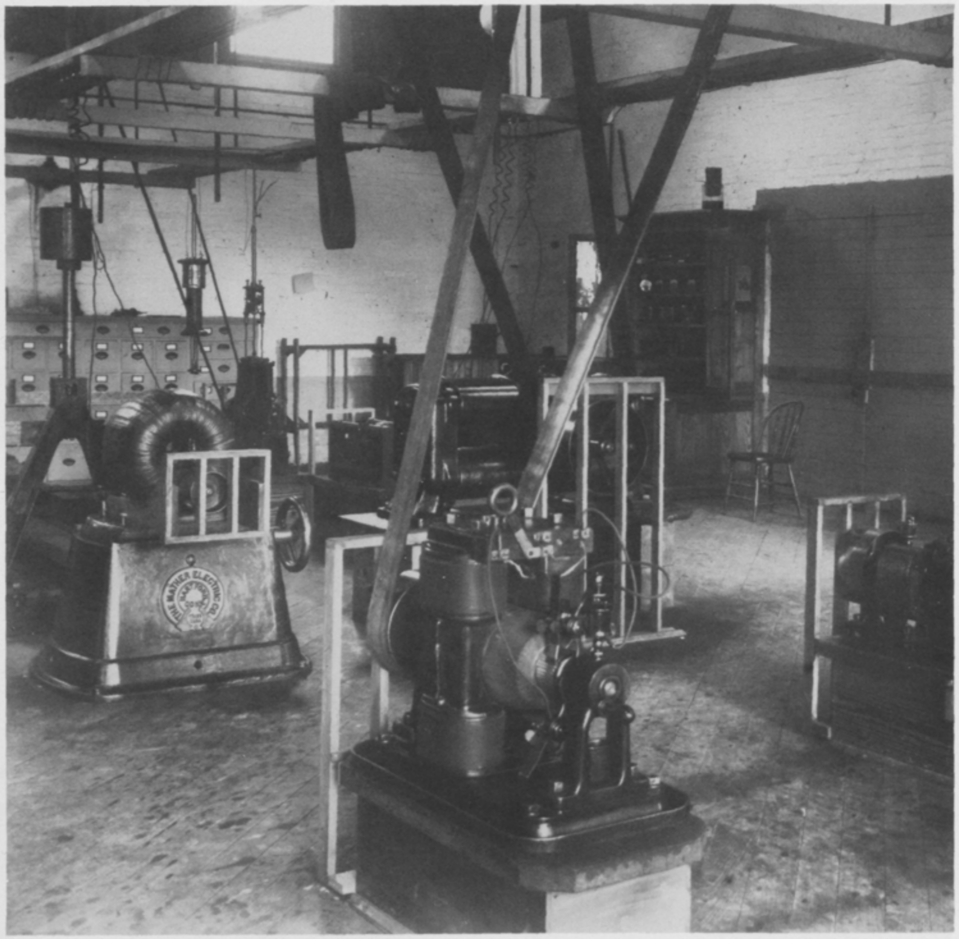
Franklin Hall in the 1880s



PIECES IN THE BUILDING OF THE CORNELL PROGRAM

The early activities of Anthony and the subsequent establishment of a course of study were the first two pieces in the building of Cornell's electrical engineering program. In September, 1883, an important third step was completed with the dedication of a new Physical Laboratory, named Franklin Hall "in honor of the first American electrician;" when those first students admitted to the electrical engineering program began their studies some ninety-three years ago, a spanking new building was ready for them. Franklin Hall was to serve as the home for Cornell electrical engineers for seventy-two years.

The final piece was placed in 1885, when Robert Henry Thurston was appointed professor of mechanical engineering and director of the Sibley College of Mechanical Engineering and the Mechanic Arts. (The appointment was made at the June 17 meeting of the Trustee Executive Committee, the same meeting at which White announced his resignation after twenty years as president.) In the early years, electrical studies had been a

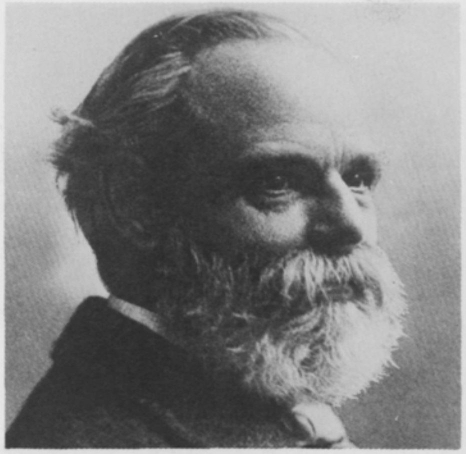


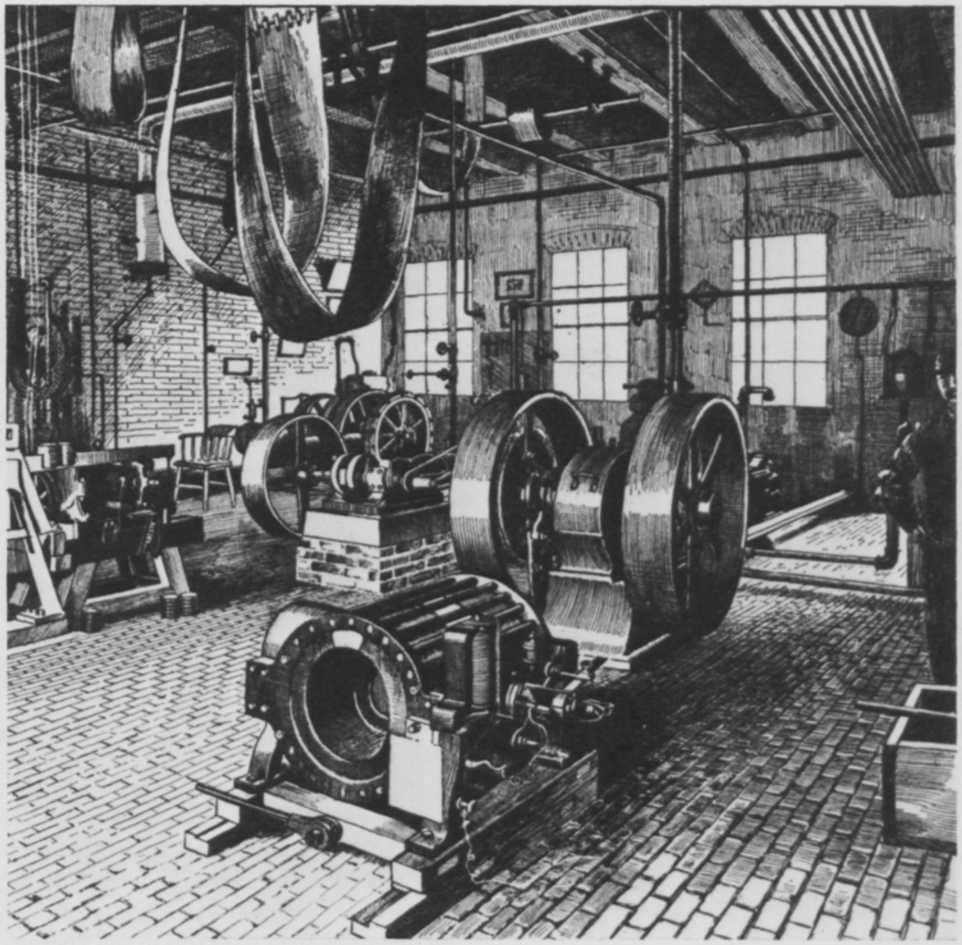
"I am extremely grateful to you and the members of the Cornell University section of the American Institute of Electrical Engineers . . . I do not feel and have never felt that I was doing anything specially meritorious. The time was ripe for something to be done and I had the good fortune to be in a position to do it."

—from a 1907 letter by William A. Anthony in response to a telegram of appreciation to Anthony "who offered the first electrical engineering instruction in this country." The telegram and letter were read at the first dinner held by the local section of AIEE

part of the physics program, but Thurston, who soon established himself as a major force on campus, set about to move the center of gravity of electrical engineering to the Sibley College. There had been, all along, some interaction between electrical and mechanical engineering. Anthony had held a joint appointment in the College of Chemistry and Physics and in the Sibley College; and, partly because early electrical technology was electromechanical, the Sibley College had been able to provide electrical engineering students with technical courses to complement the offerings in physics. What Thurston sought was a closer alignment between the two branches of engineering. An electrical engineering department was set up within the Sibley College in 1885, but the unification was hampered by the fact that physics and electrical engineering were both mainly housed in Franklin Hall. It was not until 1904, when a new building—Rockefeller Hall—was provided for physics, that a final separation of facilities and faculty occurred.

Behind all these steps in the development of electrical engineering at Cornell





Above: Robert Henry Thurston, appointed professor of mechanical engineering and director of the Sibley College of Mechanical Engineering and the Mechanic Arts in 1885, advocated the primary alignment of electrical engineering with mechanical engineering rather than with physics.

Left: This dynamo laboratory, probably located in shop buildings behind West Sibley Hall, was used in the 1890s.

Right: This engraving of a dynamo laboratory was included in a full page of "Views in the Department of Electrical Engineering of Sibley College, Cornell University," printed in The Electrical World *in 1890.*

was President White. It was fitting that at the last commencement during his term in office, in 1885, White awarded the first Cornell degrees in electrical engineering—a Ph.D. (the nation's first in electrical engineering) to James G. White, and three bachelor's degrees.

THURSTON AND RYAN: THE MEN AND THEIR ERA

The Sibley College flourished under Thurston's leadership. He had a knack of selecting talented and productive faculty members, and as a professionally productive and urbane man himself, he undoubtedly inspired men of lesser stature to reach higher than they might otherwise have done.

After Anthony left Cornell in 1887 to accept an industrial position with the Mather Electric Company in Manchester, Connecticut, his work in electrical engineering was carried on by a former student, Harris J. Ryan, who, as a member of that first formally-admitted class in electrical engineering, had graduated in 1887. Ryan had spent a year in the West with fellow Cornell men James G. White and Dugald C. Jackson, working as the Western Engineering Company. (Jackson later headed electrical engineering at M.I.T.; White later established an international consulting firm in New York City.) Ryan returned to Cornell in 1888 as an instructor in physics and a year later joined the Sibley College faculty under Thurston.

Ryan apparently chose to study at Cornell largely because of the 1883 announcement of the establishment of the electrical engineering program. The story is that he had intended to go to Johns Hopkins until a chance meeting with an enthusiastic Cornellian turned his attention to this university and its new program. As a student, he worked closely with Anthony, and in his senior year was selected to be Anthony's assistant in much of the work being done at Cornell on the establishment of electrical standards. One of the widely recognized achievements of this work was the building of a large tangent galvanometer.

After he joined the faculty, Ryan worked closely with his friends and former students Ernest Merritt and Frederick Bedell, who had become professors of physics, and this association enabled him to pioneer in the application of scientific methods to a study of the alternating current transformer. Early in his studies of alternating currents, Ryan adapted the cathode ray tube as a laboratory tool and in 1906 obtained a patent covering magnetic deflection of the beam. The cathode ray tube soon became widely used in research on rapid and complex periodic electrical phenomena because it operated without inertia.

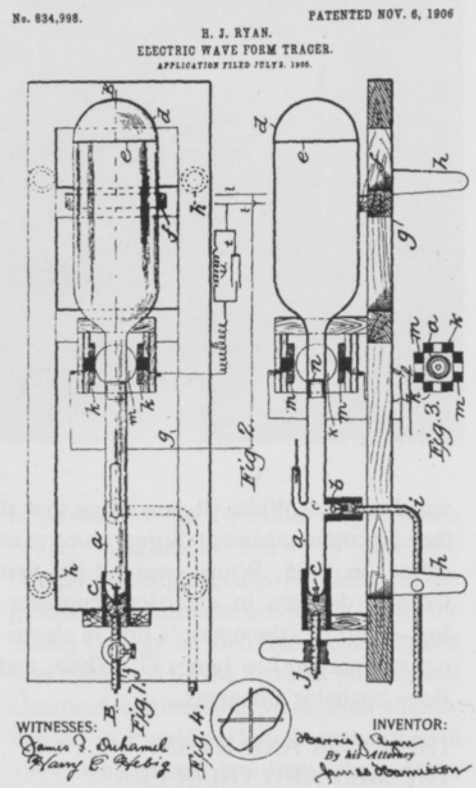
Ryan's chief work was concerned with the long-distance transmission of power, which he became interested in as a result of an undergraduate field trip to the Sprague Works in New York. During the visit, F. J. Sprague remarked in conversation with Professor Anthony that "economy in the electrical transmission of power will be directly proportional to the voltage and inversely proportional to the distance," and this idea was the stimulus for much of Ryan's subsequent research.

He also taught, for many years almost singlehandedly, all the applied courses in electrical engineering. These were augmented by offerings of Edward Nichols, Frederick Bedell, and Ernest Merritt in physics.

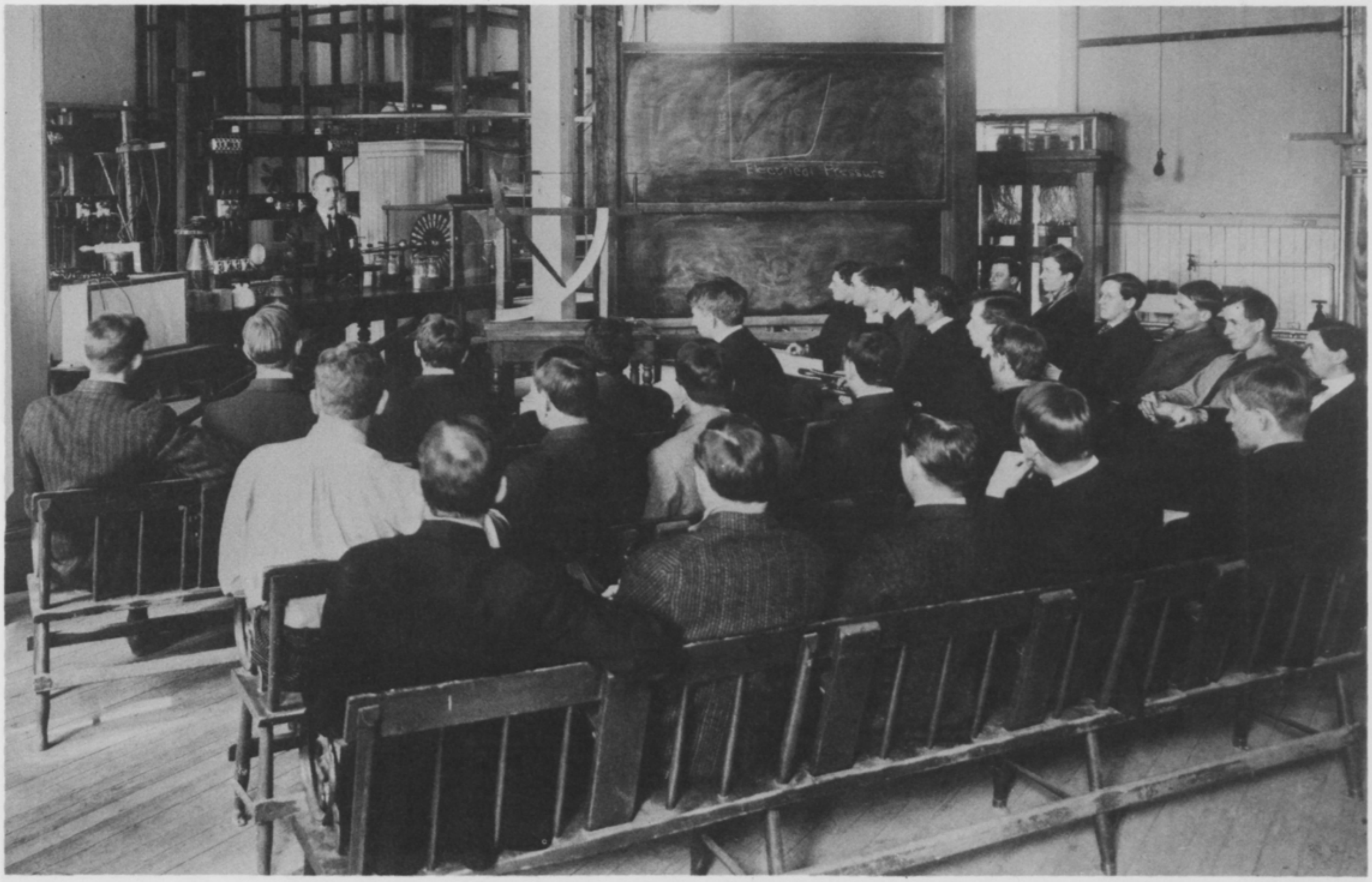
The Sibley faculty was noted for its

"The young man must therefore, above all things, retain confidence in himself and the system by which he was educated and at the same time realize that his education is of value only in proportion to his growth in practical wisdom determined from personal experience and from men upon whom the responsibilities of industry rest."

