

Centennial History of the Department of Electrical and Computer Engineering

1891-1991



College of Engineering

University of Illinois at Urbana-Champaign

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Compiled by

Edward C. Jordan,
Wendell Miller, and
Mac E. Van Valkenburg



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University of Illinois at Urbana-Champaign

Dedication



Edward C. Jordan, 1910–1991. This photo was taken in 1979.

Edward C. Jordan passed away on October 18, 1991, shortly after completing this book with Mac E. Van Valkenburg and Wendell Miller.

Ed was born in Edmonton, Alberta, Canada, on December 31, 1910. He received the BS degree in 1934 and MS degree in 1936 from the University of Alberta, and the PhD degree at The Ohio State University in 1940. Upon completing his doctoral degree, he served one year as instructor at Worcester Polytechnic Institute. He returned to The Ohio State University in 1941, where he was an instructor, assistant professor, and consultant to the Antenna Laboratory from 1941 to 1945. In 1945, he followed his mentor, William L. Everitt, to the University of Illinois.

At the University of Illinois, Ed served as associate professor from 1945 to 1947, professor from 1947 to 1979, director of the Radio Direction Finding Laboratory from 1946 to 1954, and director of the Antenna Laboratory from 1950 to 1954. In 1954, he was named head of the Department of Electrical Engineering.

Ed Jordan authored or edited nine books and published numerous technical articles. His popular textbook, *Electromagnetic Waves and Radiating Systems*, was first published in 1950 by Prentice-Hall. A second edition, co-authored with K. G. Balmain, was published in 1968. At the time of his death, he was editing the eighth edition of *Reference Data for Engineers: Radio, Electronics, Computers, and Communications* for Howard W. Sams & Co., Inc., publishers.

Ed Jordan received many honors in his career. He was elected to the National Academy of Engineering and a fellow of the Institute of Electrical and Electronics Engineers (IEEE). He received the prestigious IEEE Education Medal and the Stanley H. Pierce Award at the University of Illinois at Urbana-Champaign. He also received the Alumni Honor Award for Distinguished Service in Engineering in 1986 from the UIUC College of Engineering, the George Sinclair Award from The Ohio State University in 1988, and the Professional Achievement Award from the University of Alberta in 1988.

In the profession, Ed served as a member and chairman of numerous committees and advisory boards. He was a past chairman and an honorary life member of the IEEE Antennas and Propagation Society.

Timothy N. Trick
Department Head
November 1991

Eulogy for Edward C. Jordan

Those of you who knew Dad well know that he would much have preferred to be up here himself, just to make sure the stories get told right.

Edward Conrad Jordan was born in Edmonton, Alberta, Canada, in 1910. He used to like to tell new acquaintances that his parents were married on Christmas Day, and he was born on New Year's Day. Of course, he would not tell them that there had been a year in between — that was Dad.

Our father's life was filled with a certain amount of hardship in his early years and a lot of very hard work from beginning to end. He was a man of original intelligence, and he had the gift of seeing the brilliance in others. Over the course of his professional career, he built the Department of Electrical Engineering at the University of Illinois at Urbana-Champaign into one of the best in the nation, and although he never would have said it, probably the best in the world.

His also was a life filled with a solid 45-year marriage to our mother, Mary Walker Jordan, and the raising of three sons, whom so far have been able to stay out of serious trouble.

It was a life filled with a love of golf, about his only serious recreational pursuit. He used to enjoy the quote by Bob Hope that "If you watch a game, it's fun . . . if you play, it's recreation . . . if you work at it . . . it's golf!" But the leisure time for golf was to come later.

Dad grew up in Edmonton, where his father was a tailor. He was the oldest child and only son, and along with his sisters Doris and Marie, he learned the value of hard work at an early age. Dad had the misfortune to begin college at the start of the Great Depression, and it was a struggle to make ends meet. He was able to get a job as the first control operator at the fledgling radio station at the University of Alberta, CKUA. This was in the pioneering days of radio, and the equipment was still in its infancy. There was one professor who would deliver some of his lectures on the air and who caused no end of problems. It seems this professor whistled his s's. Every time he would give a lecture, he would blow

out the tubes in the broadcast equipment, and the station would go off the air. Not good for the young operator. So Dad invented the first automatic gain control for broadcast equipment to dampen the feedback, and the station continued on the air, whistled s's and all. Dad also used his ingenuity to overcome a severe hearing loss, inventing his own hearing aids until the commercial variety came into widespread use.

One of Dad's proudest moments was when he took part in the first ever around-the-world hookup of radio stations on Christmas Day, 1929. It was a thrill for the 18-year-old radio engineer to hear the BBC in London come on the line, checking the circuits. "Hello Montreal, are you there, Montreal? Come in Edmonton, can you hear us, Edmonton?" At the end of the program, the BBC signed off, then Montreal, then down the line to tiny CKUA and Dad. He later wrote down what happened.

"When I returned home, I learned that my mother and dad had sat up in bed listening to the program on the radio set I had made. Mother told me that when Dad heard me make the final sign-off announcement, he stood up in bed with arms above his head and shouted, 'That's my boy!'"

Times were difficult in the 1930s, and after receiving his BS and MS degrees at Alberta, Dad went across Canada by cattle train to work in the nickel mines in Ontario. His mother packed a large basket of chicken, which was supposed to last him for the journey, and he sat in the unheated caboose of the cattle train, playing poker with the cowboys. He worked at the nickel mines for a year, then went to The Ohio State University to get his PhD degree. In 1940, he returned to Edmonton and married Mom, and they settled in Columbus, where Dad became a naturalized citizen. It should be noted here that Mom remained a Canadian citizen because every time she went to sign the papers, she said they were so rude to her she would just as soon remain a Canadian! After oldest son Bob was born, they followed William L. Everitt, who was Dad's mentor and friend, from The Ohio State University to the University of Illinois. In 1954, at the age of 43, Dad was named head of the Department of Electrical Engineering. Over the next 25 years, he lured the creme de la creme to the U of I. Those in the department will remember that Ed Jordan had the ability to keep the well-developed egos in balance, while providing them with the tools they needed to become even greater.

During these years, he and Mother traveled the world, usually in connection with an engineering conference, more often than not taking the three boys, Bob, Dave, and Tom, along whether they wanted to go or not. Any couple that can travel for two months in a tiny Peugeot with two teenage sons and an 11-year-old must make up in patience what they may lack in common sense. But they did it and were patient with one another as well.

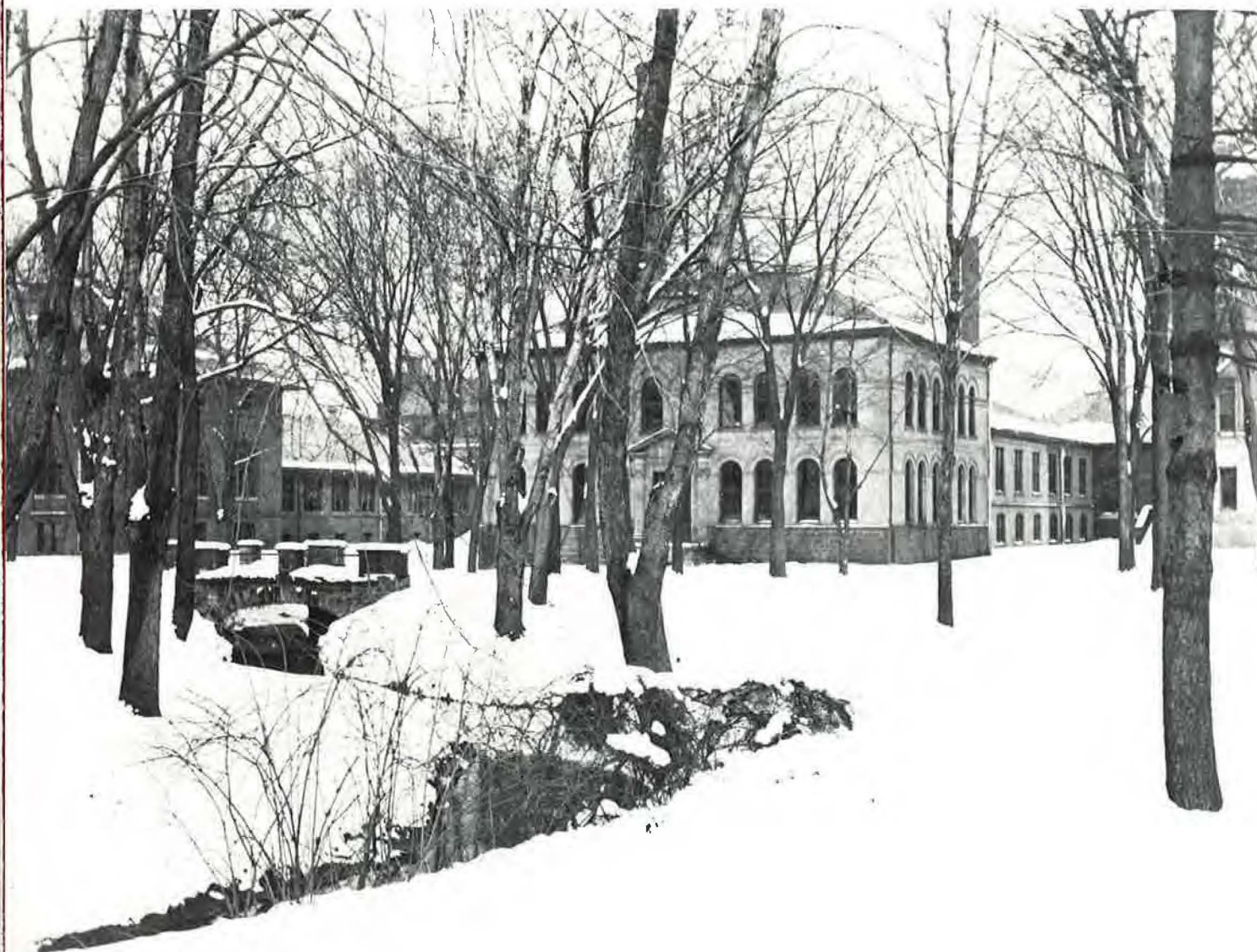
After we were grown and had left home, Mom and Dad continued to travel, usually finding a Rotary meeting and a nearby golf course for Dad. During Mom's two-year illness, Dad was her constant companion and care giver, right up to her death in 1986. Some may not know that Dad continued to go to the nursing unit to visit old friends and golfing partners for the rest of his life.

After the sad and stressful time in 1986, Dad was blessed to find love and happiness again with Caroline Egbert. When he and Kay decided to get married in 1990, I remember how touched I was when Dad called to ask me to be his best man. It's not every kid who gets to act as best man for his 79-year-old father! I was proud.

In summing up his life, I think one of the salient truths is that Edward Jordan was a kind man, a generous man. Whether it was a new foreign graduate student at the university, a neighbor in financial difficulty, or an old golfing partner in the hospital, Dad was there with help and genuine concern. He really cared about those around him, and we cared about him. His was a full life, one filled with accomplishment and enjoyment. One that he brightened with his good humor and storytelling. We shall miss him very much.



Thomas C. Jordan
October 22, 1991



The Boneyard and part of the engineering campus ca. 1910 (right) and 1915 (above), taken from what remained of the university Arboretum.

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This history of the Department of Electrical and Computer Engineering at the University of Illinois at Urbana-Champaign was compiled to commemorate the centennial celebration of the department. As the department prepares to celebrate its centennial, it is recognized as one of the largest and most prestigious departments in the nation. At this writing, the department grants more BS, MS, and PhD degrees than any other electrical and computer engineering department in the country. The department has made many fundamental contributions in the areas of physical electronics, electromagnetics, computing, systems, and bioacoustics. Many of its faculty members and alumni have distinguished themselves in their careers. This history captures that rich heritage, and it is my hope that it will inspire the faculty members, students, and alumni who follow us to continue that tradition of excellence and to aspire to even greater heights.

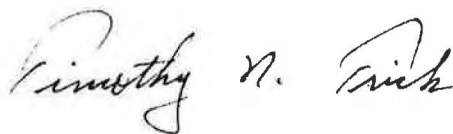
The first two chapters are adapted from material written by Wendell Miller, who was associated with the Department of Electrical and Computer Engineering at the University of Illinois as a student, faculty member, and emeritus professor for nearly six decades. In this period, a monumental transformation occurred in the departmental instructional and research programs, which today encompass a broad spectrum of interdisciplinary subjects.

Professor Miller traced the origin of electrical engineering at Illinois and described its evolution to the year 1945. Other staff members contributed to the years after 1945. Much of the material has come from *Illini Years* by Carl Stephens, *History of the College of Engineering* by Baker and King, and issues of the *Illinois Technograph* and *E²A² Newsletter*. Two important name changes occurred in the last quarter century. In 1966, the name of the university officially became the University of Illinois at Urbana-Champaign, and in 1984 the department changed its name to the Department of Electrical and Computer Engineering.

I wish to express my deep gratitude to Ed Ernst, Ed Jordan, Wendell Miller, and Mac Van Valkenburg. My gratitude also goes to the many emeritus and active faculty members and friends who contributed to this book, including John Farley for his contribution of the Eta Kappa Nu story and Edgar C. Hayden for his ideas and many photographs.

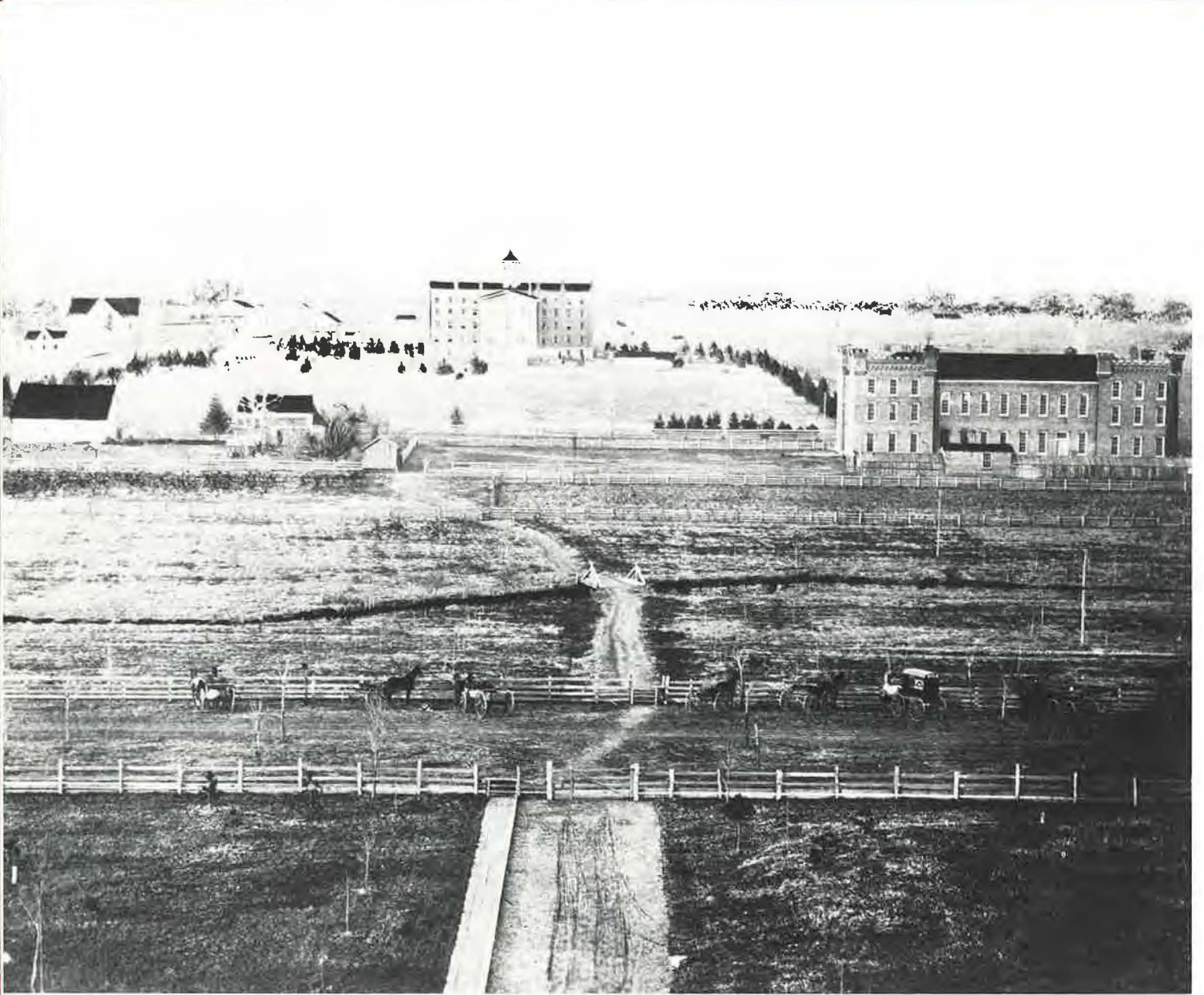
Staff members who have helped along the way include Mary Wood and Emma Marshall. Professor Maynard Brichford of the University Library assisted in retrieving and identifying pictures from the University Archives.

I especially acknowledge the efforts of Norma Danowitz, who assisted in every phase of compiling information, writing some sections, and editing copy. Her relentless pursuit — from the University Archives to the basement of the Everitt Laboratory — also resulted in many of the photographs in this book.



Timothy N. Trick
Department Head
November 1991

Chapter One-In the Beginning



A campus view in 1874 from an upper floor of the new University Hall, looking north. Note the horses and buggies on Green Street, the Boneyard and bridge, the old University Hall in the upper center, and the Drill Hall and Machine Shop on the right.

The Founding of the University

On July 2, 1862, President Abraham Lincoln signed the Morrill Land Grant Act. The act provided each state or territory, upon application, with 30,000 acres of scrip land for each senator or representative in Congress “for the endowment, support and maintenance of at least one college whose leading subject shall be, without excluding other scientific and classical studies, and including military tactics, to teach such branches of learning as are related to agriculture and the mechanical arts—in order to promote the liberal and classical education of the industrial classes in the several pursuits and professions of life.”

The term scrip referred to government lands in undeveloped locations, usually in the wide open spaces of the west; these lands carried a nominal book value of \$1.25 per acre. The land, as determined by each state or territory, could be retained indefinitely or it could be sold; in either case, the money derived from the land was to be used to develop and operate the prescribed educational institution.

The Land Grant Act, originally sponsored by Justin S. Morrill, a senator from Vermont, laid the foundation for the nationwide development of higher education supported jointly by federal and state or territorial governments. With two senators and 14 representatives in Congress, the state of Illinois became eligible for a grant of 480,000 acres of public scrip land with a book value of \$600,000. The General Assembly of the state of Illinois took steps immediately to secure the advantages of the Morrill Land Grant Act, and on February 14, 1863, legislation was approved to accept the donation of public lands from Congress for the purpose of establishing a state university.

Although the State Legislature took only a few months to decide to accept the benefits and obligations of the Morrill Land Grant Act, it required the next four years to determine the location of the university. Several communities in the state competed for the university site by offering sizable sums of money to help establish the campus. Prominent citizens from Chicago made determined efforts to have the mechanical arts division located in Cook County; large sums of money and other inducements were pledged in an effort to gain the favor of the Legislature.

To supplement the 480,000 acres of scrip land provided in the Morrill Act, Champaign County offered to provide a site of 1,000 additional acres, a donation of \$400,000, and a “splendid building costing \$175,000 and ready for use.” This building had been constructed in 1861–62 to establish the Urbana and Champaign Institute, a coeducational boarding school. The building stood at the north end of the former Illinois Field, now the site of the Beckman Institute for Advanced Science and Technology. The five-story brick structure, which faced University Avenue, was 125 ft east and west and 40 ft wide, with a four-story, 44 × 70-ft wing on the back. It contained recitation rooms, kitchen, dining room, chapel, and 60 dormitory rooms for 130 students.

In addition to these inducements, M. L. Dunlap, a private citizen, agreed to provide \$2,000 worth of shade and ornamental trees, and the Illinois Central Railroad pledged the sum of \$50,000 in freight charges over its lines.

From Chuck Flynn, editor emeritus of the *News-Gazette*, we learned that Clark Griggs, a wealthy Urbana farmer, was determined that the site of the university would be in Champaign County. Griggs had served as mayor of Urbana and, in 1867, was a member of the State Legislature. After a lengthy period of political maneuvering and often times intense debate, the Griggs Bill was passed by the Illinois General Assembly on February 25, 1867, and signed by Governor Oglesby on February 28, 1867. This bill provided specifically for the establishment in Urbana of an educational institution furnishing instruction in agriculture and mechanical arts.

Thus the debate over the location of the school ended abruptly but without unanimous agreement. A major factor that gave Urbana precedence over other proposed locations was the offer of an existing building with facilities for 130 students. The university could start immediately without waiting for a building to be constructed.

With location of the university determined, a Board of Trustees was established; it consisted of the governor of the state, the superintendent of public instruction, and the president of the State Board of Agriculture, all members ex-officio,

together with 28 citizens to be appointed by the governor. The first meeting of the board was held in Springfield on March 12, 1867, just 12 days after the signing of the Griggs Bill; their first action was to appoint John Milton Gregory as regent of the university beginning April 1, 1867. At the second meeting of the board on May 7, 1867, which was held in the chapel of the Urbana and Champaign Institute, the following outline for departments and courses of study was adopted:

- I. Agriculture Department
 - A. Agriculture
 - B. Horticulture
 - C. Landscape Gardening
- II. Polytechnic Department
 - A. Mechanical Science and Art
 - B. Civil Engineering
 - C. Mining and Metallurgy
 - D. Architecture and Fine Arts
- III. Military Department
 - A. Engineering
 - B. Tactics
- IV. Chemistry and Natural Science
- V. Trade and Commerce
- VI. General Science and Literature
 - A. Mathematics
 - B. Natural History, Chemistry, etc.
 - C. English Language and Literature
 - D. Modern Languages and Literature
 - E. Ancient Languages and Literature
 - F. History and Social Science
 - G. Philosophy (Intellectual and Moral)

The granting of degrees was not considered by the founders. Their original thought was to allow students to take any course they desired and to leave any time they pleased. Instead of diplomas at the end of their enrollment, certificates were given at the time of entrance.

The Urbana and Champaign Institute, later called Old University Hall, served as the only building from 1868 to 1872. From *Illini Years*, we learn that

The top two floors of the building served as a dormitory. Students arrived with beds, bedding, and stoves. Coal was purchased wholesale by the university and sold to students at cost. The rental charge for a student and his furnishings was four dollars per semester. Eating and sleeping as well as all scholastic, social, and religious activities took place in the one building, which the students dubbed The Elephant.

In 1872, the Drill Hall and Machine Shop Building was constructed near the intersection of Springfield Avenue and Burrill Avenue. In 1873, the Main Building, later called University Hall, was completed south of Green Street on land now occupied by the south half of the Illini Union Building.

The institution was first named the Illinois Industrial University, and its objective was to provide advanced education for the mass of working people in Illinois rather than for the privileged few. The students, originally all male, were required to wear uniforms, grey in color and tailored after those worn by cadets at West Point. Tuition was free initially but soon became \$15 per year for Illinois residents and \$20 per year for out-of-state residents.

Students were required to drill three hours weekly and to march to and from daily chapel under the direction of a military officer. In addition, all students were required to perform two hours of manual labor each day for which they were not paid; this manual labor usually pertained to beautifying the grounds surrounding the one building, old University Hall, by constructing boardwalks, erecting wooden fences to keep the cattle out, and landscaping with trees and shrubbery.

In 1880, Selim Hobart Peabody, a professor of mechanical engineering, was appointed regent; he served until 1891. The final years of the nineteenth century were lean years, and university funds were extremely limited. The state contribution to the university at that time was \$22,000 per year. Faculty salaries, averaging about \$2,000 annually, had to be cut by 10%; student fees rose from \$15.00 to \$22.50 per year, and enrollment declined. Even with these difficult times, Peabody can be remembered for a significant step forward in the history of the university.

In 1885, with the backing of the alumni body, Peabody changed the name from the Illinois Industrial University to the University of Illinois. Not everyone was happy with the change; many protesters proclaimed that the people were being robbed of a labor school. The majority, however, greeted the change with enthusiasm.

The First Thirty Years: 1867-1897

The College of Engineering, originally named the Polytechnic Department, was established in 1867 when the Illinois Industrial University first opened its doors. The school year consisted of three terms of 14, 12, and 10 weeks. The four original courses of study in the Polytechnic Department were mechanical science and art, civil engineering, mining and metallurgy, and architecture and fine arts.

Following a four-year period during which all courses were elective, the 1872-73 *University Catalogue and Circular* listed prescribed course outlines for each curriculum of the Polytechnic Department. The first degrees of Bachelor of Science, Bachelor of Letters, and Bachelor of Arts were granted on June 6, 1877, to those who had completed the four-year prescribed curriculum in their chosen fields. Algebra, geometry, trigonometry, and calculus were required courses in the polytechnic curricula. It is interesting to note the further requirements of three terms of English or French, three terms of German, one term of astronomy, one term of geology or mental philosophy, and three terms of vacation journal and memoir. Elective courses included Butler's analogy, elocution, evidences of Christianity, history of inductive sciences, and penmanship. The course description for vacation journal and memoir reads as follows:

Journals of travel are required to be kept during summer vacations; entries should be made as often as once a week and consist of notices of manufactories, especially of their peculiar mechanical methods and machines. Dimensions of large or important machinery, such as stationary engines of water works, blowing or hoisting machines, and machinery in use in mining or other operations, may form a part of the record. The journals of the first vacation are to be read and discussed in connection with the class in Designing and Shop Practice, and those of the second in connection with the class in Cinematics and Principles of Mechanism. They should be illustrated by sketches reproduced upon the blackboard.

Reports of memoirs upon visits and observations of the third vacation will be required instead of journals, to be read in the class in Machine Drawing during the middle term of the fourth year.

These reports should be made upon rare and interesting mechanical operations, such as making gas pipe, spinning zinc, copper and brass ware, manufacturing saws, etc. They will be placed in the Library of the School and should be illustrated by ample sketches and drawings.

From the beginning, it was clear that a knowledge of the physical laws of light, sound, electricity, and magnetism was fundamental to the training of every student in the Polytechnic Department. Accordingly, these subjects in physics were required and were administered by the Department of Mechanical Science and the Department of Metallurgy and



The Urbana and Champaign Institute was built in 1861-62 as a co-educational boarding school. It was located at the north end of Illinois Field, where the Beckman Institute stands. The availability of this building was a principal inducement for locating the university in Urbana. Note the landscaped grounds—a result of the daily labor required of all students. Students dubbed the building The Elephant.



Drill Hall and Machine Shop in 1872 near the intersection of Springfield Avenue and Burrill Avenue.

Mining. The first administrator of these required courses, from 1869–78, was Stillman William Robinson, professor of mechanical science. He was followed in 1879–85 by Selim H. Peabody, professor of mechanical science and the regent of the university. From 1885–89, Theodore Comstock, professor of metallurgy and mining, served as administrator until the newly formed Department of Physics assumed responsibility in 1889.

The first reference to electrical equipment was contained in the 1869–70 *University Catalogue and Circular*, describing the physical laboratory equipment as follows: “The collection of apparatus includes a Grove’s battery of six cups, an induction coil, model telegraphic apparatus, Madgeburg hemisphere, magnets, and other related equipment.”

In 1873, the first Physical Laboratory was established in the newly completed Main Building, later named University Hall. The 1874–75 catalogue stated: “The Physical Laboratory is amply provided with illustrative apparatus for use in the adjacent lecture room connected by sliding doors so that the apparatus is convenient either for use in the lectures or for the laboratory work.”

The 1878–79 catalogue boasted that the equipment in the Physical Laboratory included “. . . a collection of apparatus from the most celebrated European and American makers,



The Main Building, pictured in 1873 and later called University Hall, was completed on the site of the Illini Union Building on Green Street.



Samuel Wesley Stratton was the first head of the Department of Physics, 1889–1892. This photo was taken in 1890.

costing over \$5,000 and illustrating the subjects of mechanics, pneumatics, optics, heat and electricity.”

When the Department of Physics was established in 1889, Samuel Wesley Stratton, who later became president of Massachusetts Institute of Technology, was placed in charge. Stratton recognized the potential of electricity and related phenomena and supported that newly developing field of technology. Under his direction, the first electrical laboratory was constructed in 1891 in a basement room under the chapel in the Main Building, and the first courses in electrical engineering were offered. The year 1891, therefore, has become the accepted date for the establishment of the Department of Electrical Engineering, with the first degrees being awarded in 1893.

In 1891–92, the *Illinois Technograph*, which began publishing in 1886, contained the following in issue no. 6:

The instruction in electricity begins with the third term of physics in the sophomore year. The laboratory work in electricity includes simple problems in electrical measurements, which are designed to acquaint the student with terms and the use of electrical apparatus. Later on, students in advanced classes take up testing of primary and secondary batteries, cable testing, designing of electrical machinery, installation of light and power plants, the transmission of power by electricity and, lastly, photometry.

In a short time, the Electrical Laboratory established by Stratton in one basement room had expanded into the entire basement floor of the east wing of the Main Building. These instructional and experimental facilities included a dynamo laboratory, an electrical measurements laboratory, a battery room, a photometry room, and a tool room and shop.

Initially, the prime mover of the laboratory was a 10-hp “grasshopper” Atkinson gas engine; however, with the advent of incandescent lighting, a 60-hp “Ideal” high-speed steam engine was installed to provide the first unit of the original University Hall power plant. Steam for this unit was provided by the adjacent Steam Heating Plant, built in 1881. Within a year, a fairly representative collection of belt-driven, direct current and alternating current generators was acquired for the

Bernard V. Swenson is considered to be the first head of electrical engineering. He served for 10 months in 1895–96, when physics and electrical engineering were temporarily separated.



William Esty became head of the Department of Electrical Engineering in 1898, when electrical engineering became the fifth department in the College of Engineering.



combined Electrical Laboratory and University Hall power plant. The direct current machinery for the power plant included a Brush 10-light arc lighting plant, a Thomson-Houston 3-light arc lighting plant, an Edison 100-light incandescent plant, and a 500-volt generator. The alternating current machinery for the power plant included a Thomson-Houston 300-light generator, two single-phase Westinghouse generators, and a number of transformers. The 1892–93 catalogue stated the following concerning the smaller items of laboratory equipment:

The Electrical Engineering Laboratory has been supplied with apparatus from the leading makers at home and abroad. There are several forms of Wheatstone bridges, resistance boxes including an Anthony 100,000 ohm box, a Nadler Bros. subdivided megohm box, and assortment of switches, keys, condensers and the leading forms of “deadbeat” and ballistic galvanometers, including a Thomson high resistance and an Edelman “deadbeat” galvanometer and several D’Arsonval galvanometers. The laboratory is also supplied with artificial standards of resistance, standard cells, Kelvin’s current balance, ammeters, voltmeters, and wattmeters. Current is brought to the room from the dynamo and battery rooms.

A large lecture room for physics and electrical engineering is located on the third floor of the east wing of the Main Building directly above the chapel; it is supplied with current from the dynamo and battery rooms in the basement and is wired for both arc and incandescent lighting.

In June 1892, Stratton resigned to accept a position in the Department of Physics at the newly established University of Chicago, and Daniel W. Shea was appointed assistant professor and head of the Department of Physics. Shea had been an assistant professor of physics at Harvard University before coming to the University of Illinois in 1892. Two years later, he was promoted to full professor and remained at Illinois until 1895, when he resigned to become the first professor of physics at the Catholic University of America in Washington, D.C.

During the brief period of Shea’s stay at Illinois, several momentous events occurred in the College of Engineering and in the Department of Physics. First and foremost was the construction of the new Engineering Building in 1893–94 at a cost of \$172,000. The *History of the College of Engineering* by Baker and King states:

The site chosen for the location of the new Engineering Building was on the north side of Green Street, midway between the north and south group of buildings, facing the latter. Construction work was started late in 1893, and the cornerstone was laid on December 31, 1893. The structure, completed late in the fall of 1894, was formally dedicated with appropriate ceremonies on the 15th day of November of that year, the same day as the formal inauguration of President Draper.