—from a paper read by Harris J. Ryan before the Electrical Society of Cornell University in the year 1900



Harris J. Ryan was one of the first great Cornell electrical engineers. Above: The drawing for a cathode ray tube modification patented by Ryan in 1906.



Harris J. Ryan for many years taught almost all the electrical engineering courses at Cornell.

giants—William Durand, Rolla C. Carpenter, and John H. Barr, as well as Thurston and Ryan. But Thurston died in the fall of 1903, and his passing led to the decline of a distinguished American engineering school. In 1904 Durand left the Sibley School to become head of Stanford's Department of Mechanical Engineering; a year later Ryan followed him to become head of the Department of Electrical Engineering, where he remained until retirement in 1931.

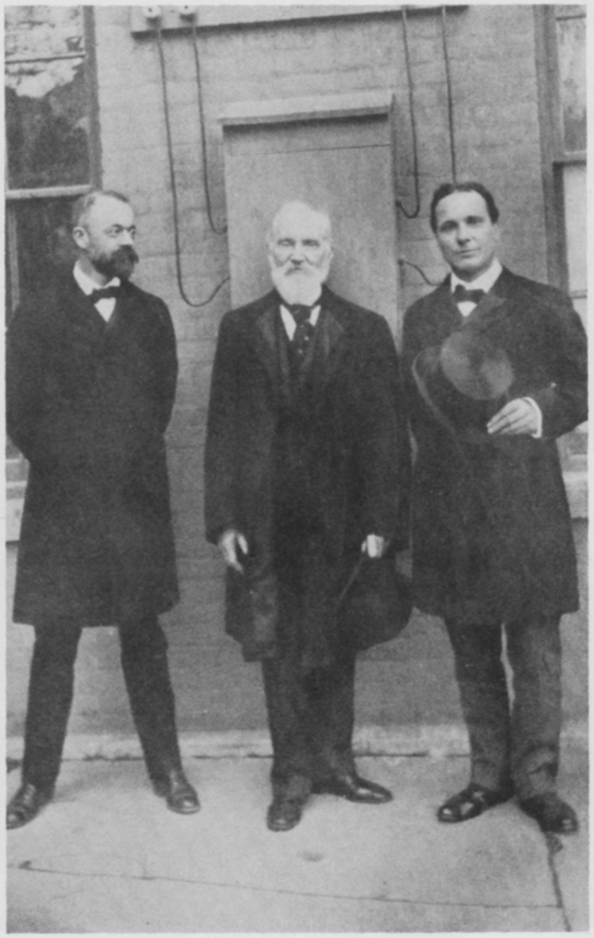
Ryan had prepared almost one thousand Cornellians for electrical engineering careers in the sixteen years he served as a Cornell faculty member, and he left a long-lasting legacy to the University, to the profession, and to the nation. His reasons for leaving Cornell may have been complex. He had reason to feel himself a worthy successor to Thurston. And perhaps the opportunity to head an autonomous department of electrical engineering was more appealing than remaining under the wing of a mechanical engineering school. Electrical engineering was becoming the dominant technology in American industry and men like Ryan must have felt that their discipline should have a position in educational institutions equivalent to that of the more traditional branches of engineering.

THE SIBLEY COLLEGE AFTER THE TURN OF THE CENTURY

The successor to Thurston as head of the Sibley College was Albert W. Smith, a Cornell graduate of 1878 and a member of the Stanford faculty. After Ryan's

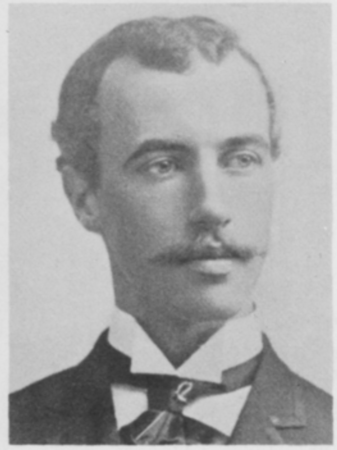
"There are four elements of success in technical education, namely, teachers who can teach, students who can learn, equipment which can be used efficiently, and a curriculum of studies which will economize the student's time, but will at the same time force him to such mental exercise that he will become a clear thinker."

—Henry H. Norris in an article in *The Sibley Journal of Engineering* in 1908



Merritt

Bedell



"There are two primary duties of high leadership (in a profession). One is to help others to climb as high as possible . . . The other . . . toward future generations, to open new vistas for them and to make their life paths easier and more fruitful."

—Vladimir Karapetoff in a talk to employees of Westinghouse Electric reported in *The Sibley Journal of Engineering* in 1924

departure the following year, in 1905, leadership of the electrical engineering department was assumed by Henry H. Norris, who had joined the faculty in 1896 and remained until 1914, when he resigned to become editor of *Electrical World*, a major trade journal of the day.

After Norris left, a long-time member of the faculty, Vladimir Karapetoff, was named to a brief tenure as acting professor in charge of electrical engineering. Karapetoff had joined the electrical engineering faculty at the tail end of the Ryan era, in 1905, and served for thirty-five years, up to the beginnings of World War II in Europe. Known as "Kary" to generations of Cornellians, he appears to have been an original character with wide interests, including music and politics, and he contributed much to the color of the department.

In 1916 Alexander Gray, a bright young Scotsman who was on the McGill University faculty, became head of the department. He served only five years, for in 1921, just a few months after the establishment of a separate school for electrical engineering, he died at the age of forty.

Three physics professors who contributed substantially to the early Cornell program in electrical engineering were Edward Nichols, Frederick Bedell, and Ernest Merritt. Nichols is seen in the photograph at far left with Lord Kelvin (center) and Cornell President Jacob Gould Schurmann (at right) during a visit by the famous British scientist to the University in 1902. The photograph was taken by Professor Moler just outside the Dynamo Laboratory.

After the departure of Harris J. Ryan, leadership of the electrical engineering department was assumed by Henry H. Norris and then by Vladimir Karapetoff. Professor Norris is shown below in his classroom, giving instruction in the "Design of Street R'y Motors."

Norris

Karapetoff

THE LONG WAIT FOR A SEPARATE IDENTITY

A long overdue development—the formation of a College of Engineering with separate schools of civil, mechanical, and electrical engineering—occurred in 1921. Before this rearrangement, engineering had been organized under the College of Civil Engineering and the Sibley College of Mechanical Engineering, which covered all the technologies, including electrical engineering, that had emanated from the mechanic arts. The new organization, which had been recommended after a three-year effort on the part of a trustee committee headed by Henry H. Westinghouse (an 1872 Cornell graduate and brother of George Westinghouse), finally liberated electrical engineering by giving it autonomy and a status equal to that of the older disciplines. Before 1921, electrical engineering was an adjunct of mechanical; students who majored in electrical engineering received degrees in mechanical engineering. And the faculty was small: when Gray became head of the department in 1916, for example, there were only two other Sibley professors whose principal interests were in electrical engineering.

Momentum in the academic world depends upon the intersection of various forces, often competing, within and outside the institution. When electrical engineering instruction was being pioneered in the 1870s and 1880s, the Cornell president had strong interests in science and technology and figured directly in many of the important decisions that shaped the Sibley College and the emerging discipline of electrical engineering. His successors in the presidency—Charles Kendall Adams, Jacob Gould Schurmann, and Livingston Farrand—do not appear to have had a comparable interest in technology and its development, even though

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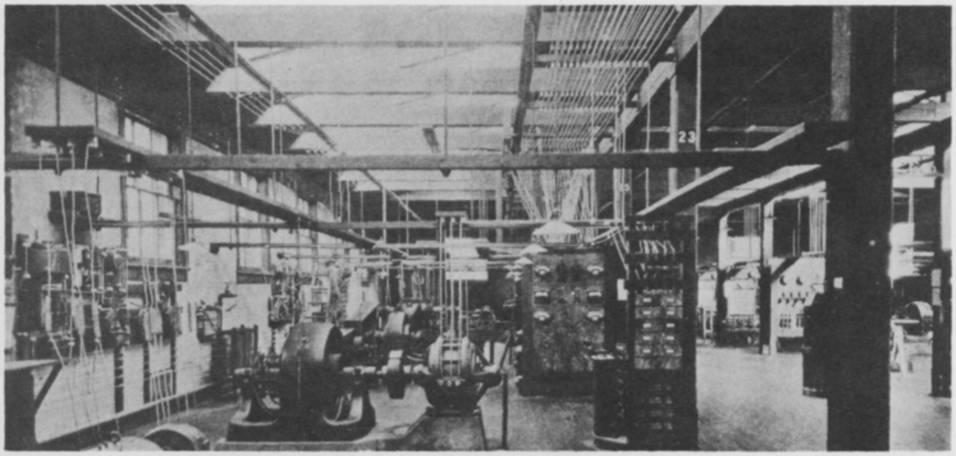

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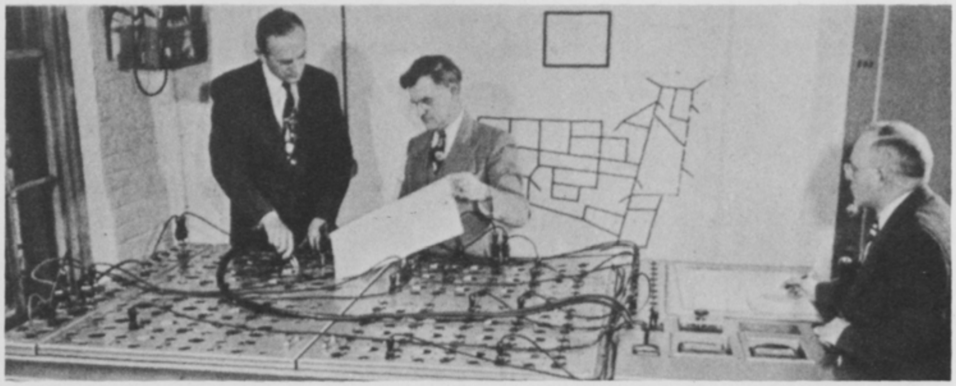

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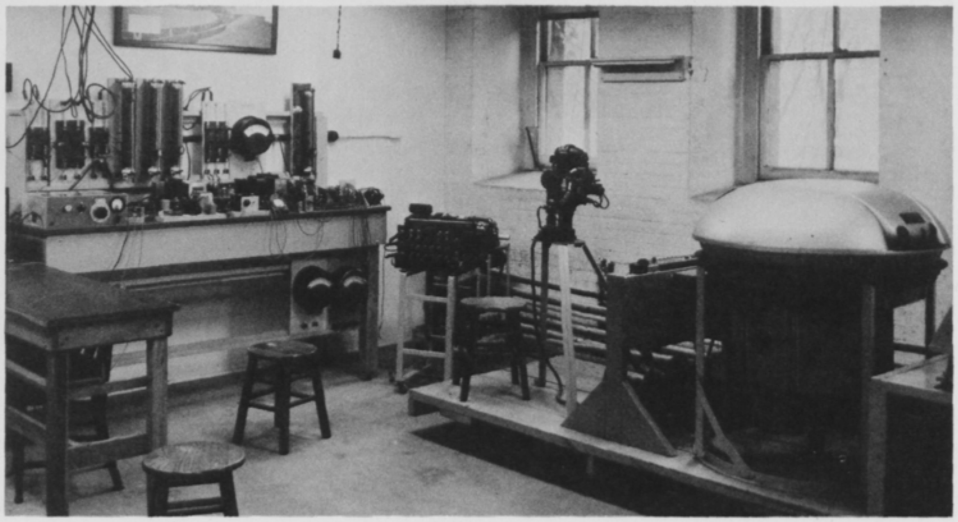

1. This electrical machinery laboratory in Rockefeller Hall was used from 1905 to 1916.

2. Three professors who were leaders in the development of research after World War II were (left to right) Malcolm S. McIlroy, Jack Tarboux, and Walter R. Jones. The machine is an early McIlroy nonlinear system analyzer.

3. This Franklin Hall laboratory was the forerunner of the servomechanism and computer laboratory in Phillips Hall.

4. A familiar sight to hundreds of Cornell engineers was this demonstration board in the main Franklin Hall lecture room, used from 1921 to about 1955.

5. Early analog computers were part of the original equipment in Phillips Hall.

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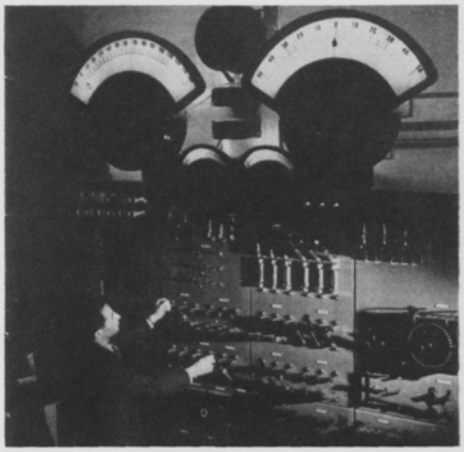

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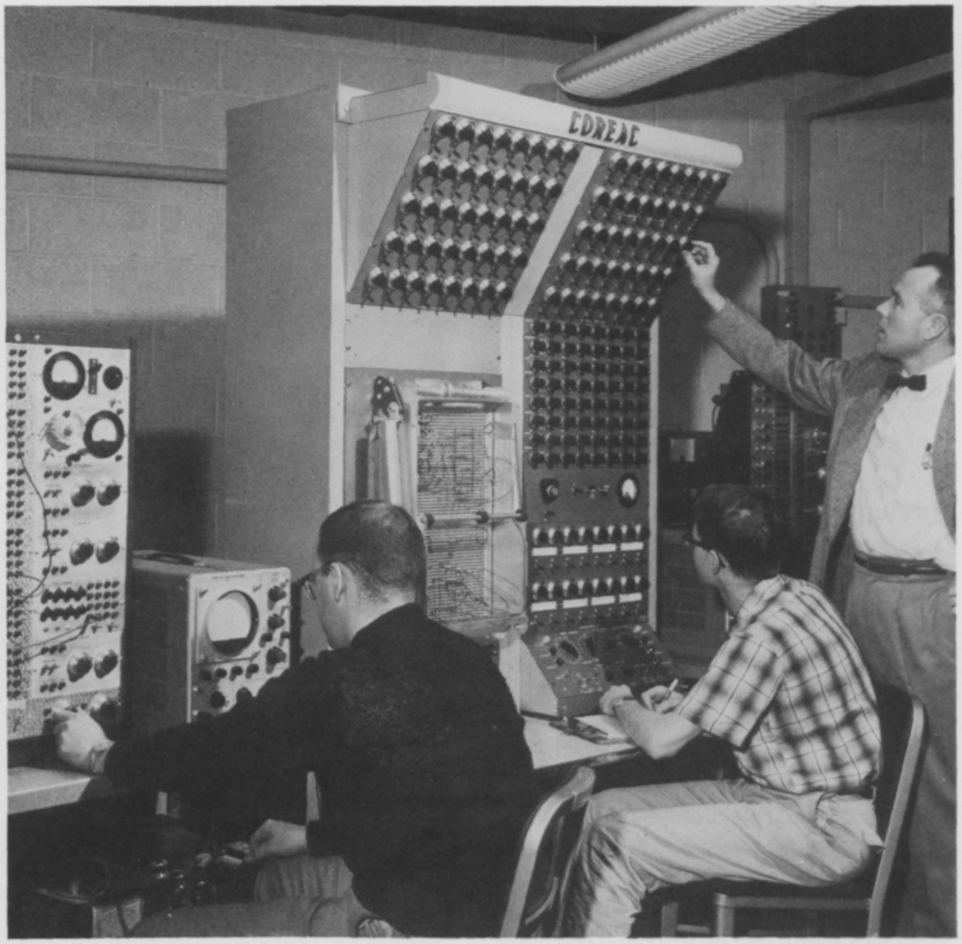
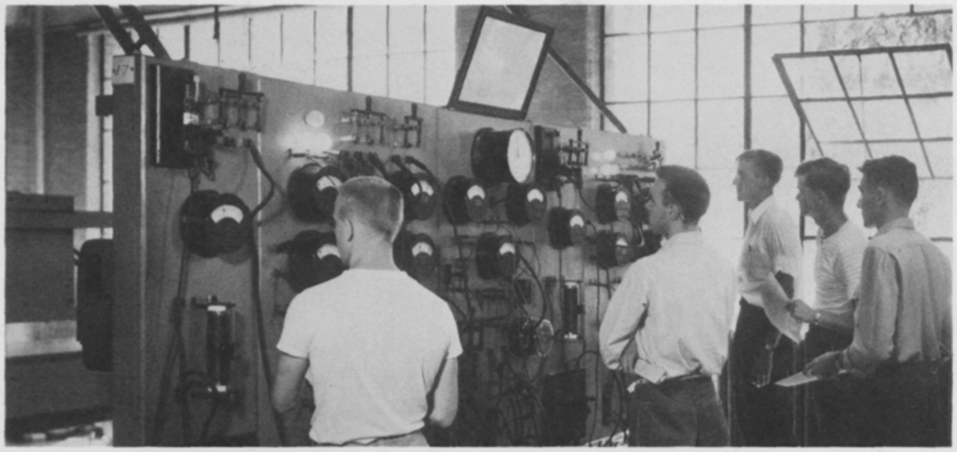
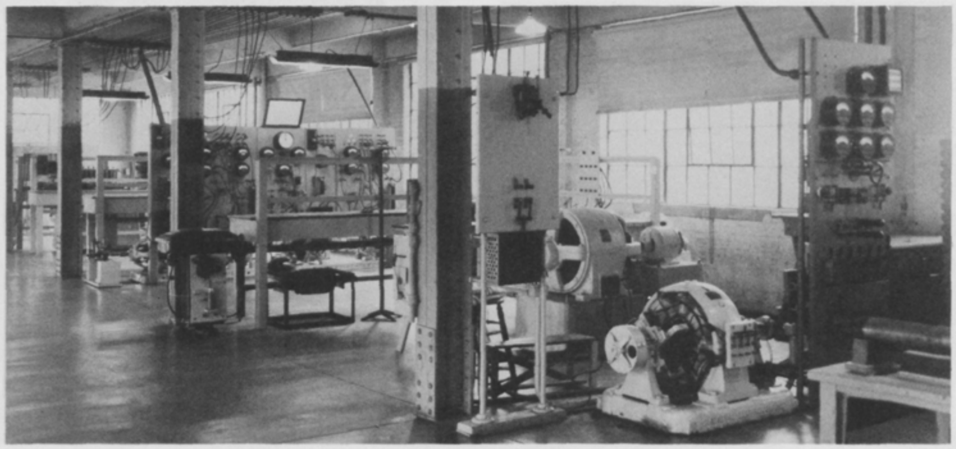