As soon as space became available, Shea moved his Department of Physics and the electrical classrooms and offices from the Main Building (University Hall) into allocated space in the new Engineering Building; however, the electrical laboratories containing heavier dc and ac machinery and associated equipment remained in the basement of University Hall. Some of these units served a dual purpose by providing energy for the University Hall power plant and for student instruction.

In November 1895, following the resignation of Shea, the administration of physics and electrical engineering was separated temporarily. Fred A. Sager was placed in charge of the Department of Physics, and Bernard V. Swenson became the first head of electrical engineering. However, ten months later, with the arrival of Albert Pruden Carmon in September 1896 from Stanford University as head of physics, the electrical engineering courses were again placed under the administration of the Department of Physics. Following this period of frequent administrative changes, it is interesting to note that Carmon remained head of the Department of Physics until his retirement in 1929.

Even though the electrical engineering courses were administered by the Department of Physics, 3 students received BS degrees in electrical engineering in 1893, 9 in 1894, 8 in 1895, 11 in 1896, 14 in 1897, and 18 in 1898. With this growth and increasing interest, the university administration could no longer consider electrical engineering to be a part of the Department of Physics; therefore, in the fall of 1898, physics and electrical engineering were again separated and electrical engineering became the fifth department in the College of Engineering, with William Esty in charge.

In 1897, \$40,000 was allocated for the construction of the Mechanical and Electrical Engineering Building, a T-shaped structure with a three-story front, 50 × 100 ft, and a one-story rear wing, 50 × 90 ft. The location of the new building was designated as “north of the Boneyard branch and east of Burrill Avenue.” In 1991, this is recognized as the north half of the Electrical Engineering Research Laboratory.

It was also decided that electrical engineering would occupy the three-story portion of the building facing Burrill Avenue and that mechanical engineering would occupy the rear 50 × 90 ft one-story wing. From Burrill Avenue, entrance to the building was gained either by a lower floor doorway, called the students’ entrance, or by climbing a double stairway to a second floor doorway, called the main entrance, which led directly into the large dynamo laboratory.

The basement of the three-story electrical engineering portion of the building contained a calibration room, a high potential laboratory, a student shop, a storage battery room, a

stock room, a tool room, and a toilet. The Electrical Dynamo Laboratory occupied the entire main floor. The south end of the huge laboratory contained a machinists’ room, a students’ workroom, an instrument room, and a tool room separated from the main laboratory by low-paneled partitions and wire railings. The third or top floor above the Electrical Dynamo Laboratory contained a large lecture room, student thesis room, a photometry room, and staff offices.

Even with this additional space, the department was unable to find room for all its activities in the new Mechanical and Electrical Engineering Building. A recitation room, a drafting room, a seminar room, and the office of the department head remained in Engineering Hall, which had been erected in 1893. The department also occupied six large “pier rooms” on the main floor of Engineering Hall. These rooms had been used for sensitive electrical and magnetic measurements by the Department of Physics. The laboratory tables were mounted on foundation piers extending down into the ground to provide surfaces free from local vibrations and disturbances—hence the name pier rooms.

The construction of the Mechanical and Electrical Engineering Building was unique. Issue no. 12 of the *Illinois Technograph* commented on the construction of the building:

The floors above are supported upon steel girders and yellow pine beams. The entire upper story and roof are supported by six steel trusses of the Fink type. The upper floor and partitions are suspended by two steel rods attached to each truss. The ceiling joists are carried directly upon the horizontal lower chords. The floors are capable of carrying a load of twenty-five hundred pounds per square foot.

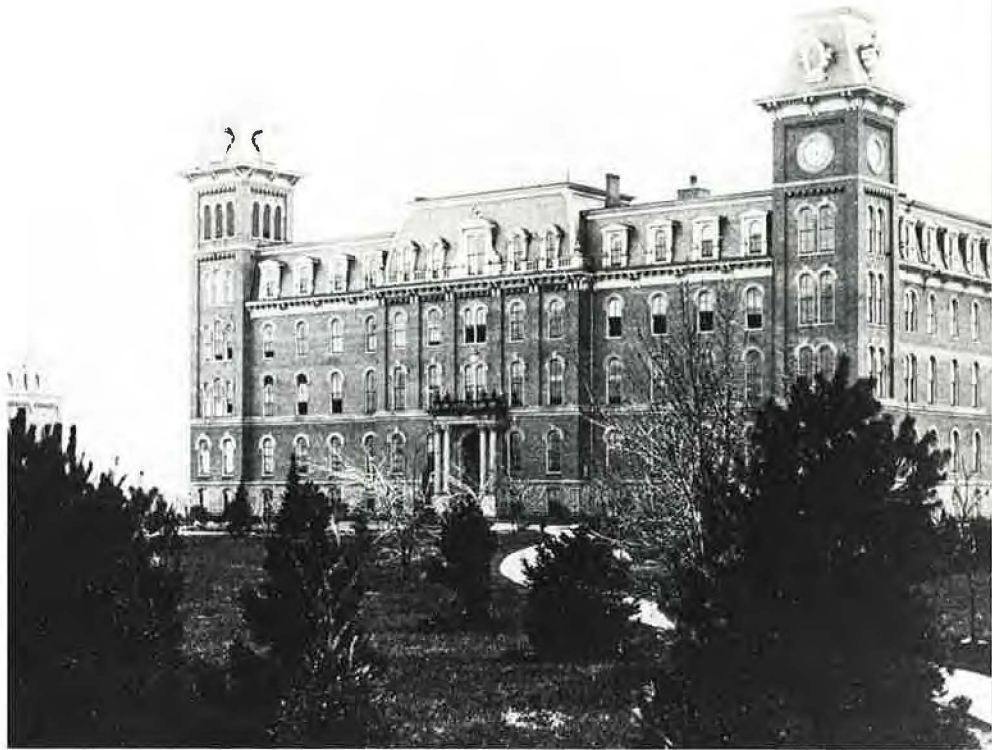
In other words, the upper floor is suspended from the ceiling trusses, which eliminates the need for supporting columns on the main floor.

The Mechanical Engineering Steam Laboratory occupied most of the one-story east wing of the building, which is 50 × 90 ft. Similar methods of construction were used, as reported in the same issue of the *Illinois Technograph*: “The roof of the Steam Laboratory is supported by eight exposed steel Fink trusses with horizontal chords. They carry a line shaft and the track for a four-ton traveling crane.” Wooden doors can be seen on the east end of the building, which allowed the crane to carry loads to and from the outside.

The Department of Electrical Engineering and the Department of Mechanical Engineering shared the building for seven years, until mechanical engineering moved its steam laboratory into a new building in 1905. The Department of Electrical Engineering expanded into the east wing, and with this additional space, most activities of the department could be located under one roof.



The Mechanical and Electrical Engineering Building in the early 1900–05 era. Note the boiler house for the Boneyard Power Plant in the right background.



Another view of the Main Building, later called University Hall, taken from Green Street in 1879, shows its location with respect to the first chemistry building, Harker Hall, which still stands in 1991.



The new Engineering Building, known today as Engineering Hall, was built in 1893-94 at a cost of \$172,000.

Chapter Two - The Department in the 20th Century



Professor Morgan Brooks proudly displays his new 1910 automobile in front of the Mechanical and Electrical Engineering Building. Note the double stairway to the main entrance with the student entrance below.

In 1899, William Sleeper Aldrich succeeded William Esty as the head of electrical engineering. Aldrich served until 1901.



The Beginning of the Century

As mentioned in Chapter 1, William Esty was named head of the Department of Electrical Engineering in the fall of 1898, when the department was again separated from physics. He served in that capacity for only one year but remained on the electrical engineering staff until 1901. At that time, he accepted a position at Lehigh University and later became head of the electrical engineering department there.

William Sleeper Aldrich, a professor of mechanical engineering at the University of West Virginia, was employed in the fall of 1899 as professor of electrical engineering and head of the Department of Electrical Engineering, succeeding William Esty. He resigned in 1901 to become director of the Clarkson Memorial School of Technology, Potsdam, New York.

Morgan Brooks, from the University of Nebraska, was then hired by the University of Illinois as professor of electrical engineering and head of the department. He served as department head until 1909 and remained as professor of electrical engineering until his retirement in 1929. Despite these frequent administrative changes, the department continued to develop, and the need for additional laboratory and classroom space was always a primary concern.

During these early years of the twentieth century, the east wing of the Mechanical and Electrical Engineering Building served a dual purpose. The steam engines and generating units of the Boneyard Power Plant (1897–1910) were housed at the east end of the wing adjacent to the steam boiler units in the Electrical Engineering Annex. Because steam was readily available, this area also served as the steam machinery laboratory of the Department of Mechanical Engineering.

In 1905, mechanical engineering moved its steam machinery laboratory into a new building; in 1910, the operation of the Boneyard Power Plant was discontinued, and its steam engines and generators were removed from the east wing. These changes enabled the Department of Electrical Engineering to occupy the entire building. The east wing was soon remodeled to contain two large lecture rooms, two classrooms, and a high-voltage laboratory, freeing space on the third floor facing Burrill Avenue for departmental offices, a graduate study room, and a library.

Ernest Julius Berg, an engineer with General Electric Company and a lecturer at Union College, Schenectady, New York, was employed in 1909 as head of electrical engineering. He was enticed to come to Illinois when several large Illinois corporations agreed to supplement his university salary by giving him retainer fees as a consulting engineer. Berg remained as head until June 1913, when he resigned to return to his former positions with General Electric Company and with Union College.

Ellery Burton Paine, after several years of experience in industry and university administration, came to the University of Illinois in 1907 as an assistant professor of electrical engineering. Following the resignation of Berg in 1913, Paine became acting head of electrical engineering and then head of the department, a position he held for 31 years until he retired in September 1944.

Following the acquisition of the east wing of the Electrical Engineering Building in 1910, the department operated quite well within its allocated space during the next decade. Student enrollments, however, continued to increase year after year, and by 1925 modifications in space use were necessary. The huge dynamo laboratory (room 200) had become inadequate to serve the demands for instruction in the area of ac and dc power machinery, which at that time comprised the major portion of the department's instructional activities. In 1925–26, room 207 in the east wing was converted into a smaller dynamo laboratory to supplement the larger one in room 200.

While the Department of Electrical Engineering was evolving on the north bank of the Boneyard, the Department of Applied Mechanics was developing on the south bank in a building somewhat resembling the Electrical Engineering Building. It consisted of two floors above ground facing Burrill Avenue and an east wing of two floors, which served as the hydraulics laboratory. In 1928–29, a new building (later renamed Talbot Laboratory) was constructed for the Department of Theoretical and Applied Mechanics on the west side of Burrill Avenue. The Applied Mechanics Laboratory was then vacated, and this space was assigned to electrical engineering. In the summer of 1929, a connecting structure was built across the Boneyard, thereby joining the

Morgan Brooks served as department head from 1901–1909 and remained a professor of electrical engineering until his retirement in 1929.





The Electrical Engineering Laboratory (left) and the Applied Mechanics Laboratory (right) were connected in 1929 to house the Department of Electrical Engineering. This picture was taken in the early 1950's, before some 800 elm trees on campus were killed by the Dutch elm disease.



Applied Mechanics Laboratory in 1928. This space was assigned to electrical engineering when a new building (later renamed Talbot Laboratory) was constructed for the Department of Theoretical and Applied Mechanics.

Electrical Engineering Building and the former Applied Mechanics Laboratory. These two buildings and the connecting structure formed the Electrical Engineering Research Laboratory.

The main floor of the newly acquired Applied Mechanics Laboratory (facing Burrill Avenue) was converted into another large dynamo laboratory. The equipment housed in room 207 at the north end was moved into room 214 of this new facility (later renamed the Solid State Devices Research Laboratory). The second floor above room 214 (facing Burrill Avenue) was remodeled to provide facilities for the radio laboratory, which had occupied room 204 at the north end.

The east wing of the former Applied Mechanics Building had been the hydraulics laboratory; the lower basement floor of this wing was transformed into research rooms for members of the staff and for graduate students who were conducting thesis studies and experimental work. The upper floor of this east wing was converted into a large lecture room containing 300 seats for general use by electrical engineering and by other departments in the College of Engineering.

With the acquisition of the Applied Mechanics Laboratory and the connecting hallway structure, the crowded conditions in the north end of the building were eased considerably. The rooms on the third floor of the north end, which had served as the departmental offices, were converted into a communications laboratory, containing all the latest telephonic equipment.

The 100-kW synchronous motor-generator set, which had been a part of the old Boneyard Power Plant, was moved from the rear of room 207 into the small room at the north end of the connecting hallway (201 EERL), replacing the 85-kW set as a source of direct current energy for the dynamo laboratory in room 200.

Meanwhile, in 1930, the old Boiler House of the Boneyard Power Plant was vacated by the Department of Applied Mechanics, the Department of Civil Engineering, and the University Garage, and the Department of Electrical Engineering was offered this entire facility. By 1932, the south end of the old Boiler House (renamed Electrical Engineering Annex) had been transformed into a high-voltage laboratory containing a huge Tesla coil and associated apparatus. The removal of the high-voltage equipment from room 206 of the Electrical Engineering Building provided space for high-frequency experimental work. Both of these programs on high voltage and high frequency were under the direction of Joseph Tykociner.

Ernest Julius Berg, who served as department head from 1909–13, was enticed to come to Illinois when several corporations agreed to give him a retainer fee as a consulting engineer.



Ellery Burton Paine came to the University of Illinois in 1907 as an assistant professor. He became acting head and then head of electrical engineering in 1913. He led the department for 31 years until his retirement in 1944.



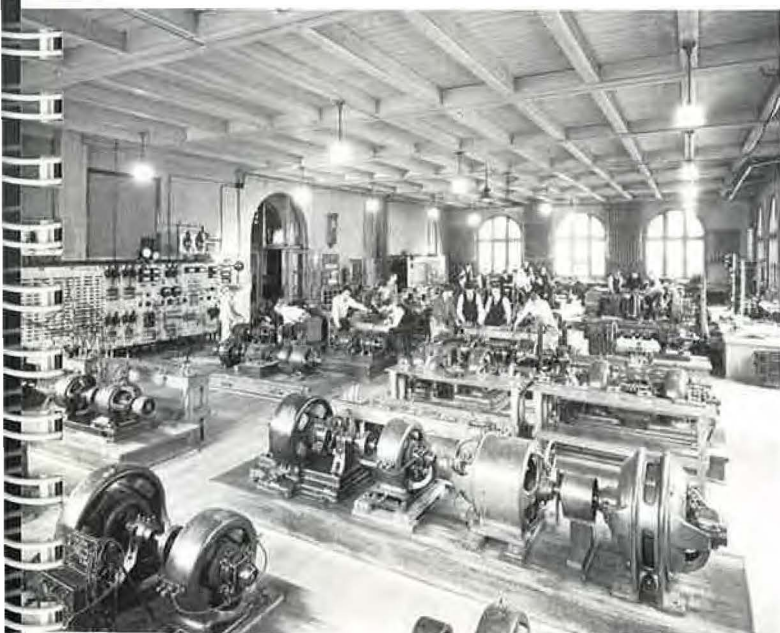
The north end of the old Boiler House was remodeled in 1934 to provide space for the illumination courses. A large photometric laboratory was constructed in the basement, and a classroom seating 40 students, a spectrophotometry laboratory, and a staff office were provided on the main floor. These facilities for instruction in the field of illumination were considered the finest in the nation.

The large lecture room seating 300 people in the south wing of the Electrical Engineering Building was modified in 1948 to provide 12 smaller rooms for offices and laboratories. Otherwise, the building space allocated to Electrical Engineering did not change materially from 1934 to 1949. Student enrollments continued to increase and additional staff members were employed. To provide for these increases, classrooms and office space were acquired on the second floor of Engineering Hall.

In 1941, with the advent of World War II, the United States Armed Services contracted with the university to train recruits on an accelerated basis. Most of this training focused on subjects related to electrical engineering. The U.S. Army established similar units of Armed Services Training Programs, and Wright-Patterson Air Force Base, Dayton, Ohio, sent civilian employees for Engineering Specialized Manpower War Training programs.

The Department of Electrical Engineering was literally swamped with students. Most staff members were assigned teaching loads of 18 to 24 classroom hours per week, with class sizes far greater than normal. Classes were scheduled from 7:00 a.m. to 10:00 p.m., six days per week. These conditions of too many students and an insufficient number of staff continued until the end of World War II in 1945. From 1945–48, the army continued to send officers for graduate study in electrical engineering.

In the meantime, in 1944, Ellery B. Paine, who had served the department well during his 31 years as department head, retired, and William L. Everitt became the seventh person to serve as head of electrical engineering at the University of Illinois. People who were associated with the department during those postwar years witnessed a most aggressive and dynamic example of leadership. Under Everitt, the Department of Electrical Engineering was transformed into one that included all aspects of research and instruction encompassed in the broad spectrum of subjects related to electrical engineering.



Professors H. N. Hayward and E. A. Reid are pictured in the Machine Laboratory circa 1936. Lamp banks on wall served as resistance loads. Note that the machines are now direct drive rather than belt drive.



Professor William Littell Everitt, head of the Department of Electrical Engineering from 1945–49 and dean of the College of Engineering from 1949–68.

Overview since 1945

Immediately after World War II, colleges and universities across the nation experienced rapid growth in enrollments. The Department of Electrical Engineering (the name was changed to the Department of Electrical and Computer Engineering in 1984) at the University of Illinois was no exception. As young men returned from their service duty, they enrolled in large numbers to take advantage of the GI Bill, and engineering attracted many students because the advances and discoveries made during the war had raised awareness of the profession. This was also the time of the first female electrical engineering graduate. Although some women students had graduated from the College of Engineering, in 1945, Lois Hume Windhorst was the first to receive her bachelor's degree from this department.

The sudden rise in enrollment figures, as shown in the graph, gave impetus to the design and construction of a new

building for the department. The department needed to become research oriented and needed new facilities to adapt to this new focus. It was an exciting time—a time for visionary leadership to guide the department into a rapidly changing future.

William L. Everitt was to fill that role. Already well known for his many contributions, Everitt came to the University of Illinois with influence, power, and respect. Because of those qualities and the fact that his work in Washington, D.C., had put him in close contact with other top people, he was able to recruit “stars” to come to Illinois.

As Everitt drew other top researchers to the department, an influx of new research dollars came with them. Concomitantly, the graduate program grew and expanded with students eager to study with engineers of such fame. Since the years before World War I, the graduate program had remained small and constant. At that time, there was little interest or need for an advanced degree in engineering unless college instruction was the career goal. The following graphs depict these trends.

Figure 1—Undergraduate Enrollment by Degree

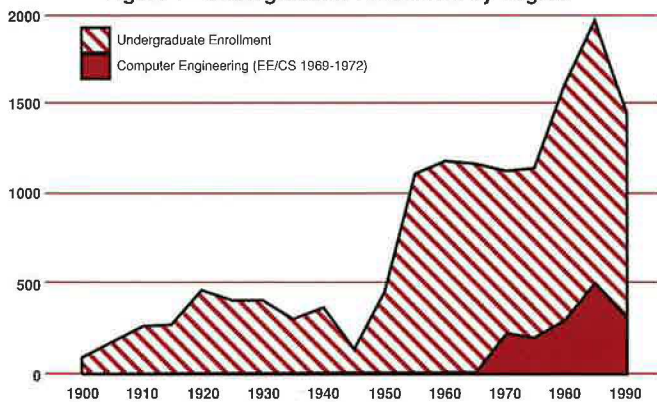
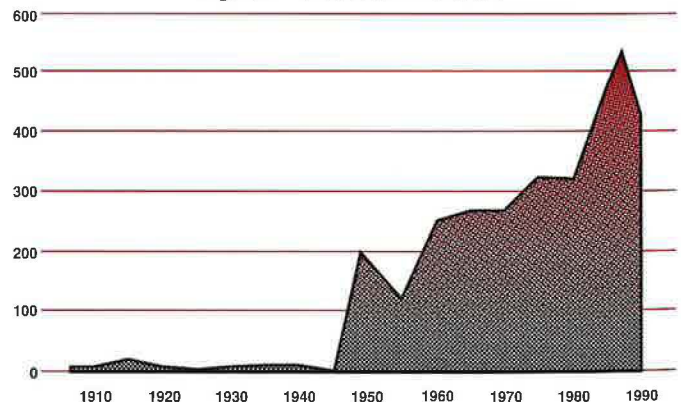


Figure 2—Graduate Enrollment





John D. Ryder became head in 1949 after Everitt assumed the deanship in the college. Ryder served until 1954.



Edward C. Jordan was head of the Department of Electrical Engineering from 1954–1979.

In figure 4, note the sharp contrast in percentage of advanced degrees granted in 1940 vs. 1990. High technology industries today require more engineers with advanced degrees. In 1990, the department holds the unique distinction of ranking as one of the nation's largest BS degree granting departments and one of the largest PhD degree granting departments in the field.

At the time of Everitt's arrival at Illinois, the department was housed in what, in 1991, is called the Electrical Engineering Research Laboratory (EERL). The new Electrical Engineering Building, dedicated in 1949 and later renamed the William L. Everitt Laboratory, bears the mark of his philosophies. Everitt believed that class size should be kept small and that research was of top priority. The design of the new building reflected this philosophy; classrooms held a maximum of only 25 students, and there were spacious laboratories and shops to accommodate the research that was so much a part of his vision. Later on, when student numbers reached unimagined heights, some walls were moved to accommodate larger classes.

Two symposia were held when the building was dedicated in 1949. One was titled "The Development of an Electrical Engineer" and the other was "The Expanding Frontiers of Electrical Engineering." Speakers included Robert E. Doherty, president of Carnegie Institute of Technology, and Everitt E. Lee, president of the American Institute of Electrical Engineers.

In 1949, when Everitt became dean, the departmental search for a new head led to John D. Ryder, who was on the faculty at Iowa State University. Ryder served as head of the department from 1949 to 1954, when he left to become dean of engineering at Michigan State University. Upon his retirement from Michigan, he moved to Florida, where he taught part time at the University of Florida.

In 1954, Edward C. Jordan, who had come to Illinois from Ohio State University in 1944 with Everitt, became the next head of the Department of Electrical Engineering. Except for the year of his sabbatical leave in 1965 at the Arecibo Observatory in Puerto Rico, he served until 1979. During his leave,

Figure 3—ECE Graduates by Degree

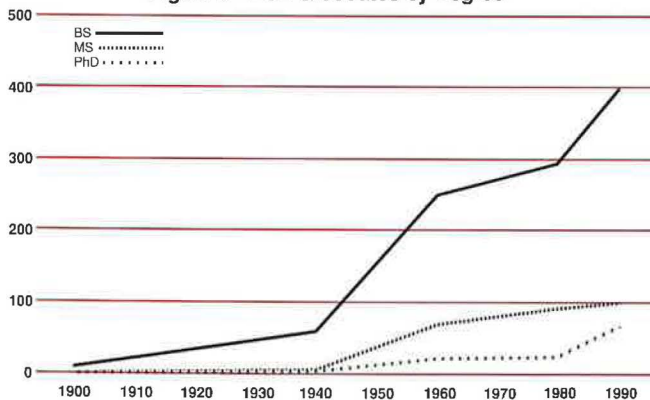
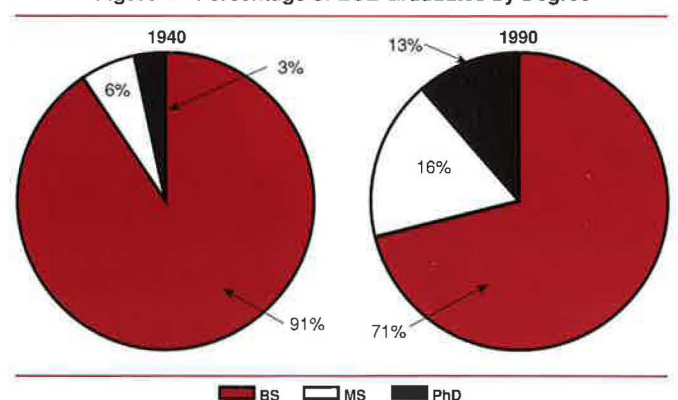
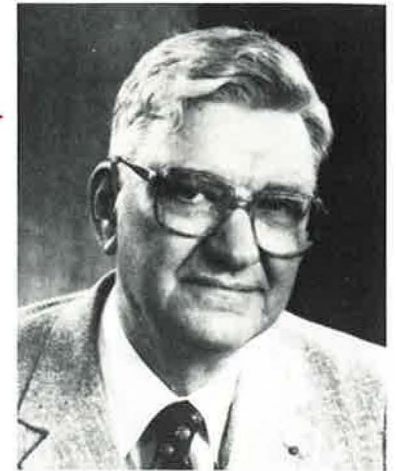


Figure 4—Percentage of ECE Graduates by Degree





M.E. Van Valkenburg served as acting head for Jordan in 1965.



From 1979–1985, George W. Swenson, Jr., was department head.

M. E. (Mac) Van Valkenburg served as acting head. Van Valkenburg served as dean of engineering from 1984 to 1988. Jordan remained active on campus after his retirement.

The first national rankings of universities and departments were made in 1964. In these and subsequent rankings, the Department of Electrical and Computer Engineering has consistently been in the top four. Because the Massachusetts Institute of Technology and Stanford University are private schools, the University of Illinois claims the highest rank among state universities.

During Jordan's 25 years as head, the department continued to grow in several areas. Faculty size burgeoned in the postwar years, but salaries did not take a commensurate growth until the 1960s. The economic recession of the early 1970s resulted in a somewhat slower growth period, which began to turn upward again by about 1976.

Computer science degrees were first offered through the Department of Mathematics and the Department of Electrical Engineering. Figure 1 pictures enrollment in the computer programs. From 1969 to about 1973, a joint EE/CS bachelor's degree was offered. In 1972, the Department of Computer Science initiated a bachelor's degree program, which removed a number of students from this department. The Department of Electrical Engineering also initiated a computer engineering program in 1972, and enrollment remained strong until the mid-1980s.

When Jordan retired in 1979, George W. Swenson, Jr., served as department head until 1985. Jordan then returned to research in the department. He retired in 1988 and died in 1991.

Enrollments at the undergraduate and graduate levels peaked at record levels in the mid-1980s. Class sizes became

Figure 5—Number of Faculty

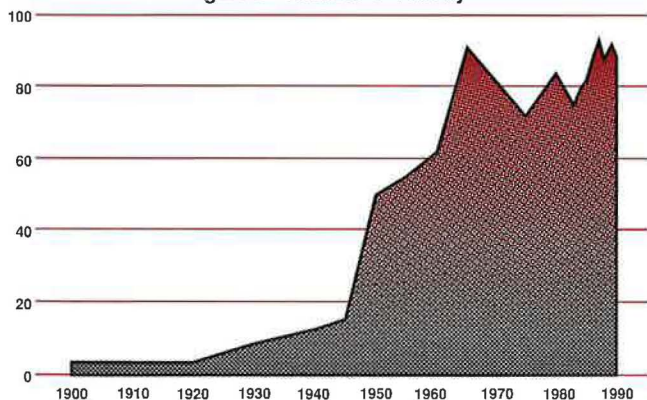


Figure 6—ECE State, Research, and Gift Expenditures, 1910-1990

	1910	1920	1930	1940	1950	1960	1970	1980	1990
State	\$19,000*	\$22,252	\$55,609	\$73,627	\$420,438	\$684,203	\$1,469,317	\$3,176,480	\$7,281,627
Research	NA	\$1,000*	NA	\$7,500	\$715,525	\$1,600,000	\$3,500,000	\$6,000,000	\$13,295,200
Gifts	NA	NA	NA	\$2,000*	\$30,000*	NA	NA	\$156,000	\$1,622,900

*Estimate NA – not available

too large, and the quality of student/faculty interaction deteriorated. The College of Engineering submitted a multiyear \$18 million engineering revitalization program to the state legislature, which was approved and funded in part for a few years. New faculty members were recruited in the early and mid-1980s to handle the increased instructional load. However, the engineering revitalization program was curtailed after only half of the funds were received. The department reduced enrollment at both the undergraduate and graduate levels in the late 1980s to improve the quality of education.

Figure 6 charts the department's expenditures over the years in various categories. We have an accurate record of state expenditures for each year. However, before 1940, we have no record of research funds from external sources. We know that Professor Tykociner was the only research professor in the department in this period, and he spent \$1,000 in

1921 on his sound-on-film project. It is doubtful that he had more than a few thousand dollars annually to conduct his research. Also, no accurate record was kept of gifts before 1980. Gifts come in the form of scholarships, fellowships, equipment, and unrestricted funds for research or instructional programs. Before 1980, we estimate that gifts constituted less than 3% of the department's annual income. Figure 7 gives the same information adjusted for inflation in 1984 dollars.

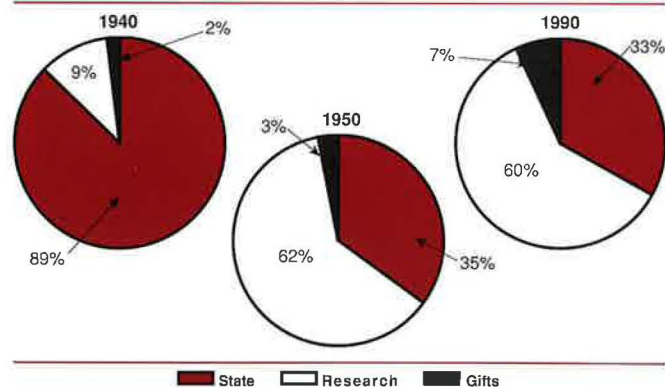
Figure 8 illustrates the dramatic changes in the sources of funding for the department. Before World War II, approximately 90% of the department's budget came from tuition and state appropriations. Since World War II, only approximately one third of the department's budget comes from tuition and state appropriations. In recent years, gifts from industry and alumni have become more essential for the support of instructional laboratories and research.

Figure 7—ECE State, Research, and Gift Expenditures, 1910-1990
Adjusted for Inflation (1984 Dollars)

	1910	1920	1930	1940	1950	1960	1970	1980	1990
State	\$234,555*	\$128,291	\$391,487	\$566,192	\$1,745,238	\$2,307,817	\$3,782,022	\$3,861,853	\$5,559,571
Research	NA	NA	NA	\$57,675	\$2,970,144	\$5,396,800	\$9,009,000	\$7,290,000	\$10,224,009
Gifts	NA	NA	NA	NA	NA	NA	NA	\$150,148	\$1,248,010

*Estimate NA - not available

Figure 8—Percentage of ECE State, Research, and Gift Expenditures





Timothy N. Trick, who joined the department in 1965, became head in 1985.

Because the department has been in a growth mode over the years, figures 9 and 10 depict the state funding per student and research funding per graduate student at 10-year increments. Note the 20-year cycle. After World War II, there was a great spurt of government funding for education and research. The Korean War was followed by a recession in the 1950s, and the demand for engineers decreased as did the dollars per student. In 1957, Russia launched Sputnik; the economy improved in the 1960s, and the demand for engineers increased as did funding for education and research. In the 1970s we see the effects of the Vietnam War and another recession. Funding levels dropped as did the demand for engineers. By the late 1970s, a shortage of engineers developed again, and in the 1980s funding for education and research increased. As we enter the 1990s, we are in a recession; the demand for engineers has decreased, and we are beginning to see decreases in state funding and a leveling of research expenditures. Is this the down side of another 20-year cycle?

After Swenson returned to research in 1985, Edward W. Ernst served as interim head while a search was in progress. The search ended in the appointment of Timothy N. Trick as the department head in 1985. Trick had joined the faculty at Illinois in 1965. Ernst became an associate dean in the College of Engineering. Later, he was a program director at the National Science Foundation and then returned to teaching as an Allied Signal Professor at the University of South Carolina.

Due to the continued growth since 1944, the Department of Electrical and Computer Engineering long ago outgrew Everitt Laboratory. In 1991, the department is located in parts of nine different buildings. An \$18.7 million gift has been obtained from the Grainger Foundation for a new engineering library, and EERL and the EEA are scheduled for demolition in 1993 to make room for the library and a mall. The college's highest priority for capital funding is a new electrical engineering building.

Figure 9—State Funding per Student
Adjusted for Inflation (1984 Dollars)

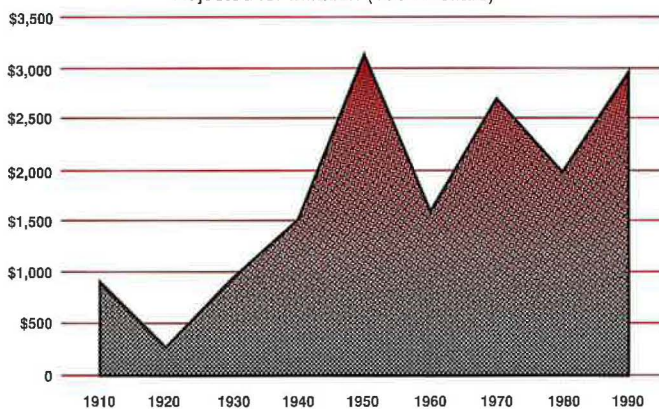
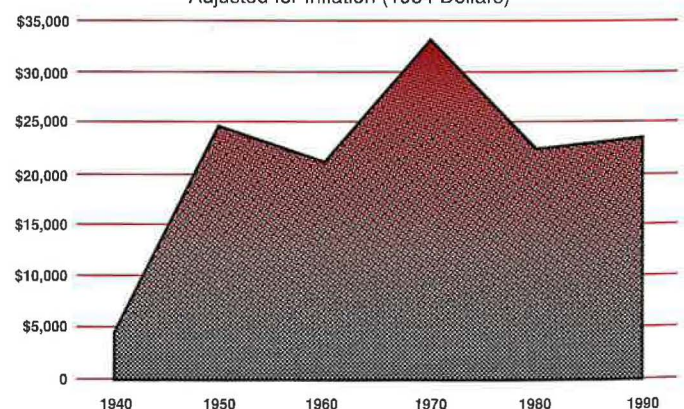


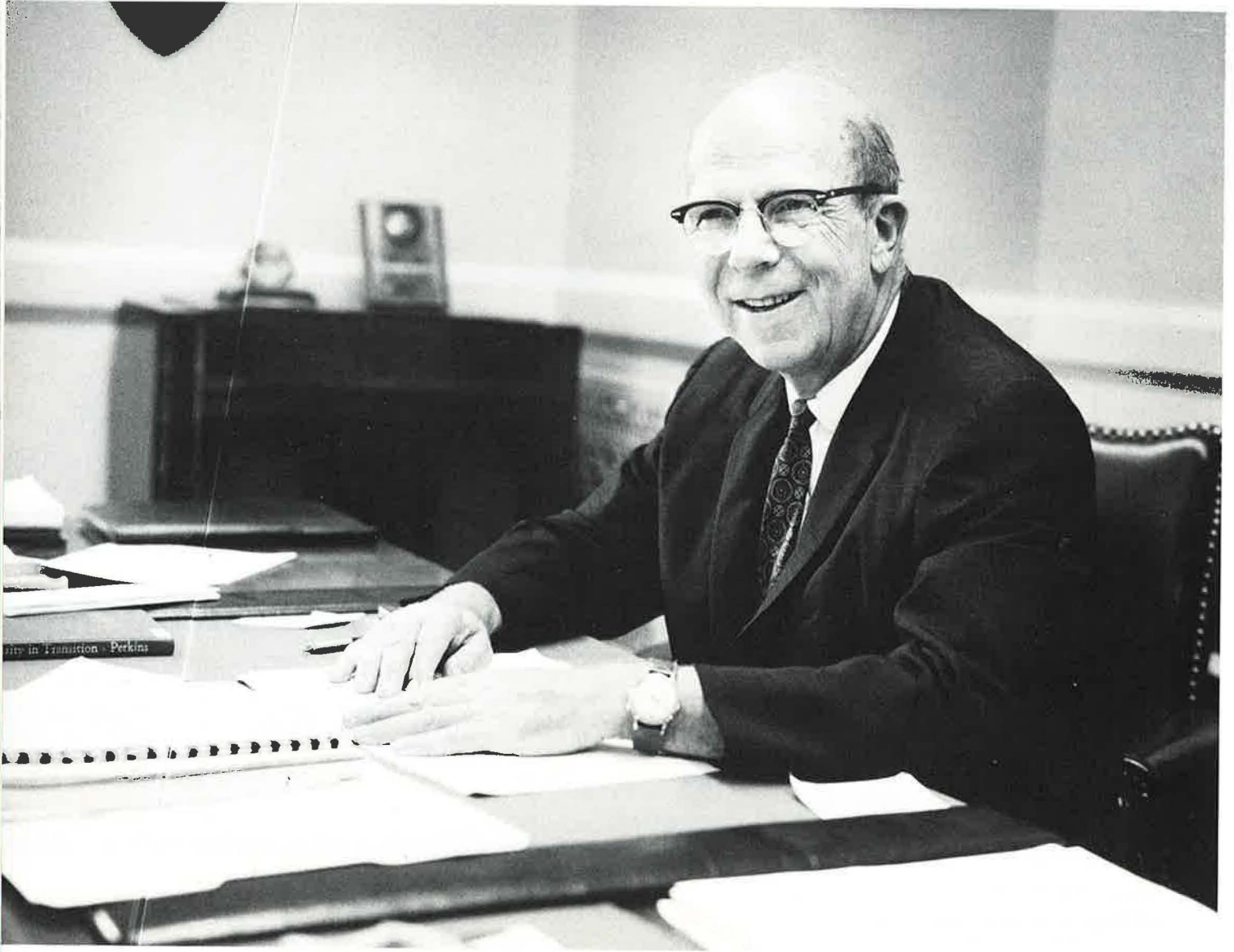
Figure 10—Research Funding per Graduate Student
Adjusted for Inflation (1984 Dollars)





Dedicated in 1949, the Electrical Engineering Building was later renamed the William L. Everitt Laboratory. The third floor was added in 1965.

Chapter 3-Department Notables



Dean William L. Everitt at his desk in 1949.

Everitt at Illinois

The appointment of William L. Everitt as head of the Department of Electrical Engineering was a significant factor in our emergence as one of the leading departments in the United States and perhaps even the world.

How did this fortunate event happen? We first review the history of his appointment.

When Ellery Paine was scheduled to retire in 1944 after heading the department for 31 years, the problem of finding a successor arose. Members of the department approached Dean Enger with the suggestion that instead of initiating a national search, as was usual, the successor should be selected from among the existing faculty. They suggested that Abner R. (Buck) Knight should be appointed head with Charles H. Keener as associate head to carry most of the administrative load. Knight was well known and liked throughout the campus and Keener was known to be most effective in handling administrative details and class scheduling, so it would have made a good combination.

When Dean Enger raised questions about the plans for research, he was told that the faculty members had decided not to try to conduct research in the department because research in electrical engineering required large and expensive equipment available only in large industrial companies, such as General Electric and Westinghouse. It was at this point that the dean instituted a national search, which resulted in William L. Everitt being selected as the new head.

Everitt had an outstanding career at The Ohio State University, rising through the ranks to professor. His book, *Communication Engineering*, based largely on his own research results, had attracted graduate students from all around the world. In 1941, he was given leave of absence from OSU to serve during the war as director of Operational Research in the Office of the Chief Signal Officer. When he was appointed as department head at the University of Illinois in 1944, he was given a one-year leave of absence by Illinois to complete his war work in Washington, D.C. During the academic year 1944-45, Knight served as acting head of the department, with Keener handling the administrative details.

Although Everitt was not yet actively on board as head, plans moved forward to construct a new building. Together with several members of the department (Archer, Faucett, and Keener), Everitt visited other electrical engineering departments, including Ohio State University, to gain ideas for desirable layouts and new equipment. Plans for the new building called for 50,000 sq ft of floor space, but with rapidly rising construction costs in the immediate postwar years, actual construction was scaled down by nearly half. Still, the cost ended up at almost double the budgeted amount.

After three years of planning and construction, the new building was scheduled for occupancy in the fall of 1948. As is often the case, there were a few unfinished details remaining on the moving date. In this case, the new Electrical Engineering Building was still without electricity on September 16, the first day of classes. Undaunted, a group of professors decided to hold their first classes in the new building at the scheduled time of 7:00 a.m.

The following day, the *News-Gazette* featured a story of the opening of the new electrical engineering building. Instead of the usual tape-cutting ceremony, it showed pictures of a group of professors and their students leaving the old building and entering the new building. The third picture showed Everitt congratulating Paul Egbert on beginning classes in the new building. Because it was still relatively dark at 7:00 a.m., the group carried candles and miner's lamps and wore miner's hats.

William L. Everitt leads the first class of the day from the old building to the new building.



Entering the newly completed building, now known as Everitt Laboratory.



"Newly completed except for the electricity!" The first class was held using candles and miners helmets for illumination.





The Electrical Engineering Building (renamed Everitt Laboratory) before the addition of the top floor. In 1958, a unidirectional antenna was installed on the roof as a feed on a "moon-bounce" parabolic reflector. This was the first application of a log periodic antenna.

It is said that the university architect, Ernest Stouffer, was not happy about the publicity given to the builder's failure to meet the deadline. Most other people, however, seemed to derive a certain amusement from the fact that the new Electrical Engineering Building should open without electricity.

Everitt was born in Baltimore, Maryland, and raised in the East. He pursued his early academic career at Cornell University (BS 1922) and the University of Michigan (MS 1926), while serving as an instructor at both institutions. In between, he spent two years as an engineer at North Electric Manufacturing Company in charge of automatic PBX development. With this background, he went to Ohio State University, where he received his doctorate (1933) and spent 18 years as a member of the faculty. While at Ohio State, he published *Communication Engineering*, which had a profound effect on the profession, changing it from power-dominated electrical engineering to a balanced power-electronics field and hence to the expanded coverage of the early 1990s.

Everitt could surely have remained at Ohio State University for the remainder of his career. Instead, he was convinced that there was a great opportunity at the University of Illinois and, when chosen, he accepted with enthusiasm.

Everitt's appointment as head carried with it a mandate to keep the department at the leading edge of the field by

developing it from a teaching department to one whose faculty was engaged in both research and teaching. Before 1945, the only research appointment in the department was that held by Joseph T. Tykociner, whose interests spanned a range of topics (for more information on Tykociner, see Chapter 3).

There was other research done in the department, but it was carried out by faculty members on top of full-time teaching loads. This situation was common in electrical engineering departments throughout the nation, a marked contrast to physics and chemistry departments, whose faculty members were hired for both teaching and research with reduced teaching assignments to enable them to devote time to research.

Although the university administration encouraged and applauded the move toward research in the department, it was unable to provide the funds required for both research and for teaching the rapidly increasing number of students during the immediate postwar years. All faculty members were now encouraged to seek research support from government agencies such as the Office of Naval Research, Wright-Patterson Air Force Base, Air Force Office of Scientific Research, Bureau of Ships, and Signal Corps; part or all of their research assignments were paid, in the beginning, from these outside funds. With this infusion of funds, the department was able to grow rapidly and maintain quality teaching while providing the research activities required for graduate student research.

During the four-year (1944/45 to 1949) period of Everitt's headship, the department experienced a remarkable growth in the number of faculty members and students. From an active faculty of 21 in 1945 (6 of whom were on leave of absence), the department grew to 45 professorial faculty (assistant professor through professor), 12 instructors, and 65 part-time graduate assistants. During the same period, the student body increased from 29 undergraduates and no graduate students to 260 undergraduates and 156 graduate students. Nearly all of the graduate students were also teaching assistants, research assistants, or research associates. The new research projects provided both the financial support and research topics for this wave of postwar graduate students.

Everitt's technical and professional contributions were numerous. While at Ohio State, he developed the principle of the radio altimeter, which is now used as standard equipment on all of the larger aircraft. In 1938, he organized and directed the first broadcast engineering conference, which brought together radio station engineers from the United States and Canada for an engineering short course on the technical problems of radio stations.

Everitt's leadership in engineering education is evidenced by the fact that he held nearly every major office in the key professional and engineering education societies. He was president of the Institute of Radio Engineers (IRE), president of the American Society for Engineering Education (ASEE), and president of the Engineers' Council for Professional Development, now known as the Accreditation Board for Engineering and Technology. He was also awarded almost every major medal or award given by these and other professional societies, including the IRE Medal of Honor, the American Institute of Electrical Engineers (ASEE) Lamme Medal, and the AIEE Medal for Electrical Engineering Education. He was awarded ten honorary doctorates.

Over the years, he served an average of about three years on each of 36 committees of these technical societies, and he was chairman of many of them. His leadership in electrical engineering, particularly in the communications field, made him much sought after as an adviser to many governmental services. During World War II, he was director of Operational Research in the Office of the Chief Signal Officer; and in 1946, he was awarded the War Department's Exceptionally Meritorious Civilian Award. Among many other advisory appointments, he had served as a member of the President's Communication Policy Board and as a member of the Research and Development Board of the Department of Defense. He was a founding member of the National Academy of Engineering.

In 1923, he married Dorothy Irwin Wallace; they had three children. She died in 1978. Two years later, he married Margaret L. A. Larson and gained five stepsons. Many of his graduate students called him "Uncle Bill," and his students

and children alike loved for him to stand on his head — his great balancing feat that he was likely to do anywhere at any time.

When he became dean, he was concerned that the press of administrative duties would cause him to lose touch with the technical advances of his field. It is typical of the man that, to ensure against this eventuality, he undertook the editorship of the Prentice-Hall series of electrical engineering texts. In this capacity, he edited more than 100 textbooks ranging from basic electrical engineering to information theory.

As dean of the college from 1949 to 1968, Everitt was successful in maintaining his reputation for accessibility. His open-door policy was so widely known that when he retired, fellow administrators mounted the "unused" knob from his office door on a plaque and presented it to him as a tribute.

After a long and celebrated career, he died on September 6, 1986. Perhaps his most personal philosophy, which describes how he lived his life, is best explained in this quote from the distinguished dean: "I am an optimist rather than a pessimist. It is possible that the pessimists may be proven right in the long run, but we optimists have a better time on the trip."

Dean William L. Everitt standing on his head at a student/faculty banquet, after rendering his song "the bald-headed end of the broom," accompanying himself on the piano.



John Bardeen

John Bardeen and his life's work have changed technological history in countless, unheralded ways. "John Bardeen personified the ideal university professor: gifted mind, productive career, warm heart, and kind spirit," said University of Illinois President Stanley O. Ikenberry. "For generations to come, John Bardeen will represent the best of Illinois." A two-time Nobel Prize winner, Bardeen won the Nobel Prize in physics in 1956 for co-inventing the transistor and in 1972 for co-developing the theory of superconductivity.

He was born on May 23, 1908, at Madison, Wisconsin. His father was dean of the medical school at the University of Wisconsin, and his mother was an artist and interior designer. He received his BS in 1928 and his MS in 1929 in electrical engineering, both from the University of Wisconsin. After spending three years doing research at the Gulf Research

Laboratories in Pittsburgh, Pennsylvania, he returned to his graduate studies in 1933 and received his PhD in mathematical physics from Princeton University in 1936. He held a fellowship at Harvard University, taught at the University of Minnesota, and was a physicist with the Naval Ordnance Laboratory in Washington, D.C. In 1945, he joined the newly formed research group in solid-state physics at the Bell Telephone Laboratories, Murray Hill, New Jersey. It was there that he became interested in semiconductors and, with W. H. Brattain and W. Shockley, discovered the transistor effect in late 1947.

While at Bell Labs, John Bardeen maintained close ties with several universities. Illinois was attractive to him because Fred Seitz was here as a member of the Department of Physics, and he had brought with him a group of physicists working in the solid-state field. At the University of Illinois, the initiative was taken by Dean William Everitt and F. Wheeler Loomis, then head of the Department of Physics, to attract Bardeen. Bardeen was made an offer, and the legend is that "it broke the \$10,000 limit" then imposed on faculty salaries by the university.

In 1951, John Bardeen left Bell Telephone Laboratories to become professor of physics and electrical engineering at the University of Illinois. Space was made available through Dean Everitt in the Electrical Engineering Building (renamed EERL) in space that had just been vacated by the ILLIAC project, which had moved to the Engineering Research Laboratory. While at the University of Illinois, Bardeen maintained active interests in engineering and technology. He began consulting for Xerox Corporation in 1951, when it was still called Haloid and the research department was located in a frame house in Rochester. He also consulted for General Electric and several other firms.

Besides his position at the university and his consulting work, Bardeen also served on the President's Science Advisory Committee from 1959 to 1962 and on the White House Science Council in the early 1980s. His honors included the National Medal of Science in 1965, the Presidential Medal of Freedom in 1976, and the Lomonosov Prize from the Soviet Academy of Sciences in 1988.

Upon his retirement in 1975, he became professor emeritus. With that title, he remained active at the university and in his profession until his death. During his 60-year scientific career, he made significant contributions to almost every aspect of condensed matter physics. His research spanned the electronic behavior of metals, the surface



John Bardeen displays an oscillator containing his Nobel Prize winning invention, the transistor.

properties of semiconductors, the theory of diffusion of atoms in crystals, and quasi-one-dimensional metals. In his 83rd year, he continued to publish original scientific papers.

Bardeen received 16 honorary degrees and was elected to the National Academy of Sciences, National Academy of Engineering, and the American Philosophical Society. In 1990, the Sony Corporation established the John Bardeen Chair in Physics and Electrical and Computer Engineering at the University of Illinois. The \$3 million gift was the largest single endowment ever made to a U.S. university by Sony.

Bardeen was one of only 11 recipients of the Third Century Award, which honors exceptional contributions to American creativity as part of the 200th anniversary of the U.S. patent and copyright laws. He was also named by *Life Magazine* as being among the 100 most influential people of the century.

Respect for Bardeen went beyond scientific circles. In 1989, he was asked whether he felt the community had adequately recognized his work. Characteristically, he shifted the focus from himself to higher education in general.

"I'm not concerned with my reputation," he said. "But in general I don't believe the community and the state realize what they have at the university, what we're doing."

Real estate developer Tom Harrington of Champaign, who lived next door to Bardeen for nine years, recalled the day in 1956 when he asked Bardeen about his new Nobel Prize. Harrington, Bardeen's newspaper carrier at the time, said Bardeen invited him in, signed a program from the awards ceremony, and gave it to the youngster.

"He was a complete gentleman, very unassuming, one of the nicest people you'd ever want to meet," Harrington said. "You'd never know how famous he was."

Besides being an exceptional physicist and outstanding electrical engineer, Bardeen was also a good golfer and once shot a hole-in-one. He seemed so proud of this feat and so modest about the Nobel Prize that some of his colleagues wondered which he considered the greater accomplishment. Some time after winning the second Nobel Prize in 1972, Bardeen was lead-off speaker at the opening session of an industrial affiliates conference at the Department of Electrical Engineering. The chairman of the session deemed this to be an opportunity to get an answer to the question, so he asked

Bardeen directly which he considered the greater accomplishment—the Nobel Prize or the hole-in-one? When Bardeen rose to begin his talk, he responded by saying, "Well, perhaps two Nobel Prizes are worth more than one hole-in-one."

John Bardeen married Jane Maxwell in 1938; they had three children and six grandchildren. He died in Boston, Massachusetts, on January 30, 1991, of cardiac arrest while recovering from exploratory surgery that revealed lung cancer.

For all the impact his inventions had on humanity, he is described by colleagues as not only brilliant but quiet and humble. In the sense that the steam engine made the Industrial Age possible, the transistor made the Information Age possible. Yet, he did not make his friends or colleagues feel that he was superior to them. Humility—the mark of most of the truly great people — endeared this great man to those who knew him.



UPI photo

John Bardeen accepts the 1956 Nobel Prize in physics for achievement in the area of microelectronics. Sweden's Crown Prince Carl Gustaf, heir to the throne, represented his ailing grandfather, King Gustaf IV Adolf, in this ceremony on December 10.

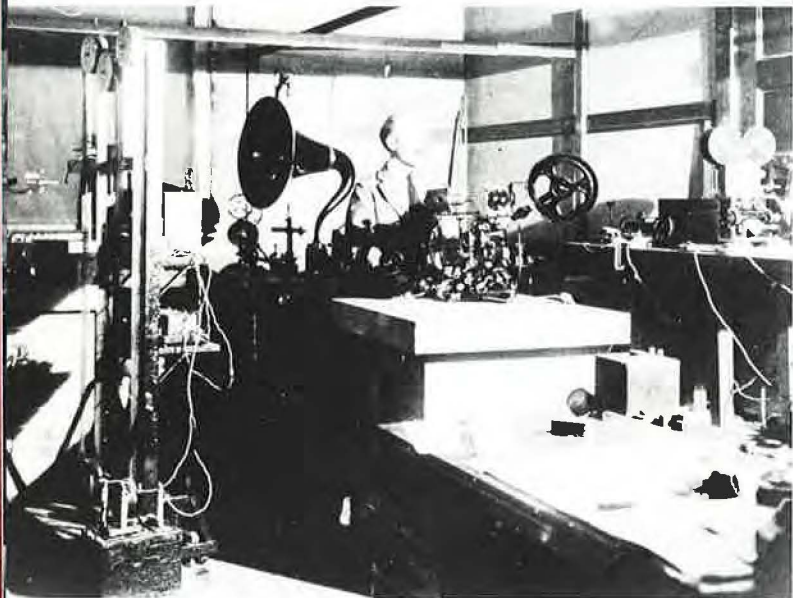
Tykociner's Pioneering Contributions

His name does not appear in any of the credits, but former University of Illinois electrical engineering professor Joseph T. Tykociner has played a role in almost every talking film ever produced. In 1922, the Polish immigrant developed the sound-on-film process.

The idea actually grew out of Tykociner's earlier interest in designing the perfect phonograph, which would "discard the mechanical method of recording sound and . . . do it somehow electrically." He began experimenting with this idea in a make-shift lab on his back porch while attending night school at Cooper Union in New York City around the turn of the century. Then, after viewing his first motion picture, Tykociner became consumed with the idea of combining his phonograph work with the projection of moving pictures. He created two models of a sound-recording camera.

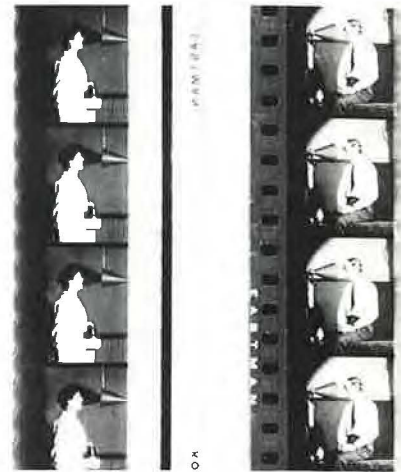
According to R. A. Kingery, R. D. Berg, and E. H. Schillinger in *Men and Ideas in Engineering: Twelve Histories from Illinois*, the first model used sound "to control the pressure of a gas jet in a lantern and moved a photographic plate past the flickering flame." In the second, "light was passed through the opening of a vibrating shutter controlled by the diaphragm of a telephone receiver."

Both experiments failed, and Tykociner put his research aside to take a position with the Marconi Wireless Telegraph Company in England. He joined the Telefunken Company in



Professor Tykociner demonstrates an apparatus in his laboratory in 1921-22.

Mrs. Tykociner and Ellery Paine, head of the Department of Electrical Engineering, starred in the first public demonstration of Tykociner's invention in 1922.



Berlin in 1904 and the Siemens & Halske Company in 1905. Tykociner was commissioned to introduce wireless technology in Russia and was honored by the Czar for establishing a radio link between the naval fleets in the Black Sea and the Baltic Sea during World War I.

Tykociner loved to tell the story of his kidnapping by the Russian navy during the early months of the Russo-Japanese War. He was installing a radio transmitter on the Admiral's ship when orders were received to set sail and engage the Japanese navy. They immediately set sail with Tykociner on board. He quickly radioed his company in Germany, and they arranged for him to be rescued by a German ship. Tykociner considered this very fortunate, because most of the Russian fleet was destroyed in the ensuing battle.

In 1918, he returned to Poland to resume work on his sound-on-film idea. He then accepted a job with Westinghouse in the United States but, failing to gain the company's interest in his scheme, he accepted an offer from the University of Illinois to be one of its first research professors of electrical engineering.

When department head Ellery B. Paine discussed possible research topics with Tykociner, the new professor said he already had a project in mind.

"I want to record sound on film," Tykociner told a skeptical boss.

"You can't photograph sound," Paine said.

"Certainly not," Tykociner said. "But it is possible to photograph a light modulated by sound."

"Can you prove it will work?" Paine asked.

"Prove it?" said an annoyed Tykociner. "That's why you do research."

With a budget of only \$1,000, Tykociner's research showed results in just ten months. He presented his first public demonstration of sound-on-film in the old Physics Building (now Metallurgy and Mining) on June 9, 1922,

during a meeting of the Urbana chapter of the American Institute of Electrical Engineers.

In disbelief, the audience watched the double feature. In the first film, Tykociner's wife, with bell in hand, stated, "I will ring." The bell rang, followed by Helena Tykociner's question, "Did you hear the bell ring?" In the second film, Ellery Paine recited Lincoln's Gettysburg Address.

Tykociner had produced what is called a variable-density sound track along one side of the same film that records the picture images. With pictures and sound track on the same film, the two are always synchronized.

An important part of the projector designed by Tykociner was the photoelectric cell—or "electric eye," as it was called—that had been developed by University of Illinois physicist Jacob Kunz. Much of the other equipment was built or borrowed by Tykociner. The student-run radio station lent its vacuum tubes with the condition that they had to be returned each night to prevent any interruption of broadcasts.

Although Tykociner's invention made front page news in the New York papers, not everyone was enthralled with it. George Eastman, considered an authority on all aspects of photography, said that the public would never accept it. Other skeptics believed that "human beings were just not meant to handle two illusions at once."

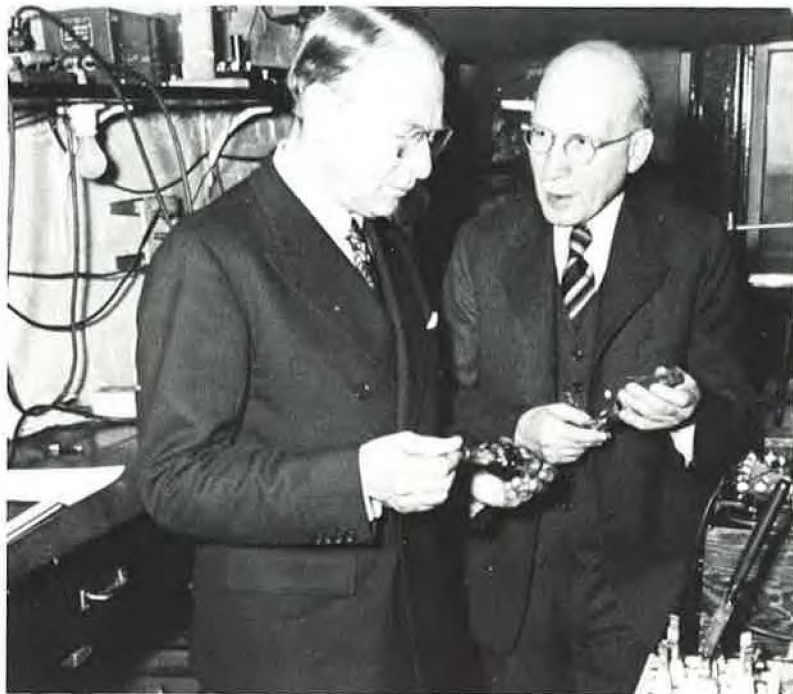
Tykociner's hopes for marketing his invention were dashed when he and University of Illinois President David Kinley could not agree on a plan for promoting and patenting the sound-on-film. The process was successfully patented in 1923 by Lee DeForest and licensed in 1926 by Westinghouse Electric Company. In 1927, Warner Brothers introduced the first commercial talking film, "The Jazz Singer," but they did not use Tykociner's or DeForest's technology. The sound was, instead, produced by a phonograph record. After that, Tykociner turned his attention to other areas of electronics research, including photoelectricity, detection of faults in high-voltage cables, piezoelectricity (electricity induced by pressure and used in transducers), and microwave transmission and reception.

A 1960 story in the *Chicago Tribune* noted that Tykociner's experimentation in the mid-1920s with model antennas could have led to the earlier development of radar had his work not been prematurely corralled. According to the *Tribune*, "Tykociner was experimenting with very short wave electronic radiation and could find no place to do this work except a pasture on the agricultural campus. He found his signals being reflected by cows that wandered into the line of his instruments. He instructed an assistant to larrup them with a club and run them to the far end of the pasture. The boviphiles in the animal husbandry department got word of this and caused Tykociner to be evicted from the pasture,

which is possibly why the development of radar was set back a couple of decades."

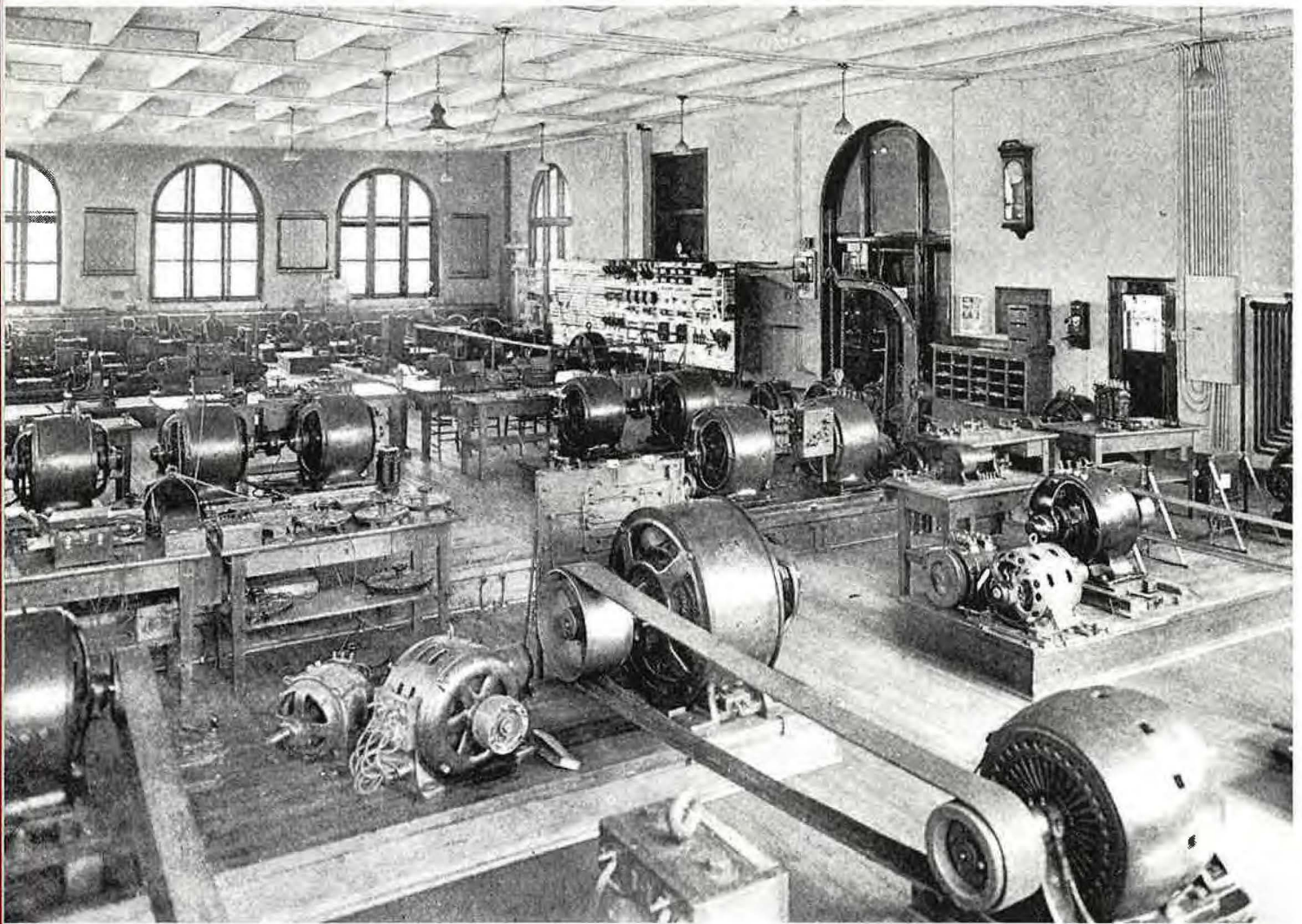
Tykociner retired in 1949, but his scientific curiosity continued. In 1959, he published his first book on "zetetics," which he defined as "the science of research." Zetetics, he once elaborated, is "the totality of recorded, systematized knowledge as related to such methods of research, mental processes, and psychological factors and environmental conditions as lead to new problems, stimulate creative imagination, enhance selective thinking, and generate original, fruitful ideas." Tykociner subdivided zetetics into categorized bodies of knowledge and explored the interrelationships among them. For several years, he taught a course at the university on zetetics.