more than half the total Cornell enrollment in the early 1900s was in engineering. The University was unable or unwilling to close the gap between the engineering faculty salaries here and elsewhere, and other institutions, most notably Stanford University (whose president, David Starr Jordan, was a Cornellian) attracted many Cornell faculty members. In addition, Cornell lost its two engineering "giants" with the deaths, in the same year, of Thurston and of Estévan Antonio Fuertes, the distinguished head of the civil engineering college. The replacements for these two vigorous and aggressive leaders—men who had added much to the development of American technology as well as to the Cornell programs—simply did not have the charisma or stature to fill the gaps. The result of all these circumstances was a loss of momentum in engineering education at Cornell.

Another factor contributing to momentum is the extent to which like-minded people come together in their day-to-day working environment. At Cornell the cooperative efforts of faculty members in physics and in electrical engineering largely accounted for the University's impressive record of producing, for many years, the largest number of electrical engineers with advanced degrees in the nation. This coupling was disrupted when the physics department acquired its new building in 1904, leaving electrical engineering behind in Franklin Hall. And Ryan's departure a year later severed the only remaining active link: the close association of Ryan with Nichols, Merritt, and Bedell that had generated much of the spark in electrical engineering teaching and research.

Right: An A.C. synchronizer board was part of the equipment in the Rand Hall laboratory that was the main electrical machinery facility from about 1916 to 1955, when Phillips Hall was opened. The photograph below shows a view of the Rand Hall laboratory.





BETWEEN THE WORLD WARS: A PERIOD OF GROWTH

Shortly after the death of Alexander Gray in 1921, Dexter S. Kimball, Cornell's new and first dean of engineering, announced the appointment of Paul M. Lincoln as director of the School of Electrical Engineering. Lincoln was the brother of the founder of the Lincoln Electric Company in Cleveland and was himself well known nationally. His extensive industrial experience included seven years as superintendent of the Niagara Falls Power Company plant, and he had been president of the American Institute of Electrical Engineers. He served as director of the Cornell school for some sixteen years, until his retirement in 1938, and during that time he built the faculty from eight members to nearly twenty. However, his tenure covered a difficult time—the years of the Great Depression—and the financial situation at Cornell reflected the national condition. Faculty salaries, already comparatively low, were cut and men served in the rank of instructor for periods sometimes as long as a decade. Established leaders could not be brought to Cornell, for there was no money to pay them. To add to the problems, Franklin Hall had become depressingly obsolete by the early 1930s, when it reached its fiftieth anniversary.

A rising young star, William A. Lewis, assumed the directorship of the School of Electrical Engineering in 1938. In addition to a distinguished record of scholastic achievement at Caltech and solid industrial experience at Westinghouse, he had a vigor that seemed to be contagious. The sparks began to fly once again. A high-voltage laboratory was established and considerable research was undertaken in the power field. A faculty that had weathered some dark days saw a new horizon.

IMPACT OF WORLD WAR II AND THE POSTWAR PERIOD

Then World War II hit and the Cornell engineering program underwent a rapid transformation. The College became a center providing special programs for the Navy in diesel and steam engineering and for the Army Signal Corps in preliminary training in radar techniques. A large contingent of Naval V-12 students attended year round, earning bachelor's degrees in

In the Naval Diesel School operated at Cornell during World War II, instruction included operation of A.C. synchronizers and machines. The Diesel laboratory was housed in a temporary building. After the war, certain electrical equipment was moved to Phillips Hall, where some of it is still in use.

electrical engineering in three years. New courses were introduced to respond to emerging technologies in such areas as ultrahigh-frequency techniques and radar and servo systems. In the middle of this period, Bill Lewis left Cornell to become dean of the graduate school at the Illinois Institute of Technology, and for the balance of the war years the School was administered by a faculty committee chaired by Everett M. Strong. This developed in 1946 into an unusual and significant feature of the School, still functioning today: a permanent elected faculty committee to work with the director in formulating policy. In the fall of 1945, Charles R. Burrows, a senior scientist at the Bell Telephone Laboratories, was named director of the School.

After the war, engineering enrollments boomed. Supported by the G.I. Bill, thousands of young people—many of them representing the first generation of their families to attend college—sought higher education. They entered the nation's universities and colleges as adults, having experienced the ravages of war, and generally were highly motivated, anxious to acquire their education and embark on their careers as soon as possible.

The new circumstances also brought changes to the institutions. Schools suddenly found themselves able to be more highly selective, and they found it necessary to provide instruction in many new areas of science and technology. In World War I the emphasis had been on development of the chemical technologies, especially those concerned with the synthesis and manufacture of organic chemicals; but in World War II the crucial need had been for advances in nuclear physics, electronics, and related technology, and this resulted in a dramatic growth of postwar activity in the areas of physics and electrical engineering. The electrical engineer of the pre-World War II era was largely a power man—in contemporary terms, an electromechanical engineer; in the postwar period he was likely to be a specialist in one of the rapidly developing new technologies. And throughout the past twenty-five years, technical education, especially in electrical engineering, has been changing at least as fast as the technology itself.

A further stimulus was the entry of the

Right: This polar-mounted equipment was used in the 1950s in early radiophysics and space research at Cornell. The people in the photograph have been identified as S. Michel Colbert (on the platform), who is now a staff member of Cornell's Center for Radiophysics and Space Research, and Ralph Bolgiano, now professor of electrical engineering and then a graduate student.

Below: The world's largest radar-radio telescope was conceived and designed by Cornell engineers and built under their supervision at Arecibo, Puerto Rico, in the early 1960s. The dish-shaped reflector is 1,000 feet in diameter. (A discussion of this facility is included in the accompanying article by G. Conrad Dalman.)

Photographed at the dedication of Phillips Hall in 1955 were, left to right, S. C. Hollister, dean of the College of Engineering; Ellis L. Phillips; Mrs. Ellis L. Phillips; and Cornell President Deane W. Malott. The building is shown below.

federal government into contract research sponsorship at universities. In engineering fields, the government's aims were to sustain the flow of technological activities that had been so critical to the success of the Allies in World War II and to aid in the education and development of engineers who could work in the new technologies.

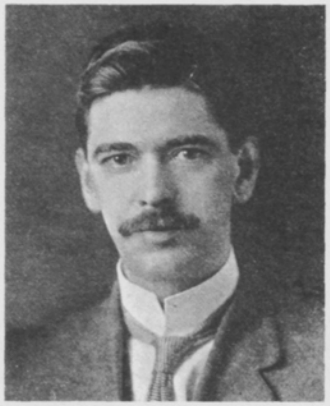
These three factors—the G.I. Bill and the returning veterans, the visibility of electronics technologies, and federal support of research—brought new life to electrical engineering at Cornell and elsewhere.

FROM THE IONOSPHERE TO SOLID-STATE DEVICES

During the twelve years that Charles R. Burrows directed the Cornell School of Electrical Engineering, twenty new faculty members were added (eleven of these are still active). Burrows had a great interest in radiophysics, especially wave propagation, and this was reflected in the interests of the professors he appointed, as well as in the contract research undertaken by groups in the School. Henry Booker, William Gordon, Charles Seeger, Ralph Bolgiano, Benjamin Nichols, Donald Farley, Neil Brice—all these contributed to research programs which developed in solar and radio noise and ionospheric propagation and scattering. Cornell became one of the world's centers for radiophysics and space research.

One of the internationally recognized achievements in this area was the conception, design, and construction of the world's largest radar-radio telescope in Arecibo, Puerto Rico. Gordon, a graduate student of Burrows and Booker, was mainly responsible for the conception of this immense "eye-and-ear," and had overseen the installation of the dish and the subsequent establishment of an international research program at the Arecibo observatory before leaving in 1966 to become dean of engineering and science at Rice University. He had drawn extensively on Cornell faculty resources not only in electrical engineering, but also other areas, especially civil engineering.

Another important construction project during Burrows' term as director was the long overdue building of a new home for the School of Electrical Engineering. Phillips Hall, a gift of the Ellis L. Phillips



Alexander Gray, director
1916–1921

Paul M. Lincoln, director
1922–1938

LEADERSHIP OF THE CORNELL SCHOOL OF ELECTRICAL ENGINEERING

(Prior to the formation of the School in 1921, electrical engineering was a department in the Sibley School of Mechanical Engineering)

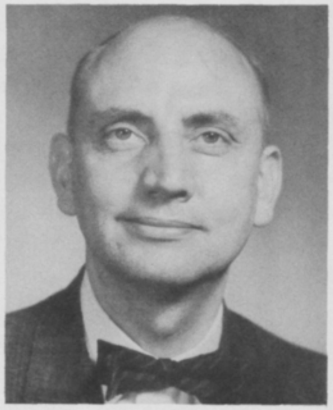
William A. Lewis, director
1938–1942

Everett M. Strong, chairman
1943–1945

Charles R. Burrows, director
1945–1957

W. H. Erickson, acting director
1957–1959

Henry G. Booker, director
1959–1963



Glen Wade, director
1963–1965

Herbert J. Carlin, director
1966–1975

G. Conrad Dalman, director
1975–

LONG-TERM FORMER FACULTY MEMBERS ASSOCIATED WITH ELECTRICAL ENGINEERING AT CORNELL

(Professors with Fourteen or More Years of Service)

William A. Anthony	1872–1887	Paul M. Lincoln	1921–1937
George S. Moler	1875–1920	Lawrence A. Burckmyer	1922–1962
Edward L. Nichols	1887–1919	True McLean	1923–1966
Harris J. Ryan	1888–1904	Michel G. Malti	1923–1962
Ernest G. Merritt	1889–1935	Miles G. Northrop	1924–1942
Frederick Bedell	1892–1937	Everett M. Strong	1924–1969
Henry H. Norris	1896–1914	Walter W. Cotner	1925–1964
George S. Macomber	1902–1916	Wilbur E. Meserve	1926–1968
Vladimir Karapetoff	1904–1939	Howard G. Smith	1933–1974
John G. Pertsch	1911–1928	A. Berry Credle	1941–1957
William C. Ballard	1912–1952	Robert E. Osborn	1944–1976
Robert F. Chamberlain	1912–1952	Casper L. Cottrell	1944–1963
Burdette K. Northrop	1920–1924	Stanley W. Zimmerman	1945–1974
	1929–1958	Henry G. Booker	1948–1962
Joseph G. Tarboux	1919–1929	William E. Gordon	1948–1966
	1945–1952	Clyde L. Ingalls	1948–1971

Foundation, was completed in 1955 and named in honor of this 1895 Cornell graduate who had been the founder and chief executive of the Long Island Lighting Company. An important participant in the move to Phillips Hall was A. B. Credle, the assistant director of the School.

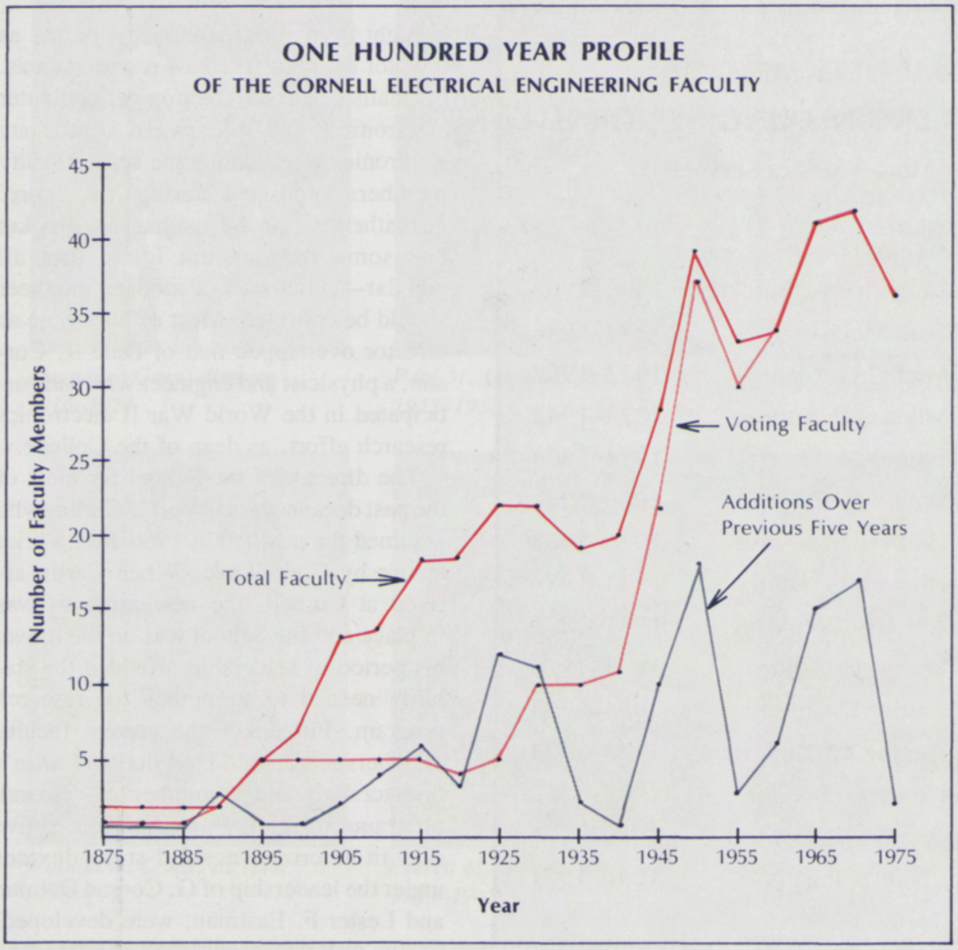
The construction of Phillips Hall was followed shortly by new buildings for mechanical, aerospace, metallurgical, and civil engineering, and by a facility to house the engineering library and the College administrative offices. New facilities had been the dream and the need for half a century, and their realization in a whole new engineering quadrangle was largely the result of efforts by S. C. Hollister, dean of engineering at Cornell from 1937 to 1959.

Burrows resigned as director of the School of Electrical Engineering in 1957, primarily because of failing eyesight. William H. Erickson, a member of the faculty since 1945, served as acting director until the appointment of Henry G. Booker in 1959.

Booker, who had been a member of the electrical engineering faculty for a decade, brought to his brief (four-year) period as director an interest in new research areas. Specialists in laser electronics, computer electronics, and microwave solid state electronics were among the seven faculty members appointed during his tenure. A mathematician by inclination, Booker had some independent ideas—not all popular—about how a modern engineer should be educated. Most of his tenure as director overlapped that of Dale R. Corson, a physicist and engineer who had participated in the World War II electronics research effort, as dean of the College.