Although Tykociner is largely unknown by the general public, his achievements were eventually saluted by the university and his colleagues. In 1964, he received the Award of Merit of the National Electronics Conference, and in 1965 he received an honorary doctorate from the University of Illinois. He died in 1969. In 1972, the University of Illinois initiated the Tykociner Memorial Lectures, presented biennially by leading scientists and educators.



1951 photograph of Vladimir Zworykin, president of RCA, and Professor Joseph T. Tykociner.

Chapter 4-Research Laboratories



*Machinery room in the old Electrical Engineering Lab showing various types of generators and motor units.
Photograph is from a 1919 publication about the college.*

Antenna Laboratory and Electromagnetics Laboratory

Electromagnetics research in the University of Illinois Department of Electrical Engineering goes back at least to the 1920s. In those days, Joseph Tykociner set up experimental equipment on the South Farms to measure the radiation patterns of antennas. His success was limited, however, because the cows introduced appreciable experimental error.

The years immediately following World War II were a period of rapid growth, which included the establishment of the Antenna Laboratory with Edward C. Jordan as director. Cleve Nash investigated many different antenna shapes. Some typical ones are shown in the photograph below. A major emphasis was on antennas for high-speed aircraft. Many versions of slot antennas were investigated. Of particular interest were antennas for electronic countermeasures systems. One requirement for antennas in such systems is extremely wide bandwidth. Raymond DuHamel, who had recently received his PhD degree from the University of Illinois, returned from industry in 1953 to assist with directing research in this area.

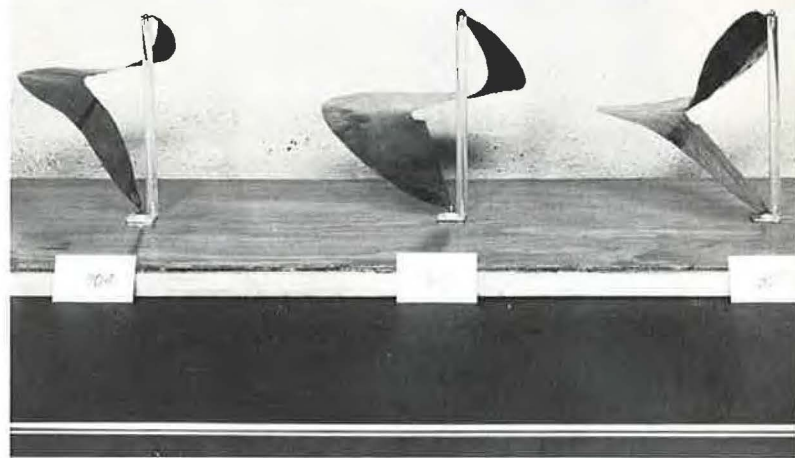
When Jordan became head of electrical engineering in 1954, he brought Victor Rumsey from Ohio State University to lead the Antenna Laboratory and added Paul Mayes from Northwestern University to the staff. Rumsey proposed that antennas should be described as much as possible by angles, rather than lengths, and should be "frequency independent" with very broad bandwidths. John Dyson, at that time a graduate student, began to study logarithmic spirals. The technique for connecting the terminals of a balanced spiral slot antenna to the measuring instruments was troublesome. Robert Hansen, a graduate student who later became a well-known consulting engineer, suggested that the shield of the cable could be bonded to the ground plane without disturbing the antenna performance, because the ground plane currents had to decay to negligible values before reaching the edge. The feeding method became known as the infinite balun and found widespread use. At the same time, studies were underway on loop antennas with ferrite cores by Walter Weeks, a graduate student who later wrote a widely used text on antennas. Radiation from dielectric rod and slotted waveguides, the excitation of open waveguides, and early versions of optical fibers were also topics of study.

When P. Edward Mast joined the laboratory as a graduate student, his first task was to construct and test some fin (triangular sheet metal) antennas. Although described mostly by angles, these antennas did not have frequency-independent

patterns. After observing some of the results from these measurements toward the end of one week, DuHamel returned the following Monday with the observation that projections should be added to the fin. This led to the first linearly polarized log-periodic (LP) radiators, later called trapezoidal-toothed LP antennas.

Dwight Isbell, an undergraduate student with industrial experience, was hired to help test LP structures. DuHamel and Isbell demonstrated frequency-independent performance in certain planar LP antennas, and Dyson found similar behavior with spirals. Dyson became the "spiral antenna man," writing his PhD thesis on the topic and publishing many papers about spirals. He remained on the Antenna Laboratory staff after graduation.

After DuHamel left in 1956 to head antenna research at Collins Radio, Isbell continued to work on LP antennas. Mayes suggested that the planar LP could be converted to a unidirectional radiator by reducing the angle between the halves to make a horn. Isbell found, however, that the LP horn did not radiate from the open mouth but toward the small end. It took several months before an explanation of this strange behavior was forthcoming. In July 1958, Isbell's unidirectional antenna was installed as the feed on Harold Webb's "moon-bounce" parabolic reflector atop the roof of



Typical antenna shapes.



Spirals on a conical shaped unidirectional antenna.

the Electrical Engineering Building. This was the first such application of an LP antenna. Taking a cue from Isbell's success with unidirectional LP antennas, Mayes suggested a similar effect might occur with spirals. Dyson confirmed that spirals on conical surfaces were indeed excellent unidirectional antennas, and he conducted extensive experimental investigations of antennas like that shown in the photograph above. Later, Dyson and Mayes collaborated on a study of four-arm conical spirals, demonstrating that a wider variety of radiation patterns was possible, including circularly polarized radiation over a hemisphere.

In the meantime, Isbell realized that an array of dipoles could be made to radiate toward the feedpoint by transposing the cascaded feedline between each pair of adjacent dipoles, and he thus invented the LP dipole array. Within a few months of publication of his technical report on the antenna, the log-periodic dipole (LPD) was being manufactured and sold by numerous firms. Robert Carrel wrote his PhD thesis

on the analysis and design of the LPD in 1960, and it was an instant hit, reprinted several times until eventually several hundred copies were distributed. Carrel and Mayes developed the LP resonant-V (LPV) array, which became a popular antenna for television reception.

Mast remained on the laboratory staff after receiving his PhD in 1955. During the period 1956–58, Yuen T. Lo and Raj Mittra joined the Antenna Laboratory. Georges A. Deschamps came from ITT in 1958 to take over as director after Rumsey left in 1957 for the University of California at Berkeley. Already well known for his contributions to the theory of microwave measurements, Deschamps enhanced his fame by publishing on a variety of topics, including exterior differential forms, noise theory, and partial polarization. The movement toward theoretical analysis was accelerated. Papers were published on prolate spheroidal wave functions, Wiener-Hopf integral equations, impedance properties of complementary antennas, chromatic aberrations of zoned mirrors, and correlation techniques in antennas.

In 1958–59, Lo joined Mittra and Kung C. Yeh of the Radio Propagation Laboratory to offer a course in mathematical techniques for electromagnetics. In that course, Lo introduced and advocated the method of moments. It failed to gain much attention because of the very limited computer facilities at that time. A few years later, a paper by Lo on this method appeared in the *Proceedings of the Institute of Electrical and Electronics Engineers*; the method became an immediate success and widely used.

When most frequency-independent antennas continued to defy exact analysis, an approximation involving periodic structure theory proved to be useful. Extensions were made to flush-mounted LPs and multiterminal spirals. Several antennas were developed for millimeter waves. The feed system of the University of Illinois radio telescope was designed by Lo, incorporating many conical log-spirals. The problem of maximizing the signal-to-noise ratio in receiving antennas was solved by Lo and one of his students, Shung-Wu Lee. Lo also developed a theory for random arrays wherein the placement of elements is determined by "playing a game" rather than on the conventional basis of a regular grid. Lo claimed that, using his method, "a drunken sailor could design a more efficient large array than could an engineer with a PhD."

The major addition to the Electrical Engineering Building in 1963 presented an opportunity for the Antenna Laboratory to expand into spacious new quarters, complete with a $12 \times 12 \times 50$ -ft anechoic chamber. Also in 1963, Paul W. Klock joined the staff after receiving his PhD from the department. He worked in the areas of propagation on helical structures, antennas in ionized media, and numerical antenna analysis.



Paul Mayes (right) and Robert Carrel developed the log-periodic antenna. It became the most popular antenna for television reception and is one example of a by-product from military research conducted at the university

In the 1960s, by using the concept of duality in Maxwell's equations, Lo suggested the possibility of producing perfect, circularly polarized waves by using a special type of waveguide and horn antennas. Boundary conditions, the same for both electric and magnetic fields, were later realized with corrugated structures, and Lo and his student, M. Al-Hakkak, were among the first to formulate a complete and rigorous theory for these devices. In 1991, these antennas are still used widely as feeds for large reflector antennas in space communications.

Lee stayed at the laboratory after receiving his PhD in 1966, spent 1969–70 at Hughes Aircraft, and returned to the University of Illinois in 1970. He has made numerous contributions in the areas of phased arrays, reflector antenna analysis, uniform and geometric theories of diffraction, magnetic levitation, and general electromagnetic theory. Mittra and his students have published prodigiously on numerical electromagnetic analysis, with particular emphasis on spectral domain techniques. They have also contributed in many other areas: remote sensing, reflector antenna analysis, diffraction and scattering theory, frequency selective surfaces, microwave and millimeter wave-integrated circuits and antennas, and electromagnetic coupling. Papers on polarization of waves, noise excitation of antennas, and diffraction theory were authored by Deschamps and Mast. To reflect the broadening scope of activities, the name of the laboratory was changed in 1973 to Electromagnetics Laboratory.

In the 1970s, Lo and his student, William F. Richards, conducted a study on aberration-corrected artificial dielectric lenses. Several companies had fabricated such lenses, but none performed properly. The theoretical study finally provided the explanation that artificial dielectrics made of periodic scatterers inherently have the adverse properties of anisotropy, birefringence, and dispersion. Although the problem of how to make these lenses work was not solved, Lo was able to develop a series of optical demonstrations (he called them "Polart") to show his students the strange behavior of electromagnetic waves in such media. A show-and-tell lecture based on many examples of the media was so well received that Lo was invited to present it to many meetings of chapters of the Institute of Electrical and Electronics Engineers (IEEE), both in the United States and abroad. Lo quipped that he "could not make a good antenna, but could make nice toys."

Lo and his co-workers developed a widely used "cavity-model" theory for microstrip patch antennas. Lo served two terms as IEEE Distinguished Lecturer on this subject. Mayes and his students developed the monopole-slot element, applied it to frequency-scanning and frequency-independent arrays and, as a single element, for mobile reception in cellular radio systems.



Edward C. Jordan explaining antennas developed at the University of Illinois.

The Electromagnetic Communication Laboratory was established by Mittra in 1984. The scattering from arrays of resistive strips and other conducting shapes have been investigated. Studies of coupling in multiconductor lines can be applied to high-speed data transmission. Several tasks are related to scattering from discontinuities in strip transmission lines. The improvement of the performance of reflector antennas, particularly the huge ones based in space, continues to be of interest in the 1990s.

New communications services and other electromagnetic systems continually make new demands on the frequency spectrum. Bands available for assignment are inevitably higher in frequency. Hence, research on electromagnetic devices that can operate at higher and higher frequencies is very important. In 1991, the Electromagnetics Laboratory began up-grading the instruments to provide a higher frequency capability.

The excitation of patch antennas with slotlines and the integration of patch antennas and solid-state devices has been directed by Lo and Chuang. These efforts are important to achieve monolithic construction techniques for large phased arrays. Theoretical studies using full-wave analysis, incorporating extensive digital computation with a minimum of approximations, have been carried out by Chew and his students.

Thin resonant antennas generally operate well over a very narrow band of frequencies. Mayes and his students have investigated ways to enhance the bandwidth of low-profile antennas. The annular sector, radiating line (ANSERLIN) antenna, developed by this group, is a very simple, nonresonant, circularly polarized element. Its bandwidth is limited by pattern, rather than impedance, variation. A two- to threefold increase in impedance bandwidth has been achieved for thin resonant antennas by stacking two linearly polarized cavities and providing for electromagnetic coupling between them. A patch element that has several desirable characteristics for use in log-periodic arrays has been developed by using two different feeds, a probe and a slot, simultaneously. A low-profile, log-periodic array with 2:1 gain bandwidth has been constructed with dual-feed patch elements.

Although low-profile antennas represent a major effort within the laboratory, there were other projects underway in the late 1980s and early 1990s, several involving digital computation across the scale from personal computers (PCs) to supercomputers. A group led by Lee has reduced the complexity of scattering of electromagnetic waves from complex surfaces. They have produced computer codes for solving many such problems using PCs. Their work has applications ranging from the reduction of radar cross-section to the improvement of large reflector antennas such as those used for communication with space vehicles.

The Electromagnetics Laboratory and the Electromagnetic Communication Laboratory together form one of the largest groups in the world engaged in electromagnetics research. Their work spans antennas and arrays, scattering, mm-waves, microwave and high-speed digital circuits, electro-optics, remote and geophysical sensing, and bioengineering applications. The laboratories have a long, distinguished history and have made many major contributions. Frequency-independent (also called log-periodic) antennas can be found in practically every radio communication system, including the first space probe that landed on Venus and the U.S. vehicles that landed on the moon. This invention has been considered by many as the foremost contribution in the entire history of antennas. Work on frequency-independent antennas has continued into the 1990s, focused on types that have very low profile.

Although electromagnetics is based upon experiments of curious scientists from ancient to modern times and theories that were initially proposed more than a hundred years ago, there is still much to be learned. High technology will not progress without increased understanding of electromagnetic phenomena. In the 1990s, the University of Illinois continues to be a leading contributor to this understanding and the resulting progress.

Radio Direction Finding Laboratory

One of the earliest postwar research programs to be established in the department was a program on radio-direction finding (RDF). One of two research programs on the campus sponsored by the Office of Naval Research (ONR), it was intended as a basic research program. When the sponsor was asked by the research supervisor, Edward C. Jordan, what facets of the field might be of particular interest (ground, shipboard, aircraft RDF, frequency bonds), the answer

received was: "Look, you know Maxwell's Equations, the Russians know Maxwell's Equations; you take it from there." It would be difficult to get more basic than that.

The program began with three faculty members (Jordan, Albert D. Bailey, and Harold D. Webb) and several graduate students employed as research assistants and research associates. The research associates supervised separate parts of a multifaceted program. Over the years, nearly all aspects of radio direction finding were studied, with a major emphasis on overcoming the effects of multipath reception due to the vagaries of the ionosphere. Both small-aperture (small in wavelengths) and large-aperture systems were designed and studied.

Early experiments involved the use of an 'instantaneous' Watson-Watt RDF system (named after its British inventor) loaned to the group by the National Research Council of Canada. With the permission of the university's Institute of Aviation, the system was set up on the south side of the University of Illinois airport. The following account indicates some of the problems encountered in those early days.

The electronic equipment was housed in a 6 × 6-ft van body military truck, and power for the installation was derived from a pair of generators driven by a gas engine. The site, located between two intersecting runway/taxiway complexes, had many desirable properties; it also offered some challenging disadvantages. It lacked a direct access road, and although the site could be reached part way on taxiways, the final stretch had to be driven on the bluegrass turf. Obstruction lights had to be kept burning all night. To avoid running the engines every night, a bank of 18 6-volt automobile storage batteries, charged from the generators, was used.

One day in the winter of 1951, Edgar C. Hayden and a few colleagues went out to service the system. It was snowing and, by the time they were ready to leave, the snow had accumulated and the winds were whipping it into high drifts. Before they reached the taxiway, the drifts were too deep to drive through and the engine quit. The car had to be abandoned. The next morning, after the taxiways had been plowed, they went to rescue the car and found the engine completely packed with snow. It had to be dug out and dried before it would start. With a little shoveling, a path was opened to the taxiway, and the group drove back to civilization. They acquired a pair of snowshoes in the event of a similar recurrence.

The installation provided the RDF group with real-world experience. It was their initiation into the use of aircraft for local error assessment and into the use of pulse signals for DF diagnostic procedures. The temporal signal path resolution it provided engendered a lot of learning about skywave radio

propagation phenomena and about the effects of those phenomena on the behavior of DF systems.

The airport DF site was replaced in 1957 by an excellent 80-acre site, which became known as the Monticello Road Field Station. This larger site was selected because it was quite flat and clear of obstacles. The flatness also meant that the area was not well drained, a fact unknown until the day a heavy thunderstorm caused an underground cable conduit to flood. To prevent the lake outside from being transferred to the basement of the building, a wooden plug had to be driven into the end of a 4-in. conduit that was spouting water. As Hayden stepped outside to try to reduce the inflow of water at the other end, a bolt of lightning struck the ground less than 700 ft away. It made a breath-stopping impression that, momentarily, raised some doubt about his choice of an electrical engineering specialty involving HF antennas. It also provided dramatic evidence that lightning protection was needed for the antenna systems to be installed on the site.

Occasionally, this site played host to experimental installations belonging to other university groups. An acoustic radar was vertically directed and used in a study of bird migration. At another time, an interferometer system was used to track the first Russian satellite, Sputnik I, immediately after its launch. In October 1957, Hayden and his wife gave a small party for some friends. During the party, George Swenson telephoned to announce the successful launching of the Sputnik I. He said it was emitting beacon signals on 20 and 40 MHz and wondered if the RDF group had any receivers that covered these frequencies, especially the 40 MHz signal. To Mrs. Hayden's chagrin, Hayden abandoned the party and did not return for three days.

A receiver was found, set up at the Monticello Road Field Station, and used to intercept the Sputnik I signals. By recording the signals from repeated satellite passes, data were acquired that were used in determining the parameters of the satellite orbit. Swenson and others parlayed those initial results into a program for studying satellite signal scintillation phenomena.



A large-aperture radio direction finding system known as a Wullenweber array at the Bondville Road Field Station, October 1960. Operating at a frequency range from 4 to 16 MHz, the array uses 120 antennas and is 1000 ft in diameter.

During the early work done in the RDF Research Group, researchers found that small-aperture systems lacked sensitivity and were exceedingly susceptible to error induced by the multipath propagation effects. The quasi-coherent waves arriving over the several paths produce an interference fringe (or standing wave) pattern on a DF site. The error is called a "wave interference error." All evidence pointed toward the use of arrays of large aperture as a means of mitigating both of these deficiencies.

In 1955, the Bureau of Ships of the U.S. Navy indicated an interest in supporting the design, construction, and evaluation of a large-aperture system at the University of Illinois. Although there was some hesitancy about undertaking a large construction project, it was pointed out that the presence of such an instrument would virtually assure research support for at least 10 years. In fact, the support continued for more than 25 years.

The large-aperture RDF system that was built was patterned after one developed in Germany during World War II. The system was characterized by a circularly disposed antenna array (CDAA) of vertical antennas surrounding a cylindrical reflecting screen. The Germans had given their system the code name "Wullenweber." The University of Illinois retained the name, and it has since become a generic term denoting similar systems. The University of Illinois Wullenweber array was constructed at a site that came to be known as the Bondville Road Field Station. The array used 120 antennas and was 1000 ft in diameter (about 2 1/2 times the size of its German progenitor). The array geometry was proportioned to allow operation over the frequency range from 4 to 16 MHz.

The array was used in conjunction with a digital computer. Signals were beamed from a site in Texas and reflected to another site in Canada, so that measurements were made on the ionosphere directly above the University of Illinois campus. Data from the three points were automatically collected and synchronized by the computer. The computer was housed near the antenna array.

The design, construction, and evaluation program was very successful. It was possible to demonstrate the ability of the large-aperture DF system to mitigate the two prime deficiencies of the small-aperture systems. Much of this knowledge was available because of the concurrent, side-by-side operation of the Wullenweber system and the small-aperture Adcock systems at the nearby Monticello Road Field Station. During the 1960s and early 1970s, at least 20 operational installations, based on the University of Illinois design, were constructed at locations around the world. Most of these are still in operation in the early 1990s, and they are about to gain a renewed lease on life as modern electronic technology supersedes the original electronic technology.

The Wullenweber system proved also to be an effective tool for observing certain classes of anomalous skywave propagation phenomena. This capability arises from the "angular wave analyzer" property of the narrow scanned directive pattern. At least one PhD thesis came out of this capability; anomalous radio wave propagation from Virginia to Illinois via ionospheric structures over Canada was studied. Just watching the behavior of ionospherically propagated radio signals as displayed by the system contributed much to the education of a number of graduate students and some faculty members.

From Basic Research to Battlefield in 30 Days

As has been noted, the RDF program at Illinois was sponsored to promote basic research and, incidentally, to train graduate students in the area. To determine where research was needed, a survey was made of existing systems. It was noted that aircraft RDF systems existed that could cover from 100 KHz to 10 MHz and from 100 MHz up to frequencies as high as could be generated in those days, but there seemed to be a gap in coverage between roughly 10 MHz and 100 MHz. Consequently, attention was devoted to determining what could be done to bridge the gap. It was soon discovered that it would be virtually impossible to build an accurate aircraft RDF system in this frequency range because the dimensions of the aircraft would be comparable to the wavelengths involved (30 m at 10 MHz to 3 m at 100 MHz). Under these circumstances, the conducting surfaces of the aircraft carry large resonant currents and produce a radiation pattern dependent on the shape of the aircraft and almost independent of the pattern of the RDF antenna.

Although accurate radio-direction-finding from aircraft was not possible between 10 MHz and 100 MHz, it was unexpectedly discovered that very accurate homing systems could be designed in this frequency range. A small fixed antenna located at the junction of the nose of the fuselage and the leading edge of a wing produced a beautiful single-lobed pattern in the forward direction on the side on which the antenna was located. A second antenna that was located at the junction of nose and wing on the other side produced a similar pattern on that side. The two patterns intersected with equal field strengths in the forward direction. By modulating the signal received on the left antenna with dots and the signal received from the right antenna with dashes, the pilot could tell whether the target was to the left or the right. When the plane was turned to head directly towards the target, the signals would merge to produce a continuous tone. A solution had been found to a problem that had not been posed.

The navy had no need for a homing system in this range, so the quarterly research report was quietly deposited in navy files. Fortunately, however, the reports were also read by the air force, which suddenly found itself in urgent need of this system. This was the time of the Korean War, and the American air force needed to be able to locate the enemy radars that were used to direct the enemy anti-aircraft artillery. The U.S. Air Force had equipment to detect modern, higher frequency radar, but the North Koreans used older Chinese radars modeled after the British radars used in the very early days of the Battle of Britain. These radars operated at 75 MHz (4 meter wavelength) and required huge horns with dimensions comparable to a wavelength. They were sometimes built with chicken wire.

A call from Wright Field asked whether the RDF group would design a homing system for a specific aircraft for which they sent a scale model. They also required that the antennas be mounted on the actual combat aircraft. In those days, there was close cooperation between the RDF Laboratory and the Antenna Laboratory, both directed by Edward C. Jordan. It just so happened that the Antenna Laboratory group had designed a "partial-sleeve" antenna, which was ideal for the purpose. Working together, the two groups (Douglas Royal, Nicholas Yaru, and others) designed the system and flew the antennas to Wright Field, where they were mounted on the combat aircraft. The system was flight-tested by homing on

television stations in Dayton, Ohio, operating in that frequency range. There was only one hitch. The usual problem with aircraft antennas is that the received signal is too weak. With the large collecting surface of the aircraft used by the partial-sleeve antenna, the received signal was too strong, burning out the detectors. This difficulty was easily overcome by inserting variable attenuators to reduce the signal to the desired strength. After successful tests, the aircraft was flown to Korea and used to detect the enemy radar. The elapsed time between the request for help and battlefield application was just under 30 days.

Pioneering in Semiconductor Research

Semiconductor materials and device (transistor) research came to the University of Illinois in 1951 when John Bardeen arrived from Bell Telephone Laboratories with a joint appointment as a professor of electrical engineering and physics, both in the College of Engineering.

The Semiconductor Laboratory was based in the Department of Electrical Engineering and was housed in the Electrical Engineering Research Laboratory (EERL). The laboratory occupied the same space that had originally housed the ILLIAC computer construction. It began with mostly homemade equipment and without air conditioning. The laboratory opened in September 1952 with two postdoctoral students, Harry Letaw, Jr., and Stanley R. Morrison, and two electrical engineering doctoral students, Nick Holonyak, Jr., and Richard C. Surrin. Holonyak was Bardeen's first doctoral student. Bardeen began a range of investigations involving the contact, junction, transistor, surface, impurity diffusion, and bulk behavior of germanium (Ge). While working with Thomas A. Murrell, Surrin concentrated on synthesizing lead salt semiconductors but later shifted to Ge studies under Bardeen.

John R. Schrieffer worked in the laboratory with Bardeen to show constrained conduction in a field-induced surface channel on Ge and demonstrated, in the early and middle 1950s, the important idea of quantum size effects in semiconductors. This turned out to be a prophetic and important part of quantum well heterostructure and superlattice research, an area of work in which the University of Illinois has excelled. The field effect and quantum size effect were carried from

Bardeen's laboratory to Europe through a chain of European postdoctoral students. Through the continued chain of people and events, the discovery of the quantum Hall effect was the outcome of these original studies at the University of Illinois.

Through the years, many students have done PhD thesis work in the Semiconductor Laboratory. Holonyak went to Bell Telephone Laboratories in 1954 to work on prototype diffused-impurity silicon devices. At this time, Paul Handler came as a postdoctoral staff member to the laboratory. Research interests shifted more to Handler's interests over the years, and the laboratory was moved to the new Materials Research Laboratory building, which owed its existence mainly to Fred Seitz and John Bardeen. Bardeen wanted to expand the semiconductor work in the Department of Electrical Engineering in the early 1960s. With Edward Jordan's help, Bardeen recruited Holonyak from General Electric in 1963 to return to Illinois and later recruited Chih-Tang Sah in 1964 from Fairchild.

Holonyak brought III-V materials synthesis and epitaxial crystal growth, along with heterostructure and optoelectronics research from industry to EERL and MRL. Sah brought silicon (Si) device research, with emphasis on field effect transistors, to Illinois. Later in the 1960s, Ben G. Streetman came as a new PhD and staff member into Sah's laboratory. He also moved over to work with Holonyak on III-V problems until a separate laboratory became available in the Coordinated Science Laboratory (CSL). When Streetman left Illinois in 1982 with a strong semiconductor research background, he founded a semiconductor and microelectronics research laboratory at the University of Texas at Austin. This laboratory includes many Illinois PhDs, including J. C. Campbell, R. D. Dupuis, and D. G. Deppe. George Anner also worked in Holonyak's laboratory in the 1960s, retrained himself from circuit electronics to semiconductor device electronics, and went on to teach Si device processing to generations of students.

Over the years, the semiconductor research in the Department of Electrical Engineering and the number of prominent staff members continued to grow. Gregory E. Stillman and Karl Hess joined the department in the mid-1970s. Stillman, one of Holonyak's early (1967) PhD students, returned to Illinois in 1975 from Lincoln Laboratory at the Massachusetts Institute of Technology. Hess, an Austrian physicist, was a student of one of John Bardeen's early European postdoctoral researchers. Hess later became a professor in the department.

From its beginnings with germanium and early transistor research, semiconductor research in the Department of Electrical Engineering grew in size and prominence. In the 40-year time span involved in this growth (1951–91), electronics witnessed the overthrow of the vacuum tube and the full-scale emergence of semiconductor power devices, integrated circuits, and optoelectronics. The key role that John Bardeen played in the discovery of carrier injection on December 16, 1947, and in the discovery with his partners Brattain and Shockley of the transistor and the original bipolar transistor (the point contact transistor) is not universally known. Everything else came after this event, including the junction transistor, the second form of bipolar transistor. Bardeen's portable two-transistor oscillator-amplifier demonstration circuit, built in 1949, which uses some of the first packaged Type A point-contact transistors, is still operative and on display in the University of Illinois World Heritage Museum in Urbana.

All areas of semiconductor research at the University of Illinois could not be covered in this summary. In 40 years of PhD semiconductor research, both in the work it generated and the students it produced, Illinois has played a large role in helping to bring semiconductor science and engineering to its present dominant position in the field of electronics. John Bardeen, his work, his discoveries, and his students have made a major contribution to technological history. (For more information on John Bardeen, see Chapter 3.)

Tube Laboratory

Joseph T. Tykociner's early research before World War II dates the first days of the Tube Laboratory. His development of sound-on-film necessitated creating facilities to fabricate and process the vacuum photodiodes needed for his experiments. By the late 1930s and into World War II, a fledgling tube laboratory existed in the department. It was staffed by Tykociner and assisted by Louis Bloom, a physics graduate student, and Robert Waggoner, a technician.

With a budget for equipment and supplies of only a few hundred dollars per year, Tykociner was able to build up a primitive but usable vacuum tube processing facility in his research laboratory in EERL. He borrowed and scrounged equipment and supplies—vacuum pumps, vacuum baking facilities, hydrogen atmosphere high-temperature brazing equipment, chemical plating and cleaning facilities, and glass-blowing equipment.



Tykociner in his laboratory at the University of Illinois.

With his background and equipment, Tykociner obtained a government-sponsored contract for research on microwave tubes. This classified research involved work on microwave generating tubes, primarily split anode magnetrons. At the end of the war, when research programs were being expanded, microwave tube research was targeted as one of the important new areas for support.

Several new people were added to the faculty and staff. Arthur L. Samuel, a noted authority on electron tubes from Bell Laboratories, was brought in to head the new Tube Laboratory in 1946. He became a member of the committee involved in the computer project that evolved into ILLIAC I. Samuel is credited with developing the first computer program for the game of checkers between humans and machines. Donald Holshouser, a cathode and electron beam expert, came to the university from RCA. Another addition was Louis Bloom, who had spent the war years at RCA gaining experience in military x-band and k-band magnetrons. Also in 1946, Allen Wilson was hired to work with Robert Waggoner on the nonacademic staff.

A large contract from the U.S. Air Force was soon obtained for research on klystrons. Equipment was installed to replace or augment the facilities in the space originally occupied by Tykociner. After the new Electrical Engineering Building (now called Everitt Laboratory) was constructed, space was provided for the Tube Laboratory in EERL. The remodeled space provided special air conditioning and air filtering systems to maintain a dust-free environment.

After Samuel left the university in 1948 to take a position at IBM, the Tube Laboratory was administered for a short time by a committee consisting of Holshouser, Bloom, and Nelson Wax. In 1949, Heinz Von Foerster, with extensive experience in high-frequency vacuum tubes, joined the department and was named director of the Tube Laboratory. Also interested in cybernetics, he shifted his research there in the late 1950s and founded a new laboratory, which he named the Biological Computer Laboratory (BCL). More information on BCL appears in Chapter 6.

In 1951, two new faculty members were added to the department who established new laboratories closely related to the research of the Tube Laboratory. Ladislav Goldstein founded the Gaseous Electronics Laboratory and Paul D. Coleman established the Ultramicrowave Laboratory, which later became known as the Electrophysics Laboratory. Although neither of these laboratories were affiliated with the Tube Laboratory, their research relied heavily on the availability of the facilities originally established and supported by the Tube Laboratory. The Semiconductor Research Group, established by John Bardeen in the early 1950s, also relied on these facilities for some of their research.

By the late 1950s, Von Foerster's interests shifted to cybernetics and Holshouser's shifted to optically related research. After receiving his PhD in 1962, Oscar Gaddy joined the faculty. He and Holshouser changed the name of their group to the Electro-optics Laboratory. Holshouser performed pioneering research on microwave modulation of light using the Kerr effect. He and Gaddy worked on the dynamic crossed-field photomultiplier, which was a microwave bandwidth optical detector. The first lasers operated on campus were in this laboratory. These were optically pumped ruby lasers and visible helium-neon gas lasers.

These central facilities, known as the Special Processes Laboratories, became a meeting place for graduate students and faculty members. A coffee pot in the glass shop added to the attraction of this area, where numerous technical and political discussions took place and inventions were born that later became patented.

It was in this setting that Marvin Krasnow and Oscar Gaddy proposed to their colleagues in 1965 the first industrial affiliates program in physical electronics. After discussion, Gaddy authored the technical prospectus and Krasnow soon had more than 10 companies signed up. The program began in 1966 and has been in continuous operation since. It has resulted in close ties and working relationships between faculty members and their industrial counterparts and has provided several million dollars to support the activities of the physical electronics groups. There are other affiliate programs modeled after this one currently in operation in our department and in the College of Engineering.

The Tube Laboratory and the Semiconductor Laboratory were the foundation of the physical electronics activity in electrical engineering at Illinois. No current research is being done on vacuum electron tubes. Interestingly, when Holonyak switched from the Tube Laboratory to the semiconductor area, he received a lot of flack from his fellow students for switching to such an upstart new field; in the 1990s, however, most of the physical electronics activity is related to semiconductors. The Tube Laboratory and its central facilities played an important historical role in the development of the physical electronics research now carried out in the department.



*William J. Fry in the
Bioacoustic Research
Laboratory.*

Bioacoustics Research Laboratory

The Bioacoustics Research Laboratory (BRL) was founded by William J. Fry. Bill, as he was known by colleagues and friends, was studying physics at Pennsylvania State University when World War II broke out. He spent the war years at the Naval Research Laboratory in Washington, D.C., developing principles for SONAR system design and development. The French physicist Langevin had experimented with ultrasound as a means of detecting submarines when they appeared in World War I, but none had been detected before World War II. Thus, the creation of more adequate design principles and useful instruments was crucial. During World War II, Fry co-authored a book on these topics that can still be referenced in the early 1990s.

After the restrictions on research imposed by the exigencies of the war effort, Fry wanted to carry out his research activities in the freer university atmosphere. Returning military personnel were flocking to campuses, and university faculties and facilities were expanding rapidly after the stagnation of the Great Depression and war years. At the University of Illinois, William L. Everitt was in the process of building up the Department of Electrical Engineering. Everitt induced Lloyd DeVore, who before the war had been a professor of theoretical physics at Pennsylvania State University and Fry's teacher, to become a member of the Department of Electrical Engineering to promote and develop a research program. DeVore knew Fry was an unusually clever, independent, and ingenious solver of theoretical physics problems. Fry came to Illinois in the late 1940s and immediately endeared himself to the old-time, nonresearch-oriented faculty members by removing their numerous cherished World War I electrical instruments for trash disposal. This removal was necessary because the only space available for Fry was in the tunnel under what was then the Electrical Engineering Building and later the EERL. They developed the strained relationship that was common between the original, nonresearch-oriented faculty members and the newly arriving "scholars."

Fry wanted to study the central nervous system to begin to understand intimate details of structure and function. The methods employed up until that time were rather crude, requiring invasion of the brain tissues and producing unreasonably large lesions. Fry envisioned that focused ultrasound would be a vastly superior tool by providing for noninvasive alteration of brain tissue. He set out to develop ultrasonic surgical procedures for affecting the mammalian brain and to study the detailed neuroanatomy of the mammalian central nervous system. The use of ultrasonic surgical procedures



William J. Fry operating the neuroscience surgery unit.

was successful. By the late 1950s, it had been well demonstrated in animal experiments and was being used in medical practice at the University of Iowa (the University of Illinois Medical School exhibited no interest). Numerous patients were treated for hyperkinetic and dystonic disorders. The procedures were discussed in the December 2, 1957, issue of *Time Magazine*. The project dealing with the "wiring" diagram of the central nervous system was also successful, although details of only small sections of the cat brain were achieved. Nonetheless, the methodology was well demonstrated.

To achieve these goals, instruments were invented and developed from the mid-1940s to the mid-1960s to generate, detect, and measure ultrasound. Crucial details regarding the propagation of ultrasound in biological media were discovered. The propagation properties important for diagnostic, therapeutic, and surgical ultrasound, such as speed of sound, absorption, attenuation, scattering, and impedance, were determined. Measuring methods and instruments were developed to their full potential, and many are still employed throughout the world in the early 1990s.

Floyd Dunn and Fry attended the 1957 meeting of the American Institute of Ultrasound in Medicine in Los Angeles. During their return trip by car with Dr. Oka of Osaka, Japan, who spent a month at the University of Illinois learning neurosonic surgery methodologies, Fry developed the view that it was time to initiate a program to develop an artificial heart. The piezoelectric device that he had worked out in the car was inefficient when detailed calculations were made in the laboratory. However, less dramatic ideas were employed, and devices capable of sustaining animals for extended periods were developed and patented. The conservative attitude of the University of Illinois administration toward faculty members promoting their innovations prompted Fry to organize the Interscience Research Institute to exploit these heart devices, and they were no longer treated in BRL.

Other research topics undertaken in BRL included studies of excitable tissues, investigations of the organ of Corti, and studies of the effects of neurosonic surgical methods on animal behavior. The laboratory gained preeminence. Fry, recognizing the importance of supporting all those working in the area, created the Allerton conferences in electrical engineering. Continuing in the 1990s, these conferences allow world leaders in the field to convene and discuss in detail the problems inherent in these investigations.

It would belie the character of Fry to hold the view that this was a narrowly focused bioultrasonics laboratory; other examples of research interests suggest the scope of BRL. Unusual objects called flying saucers were being reported, and unusual abilities called extrasensory perception (ESP) were being promoted for contention with the established sciences. The military was aware of these sightings and claims but was unprepared to evaluate them. Fry was asked to investigate people, or groups of people, alleged to have special abilities. For example, one claim that was investigated was the ability to see through dense media. This ability was of interest to the military, who was open to anything that would give personnel the ability to see in "night darkness." These examinations provided curious diversions as people came to BRL for testing and BRL members traveled to other places to conduct tests.

BRL investigators were once convened to examine an individual who claimed to be able to float high in water, in violation of Newton's law of gravity. The swimming pool in



Gaseous Electronics Laboratory on the campus of the University of Illinois at Urbana-Champaign.

the Women's Building was used for the test. The results showed that the skinniest of the investigators could float as high in the water as the protagonist. In all, about a half dozen individuals were examined. All were found to be either extraordinarily clever performers or frauds. Although no conclusions were reached, the investigations provided a diversion and a great deal of fun.

Since 1977, the laboratory has been directed by Floyd Dunn. Second generation faculty members have become National Academy of Engineering members, fellows, and presidents of numerous professional societies. Third generation laboratory members are serving as administrative officers and are closely involved in scientific affairs. Graduate students are regular contributors at professional meetings.

BRL was an exciting place to be during the early days when Bill Fry was creating science. Because the war had interrupted his graduate education, he resumed his studies toward a PhD degree at the University of Texas after he suffered a heart attack in 1965. He was to receive the degree early in 1969; he died in July 1968. BRL continues to be an active, exciting site for unusual engineering and scientific productivity under the direction of Dunn.

Gaseous Electronics Laboratory

The Gaseous Electronics Laboratory (GEL) was started in 1950 when Ladislas Goldstein joined the department after a productive career at ITT Research Laboratories. Goldstein had played professional, European-style football to pay for his graduate education in the laboratory of Madame Curie at the University of Paris. He had an amazing ability to kick virtually anything to any desired target. During his years at GEL, graduate students often left a wad of paper on the floor, and when Goldstein thought they were not looking, he would kick it into the nearest wastepaper can.

Goldstein journeyed to the United States when the world was embroiled in the long and bloody struggle of World War II. One week before the German invasion of France, he deposited his thesis in its final form and started for the coast toward England. A German sniper fired at him; feeling the slow drip of warm, thick liquid, Goldstein was sure that he was bleeding. He was happy to discover that it was from a can of sardines he was carrying and that the can had stopped the bullet. He made it safely to the United States to begin the work of the Gaseous Electronics Laboratory.

Initially, the focus of the laboratory was on the fundamental processes in partially ionized gases, with special attention to those operative in the ionosphere. Microwaves were used to clarify the interaction of electromagnetic waves with the electron gas. They were used both to diagnose and modify the energy distribution and reaction rates of the charged particles.

On the home front, research was beginning to be directed toward the newest frontier—the space race. In the late 1950s, the wraps came off the research effort devoted to controlled fusion. The Gaseous Electronics Laboratory expanded its research to include this highly ionized state, which is found in a fusion reactor and in shock waves associated with reentry plasma of the space effort. About this time, Goldstein and several colleagues looked at the quantum aspects of gaseous electronics with the study of ESR and NMR of the neutral species resulting from discharges.

After the invention of the gas laser, the laboratory's effort shifted to that direction. Emphasis was on studies of the kinetics of laser discharges; diagnostics with lasers, either by interferometry, absorption, or laser-induced fluorescence; and spectroscopy aided by the laser techniques. Considerable effort was devoted to the study and modeling of discharges used for the growth and processing of semiconductors. From the early microwave diagnostics of plasmas came an easy transition to optical frequencies. Indeed, it was a matter of a mere decimal point in the frequency specification to address a classified laser contract.

As illustrious as its many exciting discoveries is the laboratory's human story. Goldstein retired in 1972, and Joseph T. Verdeyen was appointed director by the department head at the time, Edward C. Jordan. The laboratory has generated more than 85 PhD theses and supported more than 150 master's programs. The memories combine to give more than a collection of facts. It is the little personal tale that gives any history its life and color. From the fated bullet and sardine can that cleared the way for Goldstein to make his many contributions, to the various tricks that were played on Verdeyen on St. Patrick's Day over the years, it is a colorful history indeed.

Professors and students alike shared in creating these memories. Students set off liquid nitrogen explosions to greet Verdeyen after his running. They sometimes ran with him singing "Old Danny Boy," just to point out that they could sing while they ran but he was gasping for air. They were especially creative with newspapers, filling his car with them and papering closed the doorway to the toilet. The laboratory has had such a diverse research history that many departments have borrowed items as obscure as discontinued vacuum tubes. As one student remarked, the laboratory has two of every electronic device ever made.



The Gaseous Electronics Laboratory in 1958.

Electrophysics Laboratory

In the late 1940s, William J. Fry, Nelson Wax, Heinz Von Foerster, Joseph T. Tykociner, and a number of other Illinois faculty members studied a millimeter wave effect. In 1951, considering the fact that John Bardeen was joining the Department of Electrical Engineering, Paul D. Coleman accepted an invitation from William Everitt to interview with the department and present a seminar on his work. For his PhD thesis work at the Massachusetts Institute of Technology, Coleman was pursuing free electron relativistic effects to achieve electromagnetic radiation in the submillimeter range.

New ideas were needed to extend the coherent frequency frontier. The development of radar during World War II stimulated research in this area. In August 1951, Coleman and Murray D. Sirkis, whose undergraduate senior thesis work Coleman had supervised at MIT, began setting up the Electrophysics Laboratory (EPL). They were joined by Erv Kauffman and Stan Vigors. The initial research program for the new laboratory was to study the interaction of relativistic electron beams with various coupling structures. To produce coherent millimeter and submillimeter waves, the structures were studied using the relativistic Doppler effect, Cerenkov effect, and parametric effect. Parallel with this source study was a study of detectors and the linear and nonlinear interaction of submillimeter waves with matter.

In 1951, Von Foerster obtained a large contract from the Air Force Cambridge Research Center (AFCR) to study microwave-millimeter waves. Ladislav Goldstein and Coleman were added to this grant. Most of the existing equipment was for the microwave range, which was ideal for Goldstein's interest in gaseous electronics. Because, however, there was minimal millimeter equipment, Coleman split off from the AFCR work and obtained his first grant from Wright Air Development Center. The Electrophysics Laboratory soon became a strong competitor and contributor in the millimeter area. Between 1950 and 1960, the laboratory usually carried 15 to 20 students, staff, and technicians. Coleman remained the one full-time staff member; other faculty members and visiting professors came for limited periods of time. Both William Emery and Haroun Morous spent several years in the laboratory working on millimeter wave components.

There were several significant scientific achievements during this period. In the late 1950s, Richard Pantell of Stanford University joined the EPL for one year to study various interactions of relativistic electron beams. Pantell's understanding of fast and slow wave and forward and backward electron beam interactions benefited the laboratory's staff and students. Perhaps the main achievement of the period was the demonstration of coherent Cerenkov radiation by Charles Enderby for his PhD thesis. This work made the cover of the *Journal of Applied Physics* and set a power-high frequency record that lasted for more than 20 years. Follow-up studies of the Cerenkov effect in ferrite materials by Fred Rosenbaum and in magnetized plasmas by Richard Kenyon were also significant.

Richard Becker, William Stein, and Jack Baird were instrumental in securing a large Atomic Energy Commission, now Department of Energy, contract that permitted EPL to expand its millimeter equipment. Andy Swago and Murray Sirkis, who were excellent component designers, teamed up with Jack Lowe, a very talented machinist, and produced the state-of-the-art millimeter wave components. When Thomas Newkirk, an electronics technician, joined efforts with Baird, the result was an array of equipment that is still being used in the early 1990s. Newkirk spent more than 25 years helping Coleman learn the practical side of electronics.

In 1962, Coleman spent one year as a visiting professor at Stanford University. In the absence of Pantell, who was on sabbatical in England, Coleman headed a research group that was involved in quantum electronics. The Stanford experience prompted him to launch a program on gaseous molecular lasers when he returned to the University of Illinois; the program lasted from 1963 to 1980. This program required an additional staff member and, in 1972, Thomas DeTemple joined the group. The laboratory was successful in the molecular laser field, making several contributions to various lasers.

Two of the main achievements of EPL on quantum electronics were the discovery of the world's second chemical laser, the CO system, by Curt Wittig and the super-radiance work of DeTemple and his students Thomas Plant, Albert T. Rosenberger, and Samuel J. Petuchowski. In a short time, the technology in the submillimeter region went from not being able to produce any coherent signals to achieving pulsed power at the megawatt level. The work of Samuel Green on metal-oxide-metal tunneling detectors permitted the U.S. Bureau of Standards to measure the velocity of light at a new level of accuracy.

By the late 1970s and early 1980s, the Electrophysics Laboratory needed to decide where to direct its long-range research. Although the optically pumped molecular laser was

a breakthrough in achieving a coherent submillimeter-far IR source, new fundamental ideas were getting difficult to find after 17 years of research on the basic physics of the laser problem. The laser produced a high-quality signal, but it was bulky in size, inefficient, and only step tunable. In 1980, no solid-state laser existed for the far IR and semiconductor induction current source. Gunns, Impatts, and FETs were not likely to go above 100 GHz in frequency, and a new basic semiconductor source had not been invented for more than 20 years.

It was decided to study semiconductor heterostructure devices for new source-detector possibilities. Joseph Lyding and John Tucker were added to the staff to study charge-density waves in one dimensional materials, and DeTemple began studies of optical waveguides, switches, and modulators. The charge-density wave work was of particular benefit to the laboratory because this was a problem of interest of John Bardeen. Also worthy of special note is the work of Lyding on the scanning tunneling microscope. Since the retirement of Coleman in 1988, future direction of the Electrophysics Laboratory rests with his successors.

Some of the traditions of the Electrophysics Laboratory that remain in the 1990s were started in those early days. In addition to the traditional holiday party, the laboratory began writing a poem each year based on "The Night Before Christmas." Each verse remembers and recounts the special contributions of each laboratory member throughout the year. The tradition of these annual verses continues into the 1990s, giving an account of the laboratory's "people history."

During the EPL's 40 years of existence, it has had continuous research support from the National Science Foundation, Air Force Office of Scientific Research, Atomic Energy Commission, and Army Research Office and industrial help from Raytheon, McDonald Douglas, Delco, and Tektronics. Approximately 100 MS and 50 PhD students have pursued their thesis work in the laboratory, with more than 200 papers published in reference journals. The four decades of research by EPL in the millimeter-submillimeter field is unmatched in the United States.

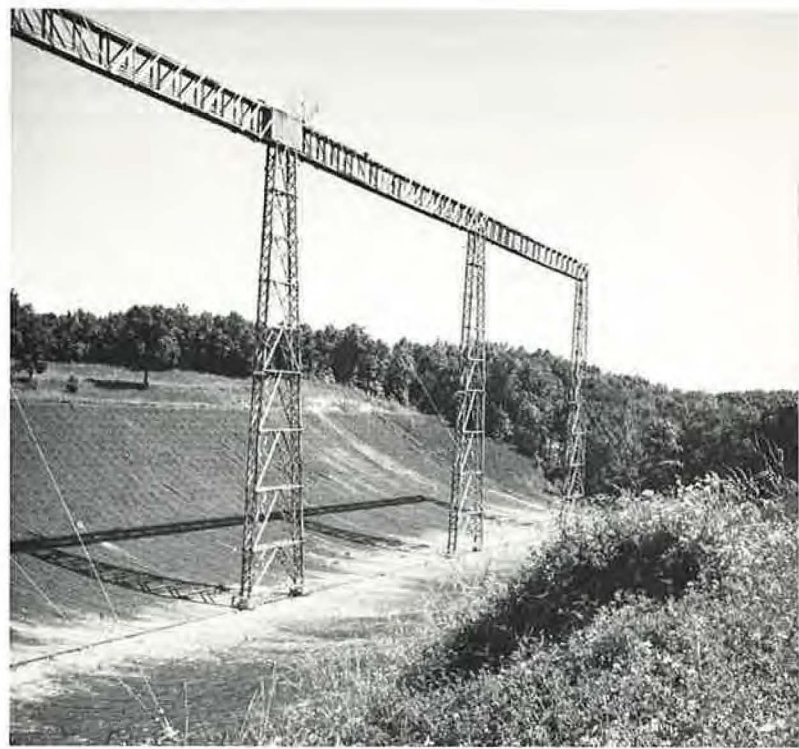
Radio Telescope Laboratory

In 1956, the University of Illinois invited George W. Swenson, Jr., to join the faculty and to design and build a large radio telescope. George C. McVittie, head of the Department of Astronomy, believed that an extensive and complete catalog of discrete, cosmic radio sources would help to distinguish among competing cosmological theories. Two major catalogs of sources had been published by radio astronomers, one in Cambridge, England, and one in Sydney, Australia. The two did not agree on the region of the sky in

which they overlapped, and it was desirable to pursue confirmation with different instruments. McVittie and Edward Jordan, head of the Department of Electrical Engineering, agreed that such a pursuit would be an appropriate area for cooperation between the departments. Swenson was, therefore, sought to undertake the job, and the Radio Astronomy Laboratory (later the Vermilion River Observatory) was begun.

The first task was to study the existing instruments used for cataloging cosmic radio sources, determine their most common errors, and then to develop a new instrument that would best complement them. The new instrument was also to compile a "deeper" catalog than previously existed.

The initial information-gathering studies of the new Radio Astronomy Laboratory took place virtually all around the globe. Swenson was sent on a tour of the world's most prominent radio observatories. This included stops at



The 600-foot-long Vermilion radio telescope, located near Danville, Illinois, was designed and built by George W. Swenson to receive signals from the stars. An array of log-spiral antennas are mounted at the reflector's focus under the horizontal truss.

Cambridge and Manchester (Jodrell Bank), England; Sydney, Australia; Paris, Nancy, and Haute Provence, France; and Dwingeloo, Netherlands.

After a careful study of the instruments used and the data obtained from those instruments, it was apparent that a new instrument design should emphasize sidelobe reduction, involve a different frequency range than existing instruments, and be large enough and have sensitive enough receivers to permit detection of sources of fainter magnitude than those in existing catalogs. To catalog weaker sources and avoid the "confusion" problem of earlier efforts, the main beam of the instrument needed to be narrow, and the sidelobe levels needed to be low. Swenson hypothesized that a filled-aperture antenna had the best chance of achieving these goals; however, that would require a very large antenna, by the standards of the day. The challenge set before Swenson was to achieve the best compromise among size, surface precision, frequency, and cost.

After studying the designs and consulting with others at each point during his worldwide journey, Swenson began to conceptualize the design and its parameters for the new radio telescope. The conventional wisdom of the day held that a resolution of several score beamwidths per source was necessary to avoid confusion. The linear dimension was determined to be about 120 m, and the configuration to be square or circular. A reasonable focal-length-to-diameter ratio for good illumination was needed and would require very high structures, which would be prohibitive for both cost and precision. The alternative was to build the reflector of earth, in large part below ground level. An extensive search disclosed a stream valley near Danville, Illinois, with a nearly north-south axis and appropriate dimensions. The geological conditions were acceptable from the structural viewpoint, and the natural dimensions of the valley dictated only minor changes in the nominal parameters. The land was available for sale, and the final values figured at: width, 400 ft; f/d , 0.39; length of reflector surface, 600 ft; and height of towers, 165 ft.

Obtaining an unassigned and unused frequency was a lengthy legal and political struggle and carries a story of its own. Finally, television channel no. 37, 608 614 MHz was assigned to radio astronomy on a worldwide basis.

Meanwhile, the telescope was completed, relying on hope and faith that the frequency question would somehow be resolved in a satisfactory way.

For help in determining the details of the design, Swenson and the others involved from the Department of Astronomy turned to the Antenna Laboratory in the Department of Electrical Engineering, then led by Victor H. Rumsey. One area of effort involved the phase adjustment of the focal line array and the illumination of the reflector. Yuen T. Lo undertook the detailed design of the array, taking into account the appropriate illumination tapering to minimize sidelobe levels. It was difficult to achieve both the number of elements needed in a uniformly spaced array and the range of element currents required to provide proper illumination tapering. Lo and Swenson decided to try using a nonuniform element spacing.

The design of this array element was done by John D. Dyson. At the time, the Antenna Laboratory team members were engaged in their pioneering studies of frequency-independent antennas, and the conical log-spiral proved to be appropriate. Its primary radiation pattern gave the proper tapering for illuminating a parabola with the chosen f/d ratio. Dyson's design gave a precise adjustment of phase with mechanical rotation, and no difficulty with phase adjustment was ever experienced during the operation of the telescope.

Throughout each stage, from conception to completion, the collaboration of talents continued to surmount the insurmountable. Design of the array transmission line probably took more engineering effort than any other task of the whole program. Every detail of the system had to be designed from scratch due to the unsuitability of most commercial components. An additional task of comparable magnitude was the design and construction of the receivers and recording system. Maintaining proper balance between the effective temperatures of reference noise sources and the ambient-temperature-dependent losses in the hundreds of feet of transmission line in the feed system required many months of tinkering and adjustment. These electronic development tasks were led by Senior Research Engineer Kwang-Shi Yang.

The first installment of the radio source catalog was the PhD thesis of John M. MacLeod, published in 1964. Subsequently, most of the accessible parts of the sky (130° from the zenith) were cataloged under the direction of John R. Dickel, who also mapped a number of galactic extended sources, and by John C. Webber. Harold D. Webb also mapped considerable portions of the Milky Way galaxy, so that most of the accessible sky was covered at least once during the years 1959-69.

About \$10,000 per year was required for mechanical maintenance. In 1969, however, at about the time the sky coverage was being completed, there was a substantial net erosion of earth from the upper slopes accumulated into the vertex of the parabola. This process resulted in progressive increase in the focal length, which eventually exceeded the available range of adjustment in the height of the focal line array. Its mission complete, the instrument was abandoned.

Wave Propagation Laboratory

The successful launch of Sputnik I in 1957 marked a milestone in technological advancement and provided a new opportunity to conduct wave propagation research. This opportunity was realized immediately by George W. Swenson, Jr., who set up a radio interferometer system in a corn field on campus. The observations from that system produced the first accurate satellite orbital elements. To form a research group, the department brought in Kung C. Yeh in 1958, N. Narayana Rao in 1965, and Chao H. Liu in 1965. The group became known as the Ionosphere Radio Laboratory in 1966. Because of changing research emphasis, the laboratory was renamed the Wave Propagation Laboratory in the late 1980s.

In the early years, the Ionosphere Radio Laboratory was one of the first laboratories in the world to set up a number of stations to monitor satellite radio transmissions. The stations were first set up on campus and in surrounding towns in Illinois. At different times, stations have been maintained outside of Illinois as far north as Canada and as close to the equator as Brazil. In the early 1990s, in collaboration with the Polish Academy of Sciences, the laboratory is conducting experiments at Spitzbergen, Norway, in the polar region of the Arctic. All of these activities required maintenance of existing radio equipment and continuous construction of new receivers. Bernard Flaherty and Tony Szelpal provided the technical expertise needed for producing experimental data of impeccable quality. Collaborative studies have taken University of Illinois students to the Arecibo Observatory in Puerto Rico, Sondre Stromfjord Observatory in Greenland, and other facilities. We have also received data from other research laboratories over the years, especially activities sponsored by the Scientific Committee on Solar-Terrestrial Physics (SCOSTEP).

Electromagnetically, the atmosphere and the ionosphere are highly complex. Wave propagation research has been expanded, not only because it is of value to the basic sciences but also because radio waves can be used as a probing tool in atmospheric research. These studies suggest how the data can be used to obtain the desired information from the atmosphere. About 50% of the PhD theses produced by the students of this laboratory are concerned with wave propagation. Work is concentrated on theoretical and numerical simulation studies relating to scattering from and propagation through a medium containing random irregularities. After data are interpreted in terms of physical parameters, the atmospheric and ionospheric research can be started.

Research in the Wave Propagation Laboratory has a broad and diverse scope. Processed data has been used in studies of ionospheric morphology, turbulent irregularities, ionospheric modeling, traveling disturbances, thermospheric winds, eclipse effects of the ionosphere, gravity waves, geomagnetic conjugate effects, magnetic storm effects, solar flare effects, plasmaspheric electron content, ionospheric bubbles, and global atmospheric waves caused by volcanic eruptions. Parallel to these studies are investigations of communications through a fading channel, characterization of satellite communication channels, multiple scattering theories, plasma instabilities, generalized stochastic equations, resonant interactions of acoustic-gravity waves, nonlinear internal waves in the atmosphere, wave-wave interactions, and MST (mesosphere-stratosphere-troposphere) radar observations of the atmosphere. The remaining 50% of PhD theses pertain to these last subject areas.

Investigation of the atmosphere and ionosphere is influenced by advancing technology; it is a multidisciplinary field that involves wave propagation, signal processing, computer simulation, electronic hardware, and atmospheric dynamics. Rockets and satellites have brought in a new platform from which the phenomena of interest can be observed. The invention of lasers and the push into millimeter and sub-millimeter wave technologies have opened new windows through which the phenomena can be examined.

The advancing electronics are responsible for introducing new modulation and coding techniques to probe the medium. For some applications, it is desirable to obtain an image of an object using emitted or scattered electromagnetic energy. Both holographic and tomographic techniques have been proposed for this purpose. The increased radiation power available from advanced-laser and radio sources has made it possible to study many new phenomena involving nonlinear processes. The recent leaps and bounds in computing power will certainly help simulation studies and large-scale modeling. All of these advancements will guarantee the continued progress of this truly multidisciplinary field into the twenty-first century.

Aeronomy Laboratory

The Aeronomy Laboratory was created in the early 1960s by Sidney Bowhill, who had been involved from 1954 to 1962 in ionospheric research at Pennsylvania State University. In the early years, the Aeronomy Laboratory collaborated with the Coordinated Science Laboratory in designing and developing a scientific rocket program sponsored by NASA. CSL had primary responsibility for the design, construction, and operation of the ground-based transmitting equipment while Leslie G. Smith, then at the GCA Corporation, had primary responsibility for the design and development of the scientific rocket payload. Radiowave propagation experiments and dc probe measurements of electron and ionization densities were conducted at several sites around the world, including locations in Virginia, New Mexico, and Florida in the United States, Canada, Puerto Rico, Norway, Brazil, and Peru. The scientific payloads also carried solar radiation detectors to measure ultraviolet and x-ray emissions. The rocket measurements were conducted mainly over the range between 50 and 200 km altitude. Frequently, the measurements were conducted in a coordinated fashion along with other rocket and ground-based experiments.

Another component of the laboratory that served to complement the rocket measurements was a ground-based measurement program conducted mainly at the field station northeast of Urbana. The partial-reflection radar experiment

operated on a frequency of 2.66 MHz and was used to measure altitude profiles of electron density in the lower ionosphere. An active theoretical program was another important component of laboratory activities and served to complement the experimental programs.

The Aeronomy Laboratory hosted several conferences in the 1960s and 1970s. These conferences were attended by scientists from many countries who had an interest in the physics, chemistry, meteorology, and electrodynamics of the upper atmosphere.

In the mid-1970s, a team of personnel from the Aeronomy Laboratory, Quantum Electronics Laboratory, and Electro-Optic Systems Laboratory combined forces to design and develop a laser radar system to measure the density versus altitude distribution of atomic sodium vapor between 80 and 100 km altitude. The first laser was a homemade flashlamp-pumped dye laser, and the first telescope used a half-meter diameter Fresnel lens. Essentially, altitude profiles of the sodium density revealed an interesting wave-like structure. Later, it was demonstrated that this structure was induced by the passage of internal atmospheric gravity waves, called buoyancy waves, in the upper atmosphere.

Other ground-based experiments developed at the Urbana field station included the meteor radar system and a VHF coherent scatter radar system to study the dynamics of the stratosphere and mesosphere. The high-powered transmitter used in these systems had been originally located at Havana, Illinois, and was used by the Smithsonian Astrophysical Observatory to study the physics of meteors.

Aeronomy Laboratory staff in the 1960s included Eugene A. Mechtly and Chalmers F. Sechrist. In the early 1970s, Leslie G. Smith joined the laboratory and directed the rocket program for many years. Other Aeronomy Laboratory staff in the 1970s included Marvin A. Geller and Susan Avery, who were atmospheric dynamics specialists. Several international researchers from Asia, Europe, South America, and other locations were visiting scientists in the laboratory during the 1960s and 1970s.

In the 1980s, the Aeronomy Laboratory played a leading role in planning and conducting the Middle Atmosphere Program (MAP), which was a project of the Scientific Committee on Solar-Terrestrial Physics (SCOSTEP) under the auspices of the International Council of Scientific Unions (ICSU). The proceedings of MAP workshops continue to be the leading source of information on MST (mesosphere/stratosphere/thermosphere) radars. In 1981, Chao-Han Liu was elected scientific secretary of SCOSTEP, and its

secretariat was moved from the National Research Council in Washington, D.C., to the Aeronomy Laboratory. The secretariat conducts the business of the organization and coordinates numerous symposia and workshops worldwide.

Since 1986, Erhan Kudeki has directed the laboratory. Research areas have focused on radar probing of middle atmospheric dynamics and ionospheric plasma instabilities. Several interferometric radar techniques suitable for high-resolution probing of these phenomena were developed at the laboratory. These techniques, including radar interferometry and frequency domain interferometry, have been incorporated into the measurement programs of most major radar observatories in Europe and the Far East. In the early 1990s, the observational program of the laboratory includes radar experiments conducted at the Urbana field station and the Jicamarca Radio Observatory, located near Lima, Peru.

Power Laboratory

The power area of the Department of Electrical Engineering continued to thrive at Illinois during the electronics revolution and the periods of unprecedented expansion in electrical technology. Several of the student design projects of the early years continue to amaze visitors of all ages. The magnetic cannon remains a classic attraction at Engineering Open House in the 1990s. Between the 1950s and the 1980s, the electrical machinery laboratory had, however, shrunk to one-sixth of its original size because other areas of electrical engineering required space.

From 1945 to 1965 was a time of rapid growth in the electric utility industry, with economy of scale bringing larger machines and lower energy costs. This rapid growth was accompanied by a massive interconnection of power systems throughout the United States and all of North America. Interconnection became so pervasive that it defied engineering analysis by even the most sophisticated network analyzer. The extent of the vulnerability of the nation's power grid was first realized in the New York City blackout of 1965. This single event initiated a whole new area in the power field. The utility industry embarked on a new nationwide program of consolidated research. The Electric Power Research Institute (EPRI) was formed in 1972. This was followed by the

creation of the U.S. Energy Research and Development Administration (ERDA) and the Department of Energy (DOE). The oil embargo brought further attention to the nation's critical dependence on energy and the move toward alternative supplies.