The director of the School for most of the past decade was Herbert J. Carlin, who assumed the position in 1966 after a brief tenure by Glen Wade. When Carlin arrived at Cornell, the new program was in place and the School was on the move; his period of leadership provided the stability needed to strengthen the research program. Fifteen of the current faculty members were appointed during Carlin's directorship, and a number of research programs, including an especially active one in microwave solid-state devices under the leadership of G. Conrad Dalman and Lester F. Eastman, were developed. Carlin resigned as director in 1975 and was succeeded by the present director, Dalman, who has been a member of the faculty since 1956.

Overall, the period since 1945 has been a full and productive one for electrical engineering at Cornell. In the postwar period, the foundation was laid for a transformation of the School's main thrust to a modern program based heavily on electrophysics. Contributing to this trend was the establishment, soon after the war, of the Department of Engineering Physics and the development of close relations between it and the School of Electrical Engineering. Once again, active collab-



Right: These four men are among the memorable figures in the history of electrical engineering at Cornell. "Johnny" Pertsch *was important in the development of the School curriculum in the years following World War I. He died early by drowning while attempting to save another's life.* A. Berry Credle, *as assistant director of the School, was a key figure during the years of rapid growth and the move to Phillips Hall.* Michel Malti *was active for many years in the teaching of upperclass courses in theory; he is especially remembered for his participation in faculty debates on academic issues.* Lawrence Burckmyer *was responsible for overseeing the machinery laboratories in Rand Hall. He chaired the Phillips Hall planning committee.*

oration developed between electrical engineering and applied physics—a relationship that had characterized Cornell's pioneering era in electrical engineering.

EFFECTS OF RECENT CHANGES IN THE ENGINEERING COLLEGE

In the 1960s the faculty of the College of Engineering introduced several changes that affected curricular arrangements for specialization in the various engineering disciplines, including electrical engineering. In 1961 while Corson was dean, a Division of Basic Studies was formed to administer and oversee a more coherent, unified underclass program for all engineering students; rather than being admitted to one of the specialty fields, students were admitted to the College and postponed entry into field programs until the junior year. (One of the authors of this article, Howard G. Smith, was appointed initial director of DBS, as it came to be called, and served for ten years in that post.)

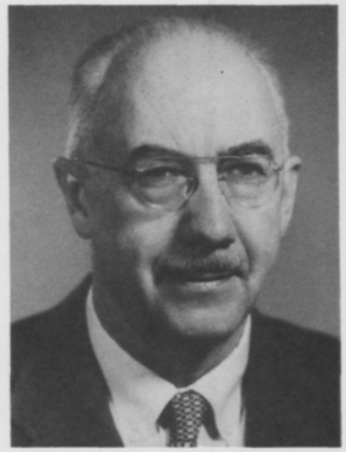
By 1965 it had become apparent that the undergraduate degree program required further revision. Since the end of World War II, a Cornell engineering education had been achieved through a five-year, professional bachelor's degree program. The plan served practice-oriented students well, but did not work to the advantage of the considerable number of students seeking careers in engineering research and development, or the smaller number who planned graduate study in nonengineering fields such as law, business, and medicine. Accordingly, the College, under the leadership of Dean Andrew Schultz, Jr., instituted a new program in which a student could earn a Bachelor of Science degree in four years, and could then complete a professional program in an engineering field with an additional year of study for the degree of Master of Engineering. Alternately, the B.S. graduate could enter a research-oriented Master of Science or Doctor of Philosophy program at Cornell or elsewhere. The M.Eng. programs in the various fields are course-centered and include practical project work carried out individually or by small groups of students.

In electrical engineering, the introduction of the M.Eng. program reestablished an element of technology (building some-

Pertsch

Credle

Malti



Burckmyer

thing that works and that has high potential of being practical) that had been somewhat neglected during the time the research program was being developed. The M.Eng. (Electrical) degree program is now an integral part of the School's overall graduate program (some students use it as preparation for doctoral work), and it has proved to be a popular choice for graduates of the undergraduate electrical engineering curriculum. Overall administration of the required design project program has been largely the responsibility of Joseph L. Rosson, now associate director of the School.

LOOKING BACK . . . AND LOOKING AHEAD

Building and maintaining a viable educational program in a rapidly changing world requires continuous attention to faculty staffing, physical facilities, curriculum, and the selection and development of students. We have chosen to recount the development of electrical engineering at Cornell mainly through the medium of "who was minding the store." In addition to the leaders we have mentioned, there have been many other independent-minded men—Lawrence Burckmyer, Berry Credle, Michel Malti, John Pertsch, Jack Tarboux come to mind—who created "sparks." And there have been scores of men who, when the faculty meetings were over, went about the fundamental, daily task of educating Cornell electrical engineers—more than six thousand in all. The physical facilities have also entered our story, for educational programs, especially in a rapidly changing field like electrical engineering, depend on the availability of adequate laboratory space and up-to-date equipment, as well as on the teaching staff.

The present is a time to look ahead as well as backward. In the immediate future, the crucial tasks are to replace equipment as it becomes outmoded and to provide for effective participation in new and developing specialties in electrical engineering. It is also necessary, in the current period of educational history, to find solutions to problems associated with the escalating costs of education—for students as well as for institutions. At Cornell, for example, a particularly pressing need is for student support in the Master of Engineering program; the College would like to be able to provide any qualified student with the opportunity to add this capstone to his or her undergraduate education without incurring substantial indebtedness.

For the School of Electrical Engineering, the problems and challenges are different today than they were a hundred years ago, but the purpose is the same: to prepare Cornellians for productive careers in an expanding field. In electrical engineering, Cornell has gone from a faculty of one to a faculty of forty; from a little hand-made dynamo to the Arecibo observatory; from the basement of Morrill Hall to the large and modern Phillips Hall; from three graduates in 1885 to more than one hundred twenty-five in 1976; from a relatively simple electrical machinery laboratory to a sophisticated semiconductor and integrated circuits laboratory.

Cornell's School of Electrical Engineering is well positioned to generate a good many more "sparks" in its second century. "What Hath God Wrought": among other things, the development of a major division of the engineering profession, a great university, and a pioneering and leading center for American electrical engineering.

For several months Howard G. Smith (left) and Donald F. Berth met regularly on Wednesday afternoons in the Carpenter Hall library to gather material for this article.

Collaborating in the preparation of this article were Donald F. Berth, director of special projects at the College and history buff, and Howard G. Smith, professor of electrical engineering, emeritus, whose experience at Cornell extends back through fifty of the one hundred years covered in the article.

Berth, founder and former editor of the Quarterly, *has written several previous articles on College history for this magazine. They include an overall history published in 1971 in a special issue marking the centennial of engineering education at Cornell, and an article in the Summer 1975 issue on John McMullen and the scholarship fund he endowed. Among the professional organizations he belongs to is the Society for the History of Technology. Berth joined the College staff in 1962 as administrative assistant to the dean, and subsequently served as director of college relations and initial director of the Engineering Advising and Counseling Center. In his present capacity he is responsible for financial development activities and participates in teaching and educational development programs. This past spring he served as acting director of the Engineering Cooperative Program. His experience includes assignments at Corning Community College and Hampshire College, and he is a consultant in development, publications, and educational innovation to several technical institutions. He holds B.Ch.E. and M.Ch.E. degrees from Worcester Polytechnic Institute.*

Smith came to Cornell as a student in 1926 and earned three degrees—Electrical Engineer, Master of Electrical Engineering, and Ph.D. (His interest in publications extends back to undergraduate days, when he served on the editorial board of the Cornell Daily Sun *and subsequently, in his senior year, as managing editor of the* Sibley Journal of Engineering.*) He joined the Cornell staff in 1931, serving first as a teaching assistant in physics and then as a member of the electrical engineering faculty. After teaching for many years in the areas of communications engineering and electrical circuit theory, he joined the College administrative staff in 1961 as director of the newly formed Division of Basic Studies. He was active also in industrial consulting and continuing education for professional engineers, and he served for many years on the policy committees of both the School of Electrical Engineering and the College of Engineering. He retired in 1974 after completing one of the longest faculty tenures in electrical engineering at Cornell.*

ELECTRICAL ENGINEERING AT CORNELL TODAY

by G. Conrad Dalman

In its beginnings, just before the start of the twentieth century, the field of electrical engineering was concerned with practical applications of the relatively new science of electricity. There were two important areas: *communications*, which involved the telegraph and the telephone, and *power*, which involved the generation and distribution of electricity. In both areas, design and operating problems dominated the work of electrical engineers.

Over the years the field has proliferated into numerous subdisciplines. Intensive work on specific problems has led to many new conceptual models with very broad applications. For example, work in telephony has led in modern times to the formulation of a comprehensive theory underlying the communication of information, and showed that messages can be transmitted in "yes or no" units called binary digits or bits; this field is now called information theory. Concepts of systems analysis, automatic feed-back control, etc., which were developed within the field of electrical engineering, are now being applied in such apparently unrelated areas as biology, economics, and management. Other "revolutions" were triggered by the advent of electron devices; for example, such singularly important devices as the transistor and the laser, spawned from the basic field of quantum mechanics, have led to the emergence of new fields such as computer technology, solid-state radio and television, solid-state radar, and optical communications. The extensive use of electron devices led to the development of electrical instruments for all kinds of observations and measurements, and the use of these instruments has transformed the operational procedures and modes of investigation in practically all areas of human activity.

In spite of these radical changes, it appears that modern electrical engineering still dedicates itself to its original goals: achieving a better understanding of communication devices and systems and of methods for producing and controlling electrical energy.

EDUCATING ENGINEERS IN A RAPIDLY CHANGING FIELD

Educators in the field of electrical engineering have learned to adapt to the rapidly changing conditions. In their curricula they offer both courses that provide the fundamental knowledge basic to engineering and courses that deal with contemporary technology. This approach enables new graduates to contribute to and participate in current programs, and also be prepared to adapt to changes that will inevitably occur in technology. At Cornell three levels of programs are offered:

(1) *Undergraduate,* emphasizing basic science and mathematics and providing a broad humanistic and social science foundation and an introduction to technology. The aim is to prepare the student to be an engineering apprentice who will develop further with time, possibly even in another direction.

(2) *Professional master's,* emphasizing a high level of technological proficiency and design competence. The purpose is to develop a full-fledged engineer, one who can be employed immediately in a productive role.

(3) *Doctoral,* with primary emphasis on research. Ph.D. study is intended to develop an electrical or electronic scientist capable of original work in novel, unexplored areas out of which tomorrow's technology may emerge.

CORNELL ELECTRICAL ENGINEERING FACULTY MEMBERS AND THEIR AREAS OF INTEREST*

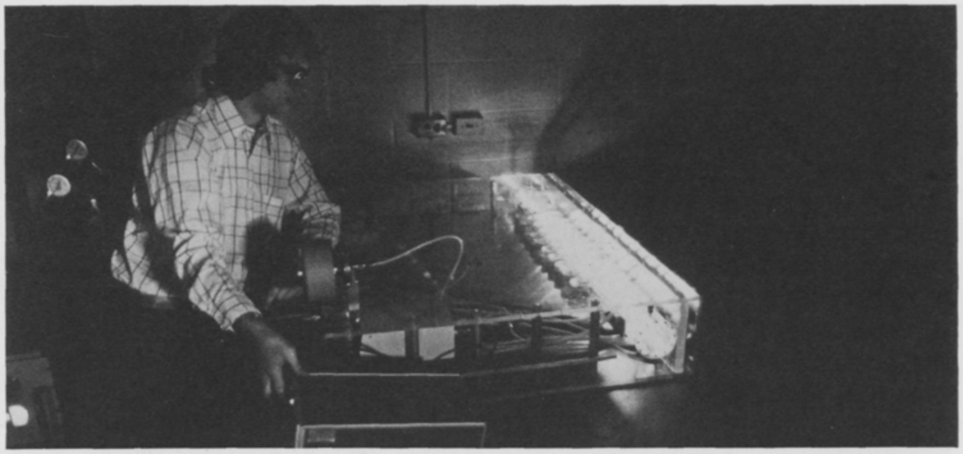
* Paul D. Ankrum: *solid-state devices, power electronics*
Joseph M. Ballantyne: *optoelectronics, integrated optics*
Toby Berger: *information theory, signal processing*
* Ralph Bolgiano, Jr.: *tropospheric radiophysics, communication theory*
* Nelson M. Bryant: *electronic circuits, instrumentation*
Robert R. Capranica: *sensory communication, neural processing*
Herbert J. Carlin: *microwave circuits, network theory*
Vincent W. S. Chan: *optical communications, information transmission*
* G. Conrad Dalman: *microwave solid-state devices and circuits*
* Lester F. Eastman: *microwave solid-state devices, GaAs and InP techniques*
* William H. Erickson: *power engineering, instrumentation*
Donald T. Farley: *ionospheric physics, radio propagation*
Terrence L. Fine: *decision theory, estimation*
Jeffrey Frey: *microwave solid-state devices, integrated electronics*
William J. Heetderks: *bioelectronics*
Michael C. Kelley: *space plasma physics, rocket and satellite instrumentation*
* Myunghwan Kim: *bioelectronics, control theory*
Walter Ku: *active networks, active and microwave circuits, signal processing*
Charles A. Lee: *solid-state physics and devices*
Richard L. Liboff: *fusion theory, electrodynamics, quantum mechanics*
* Simpson Linke: *energy systems, high-voltage transmission*
Ross A. McFarlane: *lasers, atomic and molecular spectroscopy, photochemical kinetics*
* Henry S. McGaughan: *network and communication theory*
* Paul R. McIsaac: *microwave circuits and devices, electromagnetic theory*
John A. Nation: *plasma physics, high-energy beams*
* Benjamin Nichols: *educational techniques*
Edward Ott: *plasma and ionospheric physics*
* Christopher Pottle: *computer-aided design, network theory*
* Joseph L. Rosson: *power engineering, instrumentation*
* Ravindra N. Sudan: *plasma physics, thermonuclear fusion*
Chung L. Tang: *lasers, quantum electronics*
Robert J. Thomas: *applications of control theory to power systems*
* James S. Thorp: *applications of optimization and control theory to power systems*
* Hwa-Chung Torng: *computer design and architecture, switching theory*
* Norman M. Vrana: *switching theory, hybrid computing systems, digital system design and architecture*
Charles B. Wharton: *plasma physics, microwave diagnostics*
* George J. Wolga: *lasers, atomic and molecular physics, spectroscopy*

* *Fourteen or more years of service*

The content of basic courses does not vary greatly among the electrical engineering curricula of institutions accredited by the Engineers' Council for Professional Development. The part of the curricula that deals with current technology may, however, differ radically from school to school, for essentially it is the special expertise of each of the faculty members that determines this component. I would like to define the special strengths of Cornell's School of Electrical Engineering by describing the principle areas in which members of the faculty are working.

The research and engineering development currently under way covers a wide spectrum of problems. A few examples are projects in the areas of algebraic coding, bioelectronics, computer-aided design and testing of devices, data compression, active distributed and digital networks, the application of control theory to power system stability, multiterminal communications systems, pattern recognition and speech processing, evaluation of microprocessors, quantitative design of processors, the ionosphere and magnetosphere of Earth and Jupiter, rocket and satellite instrumentation for ionospheric studies, high-energy plasmas and thermonuclear fusion, high-power (intense) ion beams, molecular and chemical lasers, electrically tuned dye lasers and semiconductor lasers, thin film optical devices, microwave solid-state devices, integrated circuit technology, and an electric automobile.

It would be impossible to describe all the various projects in a summary article, but brief descriptions of a few in each area should provide insight into the range of activities and interests at the School, and therefore into the kinds of "real world" problems that Cornell electrical engineers may be especially well prepared to confront. These various research activities fall



A Cornell project in the area of quantum electronics is the development of a very high power laser to produce pulses of ultraviolet light with peak powers in the megawatt range. This laser is used in studies, directed by Professor Ross A. McFarlane, of photochemistry and molecular energy transfer.

into two general categories: those that tend to be of a theoretical nature and have mathematics as a broad base, and those that are experimentally oriented and have a strong base of physics. There are, of course, a few cases that lie between these extremes.

QUANTUM ELECTRONICS AND OPTOELECTRONICS

Two of the newest areas of research in the field of electrical engineering are quantum electronics and optoelectronics. Both of these areas have an especially strong base in physics, since the devices involved, such as lasers and photodetectors, depend on quantum phenomena; and both are strongly oriented toward experimental work.

In the chemical and molecular laser field, current Cornell research is oriented toward the discovery and study of new laser systems. For example, tunable infrared lasers, anticipated to have applications in tunable laser spectroscopy and laser-induced chemistry, are now being developed. The relaxation and transfer of vibrational and electronic excitation in molecules through atomic and molecular collisions is being studied over an extremely wide range of experimental parameters. At Cornell laser research is interdisciplinary, with joint participation of faculty members and students in the graduate Fields of Electrical Engineering, Chemistry, and Applied Physics.

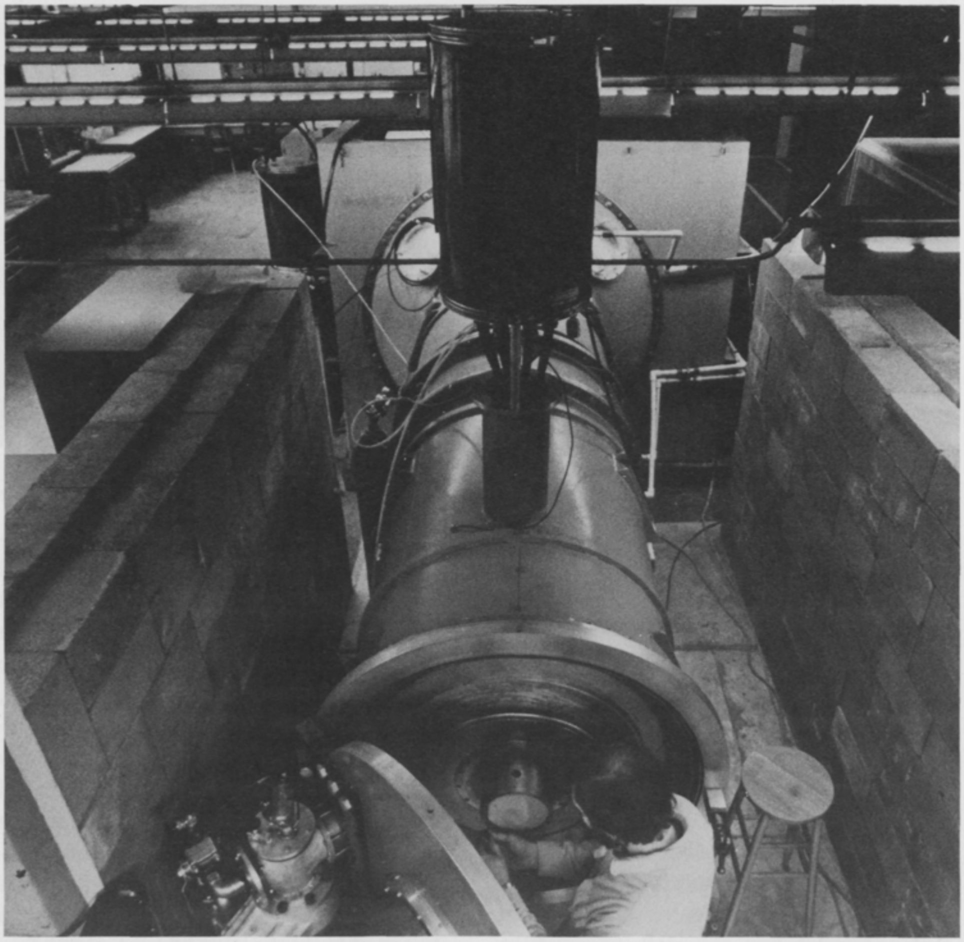
Athough optoelectronics is a relatively new area of research, its practical potential in communications technology is stirring considerable interest in the electronics industry. In view of the timeliness of this work, a discussion of optoelectronics and its possible applications is presented in a companion article in this issue of the *Quarterly*.

WORK ON PLASMAS AND OTHER ENERGY-RELATED PROJECTS

Another research area involving experimental physics is that of high-energy plasmas for possible future generation of electric power by controlled thermonuclear processes. This work is one of the segments of the broad program that has developed at Cornell in energy-related research, both theoretical and applied. Some of this work is coordinated or sponsored by interdisciplinary groups or centers such as the Laboratory of Plasma Studies and the Cornell Energy Project, and some is concerned with problems more specifically related to a particular discipline. For the past several years, energy research by members of the electrical engineering faculty and their students has been centered in cooperative efforts of broad interest, but investigations are being initiated in topics of specific interest to electrical engineering.

Programs in which members of the School are participating include projects and studies in intense relativistic electron beams and their interaction with plasmas, intense ion beams, lasers and their interaction with plasmas, collisionless plasma turbulence (waves and transport), nonlinear waves and plasma instabilities, and numerous problems involved in controlled thermonuclear power research.

Research on megavolt, terawatt electron beams, high-current multigigawatt ion beams and turbulent heating are especially noteworthy, since pioneering work in these areas has been carried out at Cornell. The electron and ion beam research is directed largely to the study of heating and confinement of thermonuclear plasmas.

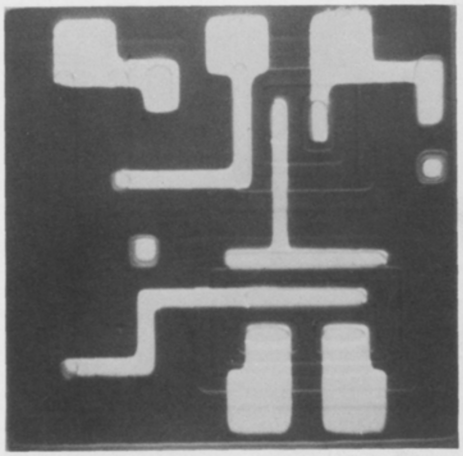


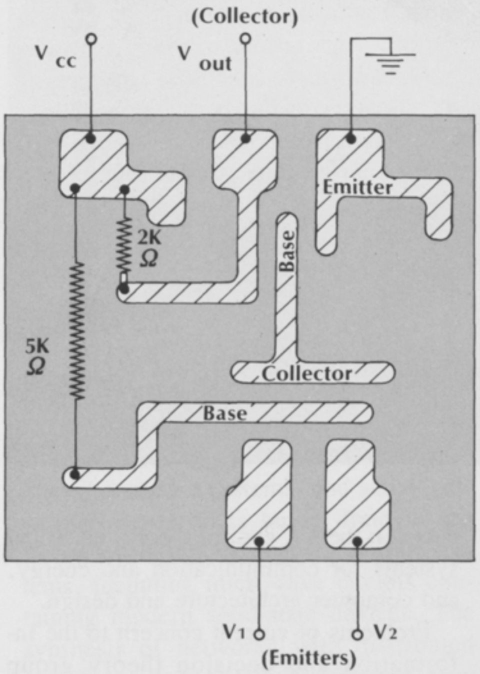
A Neptune pulsed power supply is used for generating intense ion beams in research directed by Professor Ravindra N. Sudan. This machine, capable of delivering 250 kiloamperes at 500 kilovolts for 60 nanoseconds, is used in several projects, including a study of the heating and confinement of thermonuclear plasmas.

Other work using these beams is directed to microwave generation, collective ion acceleration, and beam dynamics. Intense ion beams capable of being focused on small targets are also being developed in an effort to replace lasers in deuterium-tritium pellet implosion-type fusion systems. In the turbulent heating experiments, the possibilities for heating a fusion plasma by strong turbulence are being investigated. Theoretical work includes studies of collective processes by which relativistic beams transfer their energy to plasmas, stability and equilibrium of electron beams in different geometrical configurations, and plasma turbulence. Some of these problems are simulated by numerical models solved on the largest modern digital computers. Execution of the experimental work is strongly dependent on pulse-power technology, control of high-voltage phenomena, and the generation of strong pulsed magnetic fields.

FROM TINY CRYSTALS TO GIANT RADAR TELESCOPES

An important research area that lies directly in the mainstream of present-day electrical engineering is solid-state electronics. This encompasses studies of devices that operate over very low frequencies for industrial electronic applications, or at medium to very high frequencies for communications and radar applications. Research on microwave semiconductor devices emphasizes experimental studies with potential engineering applications, and includes work on active elements for the generation and amplification of microwave signals at both low and high power levels. The growth of the key semiconductor crystals necessary for the construction of these elements is facilitated by a controlled-atmosphere microelectronics laboratory that was set up recently in Phillips Hall.

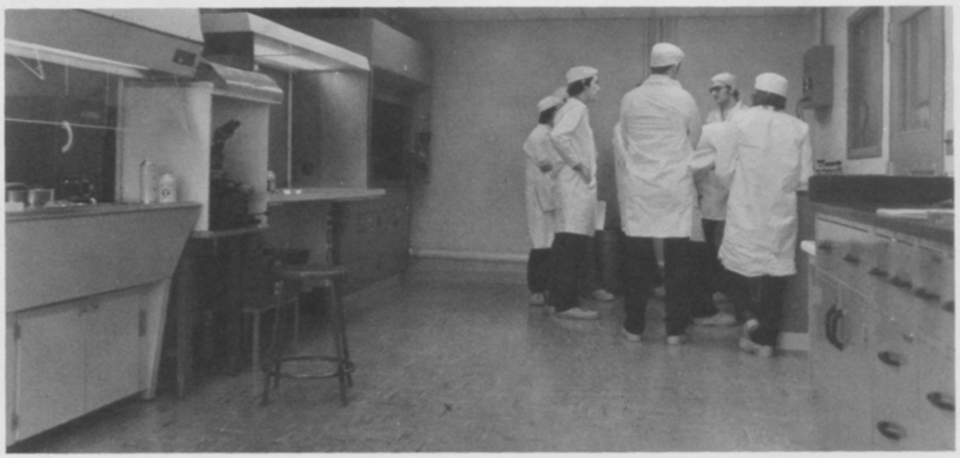


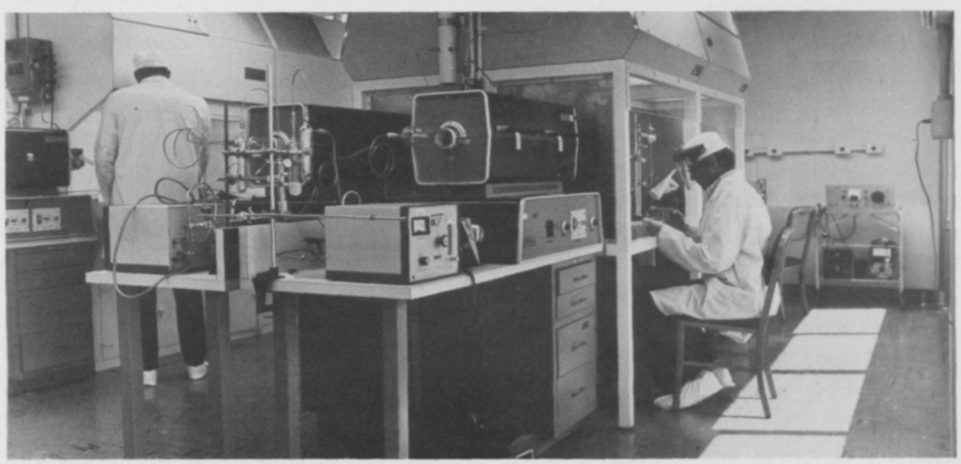


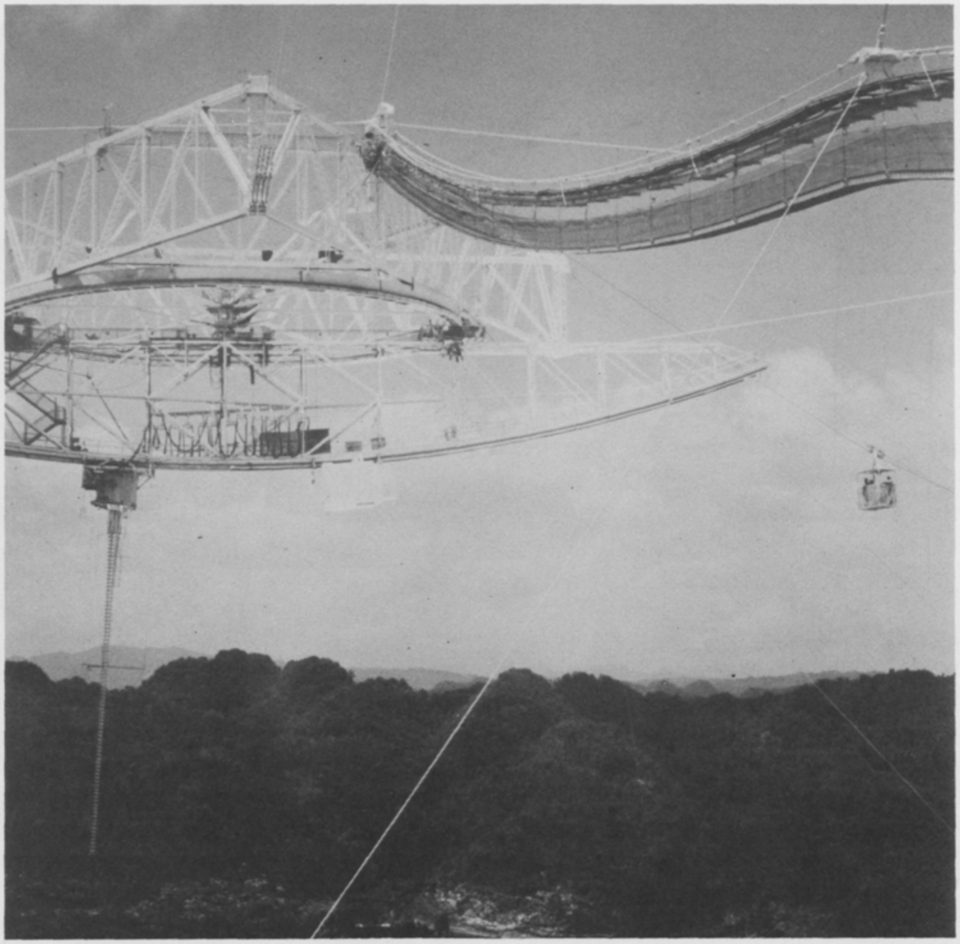
Above: This integrated circuit was fabricated in the new microelectronics laboratory on a silicon chip 0.023 inches square. At top is an enlarged photograph and below is the corresponding schematic of the double-input transistor-transistor logic NAND gate. The design and fabrication was accomplished by a fourth-year student in integrated circuit technology.

Below: A recent addition to the facilities in electrical engineering is a complex of clean rooms for crystal growth and the processing of semiconductor materials and devices. The three laboratories in the complex have humidity and temperature control and filtered air; entry is through air locks, and special clean-room apparel is worn by everyone who enters.

The microelectronics room, shown in the top photograph, is large enough to accommodate laboratory sections of ten or more students, and contains equipment of sufficient sophistication to permit research students to fabricate state-of-the-art microwave devices. The laboratory used for growing semiconductor crystals is shown in the lower photograph.







Cornell graduate students working in the area of radiophysics have access to the radio-radar observatory at Arecibo, Puerto Rico, which is operated by Cornell under contract to the National Science Foundation. This photograph shows the largest antenna of the giant telescope: ninety-six feet in length and weighing almost ten thousand pounds, it hangs from a triangular support structure some five hundred feet above the spherical reflector. Access to the platform is by a seven-hundred-foot catwalk and a cable car, both visible in the picture.

Radiophysics is another research area with a very strong base in physics. Current experimental and theoretical research in this field is concerned with a variety of electromagnetic wave propagation phenomena and their utilization in studies of the properties of geophysical plasmas and the neutral atmosphere. An active program involving rocket- and satellite-borne experiments is concerned mainly with the study of plasma instabilities and wave–particle interactions in the upper atmosphere. The radiophysics facilities used by electrical engineering research groups include the giant radio–radar installation, with an antenna diameter of a thousand feet and a 2.5-megawatt transmitter, that is operated by Cornell in Arecibo, Puerto Rico. Research is performed also at a large radar installation near Lima, Peru, and auroral research is being done with a smaller radar in Ithaca.

INFORMATION, COMMUNICATION, SYSTEMS, AND CONTROL

A wide variety of programs having a very strong base in mathematics are under way. These deal primarily with information and decision theory, control theory, electrical systems for communication and energy, and computer architecture and design.

Problems of current concern to the information and decision theory group center around novel formulations of information sources and processors (for example, sliding block codes), quantum mechanical noise and information processing limitations, and fundamental issues in the nature of uncertainty and decision making. Research is also being conducted into applied problems of optical communications, data compression, pattern classification, radar, inertial navigation, and stochastic models of language.