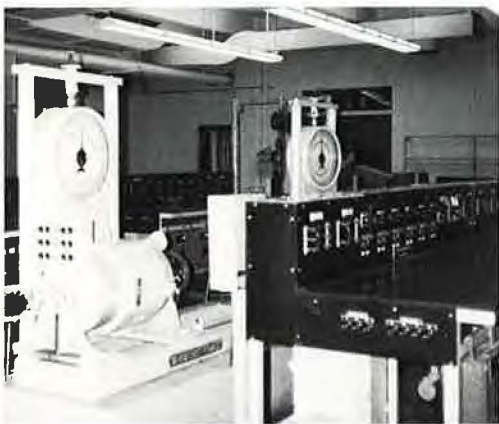
These national issues involving the generation and transmission of electrical energy caused every university in the United States to rethink its strategy in the power area. In many cases, universities had eliminated all activities in the power area and were not in a position to react to this national need. At Illinois, M. Stanley Helm, Daniel Hang, and Raymond Egbert had maintained a power systems program but were heavily loaded with teaching responsibilities and were approaching retirement. Roger Burtness, Robert Turnbull, George Miley, and Joseph Crowley had pursued interests in related areas.

Department Head Edward Jordan recognized the need to focus attention on the power area. Petar Kokotovic and Mac VanValkenburg sought to build a power program with an emphasis on systems engineering. The Illinois research in the application of singular perturbation theory to power systems would later be acclaimed as one of the most successful research efforts of the 1970s and 1980s. On July 14, 1977, the second New York blackout brought the power system problem into every living room. The impact of this second blackout was felt in power systems throughout the east and midwest. Fortunately, the academic community had reacted to the call for research in systems engineering for power and was just producing a new crop of young faculty members.

Peter Sauer joined the faculty in 1977, followed one year later by Richard Shultz and Richard Smith. With the coordination of Helm and key alumni in the power area (Porter Womeldorff and Lowell Ackmann), the faculty initiated an industrial affiliates program in power engineering. The program was created with an emphasis on both research and



1951 Electrical Machinery Laboratory



1981 Electrical Machinery Laboratory

1991 Grainger Electrical Machinery Laboratory



education. The industrial support obtained from the initial affiliate members, Illinois Power Company, Sargent & Lundy, Central Illinois Public Service Company, Public Service Indiana, and Wisconsin Power and Light, totalled \$22,000 and was used to fund undergraduate projects and graduate student research. The power affiliates program remains a key component of the power area in the early 1990s. With the arrival of Mangalore A. Pai, the power area was growing to meet the increased student interest and research challenges.

The 1980s began with an event that would have the most significant impact on the power area in modern times. Department Head George Swenson announced that the Grainger Foundation was establishing an endowment for a professorship in electrical engineering in the field of rotating electrical machinery and associated technology. The endowment was established through the efforts of David W. Grainger, president and chairman of the Board of W. W. Grainger Inc. His father, William W. Grainger, was the founder of the company and a 1919 graduate of the department.

This was the first endowed professorship in the College of Engineering and would, in the words of Swenson, "give impetus to a program which we have already identified as a pressing need, both of the institution and of the society." A revision to the endowment broadened the scope of the professorship to other areas of electrical engineering that would give impetus to the reestablishment of a prestigious program in the field of rotating electrical machinery and associated technology. The revision also established the endowment of Grainger Associates, whose teaching and research would be devoted to the field. Mac Van Valkenburg was named the Grainger Professor of Electrical Engineering and Peter Sauer was named a Grainger Associate. The power area grew at a rapid rate, with renewed student interest and increased research activities. The power affiliates program grew with the addition of Amoco, Bechtel, Commonwealth Edison, General Electric, Northern Indiana Public Service, Sundstrand, Pacific Gas and Electric, Union Electric, and Wisconsin Electric Power. The teaching and research activities grew with a strong focus on dynamic modeling and stability analysis.

These times were saddened by the death of Raymond Egbert in 1985. A memorial was established by the family to create an annual award for an outstanding senior in the power area. The size of the power area faculty was further reduced by the departures of Shultz and Smith and the retirements of Helm, Burtness, and Hang. In an attempt to continue staffing courses and expanding research, the department hosted

visitors, including Kemal Sarioglu, Mohamed Mansour, Milan Calovic, Philip Krein, Said Ahmed-Zaid, Riccardo Maino, and Brana Perunicic. Marija Ilić-Spong joined the faculty as an NSF Presidential Young Investigator and aggressively initiated new research projects.

With the guidance of Van Valkenburg as the Grainger Professor and the research collaboration with Petar Kokotovic, the power area gained recognition. A December 1986 survey report in *Spectrum* magazine listed the University of Illinois as one of the U.S. schools most often cited by respondents as having one of the 10 best power engineering programs in the country. The article concluded with a reference to Illinois as one of the bright spots in a troubled field. With the addition of Philip Krein in 1988, the power area expanded its teaching and research activities to include power electronics. Krein's experimental background added a strong new dimension to the program. The net power area faculty strength was reduced, however, with the departures of Joseph Crowley and Marija Ilić-Spong.

With the rapid decentralization of computing facilities at the university and the simultaneous increase in power area research in modeling and simulation, there was a strong need for a dedicated power engineering computing center. With funds from the Grainger Endowment, a new laboratory was created and named the Grainger Power Engineering Software Laboratory. It included four VAX stations, a 459-megabyte hard disk, tape drive, and printers. Research activities grew further in the last half of the 1980s when the National Science Foundation (NSF) initiated a new program in power systems. Mangalore A. Pai led a new research thrust in the area of dynamic security assessment of power systems, which was made possible by this NSF program.

The 1988 Grainger Lecture Series brought 15 of the top researchers in the United States to Urbana for a two-day seminar on power engineering. Topics ranged from electric machinery design and computer methods for systems analysis to new concepts in control. David Grainger and his chief engineer, Emil Bahnmaier, attended the seminars and discussed the power program with faculty members. With the new emphasis on experimental work brought by Philip Krein, the faculty presented plans to update the electrical machinery

laboratory. Under the direction of Charles Doering of the College of Engineering Development Office and Department Head Timothy Trick, a proposal was submitted to the Grainger Foundation for three major initiatives in the power area: \$500,000 for a complete remodeling and updating of the electrical machinery laboratory; \$250,000 for a new advanced power applications laboratory; and \$1,000,000 endowment for graduate student support in the power area. Almost exactly 10 years after the initial endowment was announced, the new proposal was granted by the Grainger Foundation. This second endowment stands as a benchmark in the history of the department.

The pictures of the Electrical Machinery Laboratory as it evolved from 1951 to the present show the results of this major effort. The new laboratory benches and equipment layouts were designed by Philip Krein and built by the departmental staff.

The laboratory renovation was accompanied by support from Ralph Henneman, who was instrumental in involving S&C Electric in the Power Affiliates Program. The laboratories and research effort in the power electronics area attracted the interest of the Sorensen Company in 1990 as the most recent member of the program.

The 1990s began with unprecedented optimism for the power area. Petar Kokotovic was named the Grainger Professor as the power faculty expanded their interaction with the controls area. New concepts in induction motor control initiated a major project involving simulation and experimental testing in the laboratories. The 1990 Grainger Lecture Series brought an elite group of adaptive control researchers to the campus for a three-day-weekend seminar series.

With the endowments from the Grainger Foundation and the industrial support of the Power Affiliates Program, the power program at the University of Illinois has a firm foundation for continued excellence.

Electro-Optic Systems Laboratory

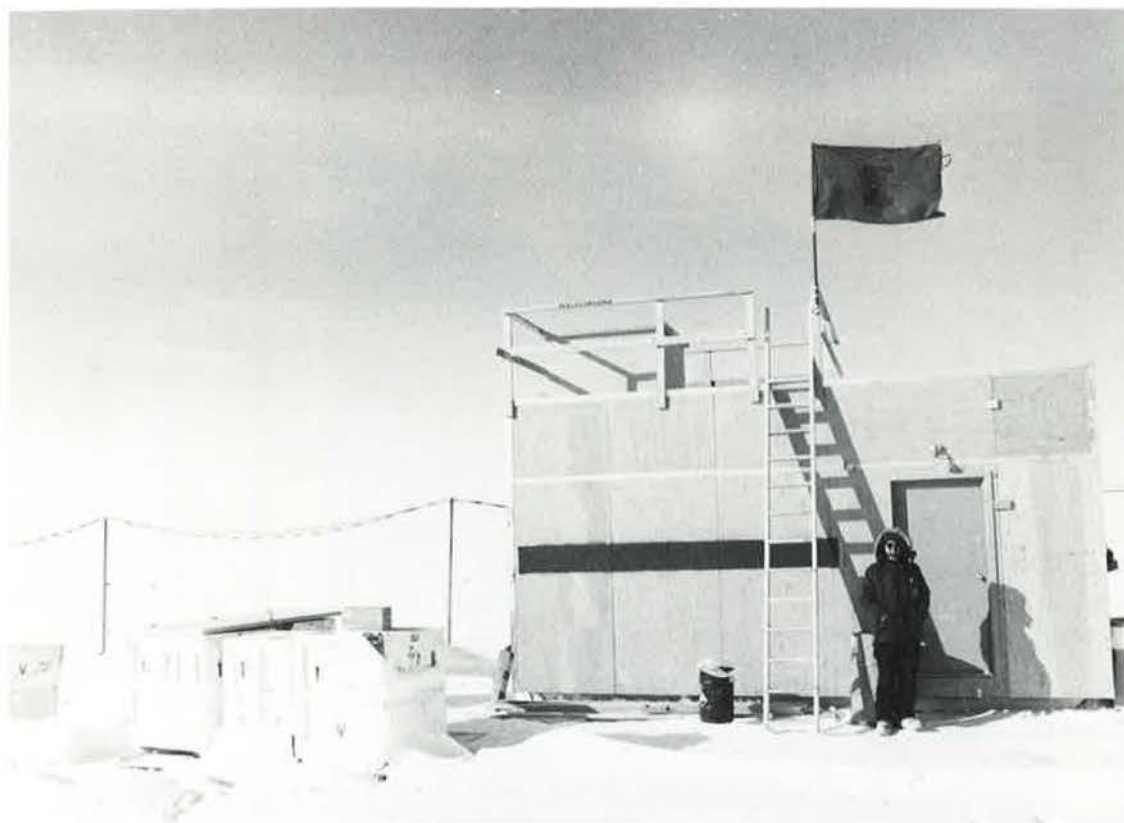
The Electro-Optic Systems Laboratory was formed in the mid-1970s under the direction of Chester S. Gardner, who had joined the faculty in 1973. When the laboratory was established, the intent was to study engineering aspects of a variety of electro-optic systems, including optical communication systems, fiber optics, holography, and laser radar. Early work included theoretical and experimental studies of optical pulse propagation in atmospheric turbulence, analysis of satellite laser ranging systems, and the development of one of the world's first sodium lidar systems. The sodium lidar system was designed to study upper atmospheric chemistry and dynamics, and the project was conducted in collaboration with Chalmers Sechrist and Henry Merkelo. In the late 1970s, Preston (Pat) Ransom joined the laboratory with his students, who were working on a variety of projects in holography.

During the 1980s, the laboratory research activities became more focused on lidar studies of the atmosphere between 20 and 100 km altitude. Lidar is an acronym for light detection and ranging. The first lidars were developed in the 1930s and 1940s using mechanically modulated search lights. These early lidars were only able to observe scattering from clouds and aerosol layers. Since the mid-1960s, all lidars have

used lasers as the light source, and thus the term lidar has become synonymous with laser radar. Lidars are used to study the composition, temperature, density, and wind structure of the atmosphere from the ground to virtually the edge of space. Several powerful and sophisticated lidar systems have been developed in the Electro-Optic Systems Laboratory to study a variety of atmospheric parameters and constituents. These instruments have been deployed around the world to make observations. Remote site campaigns have been conducted at Spitsbergen Island, Norway (78°N), White Sands, New Mexico (38°N), Arecibo, Puerto Rico (18°N), Mauna Kea, Hawaii (19°N), Adelaide, Australia (35°S), and airborne over North America and the equatorial Pacific. From November 1989 to November 1990, graduate student Richard Collins operated one of the laboratory's lidar systems as a winter-over scientist at the South Pole; this work is related to studies of the Antarctic ozone hole.

Since the 1980s, the laboratory has also been active in developing laser guide star technology for use with adaptive astronomical telescopes. This technology can be used to compensate for image distortion caused by the atmosphere, thus eliminating the "twinkle" from astronomical observations. Laboratory personnel were the first to successfully create and photograph an artificial laser guide star at Mauna Kea Observatory, Hawaii, in 1987. Subsequent work has focused on determining the laser requirements for guide star applications and on assessing the expected imaging performance of laser-guided adaptive telescopes. In 1989, George Papen joined the laboratory and became involved in several projects on photo refractive materials, optical phase conjugation, and lidar.

In 1991, much of the experimental work is conducted in the Lidar Laboratory at the Urbana Atmospheric Observatory, just north of Urbana. This new building, constructed in 1990, contains a 1-m diameter astronomical telescope, several smaller telescopes, and several high-power, tunable laser systems. The facility was used in 1991 to provide ground-truth measurements during overflights of the upper atmospheric research satellite, which was launched by NASA in September 1991.



In 1989–90, graduate student Richard Collins spent 12 months operating a lidar system at the South Pole.

Chapter 5-Associated Laboratories



The Coordinated Science Laboratory, after the move from the Electrical Engineering Research Laboratory. Built in 1962, the building is located at the corner of Springfield Avenue and Goodwin Avenue in Urbana.

Digital Computer Laboratory

Computing at the University of Illinois began in 1949, when the research board under Graduate College Dean Louis Rinenour sent a proposal to University President George Stoddard recommending that the university construct a copy of the von Neumann machine designed at the Institute for Advanced Study, Princeton University. A contract was given to the university by the Ballistic Research Laboratory at Aberdeen Proving Ground in Maryland that called for a machine to be built to be called the ORDVAC. Ralph Meager was chosen as chief engineer, and work was undertaken in 1950 and 1951 under the name of the Digital Computer Laboratory (DCL) in the old Electrical Engineering Building (now called EERL). Until the Department of Computer Science was formed in 1957, faculty members working on computers in DCL held academic appointments in academic departments, primarily electrical engineering and physics.

With commendable foresight, two of every part required for ORDVAC had been purchased or built; by November 1952, it was possible to construct a duplicate computer called ILLIAC. Hence, the University of Illinois could rightfully claim the distinction of being the first mass producer of computers (two in one year). Both computers proved to be successful. At the University of Illinois, ILLIAC I, as it became known, was used campuswide, and its success spread the computer philosophy to other campuses. In 1955–56, it was copied by Michigan State University as the MISTIC and also by the University of Sydney, Australia, where it was bravely named the SILLIAC. Later, one was constructed by Iowa State University as the CYCLONE.

ILLIAC I was used by Lajaren Hiller, director of the Experimental Music Studio, to compose and play the Illiac Suite, the first computer-composed composition. In 1966, at the Fall Joint Computer Conference, Heinz Von Foerster organized a highly creative session on computers in music. The papers presented in this pioneering session were later published in the book *Music by Computers*, edited by Von Foerster and James Beauchamp.

Coordinated Science Laboratory

The research program at CSL encompasses a variety of topics in science and engineering, with major emphasis on programs providing graduate thesis research. Students conduct research under the direction of faculty members holding joint appointments in the following departments and schools: Electrical and Computer Engineering, Mathematics, Computer Science, Mechanical and Industrial Engineering,

General Engineering, Materials Science and Engineering, Linguistics, and Library and Information Science.

Originally called the Control Systems Laboratory, CSL was organized in 1951 under the impetus of urgent military needs because of the involvement of the United States in the Korean War. Aware of the technological potential in the areas of information theory and automatic computers, the small staff, led by Francis Wheeler Loomis, Louis Ridenour, and Fred Seitz, demonstrated the technical feasibility of several completely novel ideas that, in the 1990s, form the nucleus of important military systems. These included: the coherent Doppler radar; the Cornfield System, a radar-based, computer-controlled air traffic surveillance and control system; the All Weather Attack System, an airborne, noncoherent Doppler radar; a portable sentry radar designated the AN/TPS-21; the side-looking radar; and the ground observer corps.

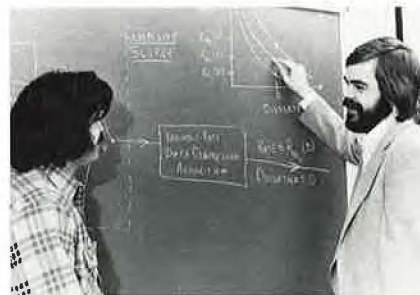
In 1959, the university and the Joint Services Committee approved the reorganization of the laboratory into an interdisciplinary and interdepartmental graduate research center. Daniel M. Alpert became the first director of the renamed Coordinated Science Laboratory. This change also marked the beginning of new objectives and activities, which included graduate students and graduate research. The first associate directors were Chalmers W. Sherwin for physics and Mac E. Van Valkenburg for engineering.



ILLIAC I was the first computer built and owned entirely by an academic institution.

As part of a program to strengthen CSL's computer and systems activities, Van Valkenburg recruited a number of new faculty members in the early and mid-1960s. These researchers later led CSL and the department to distinction in their respective fields. Van Valkenburg also organized the "Allerton Conference on Circuits and Systems" in 1963. The conference continues today as the "Allerton Conference on Communication, Control, and Computing." Van Valkenburg asked Jose B. Cruz, Jr., to establish programs in control systems. Cruz had obtained a PhD in circuit theory under Van Valkenburg and was developing a national reputation for his contributions to time-varying circuits and systems. Cruz originated graduate courses in the control area and, along with Van Valkenburg, began building a control faculty. William R. Perkins and Petar V. Kokotovic were appointed to the control faculty in the early 1960s.

The work by Cruz, Perkins, and Kokotovic on sensitivity theory and control in the presence of uncertainties gained CSL international attention from the control community. This basic work is at the heart of feedback theory and remains an important part of fundamental control theory. Other major developments coming from CSL's control group include Cruz's pioneering work on dynamic games, especially leader-follower strategies, and Kokotovic's original research on



In 1978, Professor Michael B. Pursley describes his research on universal data compression to research assistant Val Di Eulius.

singular perturbations and on adaptive control. The control group is known, in the 1990s, as the Decision and Control Laboratory and is highly regarded internationally.

Robert T. Chien (PhD '58) returned to the University of Illinois from IBM in 1964. He led a research group in coding and information theory. Later he developed research programs in design automation and artificial intelligence. In 1972 he became director of CSL, a post that he held until his death in 1983. As director, Chien strengthened systems and computing research and added new programs in semiconductor materials and devices.

Sundaram Seshu, Gernot Metze, and Franco Preparata were added to the staff in the computer area in the late 1950s and early 1960s. They did pioneering research on fault tolerant computing and computational theory. Later, Edward Davidson joined the group. Davidson and Preparata successfully recruited a number of young faculty members to CSL. Two of these faculty, Ravi Iyer and Janak Patel, formed the Center for Reliable and High Performance Computing in 1989. The computer engineering program at UIUC now ranks among the very best in the nation.

In communications, Van Valkenburg recruited Abraham H. Haddad. Later Michael B. Pursley, H. Vincent Poor, and Bruce Hajek joined the group. The group has earned a reputation for its outstanding research in spread spectrum communications, signal estimation and detection, and communication networks.

Van Valkenburg recruited Timothy N. Trick in 1965 to develop the nonlinear circuits area. With rapid developments in integrated circuits and computing, Trick's interests switched to computer-aided analysis and design of integrated circuits and digital signal processing. Upon Chien's death in 1983, Trick became acting director and then director of CSL until 1985, when he became head of the Department of Electrical and Computer Engineering. In 1986, W. Kenneth Jenkins was named director of CSL. I. N. Hajj and S. M. Kang now lead the VLSI circuits research effort in CSL. Since 1984, the Semiconductor Research Corporation has funded a major program in reliable VLSI systems. Faculty



Professors Thomas Huang (left), David Munson (center), and Kenneth Junkins meet in the director's office at CSL in 1987 to discuss the initiation of their ARO contract in high-resolution spaceborne imaging.

members from both the circuits area and computer area participate in this program. Research is conducted on reliable VLSI circuits, testing, and fault diagnosis.

Originally supporting the entire laboratory, the Joint Services Electronics Program (JSEP) constitutes about 25% of the total funding of CSL in 1991. This funding has resulted in many pioneering projects. The experimental model of an electric vacuum gyroscope provided the basis for successful development at the industrial level. The plasma display panel, invented under the leadership of Donald L. Bitzer and H. Gene Slottow, is used around the world in banking and graphics display terminals and in numerous military applications.

The capabilities of early combat surveillance radar were limited by antenna size. Sherwin conceived of a new idea that would accomplish a very high angular resolution. Based on experimental feasibility demonstrations at CSL, this work eventually led to the Army AN/UPD-1 (XPM-1) combat surveillance radar system. The work of J. D. O'Brien, W. Kenneth Jenkins, and David C. Munson, Jr., clarified the role of Doppler in synthetic aperture radar. Clearing the way for the development of a new class of SAR reconstruction algorithms, this work has been recognized as a basic contribution in the field.

PLATO, Programmed Logic for Automatic Teaching Operations, was conceived by Sherwin and developed at CSL under the direction of Bitzer. The Computer-based Education Research Laboratory was formed in 1959, and the PLATO project grew rapidly in the 1960s. Numerous innovative ideas and their development have proven CSL to be responsible for many of the systems and designs used in the 1990s.

Another development at CSL is the acoustic charge transport (ACT), which is a method to store information in analog form. William Hunsinger and Michael Hoskins developed ACT delay lines to transport charge in GaAs using the electric fields produced by surface acoustic waves. Devices using this technology have low-noise, large-dynamic ranges and wide bandwidths. Several industrial organizations have followed the lead of the University of Illinois and, in the early 1990s, are pursuing the development of this new technology, which promises significant breakthroughs in signal processing applications.

The earliest CSL research in the field of spread-spectrum communications was by a visitor, T. Kasami of Japan, in the mid-1960s. His contribution was largely unknown until it was publicized by CSL faculty members a decade later. As a result, Kasami sequences, as they are now called, occupy a position alongside m-sequences and Gold sequences as the most powerful linear sequences for DS spread-spectrum systems.

The research program in the early 1990s in spread-spectrum communications originated in 1974 with an investigation of the multiple-access capability of direct-sequence (DS) spread spectrum by Michael Pursley from the Department of Electrical and Computer Engineering. This research produced methods for signal design and performance analysis that are in widespread use in the early 1990s. The synchronization sequence in the army's SINGARS spread-spectrum radio was designed by CSL researchers. CSL research has branched out into several areas, including: frequency-hop systems, effects of fading on spread-spectrum communications, spread-spectrum radio networks, combined coding and spread spectrum to combat fading, and jamming.

A unique facility called the EpiCenter, an abbreviation for the University of Illinois CSL-Microelectronics Joint Center for Epitaxial Growth and Surface Science, is located in the CSL building. The equipment consists of seven molecular beam epitaxy chambers interconnected by evacuated stainless steel transfer lines. Established in 1988, this jointly supported, world-class facility is a center of attraction for new research activities in microelectronics materials and devices.

During the early years of CSL, the principal areas of research were the electric vacuum gyroscope, surface and vacuum physics, plasma physics, plasma display devices, computers and their application to modern systems problems, system theory, and computer science. At CSL, as it is in any active scientific and engineering research enterprise, the focus is a dynamic one—constantly being modified toward new areas that promise to be important over a long period of time.

In the early 1990s, activities include research programs in semiconductor physics, semiconductor materials and devices, high-speed devices, thin-film physics, sputter deposition of materials, microwave acoustics, surface science, quantum



This photograph, taken in 1961, shows a student using the PLATO system.

electronics, electromagnetic communications, radiation and scattering, and advanced automation. Research is also being done in digital signal and image processing, applied computation theory, human-computer interaction, computer-aided decision making, fault-tolerant digital systems, concurrent processing, computer architecture, computer algorithms, decision and control, linear and nonlinear systems, analog and digital circuits, computer vision and robotics, communications, and information retrieval.

Computer-based Education Research Laboratory and PLATO

The Computer-based Education Research Laboratory (CERL) at the University of Illinois at Urbana-Champaign is a multidisciplinary laboratory where, for the last 32 years, researchers in computer hardware, software, and courseware have successfully developed several generations of sophisticated, full-service computer networks, from PLATO I to the most recent NovaNET. The mission of CERL is to conduct research exploring the use of computers and telecommunications in addressing all types and levels of educational needs. The effectiveness of evolving research products must be established outside a laboratory setting. To maximize the impact of its innovations, CERL has always sought their timely transfer to the private sector for widespread dissemination and use.

The laboratory started in 1960 when Donald L. Bitzer, a 26-year-old PhD in electrical engineering, became director of a project with the goal of designing "an automatic teaching machine" to teach students of various levels how to use a high-speed computer. The university's ILLIAC I computer was employed as the brain of the system, whose basic teaching logic was developed by mathematician Peter Braunfeld.

Several important educational concepts were blended into the new system: rapid assessment of the student's grasp of ideas; help messages provided upon the student's request and feedback-lesson response to student's input; and information to the instructor on the student's performance. This led to improvement of teaching methods implemented in computer-based courseware. The system creators wanted to build a sophisticated, general purpose teaching system. The system was named PLATO for "Programmed Logic for Automatic Teaching Operations."

With PLATO I in 1960, which was the first generation of PLATO, a student sat at a telephone-booth-like station facing a television screen and communicated with the computer through a keyset like that of a typewriter with special keys. PLATO I only taught students computer programming.

By 1961, PLATO I became PLATO II with the addition of another teaching station. Changes in the teaching logic allowed subjects other than computer programming to be taught. PLATO I and II were run on the ILLIAC I and written in the ILLIAC language.

The next generation, PLATO III in 1966, was based on a new, commercially built CDC 1604. It was written first in assembly language. In 1964, the first program to simplify authoring was developed. Named CATO, it was based on Fortran 60. In mid-1967, Paul Tenczar, then a zoology graduate student and later president of the Computer Teaching Corporation, created Tutor, an authoring language that reduced the courseware development time from months to hours. PLATO III had 20 student stations and a variety of teaching techniques. Designed to converse with its students sequentially, PLATO III could theoretically teach as many as a thousand students eight different lessons simultaneously, without neglecting anyone.

Students' answers were judged "ok" or "no" upon pressing the key marked "judge." In addition, self-explanatory keys available to students included "continue," "reverse," "help," and "answer." PLATO kept a record for each student of every request for help, every wrong answer, and how much time was spent on each lesson.

PLATO was the world's first time-shared computer-based education (CBE) system with the first CBE authoring language. The entire concept of a user-friendly computer was born at CERL. For the first time, multiple on-line author editing was done, and computer-generated graphics and multimedia presentations were used in instructions. A given slide could be selected by an electronic system in less than a millionth of a second. A beam of light was electronically aimed at the selected slide, and a sensing tube relayed the picture to the student's television screen. PLATO could use random access audio to teach preschoolers to use a terminal, and it provided "I'm a HAPPY man!" whistling after they solved the maze successfully.

From 1965-68, Bitzer and H. Gene Slottow developed a new computer-controlled display—the plasma panel display. In 1971, the first commercially manufactured plasma displays, then named Digivue, were delivered to CERL. Later, plasma displays were used in the PLATO IV terminals. Control Data Corporation (CDC) bought limited rights to the PLATO name and system from Bitzer and the University of Illinois in the late 1960s.

In the 1970s, CDC set up a new system named MINNC in Minneapolis, Minnesota, where its headquarters were located. By 1983, CDC had sold or set up 23 PLATO systems around the world. These systems included one each in Australia, Belgium, France, Israel, Korea, Sweden, Taiwan,

and the United Kingdom, two in Canada and South Africa, and eleven in the United States. Most of these systems were linked together, allowing electronic mail (e-mail) to be exchanged.

Electronic mail, named “the notes system,” was in use on PLATO as early as 1973. A system of user/system notes consisted of public notefiles and personal notefiles, which were used for exchanging personal messages. The notefiles system evolved in a process of communicating new ideas among developers and users.

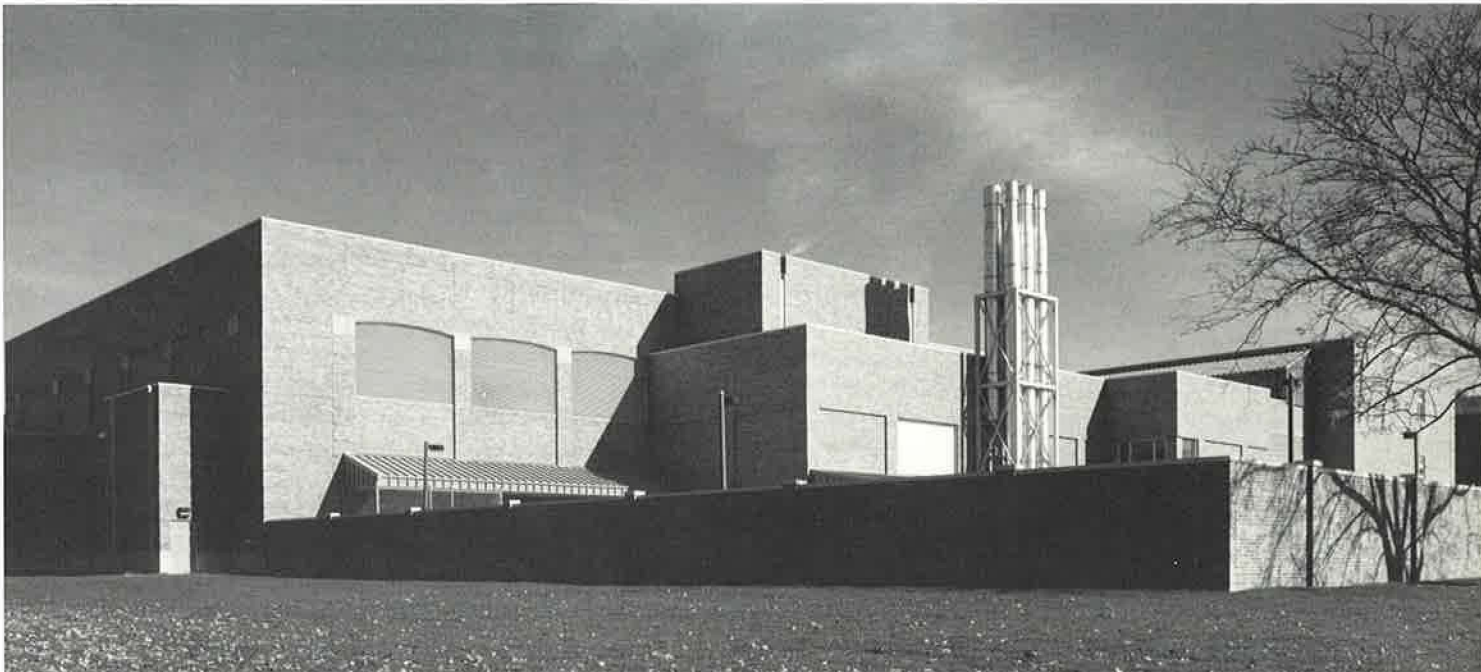
PLATO III had about 2,500 hours of instructional lessons in biology, genetics, chemistry, physics, elementary mathematics, political science, French, Latin, and Russian. By 1980, there were 7,000 hours of instructional material in more than 150 subject areas on the PLATO IV system.

A “CERL Cluster System,” intended to take advantage of a stand-alone terminal and of central PLATO at low cost, was developed in 1980. It consisted of a large microcomputer system, the “hub,” connected to intelligent terminals, the “stations,” via a local area network. The hub system provided network file storage and lesson condensing facilities in addition to the interactive and batch functions of a standard computer system. The stations supported authoring and execution of microtutor lessons and curricula.

Microelectronics Laboratory

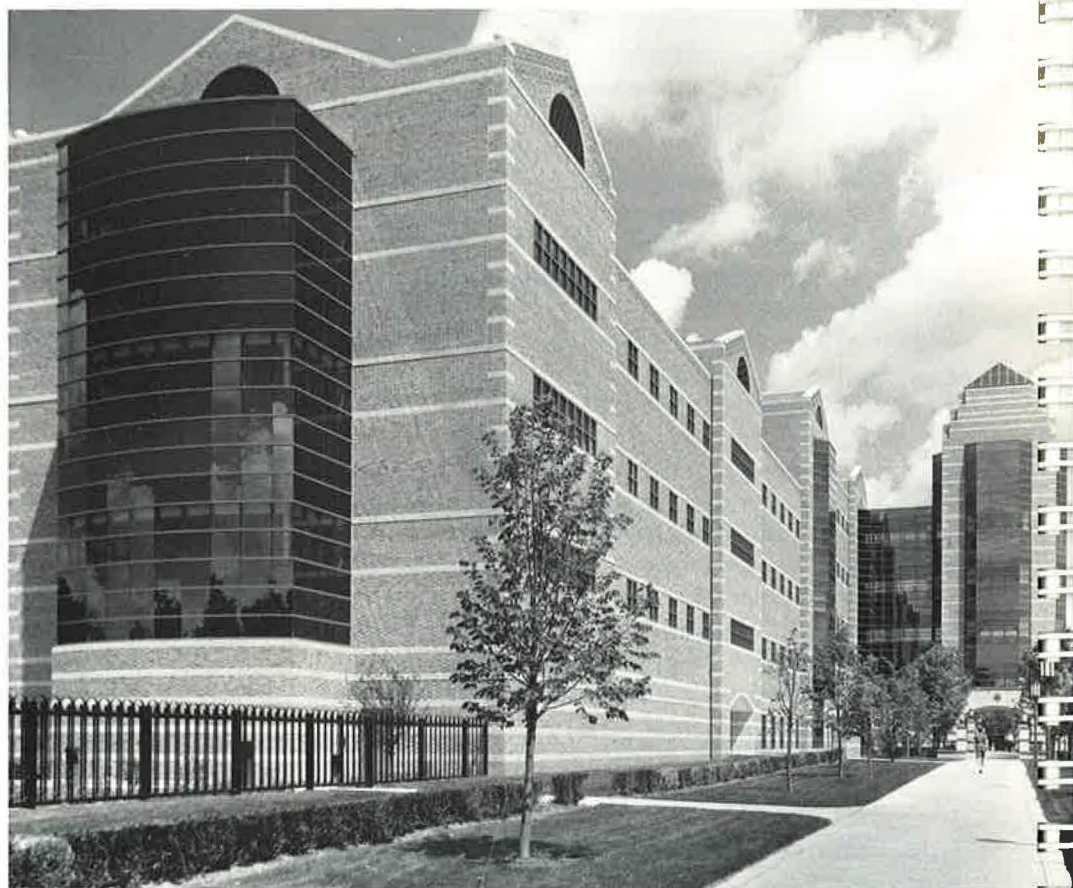
In the early 1980s, the state of Illinois committed \$3.5 million to modify a campus building to contain the Microelectronics Laboratory. James J. Coleman, Nick Holonyak, Jr., and Gregory E. Stillman lent their expertise on the feasibility of making the existing building suitable for microelectronics research. Meanwhile, a Microelectronics Board of Overseers, consisting of 13 senior leaders from industry, was assembled by the president of the university. In 1985, the board’s chairman, Motorola’s vice president for research, William Howard, advised the state and university to invest seriously in the future of microelectronics research. When the renovation plan was presented to the Board of Overseers, they suggested building a new facility.

In response to the board’s recommendation, the state committed an additional \$10 million—a total of \$13.5 million—to build a new microelectronics laboratory on the UIUC campus. Construction on the Microelectronics Laboratory building began in July 1987. The building was dedicated on October 7, 1989. Governor James Thompson and university President Stanley Ikenberry attended the ceremony. The building has 8,000 sq ft of class 100 and class 1000 clean room space; is vibrationally tuned to less than 10



Dedicated in 1989, the Microelectronics Laboratory is a multidisciplinary facility in the College of Engineering for investigating new concepts in optical and electronic materials, devices, and systems based on gallium arsenide, indium phosphide, and other group III–V compound semiconductors.

The Beckman Institute for Advanced Science and Technology is the largest and most ambitious university-based multidisciplinary research facility in the United States.



microinches; and is the first university facility to conform to the H6 fire and safety codes applicable to semiconductor laboratories. The Microelectronics Laboratory is equipped with facilities for nanolithography, growth of artificially structured materials (MBE and MOCVD), materials characterization, and high-speed electrical and optical device measurements.

Encouraged by state support, the faculty—under Stillman's leadership—presented a proposal to the National Science Foundation for an Engineering Research Center in Compound Semiconductor Microelectronics. The NSF grant, which began on May 1, 1986, provided funds to develop experimental facilities and programs for core research, education, and industry for the 1990s. The Center for Compound Semiconductor Microelectronics addresses research that is critical to the successful realization of products based on high-speed optical interconnect technologies.

Center research builds on the work begun at UIUC by John Bardeen and advanced by Nick Holonyak, Jr. Holonyak, Bardeen's first graduate student, established a solid-state electronic devices research lab at the university in 1963. Since then, the university has been a leader in academic research on gallium arsenide and other compound semiconductors. The center is the umbrella under which the university, in partnership with government and industry, has developed the essentials of faculty members, students, program monies, facilities, and leadership to continue its premier program in compound semiconductors and optoelectronic systems.

The center is located in the Microelectronics Laboratory and is a unit with departmental status in the College of Engineering. The center is managed by the director, Stephen Bishop, who is also the director of the Microelectronics Laboratory. Bishop assumed the directorate in August 1989 from Joseph Verdeyen. Verdeyen served as director from January 1988 to July 1989. He followed founding director Stillman. Each director has relied on the Technical Advisory Committee (TAC) for guidance on the center's overall research agenda. The TAC, which first met in August 1987

and has met annually since, is composed of leading managers and research practitioners from industry, academia, and government laboratories. Whether working individually with faculty members or in formal meetings with the director, the TAC assures that the center's research plan is well matched with industry needs and long-term goals.

Beckman Institute for Advanced Science and Technology

Early in 1983, administrators of the Urbana-Champaign campus of the University of Illinois decided to assemble a proposal for establishing a dramatically new venture in university-based research. The first meeting leading to what later became the Beckman Proposal was held in the office of university Vice President Morton W. Weir. Also attending were Lewis W. Barron, who directed the university's Foundation, Chancellor John E. Cribbet, Vice Chancellor Edwin L. Goldwasser, and Vice Chancellor Theodore L. Brown.

Following discussions with key campus administrators and professors in the university's Center for Advanced Study, two committees were appointed in May 1983. One of these committees, chaired originally by Gregory E. Stillman of the Department of Electrical and Computer Engineering and later by Karl Hess of the same department, consisted mainly of faculty members from engineering and the physical sciences. The second committee, under the chairmanship of William T. Greenough of the Department of Psychology, was asked to develop a program statement for an array of research spanning the life sciences and the behavioral sciences, extending from molecular biological sciences to the neurosciences and cognitive sciences.

The two committees presented their reports to campus administration in September 1983. Over the next several months, these thorough and comprehensive documents were drawn on by campus administration, in collaboration with Vice President Weir and the University of Illinois Foundation, to produce a proposal that was submitted to Arnold Beckman in fall 1984.

Beckman's gift of \$40 million was announced at the annual meeting of the University of Illinois Foundation in October 1985. The Illinois legislature, in its fall 1985 session, appropriated \$10 million toward the cost of the building. In addition, the university and the state of Illinois pledged to support the continued operations and maintenance of the institute.

As donors of the largest gift ever made to a public university at that time, Arnold and Mabel Beckman were, quite naturally, eager to see the planning for the institute move along as rapidly as possible. In keeping with their wishes, the

university acted quickly to choose an architectural firm.

The selection of Smith, Hinchman & Grylls (SH&G), a Detroit architectural engineering firm experienced in the design of research facilities, was announced on December 10, 1985. In its proposal, SH&G indicated a demanding schedule that would lead to the completion of the facility by the end of 1988. Close cooperation and exceptional commitment from all involved were required to meet the schedule for designing and building a large and complex facility such as the Beckman Institute.

In contrast to the usual procedure in planning a major facility, the Beckman Institute was without a detailed building program when the architectural firm was selected. Accordingly, the first task was to establish a program on which to base the building design. The Greenough and Hess committees were reactivated, with enlarged faculty groups representing candidate research programs to establish the space needs of research efforts. That planning process, carried out in only three months, required and received great imagination and patience from the participating faculty members.

With the program plan in hand, the building was designed in spring 1986; design development came to a close with the presentation of the building design to the Board of Trustees of the University of Illinois in July 1986. Site clearance and work on the foundation began in early December 1986; construction was substantially complete by December 1988.

Arnold and Mabel Beckman's generosity has provided the university with a rare opportunity to establish a new and important direction for university-based research. Continued commitment is required to meet the challenges of the Beckman Institute.

The Beckman Institute differs from most other interdisciplinary research institutes in the significantly broader scope of its programs. The physical design features are intended to enhance its mission as a center for cross-disciplinary scholarship among researchers in the biological and behavioral sciences, the physical sciences, and engineering. The 313,000 sq ft includes the major architectural features of a laboratory wing, an office and electronics wing, a public atrium, and a tower. One of the most important elements in stimulating interaction between researchers is the opportunity for frequent, easy contact. The institute provides many spaces that can serve as gathering places for researchers in groups varying in size from a few up to 100 people. In early 1990s, electrical and computer engineering faculty members in the Beckman Institute conduct research in computer vision, imaging, computational electronics, scanning/tunneling/microscopy, optical systems, and neural networks.



To be completed in the spring of 1992, the Computer and Systems Research Laboratory is located on the north side of the new north campus ellipse, across from the Beckman Institute.

Supercomputers

Research and Development—CSRD

The Center for Supercomputing Research and Development (CSRD) was founded in 1984 as an outgrowth of the Advanced Laboratory for Supercomputers, then part of the Department of Computer Science. The mission of the new center was to advance the state of supercomputing and to demonstrate the practicality of high-performance parallel computation across a wide range of applications. Originally,

the activities of CSRD were guided by Director David J. Kuck and three associate directors, Edward S. Davidson (architecture and hardware), Duncan Lawrie (software and operating systems), and Ahmed H. Sameh (applications and algorithms). In 1989, George Cybenko joined the center as associate director for performance evaluation and graphics, and David A. Padua became associate director for compilers. In 1990, Lawrie became head of the Department of Computer Science.

Efforts during the first four years were directed toward building the Cedar system, a parallel supercomputer system based on eight-processor clusters with an interconnection network and shared memory to accommodate up to 32 processors. In 1985, the first Alliant FX/8 arrived, and additional FX/8s were obtained and reconfigured to form the system's computational base. The interface, interconnection, and memory boards were designed at CSRD, manufactured by outside vendors, and installed beginning in 1987. Xylem, the CSRD-designed operating system based on Unix, was

developed and successfully ported to the Alliants and then to the two-cluster Cedar machine. In 1988, the first Fortran program was run on all board types, and the operating system was run on multiple clusters. In 1989, Cedar 1, consisting of four clusters of four processors each, was powered up and ran several Fortran programs successfully, showing significant speedup. Finally, in December 1990, CSRD staff demonstrated the Xylem operating system, Cedar Fortran compiler, and Cedar numerical library operating on the full 32-processor, four-cluster system. The system includes a 64-megabyte, global shared memory and shuffle-exchange based, global interconnection network. Cedar forms the basis for a class of scalable, hierarchical systems, and several industrial projects underway in the early 1990s have been influenced by this exchange.

Since its founding, CSRD has become an increasingly productive force in the supercomputing research community. Approximately 135 faculty members, staff, and students engage in cooperative research and pursue advanced degrees in the Department of Computer Science and the Department of Electrical and Computer Engineering. During 1989, CSRD led an initiative to establish a PhD concentration in computational science and engineering (CSE). It is expected that more than 50 faculty members will participate in the program, the goal of which is to educate students to be intellectually prepared to advance the field of high-performance computing into the twenty-first century. Progress in the application of high-performance computers to modern scientific and engineering problems involves an understanding of the whole computational process. The CSE curriculum will focus on whole computer systems: how to design and build efficient, fast computer systems; how to use them effectively, including compilers, system, and applications software; and components in computer architecture and performance evaluation.

In addition to extensive research and development activities, CSRD offers numerous meetings, seminars, and workshops to the supercomputing community. The corporate world participates in these activities through the CSRD Affiliates Program, which provides corporate members with the opportunity to contribute to research efforts and to benefit by gaining firsthand information about the progress of those efforts. The two-day annual meeting each spring enables representatives of the corporate community to meet with students and researchers and to attend a series of presentations at CSRD. Among the 1991 members of the CSRD Affiliates Program are Alliant Systems Corp., Concurrent Computer Corp., Control Data Corp., Cray Research, Digital Equipment Corp., Electricite de France, Fujitsu, IBM, MIPS Computer Corp., Mitsubishi, Sun Microsystems, and TASC.

CSRD has continued to grow. In the beginning, faculty members, staff, and students were located on the third floor of Talbot Laboratory, but these quarters were soon too small. To relieve the space shortage, an apartment house was moved from the site of the then-projected Beckman Institute to Wright Street, across from Talbot Laboratory, and renovated to provide offices for graduate research assistants. In December 1990, ground was broken for a new building, the Computer and Systems Research Laboratory (CSRL), which will be located on the east side of the new north campus ellipse across from the Beckman Institute for Advanced Science and Technology and the Microelectronics Laboratory. Upon its completion in the spring of 1992, CSRD will share the new 80,000 sq-ft building with the computer and systems staff from the Coordinated Science Laboratory.

Applications—NCSA

About the time CSRD was being formed, Larry Smarr, professor of astronomy, was lobbying in Washington, D.C., for a National Center for Supercomputing Applications (NCSA) at UIUC. Smarr's cross-disciplinary proposal contained contributions from several faculty members in the Department of Electrical and Computer Engineering, including a contribution from Karl Hess. When Smarr's proposal was funded, Karl Hess was among the initial users of the first supercomputing system—the \$12 million CRAY X-MP/24. Hess was doing pioneering research on the use of Monte Carlo techniques for semiconductor device simulation. Faculty members and graduate students in the Electromagnetics Laboratory were also among the early users of the CRAY.

With the availability of the CRAY, Hess received funding from NSF to establish a National Center for Computational Electronics. More than 50 universities and industries joined the center. One of the attractive features of the center was the superior computer graphics available in NCSA. Hess commented that the first video he made of a CRAY simulation of a high-speed transistor turning off and on cost more to make than the movie "Rambo."

In 1991, NCSA has 240 staff members who assist industrial partners and university scientists in using supercomputers in scientific applications. NCSA operates a CRAY 2, a CRAY Y-MP, and a 64,000 Processor Connection Machine. Numerous graphics workstations are also available for visualization of the numerical results.

Chapter 6-Developments over the Years

On September 21, 1968, William L. Everitt (left), dean of the College of Engineering, and Lou Liay (right), associate director of the Alumni Association, presented a loyalty award to John E. Farley '48, national president of Eta Kappa Nu.



Edward C. Jordan, Marcia Peterman, and William L. Everitt in 1949.



Paul Hudson, long-time executive secretary of Eta Kappa Nu, is pictured in 1977 with his wife, Gertrude.

Curricula over the Years

The curriculum in electrical engineering at the University of Illinois at Urbana-Champaign has changed over the years. The major area of transition concerns the move from an orientation toward electric power to postwar needs in communications and electronics. The changes at UIUC are representative of changes occurring at engineering schools across the nation. Most changes have been small and evolutionary; a few have been larger.

The curriculum in electrical engineering at the university did not change very much in the first 50 years. Appendix 3 lists the curricula in the years 1910, 1940, 1950, 1961, 1973, and 1989. There is little difference between the 1910 and 1940 curricula. Both required approximately 142 hours for the BS degree. The 1910 curriculum, however, was rigid; in 1940, a few options were available to the students. Wiring and Illumination was one option in the second year. In the second semester of the fourth year, students could elect to substitute courses in Telephone Transmission, Radio Communication, or Electron Tubes for E.E. 36—A.C. Apparatus and E.E. 86—Electrical Engineering Lab.

The era after World War II was one of rapid change in electrical engineering. The 1950 curriculum offered three options: power, illumination, and communication engineering. Differential Equations and Electronics were required courses in all three options. Fields and Waves, Electron Tube Circuits, and Radio Circuits were required courses in the communication engineering option. In the nontechnical area, courses were required in Rhetoric and Composition, Effective Speaking, Economics, Hygiene, Personnel Administration, Psychology, Architecture and Civilization, and Physiology. The illumination option required courses in Industrial Selling and Sales Management. The 1950 curriculum contained 144 hours. The options format disappeared in 1958.

By 1961, the curriculum clearly illustrated the impact of William L. Everitt, John Bardeen, and their protégés. Requirements included three electromagnetics courses, a fourth physics course entitled Atomic Physics and Quantum Theory, and a materials course entitled Properties of Solids. This was a modern curriculum in 1961 that reflected the rapid advances taking place in communications, solid-state devices, and nuclear energy. The curriculum required 145 hours and contained 31 technical and nontechnical elective hours.

The number of semester hours changed to 124 rather abruptly in 1973. Before then, semester hours ranged from 140 to 145. Under the 140 semester-hour curriculum, fewer than 10% of the students graduated in eight or fewer semesters. At least 50% of the students were expected to graduate in eight semesters or less with the 124-hour curriculum. Elective hours increased from 15 to 65, and the number of hours in required courses decreased from 129 to 59 hours. With the increase in elective hours came the development of departmentally approved lists of courses in several categories. Courses in each category were to be selected from these lists. Part of the increase in the number of elective hours reflected the increasing requirements in humanities and social sciences, first included to meet campus general education requirements and later expanded to comply with the new College of Engineering requirements in humanities and social sciences.

A particularly notable change was the development of the computer engineering curriculum. This was first introduced as the electrical engineering/computer science curriculum in 1969 and was known to students and faculty members as the slash curriculum. The slash curriculum was replaced by the computer engineering curriculum in 1973, the same year the number of hours required in all curricula in the department was reduced. Computer Programming (Math. 195) had been added as a required course in 1962.

Shop courses, which had been a traditional part of all engineering curricula, were removed from the electrical engineering curriculum in 1950. Engineering graphics decreased from two courses of eight hours in 1946 to two courses of six hours in 1957 and finally to one course of three hours in 1966. The requirement was removed entirely in 1970.

At the beginning of this period, College Algebra and Trigonometry were part of the curriculum. In 1953, these became requirements for admission and were no longer accepted as part of the program. Military Science was no longer required after 1964, and the requirement for physical education was dropped in 1973.

The laboratory program for the department has always been a strong part of the curriculum. In 1973, the number of required laboratories was dropped to two, and they were no longer attached to corresponding classroom courses. In addition, students were required to take two elective courses. In 1991, the laboratory program includes some 20 elective courses from which to choose.

It was difficult to get faculty members to agree to reduce the curriculum from 145 hours to 124 hours in the early 1970s. All faculty members felt that their courses were too important to be relegated to the elective list rather than required as a core course. To reach an agreement, four fundamental areas were defined: circuits, computers, solid-state devices, and electromagnetics. One required course was allowed in each area. Experience showed that this was too drastic a step. Gradually, required courses were added in linear systems, electronic circuits, and transmission lines (in the electrical engineering but not the computer engineering curriculum), and in 1979, the number of hours increased to 128.

Beginning in 1989, students were given more guidance in choosing their free and technical electives. Thus, the 1991 electrical engineering curriculum suggests, but does not require, a second course in composition, a course on effective speaking, and technical courses on thermodynamics, probabilistic methods, electromechanics, atomic physics and quantum theory, advanced calculus, linear algebra, and numerical methods. In May 1989, the University Senate passed general education requirements that made a second course in composition and the equivalent of three semesters of a foreign language mandatory.

The curriculum will continue to change with advances in technology and societal pressures. In 1991, the department offers more than 100 courses in the following fields of specialization: bioengineering and acoustics, communications, computer systems, computer vision and robotics, decision and control, digital image and signal processing, electromagnetic fields, electro-optics, lasers and plasmas, power and energy, remote sensing and propagation, and semiconductor materials, physics, and devices. The engineer of the future must clearly be prepared for a career of lifelong learning.

Solid-State Instructional Laboratory

In the early 1960s, a fundamental change in the department's policy on teaching electronics was made. Before that time, emphasis was almost entirely on vacuum tube circuits, with little coverage of the physics of the devices. The change was to teach solid-state device circuits. At that time, all engineering students were required to take a three-course sequence of M.E. 202, Phycs. 383, and Met.E. 384, and the device physics were to be covered, in a rather perfunctory manner, in the last course of the sequence. Electronics in the Department of Electrical Engineering was still circuit oriented but with transistors as the active elements rather than vacuum tubes.

In 1965, Chih-Teng Sah received an NSF grant of approximately \$54,000 to purchase equipment for a laboratory to accompany lectures specifically on semiconductor materials and solid-state devices. The experiments were heavily biased toward measurements backing up theory and covered such subjects as Hall effect, lifetime measurement, optical properties of germanium, resistivity measurements, oxidation, and diffusion. One experiment was devoted to device fabrication in which the students made alloyed tunnel diodes. The laboratory experiments were developed by Benjamin G. Streetman, Robert Pierret, George E. Anner, Frank Hielscher, and Leo Yao.



Students enrolled in E.C.E. 344 make transistors. They must clean the wafer's surface with acids and solvents because device geometries are comparable to the size of a dust particle.



Students must test the devices and the theories behind the processes used to create them.

The laboratory course was first offered in 1966–67, was equipped to handle a maximum of 30 students per academic year, and was offered to graduate students only. In late 1968, Texas Instruments Incorporated donated some equipment that was essential for making diffused planar devices. The first diffused diodes made in the laboratory were of the mesa type. Photolithography was not used; the diode mesas were masked for etching with wax dots. The course originally was taught jointly by Sah, Streetman, and Anner.

In the years between 1968 and 1972, Anner gradually took over direction of the laboratory and concentrated on obtaining equipment from industry to upgrade photolithographic facilities. At that time, the semiconductor industry was changing its production lines to handle 3-in. rather than 2-in. wafers, so the laboratory actively solicited gifts of mask aligners and related equipment. Industry also donated large quantities of the 2-in. silicon wafers. These were diced into approximately 2 cm × 2 cm pieces so that each student would have a “wafer” for fabricating. Many semiconductor companies made contributions to the new laboratory, including Texas Instruments, Motorola, Delco, and Harris, but National Semiconductor was the kingpin in helping the laboratory convert to device processing.

The first devices made in the laboratory by planar processing were diodes fabricated by Raymond Bregar in 1971–72. No photomasks were available, so he made masters

by pasting black circles on ruled mylar sheets, which were then photoreduced onto glass plates that fit mask aligners. This work was done as a special project using the laboratory facilities outside of scheduled class sessions, a mechanism that became widely used later. Bregar was the first undergraduate to go from the course directly into industry when he joined National Semiconductor in Danbury, Connecticut. He was followed by many graduates from the course, who strengthened the link between equipment and materials donated by industry to the laboratory.

By 1972–73, the course had received the designation E.E. 344, and all of the experiments in the laboratory were devoted to fabricating bipolar and MOS devices and testing their characteristics. No integrated circuits (ICs) were made because there was insufficient lab time to allow for isolation diffusions, and wafers with epitaxial layers were more difficult to come by. Also, students would prefer to make some simple devices that worked rather than ICs that did not. At that time, the course was handling 70 students per year, and students did all the fabricating and testing procedures on their wafers.

By 1982, the course was enrolling 170 students per year, including summer session. The laboratory occupied 1,680 sq ft on the first floor, west wing of the Electrical Engineering Building. General laboratory conditions were poor; there was no air filtering and no temperature or humidity controls other than those afforded by the usual building utilities. Visitors, on entering the lab and seeing diffusion furnaces, fume hoods, gas cylinders, and a dark room, often asked, “Is this an electrical engineering lab?” One visiting processing engineer from industry was aghast when he saw that students were not working in a clean room. He had to be shown a large geometry device under test to prove that it worked. An interesting sidelight is that National Semiconductor donated its masks for making 2N2222 bipolar transistors. This seemed singularly appropriate, because the 3.5 ml stripe had the form of the university’s Block I.

In 1970, Anner introduced a laboratory course on the fabrication of thick and thin film, or hybrid, circuits to satisfy certain needs of our students going into the semiconductor industry. This course was designated E.E. 346 and was located originally just south of the E.E. 344 facility in a room of roughly 900 sq ft. Much of the special equipment required

*ECE students
prepare to
evaporate
aluminum onto
their wafers with
a high-vacuum
system, which
reduces the air
pressure by
nine orders of
magnitude.*



for the thick film work was made locally or donated by industry. The two initial vacuum systems were based on commercial equipment.

During the next few years, additional equipment was donated by industry, especially mask aligners and wafer testing equipment. E.E. 344 expanded into the E.E. 346 area, and the E.E. 346 facility was moved across the hall. The informal charter for the laboratories held that their primary function was to serve the two named courses, but in addition, qualified students with special projects or master's thesis work not supported by research projects were given access to the facilities outside of scheduled class sessions. Access also was given to graduate students from sponsored research projects whose home laboratories lacked some of the facilities available in E.E. 344 and 346.

Related changes were being made also in other electronics courses. By 1966, the first electronics course in the department, E.E. 340, was converted from circuits to solid-state materials and devices, and the second course was devoted to solid-state device circuits. As an adjunct to E.E.

344, a new course E.E. 345, Bipolar Device Engineering, was added in 1975. Several other related courses, not directly connected to the laboratory, were also added covering pulse and digital circuits, large-scale integrated MOS circuits, physical electronics, and quantum electronics for engineers.

By 1980, so much additional donated equipment was on hand that was of better grade than the equipment used in E.E. 344 that tentative plans for another laboratory, Fab II, were being made. The department head, George W. Swenson, Jr., made a commitment in 1980 to move forward on Fab II by hiring John S. Hughes, a research engineer, to handle details of this new facility. This was to augment, rather than supplant, the existing laboratory, and its charter called for facilities for: individual undergraduate projects, whose numbers seemed to be rising; masters' theses, also anticipated to increase in numbers; PhD and staff research; and a do-it-yourself service center of equipment. Note that the two named courses were not included. The equipment was to be much better than in Fab I, with ability to handle 3-in. and 4-in. wafers, and the laboratory proper was to be built in accordance with commercial standards, with class 1000 clean air at a minimum and with proper temperature and humidity controls. Also, a pure water system was to be included. Planning proceeded very slowly. Where was the facility to be located? How was it to be funded? Initially the location was chosen as the west side of the basement in the Electrical Engineering Building.

Things came to a head in October 1980, when IBM Corp. donated such a large ion implanter that provisions for its location had to be made immediately. In December 1980, it was installed in room 40 of the Electrical Engineering Building, on the west side of the basement floor. It became clear that the west side of the basement was too small to contain the entire proposed facility, so design plans were prepared to use a major portion of the center section of the basement. With Anner's approaching retirement, responsibility for designing the laboratory was shifted to John S. Hughes and Arno H. Schriefer, Jr., senior research engineer. Direction of E.E. 344 was passed to James J. Coleman and of E.E. 346 to Morris Berg of the Department of Ceramic Engineering in 1982. MOSTEK was helpful in designing the laboratory, and construction began in April 1982. In that same time span, United Technologies Company donated \$500,000, part to aid in construction and the rest to go for upkeep.

In 1983, the decision was made at the departmental level to take over the Fab II facility for the newly formed Microelectronics Laboratory, especially for holding the new e-beam apparatus, until a new building for the laboratory was completed. By 1991, equipment was gradually transferred from Fab II to the new facility located near the Beckman Institute,

and work was underway to move the E.E. 344 laboratory to Fab II. The space of the original Fab I was released to other uses, and E.E. 346 was no longer in the electrical engineering curriculum, having been taken over by the Department of Materials Science and Engineering.

A Short History of Illumination Engineering

The illumination engineering program was the brainchild of Professor John Otto Kraehenbuehl. Beginning in the 1930s, he developed and taught two courses; one taught the design of lighting systems for building interiors and the other the design of wiring systems to supply electricity to the lights and motors within buildings.

At that time, nearly all of the electric light sources were incandescent lamps. These were tungsten filament descendants of the carbon filament lamps developed by Thomas Edison in 1875. Other available light sources in the 1930s, used for specific purposes, were: the carbon arc lamp used for theatrical spot lighting, the mercury vapor discharge lamp used for street lighting, and the Cooper Hewitt mercury vapor lamp used for industrial lighting. At the New York World's Fair in 1939, the fluorescent lamp was unveiled for public view.

In 1945, Kraehenbuehl designed a curriculum for a program in illumination engineering. The first course in the program was Illumination and Wiring Design, a three-hour course that combined and strengthened the two original courses offered in the 1930s.

During the period following World War II, most of the students majored in electronics, a slightly smaller group majored in power, and a smaller group, about 20 to 30 students per year, chose to major in illumination. The Massachusetts Institute of Technology, University of Michigan, and Case Institute of Technology were the only other universities in the United States offering work in illumination, and they only offered two or three courses in the field. None covered the range of material in Kraehenbuehl's curriculum.

As evidence of the program's success, the first graduates were able to compete successfully in industry with engineers who had been working in the illumination field for many years. Kraehenbuehl tracked the graduates and found that, five years after graduation, illumination majors were earning 50% to 100% more than their classmates with power or electronics majors.

The demise of the illumination program came in the early 1950s. The College of Engineering wanted a uniform program in all departments for the first two years so that students would not have to declare an area of specialization until the sophomore year was completed. The illumination course (E.E. 120) was an impediment to progress, so the committee decided to remove it from the list of requirements. With no input during the freshman and sophomore years and Kraehenbuehl's retirement, enrollment in the program dropped steadily. After students had graduated in 1956, the program was no longer offered. Since its inception, some 130 students majored in illumination engineering. It was also the major chosen by the first few women earning degrees in electrical engineering.

Knight and Fett Textbook

The circuit analysis book used in the department in the mid- and late 1940s was *Introduction to Circuit Analysis* by Abner R. Knight and Gilbert H. Fett. Although generally a popular book, it was noted for its difficult problems. The students were said to have stated that it contained four types of problems: those that only the smartest students could solve; those that only Knight and Fett could solve; those that only God and Fett could solve; and those that only Fett could solve.

Establishment of the Department's Alumni Association

In the last months of 1966, several alumni of the Department of Electrical Engineering discussed with Wendell E. Miller, associate head of the department, and Marcia Peterman, the departmental office supervisor, the possibility of organizing an Electrical Engineering Alumni Association. They decided that an organization was needed to help the alumni keep in touch with one another, with the faculty and staff, and with the activities of the department and the university. It would also serve to strengthen ties between the department and industry.

In April 1967, a letter, officer ballot, and other information were sent to 6,800 alumni announcing the formation of the Electrical Engineering Alumni Association as the 20th constituent organization of the University of Illinois Alumni Association. Replies were received from approximately 800 graduates, resulting in 447 new members of the University Alumni Association. An organizational meeting was held on June 28, 1967, in the Faculty Lounge of the Electrical Engineering Building. The first officers and board members were installed after a count of the mailed ballots.

The new association adopted E²A² as its logo and immediately became active. During the first year, regional meetings of E²A² were held at Wescon in San Francisco, California, National Electronics Conference in Chicago, Illinois, IEEE in New York, New York, and Urbana-Champaign during a football weekend. Three E²A² newsletters were also mailed.

In the years that followed, regional meetings continued to be held and many newsletters published. E²A² also initiated a program to honor alumni who had distinguished themselves in their professions by presenting them with a Distinguished Alumnus Award. These awards are presented annually at the E²A² awards banquet, which is held at Urbana-Champaign each fall during a football weekend. In 1984, the department's name was changed to the Department of Electrical and Computer Engineering. The name of the department's alumni organization was changed accordingly, and the present logo E²CA² was adopted.

In 1991, E²CA² has 5,510 members and is an active organization with four standing committees: Membership and Student Affairs, Scholarship, Legislative, and Alumni Events. Board meetings are held during the Chicago spring meeting of the American Power Conference and in Urbana-Champaign during the fall awards banquet. The newsletter has become a distinguished publication and is mailed to alumni twice a year. E²CA² gatherings are held at opportune times in various parts of the country, and one board member each year serves as a representative to the University Alumni Association. At the E²CA² board meeting on September 14, 1990, a University Alumni Association representative complimented E²CA² as one of the best of its 45 constituent groups.