Problems associated with control of linear and nonlinear systems, including problems of stochastic control, are being studied theoretically, and techniques developed in these investigations are being applied to control problems encountered in work with power systems. In the general area of power system network analysis, for example, research is being conducted on the application of control theory and computer science techniques to the transient stability problem that exists after a major power system disturbance. Control mechanisms such as a dynamic braking, capacitor switching, and governor and exciter regulation are being investigated. An integral part of these studies is concerned with the development of algorithms to provide on-line decisions for optimal coordinated application of the various control mechanisms to systems in the emergency state.

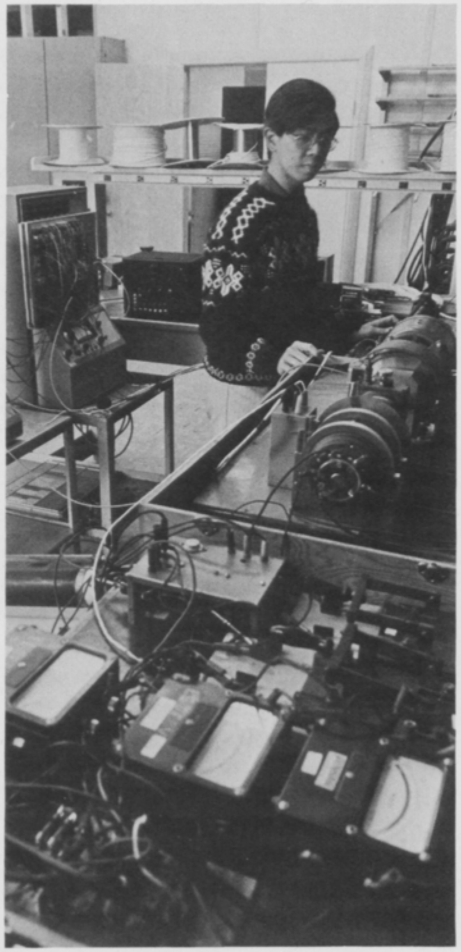
Problems of current interest in the area of electrical networks are concerned primarily with microwave circuit design, computer-aided circuit design, digital filters, nonlinear systems, and active networks. Research is being done in the theory and design of broadband active systems, including microwave circuits containing modern solid-state devices. The synthesis of networks with distributed parameters is also being investigated. New results have been obtained in gain-bandwidth theory, broadband and highly selective narrowband filters, lump-loaded transmission line structures, and linear phase microwave structures. Recent contributions also include the use of circuit methods for analyzing dispersion in dielectric-loaded and dielectric (optical) waveguides. The CORNAP computer program, developed at Cornell, is widely used in industry and at other universities to analyze complicated active linear networks using a state–space approach. The methods used in this program are currently being extended to nonlinear and time-varying networks, with particular emphasis on design optimization methods, sparse matrices, and simulation of stiff linear systems.

THE VERSATILE DIGITAL COMPUTER: CREATION OF ELECTRICAL ENGINEERS

From its first hardware realization through its several generations of improved power and capability, the digital computer has been the creation of electrical engineers who function in a wide range of activities from detailed component and logic circuit design to architectural organization of system components. In the last few years, the circuit components of the digital computer's central processing unit have been miniaturized so that all components can be placed on a small integrated circuit chip called a microprocessor. The small size and cheapness of the microprocessor has meant that the computer revolution has gone an additional big step. Electrical engineers now use the computer not only as a tool in research and education, but also as a circuit component—the microprocessor—connected to other circuit components to accomplish many new objectives as well as to radically alter and improve established ways of doing things. The digital computer, ranging in size from the microcomputer to the large multiprocessing installation, is the concern and creation of electrical engineers.

At Cornell, research on microcomputer systems has included the development of quantitative measures of evaluation. Also, methods of control for systems containing microprocessors have been studied in a

"Electrical engineering . . . activities and concerns . . . range through practically all other fields of technology"



Above: A PDP-11/40 minicomputer at the School of Electrical Engineering is used for research projects as well as for instruction.

Left: One of these projects is concerned with problems of power failure in large electric power systems. In developing techniques for on-line fault analysis, researchers headed by Professors Simpson Linke and Robert J. Thomas constructed a model to simulate a large turbogenerator and connected it to the minicomputer; when the system is subjected to a severe short circuit, control signals are generated by the minicomputer and transferred back to the model system, initiating corrective measures. Shown in the photograph are the model, analog computer controls, and (in the background) a "black box" interface unit that connects to the minicomputer.

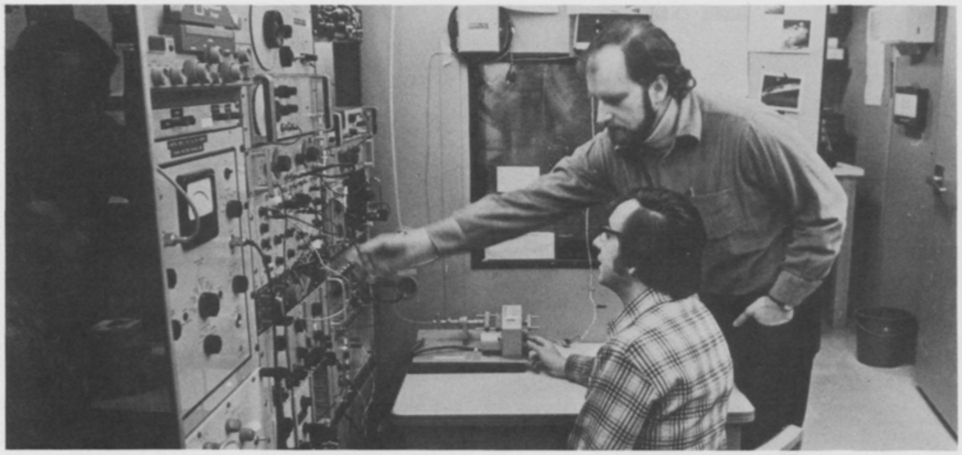
project to develop systematic techniques for the integration of microprocessors as elements in analog and digital systems. Laboratory equipment is being designed, and some has been built, to facilitate experiments in microprocessor interfacing.

In other projects, algorithms and quantitative approaches to the design of computers are being developed. Special emphasis is placed on structures in which multiple functional units are incorporated to enhance processing power.

FROM BIOELECTRONICS TO THE CORNELL ELECTRIC CAR

Bioelectronics is one of the active areas of electrical engineering research at Cornell that have a strong experimental bent. Work in this field involves the application of electrical engineering techniques to biological and medical systems and is unusual in that it draws heavily on mathematics and biological sciences, as well as on electrical signal processing and electrical instrumentation. One of the current projects is a study of mechanisms and models underlying the periodic electrical activity of single pacemaker nerve cells and circadian oscillation in the sea snail eye (see the article by M. Kim in the Spring 1975 issue of this magazine). A study of the dynamics of cancer cell proliferation includes the development of models for the design of cancer therapy. A group in electrical engineering and neurobiology is studying vocal communication among frogs and toads and the encoding of complex sounds in auditory nervous systems (see the article by Robert R. Capranica in the spring 1975 issue.)

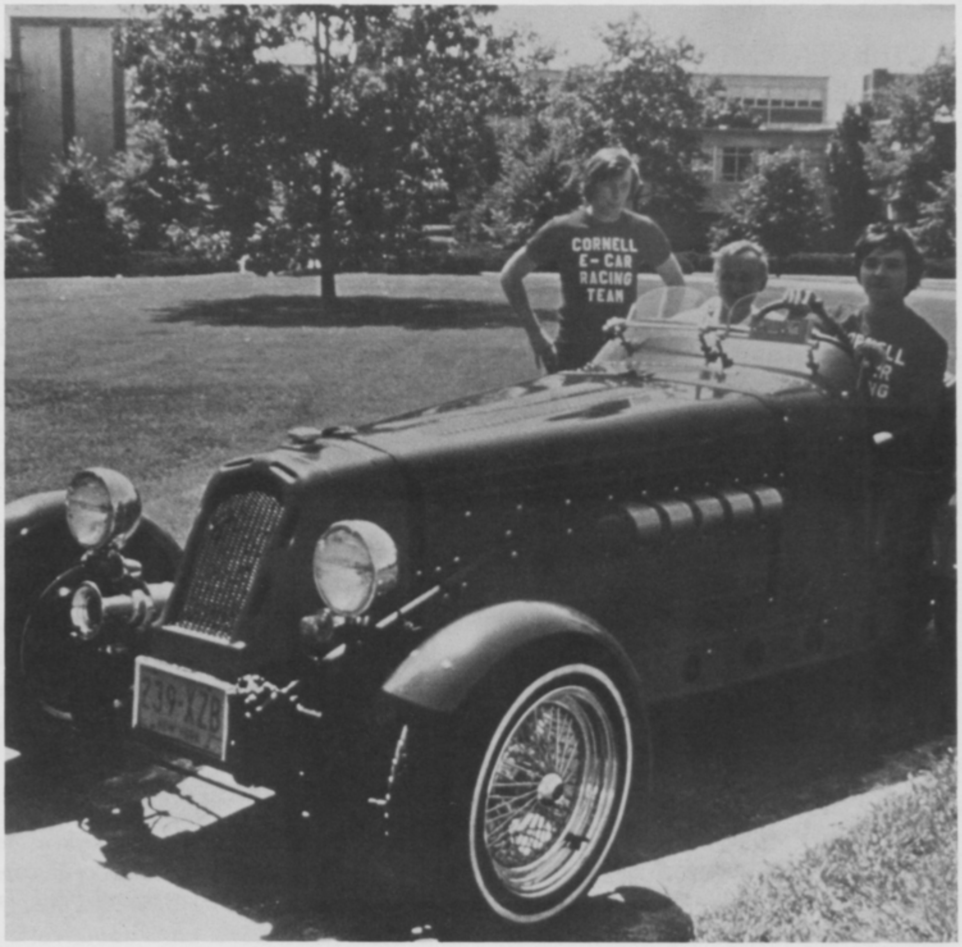
A continuing experimental project, especially for Master of Engineering stu-

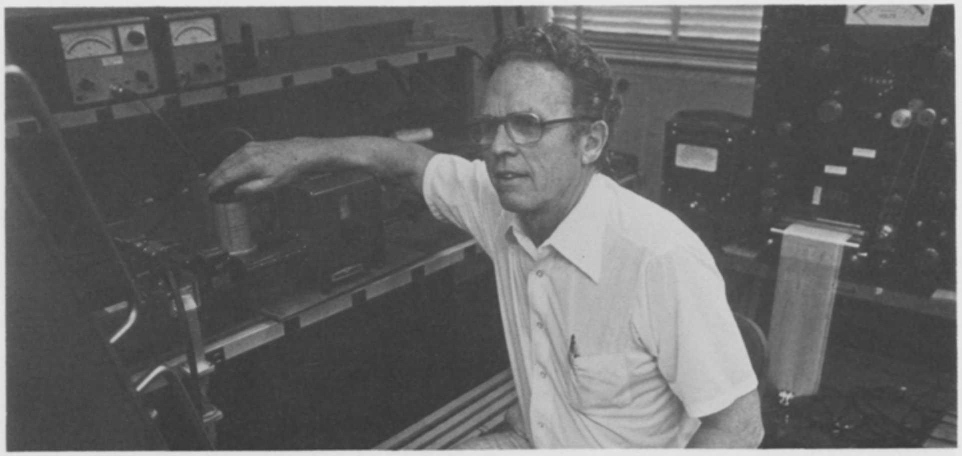


Left: Sounds used in behavioral studies of animal communication are generated electronically in bioelectronics research directed by Professor Robert R. Capranica (seated). The work also includes related neurophysiological experiments.

dents, is the design of an electric car for urban use. This work involves several electrical engineering subdisciplines, including electronics, power systems, and control systems. With the cooperation of design project groups in mechanical engineering, five successive models of the Cornell electric car have been completed.

Below: Students work in teams on various aspects of the electric car project. Right: This is the most recent of five models of the car that have been designed, built, and tested by teams of students in electrical and mechanical engineering.





AT THE CENTENNIAL OF ELECTRICAL ENGINEERING

Electrical engineering reaches into a vast profusion of activities and concerns. They range from highly specific and technical electrical engineering specialties through practically all other fields of technology, including broad areas of national concern. For example, the School of Electrical Engineering actively participates in the University's Program on Science, Technology, and Society as part of a broad effort to provide electrical engineers with acumen in the social and political implications of electrical technology.

Our program is planned to continue the Cornell tradition in electrical engineering education by providing not only thorough training in the basics of the discipline, but also the opportunity for work in a specialty area selected from a relatively large sampling of current technology. This effort is becoming more and more difficult, of course, because of the rapidly increasing sophistication of the technology. In an educational institution, there is a continual need for new and, unfortunately, rather expensive facilities: equipment that could have been purchased years ago for, say, a few thousands of dollars, now costs in the range of a few tens of thousands of dollars. Standard facilities, unheard of for use in engineering schools decades ago, include minicomputers, microprocessors, spectrum analyzers, ion implanters, sampling oscilloscopes, and dozens of other special-purpose components.

But problems are not new in electrical engineering at Cornell. Our faculty recognizes that pioneering is continuing process and that it must assume new forms as the character of a field evolves. Keeping pace—and taking the lead—in a rapidly expanding technology requires continuous effort today as it has throughout the history of electrical engineering at Cornell. That history, which spans the entire development of the technology in the United States and abroad, is still being written in the classrooms and laboratories of Phillips Hall.

Acknowledgement: The author is grateful to the members of the faculty of the School of Electrical Engineering for their considerable help in preparing this article.

G. Conrad Dalman became director of Cornell's School of Electrical Engineering last fall after twenty years on the faculty. A specialist in semiconductor microwave devices, he has had extensive research and industrial as well as educational experience.

Dalman began his professional career in industry, working for fourteen years in electron device development and research for RCA, Bell Telephone Laboratories, and the Sperry Gyroscope Company. After joining the Cornell faculty in 1956, he continued his participation in industrial activity as a consultant to several firms and as a founder of and later consultant to the Cayuga Associates division of the Narda Microwave Corporation, developers and producers of semiconductor microwave devices. He spent his most recent sabbatic leave with Cayuga Associates in a concentrated program of research and development. An earlier leave was spent at Chiao Tung University in Taiwan, where he helped set up an electronics research laboratory.

He holds an undergraduate degree in electrical engineering from the City College of New York, and graduate degrees, also in electrical engineering, from the Polytechnic Institute of Brooklyn.

COMMUNICATION WITH LIGHTWAVES

The Potential of Optics and Optoelectronics in Electrical Engineering Technology

by C. L. Tang

When the laser was first invented and enthusiastically discussed by a small group of scientists and engineers, some people said it was a solution looking for a problem. There were many skeptics. I remember reading, in a widely circulated trade journal, a well-reasoned and beautifully written article which argued eloquently and convincingly that the laser was merely an interesting scientific gadget and would have little or no technological impact. But human inventiveness often has a way of fooling such prophets.

Fifteen years of rapid development and unexpected progress have since established quantum electronics (a name adopted or claimed by people working with lasers in the early days) as a vigorous and growing field. Applications have been found in such widely diverse areas as metal processing in the automobile industry, new surgical tools, and surveying and alignment equipment for the construction industry. More exotic and futuristic possibilities include uses in isotope separation, laser-induced chemistry, and optical communication systems. Also, the laser remains one of the most versatile research instruments, enabling scientists to gain fundamental knowledge about the behavior of atoms, molecules, and condensed matter. Today, research and development programs related to this field can be found in most major industrial and government laboratories, as well as in the universities. Cornell has been engaged in such research from the beginning: quite a number of active contributors to the field today received their education here.

The quantum electronics program at Cornell is diverse and is being carried out in several departments and laboratories in the University with considerable cooperation among the various groups. One cannot do justice to the whole program by attempting to review it in an article such as this; I will, therefore, somewhat arbitrarily limit my discussion to a particular area that is perhaps the closest to the interests of the electrical engineering community.

OPTICS TECHNOLOGY AT A REVOLUTIONARY STAGE

Many of us can remember the days when electronic equipment such as radios, televisions, and even computers was constructed mainly of vacuum tubes, resistors, capacitors, and other bulky parts soldered together through connecting wires. If that way of doing things had continued, and if components had remained that large, modern electronics and consequently the space age would never have come. Without the revolutionary development of electronics technology based on solid-state components that can be miniaturized, and integrated circuits that can combine a great many components on a tiny chip and be mass produced, most modern electronic equipment and systems would not have materialized. Size and manufacturing requirements alone would have made production of complex equipment unfeasible, even though conceptually sound. In an analogous way, optics is at the threshold of a similar revolutionary development stage, I believe.

Optical devices and systems are built today much as the early radios and television sets were. They consist mainly of assemblies of individual bulk elements such as lenses, prisms, mirrors, modulators, and detectors. They are practical systems, to be sure, but truly widespread use on a massive scale in such basic industries as the telephone and other communi-

". . . optics is at the threshold of a . . . revolutionary development stage"

cations industries is still technically and economically not competitive with purely electronic systems that have the benefits of miniaturization and mass production methods. But the need is there.

The intrinsic advantage of lightwaves for communications applications is that they have much shorter wavelengths—or higher frequencies—than microwaves and radio waves, and are therefore capable of carrying a great deal more information. Data transmission and receiving rates as great as one hundred gigabits per second using a single beam of light are potentially possible. Another consideration is that as the lower-frequency part of the electromagnetic spectrum becomes more and more crowded with all kinds of uses and as the desire to transmit ever larger amounts of data more rapidly continues to increase, there is a need to push to higher frequencies for communication purposes. But for such purposes, optical systems until recently have had another major drawback. Unlike microwaves propagating through the air or electrical signals transmitting through coaxial cables, lightwaves traveling through the atmosphere can be easily scattered or refracted by disturbances such as rain, snow, or temperature gradients. In other words, the natural atmosphere is not a reliable transmission medium for optical signals.

Ways of resolving these two major problems—the lack of sufficiently small and mass-produced components and atmospheric disturbances in transmission—are now in sight. Within the last few years, there have been two developments that promise to revolutionize optical communication systems.

RECENT ADVANCES IN OPTICAL COMMUNICATIONS SYSTEMS

Recent improvements in glass technology have led to the development of optical fibers that exhibit losses orders of magnitude lower than previously thought possible. These are tiny, micron-sized glass fibers that can be manufactured industrially (see Figure 1) at low cost. With such low losses (down to two decibels per kilometer), it is now practical to use such fibers as waveguides to transmit lightwaves inside the fibers over long distances, thus avoiding the problem of atmospheric disturbances. These fibers have a number of other very attractive and significant features also. Because they are small, it is as easy to lay a bundle of many hundreds of glass fibers as it is to lay a single conventional coaxial cable. In metropolitan areas where duct space is scarce and expensive, this is obviously an important advantage. In addition, cables of these fibers are light and contain no metal; systems using such transmission lines are free from electromagnetic interferences. Such systems are particularly attractive for uses in aircraft, missiles, ships, and satellites. Hybrid systems that use electronic signal-processing methods together with optical signal generation, transmission, and detection have already been developed for various purposes and are being tested and considered for large-scale use.

Of equal importance, and with perhaps more far-reaching implications, is the emergence of a new field of research in electrooptics called integrated optics or thin-film optics. The goal of work in this area is much like that of microelectronics: it is to miniaturize optical components and use them as tiny elements in thin-film forms deposited on substrates. Conceptually this is possible. A few simple examples will show how.

Figure 1 (a)

Figure 1 (b)

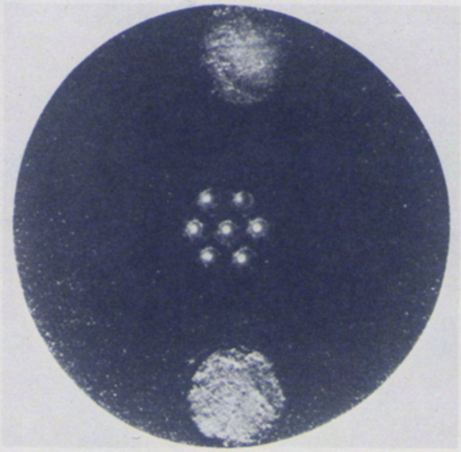


Figure 2 (a)

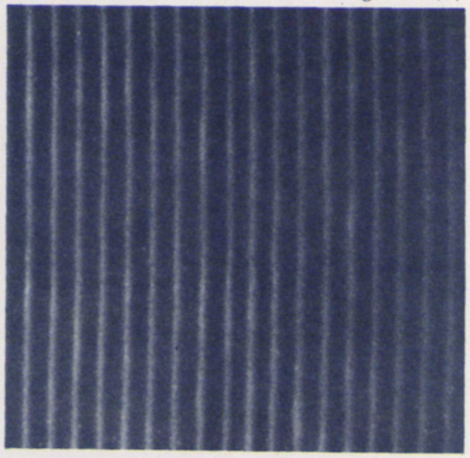


Figure 2 (b)

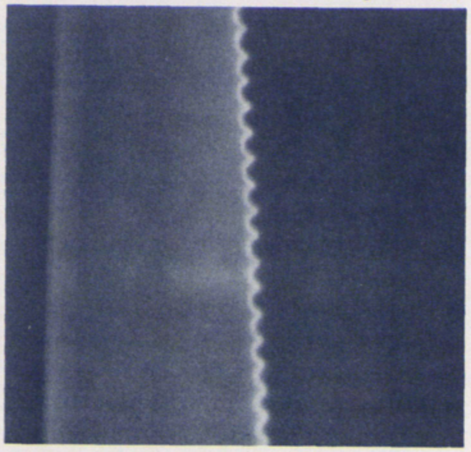


Figure 3

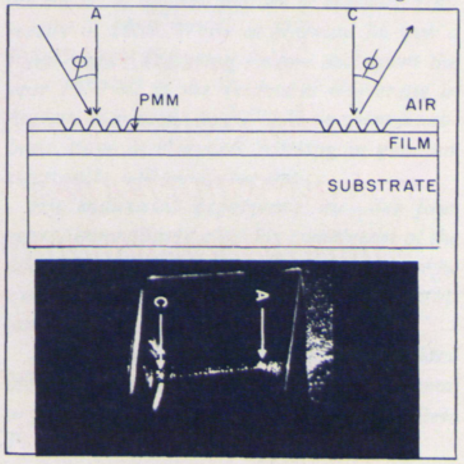


Figure 1. Cross section and side view of a multi-fiber optical cable developed by the Corning Glass Works. The cable, which has a diameter of the order of several millimeters, contains a central bundle of the tiny glass fibers encased in protective polyvinyl chloride (PVC). The two other bundles seen in the pictures are part of the protective jacket. In the cutaway photograph, the micron-sized fibers appear larger because the transmitted light is being scattered at the ends of the fibers. Cables such as this can be used for long-distance transmission of information by modulated light waves propagating inside the glass fibers.

Figure 2. Electron-microscope pictures of a grating etched onto the polished surface of a gallium arsenide crystal. The grating is nearly perfect, with lines periodically spaced 3300 Angstroms apart.

Figure 3. A grating input-output coupling experiment. The schematic shows how the light beam is coupled into the thin-film waveguide by the grating at A, and coupled out by the grating at C; ϕ is the coupling angle. The photograph below shows the actual light streak between the input and output couplers. The beam leaving C is the output beam reflected off a white card for this photograph. The gratings were fabricated, using a scanning electron microscope, in a thin layer of electron-resist (polymethyl methacrylate, PMM) coated on the thin-film waveguide.

TECHNIQUES IN THE NEW FIELD OF INTEGRATED OPTICS

The first step in integrated optics fabrication is to prepare high optical quality thin film waveguides (the order of 10^{-4} centimeters in thickness). The film, in which lightwaves can propagate and be manipulated, is deposited on substrates. Modern thin-film technology is now capable of producing a great variety of very good quality films.

The structure of such a waveguide is very simple. Basically, it consists of an

Figure 4

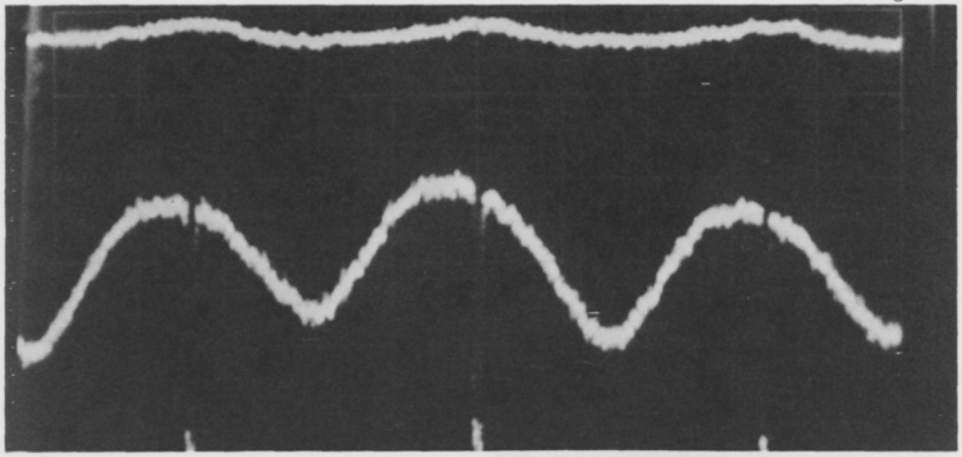


Figure 4. Experimental result demonstrating amplification at 1.06 microns in an optically pumped, neodymium-ion-doped thin-film waveguide. The top trace is the zero base line, showing a slight electric pickup signal. The bottom trace shows the detected light signal level after traversing one centimeter in the waveguide. The spikes on the lower trace show that there is an increase in the output signal level of nearly 150 percent when the waveguide is optically pumped. The remaining portion of the lower trace shows that when the film is not pumped, the only variation seen is the initial 60-Hertz signal on the input light beam. (The spikes are faintly visible between the apparent gaps on the trace and the bright spots below.)

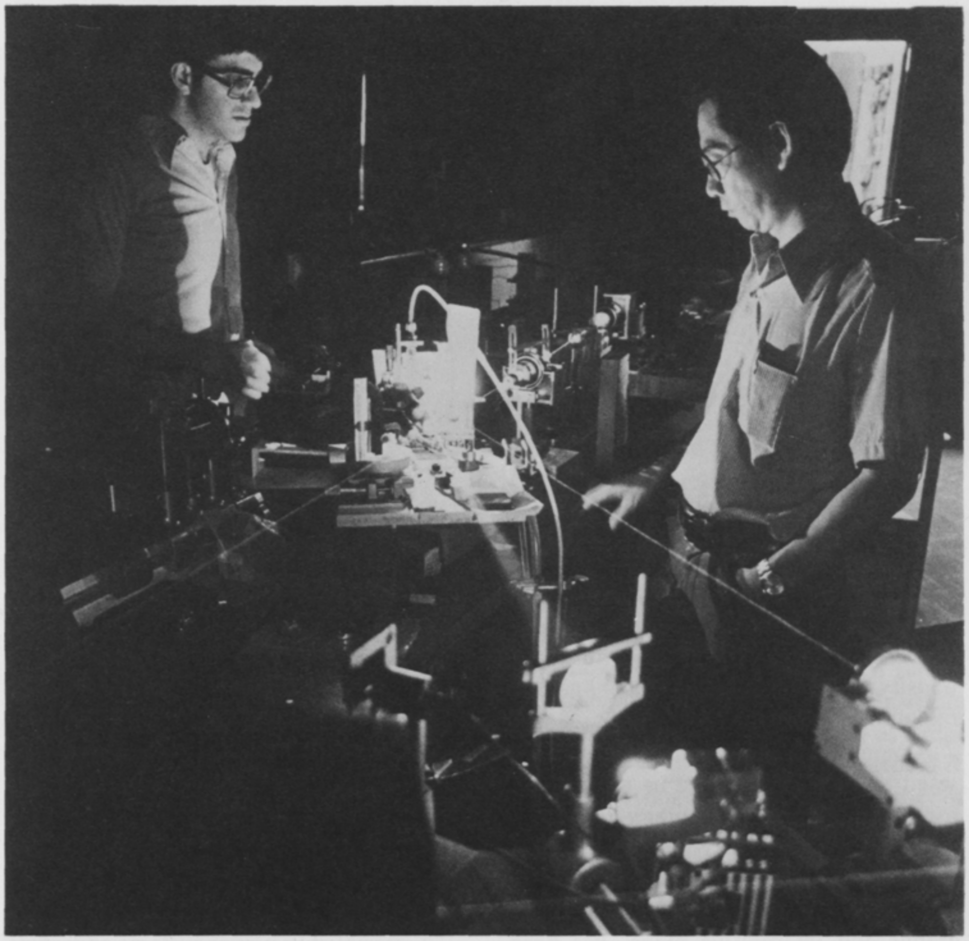
". . . completely integrated optical systems with enormous information-handling capabilities will eventually be a reality"

extremely smooth and uniform amorphous or single-crystalline transparent film deposited or grown directly on an equally smooth, optically transparent substrate of a different material, which may be a dielectric or a semiconductor. If the index of refraction of the film is higher than that of the substrate, a lightwave propagating inside the film at a small angle to the interfaces will be totally internally reflected at the interfaces and thus trapped and guided inside the film. Once trapped, the lightwave can be manipulated, amplified, or detected through various methods of controlling the properties of the film or the substrate.

Consider, for example, a mirror designed to have a particular value of reflectivity at a particular wavelength. In the bulk form, it typically consists of an optically polished glass or quartz mirror blank suitably coated with one or more dielectric layers to give the desired reflectivity. In the case of thin-film optics, the mirror is replaced by a tiny grating (on the order of 0.1 by 0.1 millimeter) consisting of parallel lines spaced periodically a few tenths of a micron apart, deposited on or scratched into either the film or the substrate surface (see Figure 2). The process for fabricating such gratings is complex, but it is now well developed. It involves the use of either lasers or modern electron microscopes that are subject to computer control.

Under a program sponsored by the National Science Foundation, Cornell researchers have pioneered the use of the electron microscopic method of fabricating gratings. Figure 3 illustrates the first experiment in which these gratings were used: in this Cornell experiment, light was coupled into and out of thin-film waveguides.

Other required operations can be ac-



The laser research program at Cornell is diverse, ranging from microoptical devices to chemical lasers. The laser shown here is an electronically tunable continuous wave dye laser developed by Professor Tang's research group. It can be repetitively tuned over a range of one hundred Angstroms every five nanoseconds: a tuning rate that is the highest ever achieved in any laser. With Professor Tang (at right) is one of his graduate students, Edward Moses.

complished by similar methods. If the film or substrate material is active and exhibits gain, thin-film laser oscillators or amplifiers can be fabricated. Figure 4 shows an example of results obtained at Cornell with a glass film suitably doped with neodymium ions and optically pumped: substantial gain is observed at the wavelength 1.06 microns, where the optical fibers have the lowest loss. If the media can be modulated either electrically or acoustically, modulators in thin-film forms are possible. Thus, information can be impressed upon or taken off the lightwave, which can be amplified, transmitted, processed, and detected with miniaturized elements and integrated planar optical systems.

Enough experiments have been performed in the last few years to convince many that completely integrated optical systems with enormous information-handling capabilities will eventually be a reality, even though much challenging work remains to be done. In the meantime, hybrid optoelectronic systems will most likely have a significant technological impact in the not-too-distant future.

C. L. Tang, professor of electrical engineering and a specialist in quantum electronics and lasers, has been at Cornell since 1964. He is part of the faculty group, including also Professors Joseph M. Ballantyne, Ross A. McFarlane, and George G. Wolga, that works in this general area of research in the School of Electrical Engineering.

Tang received his B.S. degree in electrical engineering at the University of Washington in 1955, the M.S. in electrical engineering at the California Institute of Technology in 1956, and the Ph.D. in applied physics at Harvard University in 1960. While at Harvard he was a John Parker Traveling Fellow and spent the year 1959-60 at the Technical University in Aachen, Germany. In 1970-71 he spent a sabbatic leave at Harvard, working in quantum electronics and nonlinear optics.

His industrial experience includes four years, immediately after his completion of the doctorate, at the Raytheon Company, where he was a principal research scientist and a consultant.

He is a fellow of the American Physical Society and a member of several other professional organizations and of Phi Beta Kappa, Tau Beta Pi, and Sigma Xi.

REGISTER

■ Cornell's *Donald J. Belcher,* internationally known as an expert in the interpretation of airphotos and other remote sensing imagery and their application to engineering and to land-use and resources planning, retired this summer after twenty-nine years of teaching. He has been named professor of civil and environmental engineering, emeritus.

He has not retired from an active professional life, however. He will undertake a variety of consulting assignments in developing nations, including continuing work on a resources development project in Venezuela. Although much of their time will be spent overseas, the Belchers plan to maintain their home in Ithaca.

Belcher's work has encompassed innovation in the interpretation and application of remote sensing techniques, the development of instructional programs around the world, and consulting on specific projects. At Cornell he organized and directed the Center for Aerial Photographic Studies, which developed into the present remote sensing program; over the years he generated more than $1.5 million in research contracts. He is an author of three texts and more than seventy professional papers, and (together with former applied and engineering physics professors Trevor Cuykendall and the late Henri S. Sack) obtained a patent on equipment for measuring soil moisture and density that uses fast neutrons and gamma radiation.

A pioneering project that Belcher supervised and that has served as a prototype for similar studies in many countries is the Land Use and Natural Resources Inventory of New York State. This material, including thousands of aerial photographs and interpretive maps, has been made generally available through a computerized retrieval service offered at Cornell.

As a consultant, Belcher has worked in the Middle East, Far East, Europe, Africa, and Latin America on planning and engineering problems of water supply, town and facilities siting, and agricultural and other resources development. Projects executed by his firm have included the site selections for Brasilia, the capital city of Brazil, and for the world's largest radio-radar telescope at Arecibo, Puerto Rico.

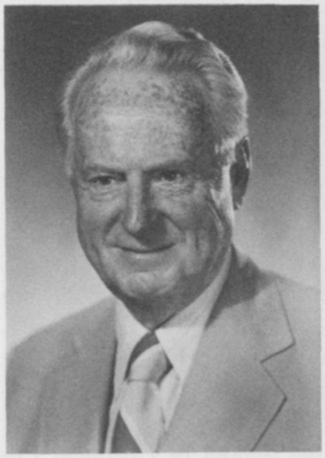
Belcher came to Cornell in 1947 after seven years on the faculty of Purdue University. His academic degrees, all from Purdue, are the B.S. in civil engineering (1934), the M.S. (1939), and the professional degree of Civil Engineer (1941). He is registered as a professional engineer in Indiana and Alaska.

■ *Robert E. Osborn* was named professor of electrical engineering, emeritus, this summer after completing thirty-five years of teaching at Cornell.

A specialist in power systems engineering and electrical machinery, he has had a leading role in organizing and teaching graduate and undergraduate courses in these areas. His activities have included the supervision of design projects by seniors and graduate students; in recent years, many of these projects have been part of a continuing program, sponsored by the National Aeronautics and Space Administration, in the design of an unmanned extraterrestrial roving vehicle simulator.

After receiving the B.S. degree in electrical engineering from Purdue University in 1933, Osborn worked for several

Belcher



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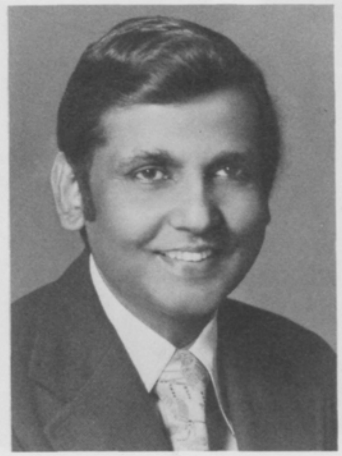
Ahimaz



months with the United States Coast and Geodetic Survey and then with the Delco-Remy Division of the General Motors Corporation. From 1935 to 1941 he served as head of the electrical engineering department of Indiana Technical College, now the Indiana Institute of Technology. During this period he set up and helped teach a course on industrial electronics for practicing engineers.

This course, sponsored by Purdue under the Engineering Defense Program, led to Osborn's first Cornell appointment, in 1941, as instructor and supervisor of instruction in the Engineering War Training Program operated by the University for upstate industries. In this position he was responsible for the supervision of some fifty instructors at the Niagara Frontier Office in Buffalo. He came to the Ithaca campus in 1944.

Osborn has maintained his interest in the industrial application of engineering education throughout his teaching career. He has had a private consulting practice since 1945, and spent sabbatic leaves at the former Cornell Aeronautical Laboratory, the Advanced Electronics Engineering Laboratory of the General Electric Company, and the Emerson Electric Company. He is registered as a professional engineer in New York State.

He has been active also in professional societies; for example, he served on the American National Standards Institute committee on rotating machinery as a representative of the Institute of Electrical & Electronics Engineers. He is a member of the honorary professional society Eta Kappa Nu.

The Osborns plan to maintain their home in Ithaca.

■ Recently named professor and director of the Division of Basic Studies at the College of Engineering is *Franklin J. Ahimaz*. He will retain his position as assistant director of the University's interdisciplinary Program on Policies for Science and Technology in Developing Nations (PPSTDN).

Ahimaz came to Cornell in 1971 as assistant dean of engineering and director of the basic studies program, but subsequently devoted much of his effort to the development and implementation of PPSTDN. As part of his work with this program, he served as principal investigator in a project, jointly sponsored by Cornell and the University of Costa Rica, to plan science and engineering programs for Costa Rican educational institutions. His extensive international experience in educational development includes five years as a senior adviser to the Faculty of Engineering of Kabul University in Afghanistan.

A native of Burma, Ahimaz studied in India for the B.S. degree in physics from Madras Christian College in Tambaram and the B.E. degree in mechanical engineering from the College of Engineering, Trivandrum. He came to the United States in 1950 for graduate study under the Fulbright-Smith-Mundt scholarship program, and earned the M.S. degree in hydraulics at Bucknell University. Later he received the Ph.D. in engineering mechanics from Cornell and then taught at Bucknell and at the Illinois Institute of Technology (IIT). For eight years he was a senior research engineer in the Experimental Stress Analysis Section of the IIT Research Institute in Chicago.

He is vice chairman of the international division of the American Society for Engineering Education.

Right: One of this year's Meredith C. Gourdine Award winners, Jacques Charles (left), is congratulated by Gourdine (at center) and minority programs director Eugene J. Wilson. The awards were made at the spring luncheon meeting of the Engineering College Council.

■ Sixteen minority students in the College received Meredith C. Gourdine Awards for leadership, motivation, and academic achievement this spring.

Among those present was Gourdine, a Cornell engineering physics graduate of 1953, who is now president of Energy Innovations, Inc. He is a member of the Engineering College Council and a former University trustee.

The annual awards, which carry an honorarium of two hundred dollars, were made for the first time last year. The 1976 prizes were provided by the Corning Glass Works and the Eastman Kodak Company.

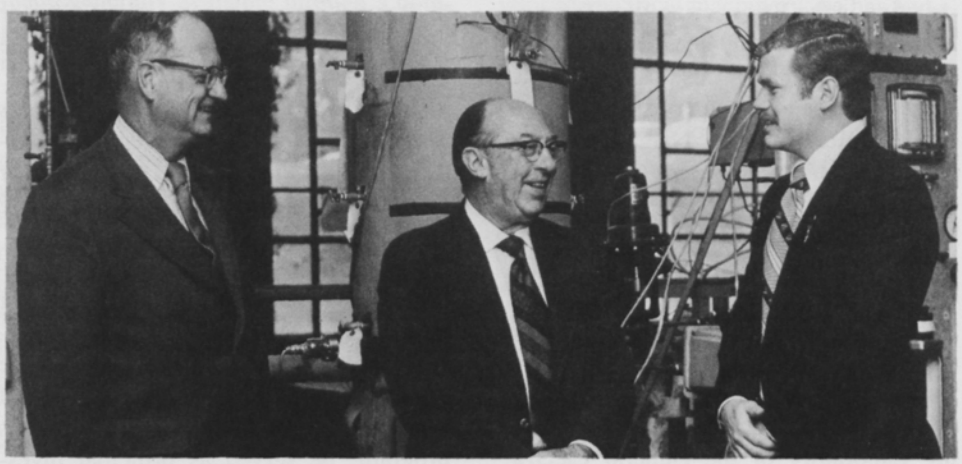
A special award "for continuous leadership" was presented to Gary Harris, a candidate for the degree of Master of Engineering (Electrical). Recognized for leadership and motivation were juniors Bruce Chapman, Rodney Reynolds, and Janine Stewart, and freshmen Donald DeBouse and Burdette Wills. Recognized for academic achievement were juniors Jacques Charles, Charles Chuang, Norman Nelson, and Robert Ormsby; sophomores Phillip Capin, Eric Law, and Lester Pang; and freshmen Enrique Hernandez, Kevin Lung, and Dexter Wong.

According to Dean Edmund T. Cranch, the awards are intended to recognize "outstanding representatives of our students from minority groups of society." It is fitting, Cranch said, that the awards are named in honor of Gourdine, whose "presence on the Cornell scene is a source of pride and incentive to engineering students from minority groups." As an undergraduate, "Flash" Gourdine was both an outstanding student academically and a star athlete on the track team; in 1952 he won a silver medal in the long jump at the Olympic Games.

■ The first Charles C. Winding Scholarship for study in the Master of Engineering (Chemical) degree program was awarded this spring to a graduating senior, Francis Sherman. As an undergraduate, Sherman had a grade-point average of 3.6 and was president of the Cornell chapter of Tau Beta Pi, national student honorary society in engineering.

The Charles C. Winding Scholarship Fund was established by chemical engineering alumni in honor of Winding, the Herbert Fisk Johnson Professor of Industrial Engineering, emeritus, and former director of the School of Chemical Engineering. (Although retired, he taught the senior design course this past spring term.) The fund goal of $50,000 was expected to be reached this summer.

Below: The unit operations laboratory in the Olin Hall of Chemical Engineering was the setting for the announcement of the first Charles C. Winding Scholarship award. From left to right are Julian C. Smith, director of the School of Chemical Engineering; Professor Winding; and Francis Sherman, the scholarship recipient.



Slate

■ Selected as recipient of the 1976 Excellence in Engineering Teaching award was *Floyd Slate*, professor of civil and environmental engineering and a member of the Department of Structural Engineering. The award, which carries a $1,000 prize, is made annually by the Cornell Society of Engineers, an alumni organization, and the Cornell chapter of the student honorary society Tau Beta Pi. The recipient is chosen on the basis of nominations by students.

Slate, a specialist in concrete, masonry, and corrosion, has been particularly interested in recent years in low-cost housing, primarily for developing nations. At the time of his selection for the teaching award, he was spending a sabbatic leave in Hawaii at the Technical Development Institute of the East-West Center in Honolulu. He has consulted, lectured, and conducted studies in many parts of the world, including Central America, Mexico, Puerto Rico, the Orient, and Pakistan.

Previous honors Slate has received include the Wason Medal for Materials Research, which he was awarded three times by the American Concrete Institute. He has been at Cornell since 1949.

■ A bicentennial look at the contributions of technology to art in America was one of the themes of this spring's annual Risley Residential College fair on the Cornell campus. Art / Technology events included video projects, an electronic music concert, a photography contest, a "Super Hot-Cold Show" from the Franklin Institute in Philadelphia, and a very popular exhibit of holography. (This exhibit was arranged by Tim Donohue, a senior in electrical engineering, with the help of engineering physics professor Paul L. Hartman and electrical engineering graduate student Larry Medwin.)

Heading the planning committee for the Art / Technology events was Mark Schwartz, assistant director of engineering admissions and a 1974 Cornell engineering graduate.

Below: Judges in the photography contest were (from the left) Dale R. Corson, Cornell president; Donald F. Berth of the College of Engineering; and Stanley J. Bowman, professor in the College of Architecture, Art, and Planning. Looking on are Sue Miller, architecture student who arranged the exhibit, and Mark Schwartz.

Above: Closed-circuit television and cameras were used in a demonstration that afforded spectators new ways of looking at themselves and their surroundings. The video projects, produced by the Center for Advanced Visual Studies of the Massachusetts Institute of Technology, were on solarization, 3-D imagery, time delay, and mirror reflections. In charge of arrangements was Ann Marion from MIT, a Cornell graduate, who took this demonstration picture of herself.

Below: A popular event was a lecture-concert by Mother Mallard, a group that uses Moog synthesizers exclusively. (The inventor, Robert A. Moog, is a former member of the Cornell electrical engineering faculty.)

■ The *Register* reports with regret the death of *Vaughn C. Behn,* associate professor of civil and environmental engineering, on June 8 in Ithaca, at the age of fifty-three.

Behn, a specialist in environmental engineering, came to Cornell in 1960 after five years on the University of Delaware faculty. Previously he had been employed as a sanitary engineer at the Atlas Powder Company and as a development engineer with the National Council for Stream Improvement. He was registered as a professional engineer in New York and Pennsylvania.

He received the B.S. degree in sanitary engineering from Rutgers University in 1943, the M.S. in industrial hygiene in 1947, and the D.Eng. in sanitary engineering and water resources from Johns Hopkins University in 1953. During World War II he served as a lieutenant in the U.S. Navy.

Throughout his teaching career, Behn maintained his interest in professional engineering practice. He served as a consultant to the Tompkins County Department of Health and to Lozier Engineers of Rochester, New York, and he did summer project work on storm water treatment with the Chicago consulting firm of Greeley and Hansen. In 1973 he spent a sabbatic leave at the University of Texas in Austin working on a project involving biological measures to combat hazards from waste disposal.

At Cornell he taught courses in the areas of water quality engineering, industrial waste engineering, and solid waste management. He was active in the Master of Engineering (Civil) program, working with students and professional consultants on group design projects.

Behn was a fellow of the American Society of Civil Engineers and a member of the American Water Works Association, the Water Pollution Control Federation, and the honorary societies Sigma Xi and Chi Epsilon.

Survivors include his wife, Vida; a son; two daughters; and a brother.

FACULTY PUBLICATIONS

The following publications and conference papers by faculty members and graduate students of the Cornell College of Engineering were published or presented during the period November 1975 through January 1976. Earlier publications inadvertently omitted from previous listings are included here with the date in parentheses: The names of Cornell personnel are in italics.

■ AGRICULTURAL ENGINEERING

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Reitsma, S. Y., *Scott, N. R.*; *Shepardson, E. S.*; *Guest, R. W.*; and *Wehe, R. L.* 1975. An Analysis of Dynamic Responses of the Dairy Cow's Teat to Step Changes in Pressure. Paper read at Winter Meeting of American Society of Agricultural Engineers, 15–18 December 1975, in Chicago, Illinois.

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McCabe, W. L., and *Smith, J. C.* 1976. *Unit operations of chemical engineering*, 3rd ed. New York: McGraw-Hill.

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ENGINEERING: CORNELL QUARTERLY

The First Ten Years of the College Magazine

The year 1976, notable for bicentennial and centennial celebrations, marks a lesser anniversary for *ENGINEERING: Cornell Quarterly*, but one that gives us a sense of continuity and accomplishment. With the spring issue, this magazine completed ten years of publication. In recognition of this milestone, we have prepared a summary listing of issues in Volumes 1 through 10, and a cumulative index of authors and those whose subject matter was presented in the form of interviews.

From the beginning, the *Quarterly* has had the format of a group of articles on a special topic, supplemented by listings of faculty publications and, from time to time, photo-essays, news about the College and its members, and editorials. The writers have been largely professors in the College, but have included also administrative personnel, members of the Engineering College Council, alumni, students, and editorial staff members. Donald F. Berth, who started the magazine, served as editor through the publication of the special one-hundred-page centennial issue in the fall of 1971. Gladys J. McConkey joined the staff as associate editor in the fall of 1970 and became editor with the winter 1972 issue. Others who have been on the editorial staff are K. Toby Clarey, Susan E. Dillmann, Nancy G. Klabunde, Judith E. Olson, and Victoria A. Groninger. David Ruether has been the chief photographer for the entire period.

Throughout the years, *Engineering* has maintained a balance in subject matter among topics on education in general and at the Cornell College of Engineering, specific research and other activities in which College people are involved, the engineering profession, and public issues in which science and technology have a special concern. The publication has been prepared for a wide range of readers, including professional engineers and scientists, leaders in business, government, and public information services, academic people, students and prospective students, alumni, and friends of Cornell. Our aim has been to inform, to interest, and to represent the Cornell College of Engineering.

We can take a measure of pride in the reputation of the magazine. Over the years it has won almost a score of national awards. In its first year, for example, it received one of two first-place awards of the American College Public Relations Association. More recent honors include a Top Ten Magazine Award from the American Alumni Council in 1973 and an Exceptional Achievement Award for coverage of public affairs from *Newsweek* and the Council for Advancement and Support of Education (CASE) in 1975. This summer the *Quarterly* was selected from hundreds of university periodicals as one of eleven CASE Exceptional Achievement Award winners. But mainly we have been encouraged by responses of our readers, by the willingness of authors to contribute (without pay) to the magazine, and by the continued support of the College and the Cornell Society of Engineers in the face of rising costs and budget cuts.

As we look back over the first ten volumes, we see some things we wish had been treated more thoroughly or originally, and we note some omissions and inadequate coverage. But we also get an impression of soundness, vitality, and diversity in engineering at Cornell. As we begin our second decade, we hope to continue to provide a worthy reflection of a worthy institution.

Engineering: Cornell Quarterly

Ten-Year Index

CONTENTS
Volumes 1–10

VOLUME 7

VOLUME 8

VOLUME 9

VOLUME 10

CUMULATIVE INDEX
Volumes 1–10

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