Marcia Peterman

When Marcia Hopperstad, newly graduated from Rockford Business College and School of Music and only 20 years old, came to Urbana-Champaign in 1930 to be interviewed by Ellery B. Paine for a secretarial job in electrical engineering, who could have foretold that this was the



Marcia Peterman in 1970.

beginning of an association with the department that was to last for more than 50 years?

She was the first and, for some time, the only secretary in the department. She began as a clerk stenographer and advanced through various titles to office supervisor, overseeing an office staff that ministered to the secretarial needs of more than 100 faculty members. During this period, she also served as secretary and then adviser to Paine and three other department heads: William L. Everitt, 1944–49; John D. Ryder, 1949–54 and Edward C. Jordan, 1954–79. She provided exemplary help and guidance to generations of students and alumni. Although she retired officially in 1977, she was reappointed on a part-time basis as staff associate to continue her work with the alumni of the department. She took special classes in languages, office management, and business law throughout her years at the university.

In 1975, a special section of the *E²A² News*, "Hats Off to Marcia," saluted some of Marcia Peterman's accomplishments. In 1977, at the time of her first retirement, she was presented with a book of some 200 letters from staff, faculty, and alumni who had come to know her over the years and whose lives had been touched by her helpfulness.

In 1945, she married C. E. Peterman. He died in 1963. She married Leo Corby in 1983, just 1 1/2 years before she died on September 30, 1984.

Peterman received several awards and honors. These included the HKN Award in 1967, the Appreciation Award from the University of Illinois Alumni Association in 1972, the AIEE Honor Award in 1975, and the Loyalty Award from the Alumni Association.

She made several trips abroad in connection with the department. She went to England, Norway, Sweden, Denmark, and France in 1968 and to Sendai, Japan, in 1971, where she attended the 1971 International Symposium on Antennas and Propagation. In 1976, she traveled to Rio de Janeiro, Brazil. She often visited Illinois alumni during these world travels.

The following selections and excerpts from some of the 200 letters presented to her at the time of her first retirement will serve to hold Peterman in the memories of those who knew her and to help those who did not know her to understand why she will not be forgotten.

During World War II, at least according to the movies, a method of challenging possible impostors was to ask them who Babe Ruth or some such famous person was. A real test to confirm that a person is truly a U. of I. electrical engineering alumnus is the answer to the question: Who is Marcia Peterman? Although the actual responses to the question might vary somewhat, I'm sure that the true alumni would have satisfactory answers, ranging from 'she's the one with all the important answers around the E.E. Department' to 'of course, she's the one who really keeps things organized.' Maybe one of the best answers would be 'she's the one to whom AC and DC mean Always Concerned and Double Concerned.' I say this because I know that thousands of E.E. students have benefitted from the personal attention you gave to their academic problems and later to their employment prospects.

There is nothing a new department head needs more than the guidance of a good secretary. I found a superlative one in Marcia, the 'creme de la creme.' She guided me in who was who, what to do, and when to do it. She knew everyone and everything about the University, the alumni, and the cities of Urbana and Champaign. But most of all she demonstrated and has continued to show a love for, and loyalty to, the Department which is unique. More than any other person in the last three decades she has represented Electrical Engineering at the U. of I. to students, faculty, and alumni.

Marcia is the best Electrical Engineering Department Head I have known. In fact, she runs the best department.

It's difficult to express adequately in words the quality you added to our happy years at Illinois. For me, however, it seems that it is simply the following: somehow you managed to make each one of us believe that we were special . . . kind of privy to your affection and interest.

I can recall more than one occasion when I felt like a 'lost soul' and needed to be pointed in the right direction. The general consensus seemed to be, 'If you don't know, ask Marcia.' No matter how busy you were, you always took time out to help keep us students from going astray. Believe me, for that I am truly grateful.

All told, it seems to me that Marcia has been the real binding agent that has made our EE Department a fraternity of friends on top of its high standing as an educational institution.

Campus Unrest, 1967-70

The atmosphere on campuses across the nation was one of growing unrest during the years 1967-70. Protest during these years was largely attributable to resentment against the unpopular war in Vietnam and military action in Cambodia. The explosion point was reached on May 4, 1970, when four students at Kent State University were killed by National Guardsmen. On the local scene, the shooting death of a black employee of a campus bookstore added fuel to the fire. A student strike committee, following the lead of students at several other universities, called for closing down the university as a form of protest.

At the University of Illinois, the response of the administration is indicated by the attached *Statement of Chancellors, Deans and Directors*, dated May 8, 1970.

STATEMENT OF CHANCELLORS, DEANS AND DIRECTORS

This University, as a University, cannot speak with one voice, for it is many voices. Therein lies its strength. The undersigned, who were present at a meeting on the morning of May 8, have agreed on the following statement as an expression of their individual views on the current crisis.

The universities of these United States face their greatest crisis in the life of this republic. That the causes of the crisis lie largely outside the universities is of little moment if those causes make impossible the proper functioning of the educational process. Universities across the land are in turmoil today not solely because of the actions of a relatively few violent individuals—they can and will be contained—but because thousands of moderate, intelligent, idealistic students are as appalled by violence and injustice as we are. Many of our students are losing faith in the established order and have moved in extraordinary ways to insist that we re-order our priorities in this nation. On May 6, Secretary of the Interior, Walter I. Hickel, wrote a letter to President Nixon charging that the government has failed its youth. He said: "My point is, if we read history, it clearly shows that youth in its protest must be heard." A nation that succeeds in alienating large segments of the best of the next generation is heading for disaster. The tragedy is that there need be no tragedy. We, as leaders of the academic community, do share the best aspirations of our students. We, too, believe the Indo-China war must be brought to an early end before it tears this great nation apart. We, too, deplore the tragic deaths at Kent State and in this community. We share concern over injustice and racial prejudice wherever it exists in society. We pledge ourselves to work to attempt to better achieve our common aspirations.

We do not believe that the existing system has failed; indeed, we have a deep faith in its capacity for flexible change and progressive evolution. We do not believe the University has failed, but we see its weaknesses and pledge to do our best to correct them.

We urge all members of the academic community to rededicate their commitment to orderly inquiry and rational discourse. We urge that no attempt be made to coerce those who wish to attend class, and that no efforts be made to impede University operations. We reaffirm our obligation to teach all those who wish to be taught.

We ask all to join with us in doing everything possible to keep this campus open so that the educational process can go on at the same time that we seek a new spirit of communication and cooperation. We agree with the editorial affirmation in the *New York Times* for May 7: "The best way that the academic community can demonstrate that there are civilized roads to a more responsible society is to stay open and concentrate on the effective harnessing of ideas to action. The irrationality of escapism is no answer. It merely leaves the arena to the Philistines."

The above statement was signed by nearly all eighteen chancellors, deans, and directors on the Urbana-Champaign campus.

The course of action proposed for the Department of Electrical Engineering is summarized in the letter of May 11, 1970, written by the department head.

Electrical Engineering Department
May 11, 1970

To: All Members of the Electrical Engineering Faculty
From: E. C. Jordan

The attached statement by Chancellors, Deans and Directors was considered at length at a meeting of Department Heads on the afternoon of May 9, and was signed by nearly all of the some ninety persons there. At the suggestion of the department heads, an additional paragraph is to be written by the Chancellor and appended to the statement urging faculty at the college, departmental or individual classroom level to encourage discussion of the issues by and with the students either in regular class periods or in special seminars.

It is important to recognize first of all, and to convey to your students what "closing down" the University means. It means that every building, office, teaching laboratory, research laboratory, library, dormitory, etc. will be closed up tight with no access to the campus. It means (probably) that all salaries will cease for the period of close down, and all

hourly workers will be laid off. Most of all, for those truly interested in voicing concern, it means the loss of their forum for dissent.

In view of these facts, and after consultations with as many members of the departmental Policy and Planning committee and Advisory committee as were available at short notice I propose the following course of action for our department.

It is expected that all regularly scheduled classes will be met to the extent feasible. Of course, if no students show up it is a different matter, but as long as even one student shows up for class there should be someone there to teach him. Under these circumstances, and indeed if less than half your class is present, it might be advisable to dispense with your regular lecture and devote the time to a question and answer period on the subject matter. If the teacher and the students feel that there is more to be gained from a general discussion of the war and the state of the nation than from regular class topics, they should feel free to carry on such discussion, bearing in mind that no instructor should try to impose his ideas or opinions on the students. Perhaps the students will be interested to learn how a respected professor views some of these problems. If any instructor intends not to meet his class and is unable or unwilling to secure a substitute, he is requested to confer first with me. Please do not fail to do this.

There is a concern on the part of some of the students that instructors may use exams to coerce them to attend class. For this reason it is required that after today exams not be scheduled until return to something like normalcy. Please follow a policy of no coercion—either way, and please observe restraint in your contacts with the students.

As will have been gathered from the above, the intention is that the University shall remain open for business, although not necessarily business as usual. No matter how strongly exercised we may be about Vietnam, Cambodia, Kent State and Mr. Houits (and I feel strongly about all of them) we have an obligation to meet with our students, and to teach those who wish to be taught. It is, after all, our job to do so.

These statements give the picture of campus unrest as seen by the university administration. As pointed out in the statement of the chancellors, deans, and directors, the university cannot speak with one voice. Another voice that should be heard is that of Subcommittee A of the University Disciplinary Committee. Subcommittee A was a campus committee established in 1967 to attempt to resolve issues and adjudicate cases arising from disruptive tactics. The subcommittee had the difficult and unenviable task of investigating and making a complete report to the administration on every incident involving disruptive tactics, particularly those accompanied by a destruction of public property, invasion of private offices, or disruption of university operations.

From the files and recollections of members of Subcommittee A is the following account of the circumstances surrounding an attack on the Electrical Engineering Building. It was one unfortunate decision that ultimately involved the Department of Electrical Engineering that day.

In general, many engineering students are more concerned, at least in the early stages of their careers, with pursuing their education than with supporting social causes through demonstrations. It is unlikely that the engineering campus and the Department of Electrical Engineering would have been affected by the turmoil except for the decision by the Engineering Placement Office to schedule the recruiters for General Electric Company somewhere in engineering rather than in a central campus location, such as the Illini Union. Because of the company's heavy involvement with military production, General Electric recruiters were a special target of antiwar demonstrators.

At 11:15 a.m. on March 2, 1970, the chairman of Subcommittee A received a telephone call from the chief of FBI personnel assigned to the UIUC campus. About 2,000 students were moving north on Third Street, and it appeared that they were headed for the Electrical Engineering Building. Their objective was to get to the recruiters from the General Electric Company, who were conducting interviews in the penthouse of the Electrical Engineering Building.

Classes were dismissed quickly, and everyone was told to leave the building. All outside doors were locked, and the elevator was run to the third floor and its door blocked from closing. The Machine Shop crew guarded the rear entrance and fire escape with heavy wrenches and tools. Two electrical engineering faculty members and two associate deans stayed with the building. Classroom chairs were stacked on the stairs to block the way to the upper floors. It took the demonstrators about 30 minutes to gain access to the building; they used a 2 x 8 plank from a street barricade to smash the front entrance of the south side. As they stormed inside, they soon found that their access to the upper floors and to the recruiters was blocked. After a period of frustration, they decided to move on. They left behind a considerably damaged building with more than 50 outside windows and many inside office door windows broken.

On the UIUC campus, as on most campuses throughout the nation, members of the faculty were deeply divided by the events of this three-year period and by the handling of the antiwar protestors. In retrospect, the UIUC was one of the few major universities that was not closed down during this turbulent period.

Biological Computer Laboratory

About 1985, Robert Noyce, co-inventor of the integrated circuit and chairman of the board of INTEL, wrote an article in the *IEEE Spectrum* advocating that the electrical engineer should study biological systems to help find a way of building more powerful computer systems. Twenty-seven years earlier at the University of Illinois, the Biological Computer Laboratory had been founded by Heinz Von Foerster for this purpose. The following account provides a tantalizing glimpse of the history of the laboratory.

In the years after World War II, the notion and the profession of electrical engineering underwent a transformation and expansion. New concepts, thoughts, ideas, inventions, and fields of study were born within the profession or were brought in from other fields of study and absorbed as part of a new self. Who would have thought that a theory of information would emerge from an engineering laboratory; that an electrical hypothesis, that is, the hypothesis that all our perceptual, intellectual, and emotional experiences are states of the electrical activity in the central nervous system, would dominate the neural sciences; that the abstract notion of computation would find its manifestation in electrical devices that, by integrating new insights from semiconductor physics, evolved into machines of such complexity that one could be tempted to make comparison of these machines with their creators? One spoke and even speaks today of electronic brains; one spoke of mentality in machines and still asks: "Can machines think?"

It is clear that, in this context, engineering and particularly electrical engineering with its large spectrum of applicability, established close ties with other disciplines whose list would run from astronomy to zoology.

One point on this large, interdisciplinary interface was the Biological Computer Laboratory (BCL), whose aim was to understand the process of cognition and to demonstrate this understanding with the appropriate software and hardware. Concepts that enjoy popularity in the 1990s—connectionism and parallelism in computer architecture or, in mathematics, iteration and recursion with their fascinating contingencies for the behavior of systems that may go into multiple stabilities or into chaos—were central objects of study 30 years ago at BCL. Most likely, the first parallel computers were built and exhibited there.

In 1960, W. Ross Ashby, a leading British neuroscientist and author of the two classics, *Introduction to Cybernetics* (1956) and *Design for a Brain* (1960), indicated that he would be ready to leave his post as director of the Burden Neurological Institute in Bristol, England, and join the University of Illinois to work in the Department of Electrical Engineering with the people of BCL. This was good news, and the provost was informed at once. He appreciated the good news, and then he asked: "Tell me, what is Dr. Ashby's background?" When he learned that Ashby is a psychiatrist, he came back with his second question: "Tell me, is it already that bad in the EE Department?"

It was not bad at all. After 10 years of service with the University of Illinois, Ashby retired and returned to England. In the first letter he sent back, which was the last letter received from him before he died, he wrote: "... thank you for the miraculous years of the Sixties. Yours affectionately, Ross."

BCL left behind a rich legacy. In its day, it was one of the few educational institutions teaching cybernetics. Between 1958 and 1975, operating under 25 grants, the laboratory produced 256 articles and books, 14 master's theses, and 28 doctoral dissertations. The topics covered epistemology, logic, neurophysiology, theory of computation, electronic music, and automated instruction.

A Matter of Units

In the early days of teaching electric circuits and electromagnetics, the question of which system of units to use was one facing the instructor and the textbook writer. At most schools, as at the University of Illinois, the Department of Electrical Engineering grew out of the Department of Physics. The tendency was to use the systems of units used in beginning physics courses. These systems included electrostatic units (ESU), centimeter-gram-second units (CGS), and Gaussian, which is a combination of ESU and CGS. On the other hand, in the field of electric circuits using volts, amperes, and ohms, the meter-kilogram-second (MKS) is the logical choice, with only the question of rationalization (where to introduce the factor 4π) left for debate. The unfortunate beginning student was faced with the difficult and confusing task of learning two or three systems of units while trying to understand the basic theory.

Fortunately, at the University of Illinois, the Department of Physics was in the College of Engineering (a rather unusual arrangement), so the question of which system to use was resolved more easily than at other schools where physics was in liberal arts. When members of the Department of Physics insisted on continuing to teach freshman physics in the old familiar systems, the head of electrical engineering, John D. Ryder, proposed that the Department of Electrical Engineering should be allowed to teach its own physics courses using the MKS system. The result was an immediate decision by the head of physics that, henceforth, all beginning physics courses would use the MKS systems.

Although the University of Illinois became one of the first schools to use the MKS system in the beginning physics courses, it did not follow that advanced courses in physics and mathematics would change their unit systems. Indeed, many advanced theory courses are taught with a total disregard for the numerical factors that depend on the system of units used. This point was brought home to a young electrical engineering faculty member who audited an advanced course in electromagnetic theory. He said it did not bother him too much that the professor put the dielectric constant $\epsilon_0=1$; nor did it worry him to put the permeability of free space $\mu_0=1$; and because the velocity of light is given by $c=1/\mu_0\epsilon_0$ it even seemed reasonable to put $c=1$. But when the professor put the rationalization factor 4π equal to 1, the young faculty member felt it was really a bit much.

Eta Kappa Nu

In 1904, six years after the establishment of electrical engineering as a separate department in the University of Illinois College of Engineering, a student, Maurice L. Carr, got the idea for a collegiate society for electrical engineering students. He interested four other students: Charles E. Armstrong, Edmund Wheeler, Milton K. Akers, and Ralph E. Bowser. They, in turn, interested five more: Fred D. Smith, Frank R. Winders, William T. Burnett, Carl K. Brydges, and Hibbard S. Greene. On October 28, 1904, Otto Wiemer was the first person initiated into Eta Kappa Nu.

The objectives of this new organization were "... for closer cooperation among students and others in the profession who by their attainments in college or in practice manifest exceptional interest and marked ability in electrical engineering." High achievement in scholarship was not the sole criteria for membership. Instead, an appraisal by members of future contributions to the field was considered more important.



The memorial boulder and plaque that commemorate the 25th anniversary of HKN are located near the east entrance of Everitt Laboratory. Alpha chapter was founded at UIUC in 1904.

The principles of Eta Kappa Nu began to spread. Beta chapter was formed in 1906 at Purdue University in Indiana. Ten other chapters were established over the next 10 years at colleges and universities.

By 1913, Eta Kappa Nu had become a national organization, and it was decided that it should be an electrical engineering honor society. Achievements of certain grade point averages were established for initiation and membership. Later, the requirements for membership were refined to being the upper quarter of the junior class or upper third of the senior class. Eta Kappa Nu became a member of the Association of College Honor Societies.

Founding members wanted Eta Kappa Nu to be more than a college society. They realized the organization could be important to an engineer working in the profession. Seeking to continue a relationship with the alumni, Carr began a publication named *The Electrical Field* in 1906. *The Electrical Field* evolved into the *Bridge of Eta Kappa Nu*, which covers subjects of interest to both students and alumni. In 1920, the *Bridge* became a quarterly publication.

When the 25th anniversary of HKN was celebrated in 1929, 22 college chapters and nine alumni chapters were active. To commemorate the date, a memorial boulder and plaque were placed outside the Electrical Engineering Building at the University of Illinois, where alpha chapter was founded.

The 50th anniversary convention celebrating the founding of Eta Kappa Nu was held at Urbana on October 15 and 16, 1954. By this half-century mark, 56 college chapters and 12 alumni chapters had been formed. Most sent delegates, and there were many representatives from industry and other universities. On the occasion of the 50th anniversary, Jesse E. Hobson, director of Stanford Research Institute and president of the National Executive Council of Eta Kappa Nu, wrote: "In the fifty years since the first informal meetings were held on the Urbana campus, Eta Kappa Nu has achieved high rank

as the honor society of one of our country's most critically important professions. It is a thread that binds together more than twenty thousand living electrical engineers and we can assure future generations that membership in Eta Kappa Nu imparts a privileged sense of brotherhood."

As the post-World War II high-tech revolution was increasing in momentum, the need for more engineers was becoming critical if the United States was to keep its status as a world power. In 1953, as a way of commemorating its 50th anniversary, Eta Kappa Nu produced a career guidance film to interest high school students in engineering careers.

The 50th anniversary movie committee was formed, with Dean William L. Everitt, College of Engineering, University of Illinois, as chair. Committee members John E. Farley, Alpha '48, president of the Chicago Alumni HKN Chapter, and Roger Wilkinson of the New York Alumni HKN Chapter wrote the script. Everitt provided valuable guidance and support and enlisted the aid of the university's motion picture and television unit to produce the movie "Engineering—A Career for Tomorrow." The out-of-pocket expenses were financed by funds raised by Eta Kappa Nu. Daniel F. Hang, also a member of the committee, engineering students, and others from the Urbana-Champaign campus appeared in the film. Scenes were filmed also in the Chicago area at Illinois Bell Telephone and Commonwealth Edison.

In 1955, as the movie committee completed its task, the Chicago Alumni Chapter formed a committee to distribute the film. This became a national HKN committee chaired by John E. Farley, with University of Illinois alumni Harold Slocum and Richard Phillips serving for many years. More than 150 copies of the film were placed in libraries in universities, high schools, and companies. Many HKN chapters as well as industry sent people to showings of the film in high schools to answer students' questions.

This project was so successful that, in 1967, work was begun on a second film entitled "Engineering—A Challenge of the Future," which was co-sponsored with the Institute of Electrical and Electronics Engineers. Funds were raised from industry by the Movie Committee, and Everitt served on the new movie advisory board. Meetings were held in Chicago and Urbana, and many people from the College of Engineering assisted in planning the new movie. More than 450 copies of this second film were sold. One important aspect of both of these films was the fact that the script covered the whole field of engineering, not just electrical engineering. Thus, Eta Kappa Nu provided a service to the engineering profession.

In 1958, Alton B. Zerby retired; he had served HKN as executive secretary for 24 years. Paul K. Hudson of the Department of Electrical Engineering was appointed executive secretary. The headquarters of Eta Kappa Nu moved from Dillsburg, Pennsylvania, to Urbana, Illinois. Hudson served with distinction for 30 years until 1988. In 1963, Hudson became editor of the *Bridge*. Hudson expanded the scope of the *Bridge* and "raised the stature of Eta Kappa Nu and the *Bridge* to new heights." Upon his death in 1988, he left many articles for future issues, which were published. In 1991, J. Robert Betten, University of Missouri at Rolla, is executive secretary and editor.

In 1979, Eta Kappa Nu celebrated its 75th anniversary in Urbana. William T. Burnett, the only living founder, was an honored guest. Alpha chapter initiated 70 new members. In 1991, HKN has over 180 college chapters in the United States and chapters in Great Britain, Argentina, and other countries.

To recognize achievement and scholarship in the field of electrical engineering, Eta Kappa Nu gives the Outstanding Electrical Engineering Senior Award to a student in the last year of undergraduate work. In addition, each year HKN gives the Outstanding Young Electrical Engineer Award for achievement within 10 years after receiving the bachelor's degree. Several other awards are presented annually, including Outstanding Chapter and Outstanding Teacher.

In keeping with the objectives of the founders of Eta Kappa Nu, it is the services that the organization has provided to students and the engineering profession and the encouragement and recognition of scholarship that have kept Eta Kappa Nu a vital and growing entity for 85 years.

Appendix I. Department Heads

Years as head of dept.	Name	Other positions in college	Year of death
1891–1892	Stratton, Samuel W.	professor from 1885–1891	1931
1892–1895	electrical engineering administrated by the Department of Physics		
1895–1896	Swenson, Bernard V.		*
1896–1898	electrical engineering administrated by the Department of Physics		
1898–1899	Esty, William	professor from 1893–1901	*
1899–1901	Aldrich, William S.		*
1901–1909	Brooks, Morgan		1947
1909–1913	Berg, Ernest J.		1941
1913–1944	Paine, Ellery B.	professor from 1907–1944	1976
1944–1949	Everitt, William L.	professor from 1944–1968, dean from 1949–1968	1986
1949–1954	Ryder, John D.		
1954–1979	Jordan, Edward C.	professor from 1945–1979	1991
1979–1985	Swenson, George W., Jr.	professor from 1956–1988	
1985–	Trick, Timothy N.	professor from 1965–	

* deceased, date unknown

Appendix II. Curricula

1910-11 Course in Electrical Engineering Course Required for the Degree of Bachelor of Science in Electrical Engineering

First Year

First Semester	Second Semester
General Engineering Drawing (G.E.D. 1) ¹	Descriptive Geometry (G.E.D. 2)
Trigonometry (Math. 4)	Analytical Geometry (Math. 6)
Advanced Algebra (Math. 2)	French 1, German 3, 5, or 6, English 2, Rhetoric 11, or Spanish 1
French 1, German 1 or 4, English 1, or Spanish 1	Shop Practice (M.E. 41)
Shop Practice (M.E. 41)	Military Drill (Mil. 2)
Military Drill (Mil. 2)	Drill Regulations (Mil. 1)
Gymnasium (Phys. Tr. 1)	Gymnasium (Phys. Tr. 1)
<i>Total</i>	<i>Total</i>
18	19

Second Year

First Semester	Second Semester
Differential Calculus (Math. 7)	Integral Calculus (Math. 9)
Physics Lectures (Phycs. 1)	Physics Lectures (Phycs. 1)
Physics Laboratory (Phycs. 3)	Physics Laboratory (Phycs. 3)
Rhetoric 1	Rhetoric 1
Machine Design and Mechanism (M.E. 24)	Analytical Mechanics (T. & A. M. 7)
Machine Shop (M.E. 42)	Chemistry ² 1b or 1a
Military Drill (Mil. 2)	Military Drill (Mil. 2)
<i>Total</i>	<i>Total</i>
19	18

Third Year

First Semester

Engineering Materials (T. & A. M. 6)	1
Analytical Mechanics (T. & A. M. 8)	2 1/2
Resistance of Materials (T. & A. M. 9)	3 1/2
Dynamo–Electric Machinery (E.E. 3)	3
Electrical Engineering Laboratory (E.E. 22)	2
Electrical and Magnetic Measurements (Phys. 4)	2
Chemistry (2 and 3)	4
<i>Total</i>	18

Second Semester

Hydraulics (T. & A. M. 10)	3
Alternating Currents (E.E. 5)	4
Electrical Engineering Laboratory (E.E. 23)	2
Electrical and Magnetic Measurements (Phys. 4)	2
Surveying (C.E. 10)	2
Mechanical Engineering Laboratory (M.E. 13)	3
Integral Calculus (Math. 9a)	2
<i>Total</i>	18

Fourth Year

First Semester

Seminar (E.E. 13)	1
Advanced Alternating Currents (E.E. 14)	4
Electrical Engineering Laboratory (E.E. 24)	2
Electrical Design (E.E. 32)	2
Thermodynamics (M.E. 15)	3
Principles of Economics (Econ. 2)	2
Steam Engineering (M.E. 23)	2
<i>Total</i>	16

Second Semester

Seminar (E.E.13)	1
Advanced Alternating Currents (E.E. 17)	4
Electrical Engineering Laboratory (E.E. 27)	2
Electrical Design and Power Plants (E.E. 34)	3
Thesis (E.E. 35)	3
Economic Problems (Econ. 16)	2
<i>Total</i>	15

¹The numbers in parentheses refer to courses in the General Description of Courses.

²Students who have had chemistry in the high school equivalent to Chemistry 1b will register in Chemistry 1a.

1940-41 Curriculum in Electrical Engineering
For the Degree of Bachelor of Science in Electrical Engineering

First Year—Common program for freshmen

First Semester	
Chem. 2 or 3—Inorganic Chemistry	3 or 4
G.E.D. 1 or 4—Elements of Drawing	4
Math. 2—Advanced Algebra	3
Math. 4 or 5—Trigonometry	2
Rhet. 1—Rhetoric and Composition	3
Physical Education	1/2
Military Science (for men)	1
Engineering Lecture	0
<i>Total</i>	16 1/2 or 17 1/2

Second Semester	
Chem. 4—Metallic Elements	4
G.E.D. 2—Descriptive Geometry	4
Math. 6a—Analytic Geometry	4
Rhet. 2—Rhetoric and Composition	3
Hygiene	2
Physical Education	1/2
Military Science (for men)	1
Engineering Lecture	0
<i>Total</i>	18 1/2

Second Year

First Semester	
E.E. 14—Wiring and Illumination or approved elective ¹	3 or 4
Math. 7—Differential Calculus	5
M.E. 85 or 87—Pattern and Foundry, or Machine Tool Laboratory, or approved elective ¹	3
Phyics. 1a—General Physics	4
Phyics. 3a—Physics Laboratory	1
Physical Education	1/2
Military Science (for men)	1
<i>Total</i>	17 1/2 or 18 1/2

Second Semester	
E.E. 14—Wiring and Illumination or approved elective ¹	3 or 4
Math. 9—Integral Calculus	3
M.E. 87 or 85—Machine Tool, or Pattern and Foundry Laboratory, or approved elective ¹	3
Phyics. 1b—General Physics	4
Phyics. 3b—Physics Laboratory	1
T.A.M. 1—Analytical Mech. (Statics)	2
Physical Education	1/2
Military Science (for men)	1
<i>Total</i>	17 1/2 or 18 1/2

Third Year

First Semester	
E.E. 25–Introduction to Circuit Analysis	4
E.E. 75–Electrical Engineering Lab.	2
Math. 9a–Integral Calculus	2
M.E. 10–Thermodynamics; or Physcs. 44a– Electrical and Magnetic Measurements	3
T.A.M. 2–Analyt. Mech. (Dynamics)	3
T.A.M. 4–Hydraulics	2
T.A.M. 64–Hydraulics Laboratory	1
<i>Total</i>	17

Second Semester	
E.E. 26–Direct Current Apparatus	3
E.E. 76–Electrical Engineering Lab.	3
E.E. 50–Introduction to Applied Electronics	2
M.E. 10–Thermodynamics or Physcs. 44a– Electrical and Magnetic Measurements	3
T.A.M. 3–Resistance of Materials	3
T.A.M. 63–Resistance of Materials Lab.	1
Approved elective	3
<i>Total</i>	18

Fourth Year

First Semester	
E.E. 35–A.C. Apparatus	4
E.E. 55–Electrical Design ²	2
E.E. 85–Electrical Engineering Lab.	2
E.E. 95–Seminar	1
E.E. 99–Inspection Trip	0
M.E. 3–Steam Engineering	3
M.E. 61–Mechanical Engineering Lab.	2
Nontechnical elective	3 or 4
<i>Total</i>	17 or 18

Second Semester	
E.E. 36–A.C. Apparatus ³	4
E.E. 56–Economics of Electrical Systems	4
E.E. 86–Electrical Engineering Lab. ³	2
E.E. 96–Seminar	1
E.E. 98–Thesis ⁴ or technical elective	3
Approved elective	3 or 4
<i>Total</i>	17 or 18

¹One semester shop laboratory and one semester E.E. 14 required.

²E.E. 51 or 54 may be substituted for E.E. 55

³Six hours from E.E. 48, 52, 54, 58, 59, 84, and 89 may be substituted for E.E. 36 and 86.

⁴Only high-grade students are allowed to take a thesis course.

1950 Curriculum in Electrical Engineering
For the Degree of Bachelor of Science in Electrical Engineering

First Year

First Semester	Second Semester
Chem. 102 or 103—General Chemistry 3 or 4	Chem. 104—Chemistry of the Metallic Elements 4
G.E.D. 101—Elements of Drawing, or G.E.D. 104—Advanced Drawing 4	G.E.D. 102—Descriptive Geometry 4
Math. 112—College Algebra 3	Math. 122—Analytic Geometry 4
Math. 114 or 115—Plane or Advanced Trigonometry 2	Rhet. 102—Rhetoric and Composition 3
Rhet. 101—Rhetoric and Composition 3	Hygiene 2
Engineering Lecture 0	Engineering Lecture 0
Physical Education 1	Physical Education 1
Military (men) 1	Military (men) 1
<i>Total</i> 17 or 18	<i>Total</i> 19

Second Year

First Semester	Second Semester
Econ. 108—Elements of Economics 3	E.E. 126—Electric Circuits and Fields 4
Math. 132—Calculus 5	Math. 142—Calculus 3
Phy. 103—General Physics (Mechanics, Heat, and Sound) 5	Phy. 104—General Physics (Electricity, Magnetism, Light and Modern Physics) 5
Speech 101—Principles of Effective Speaking 3	T.A.M. 154—Analytical Mechanics 4
Physical Education 1	Physical Education 1
Military (men) 1	Military (men) 1
<i>Total</i> 18	<i>Total</i> 18

Third Year—Power Engineering Option and Communication Engineering Option

First Semester	Second Semester
Econ. 248—Personnel Administration 3	E.E. 288—Economic Aspects of Engineering 3
E.E. 320—Circuit Analysis 4	E.E. 322—Circuit Analysis 4
E.E. 321—Circuit Laboratory 1	E.E. 323—Circuit Laboratory 1
Math. 345—Differential Equations and Orthogonal Functions 3	E.E. 334—Electrical Power Apparatus and E.E. 335—Electrical Power Apparatus Laboratory ¹ , or E.E. 351—Networks and Lines ² 4
M.E. 202—Thermodynamics 3	E.E. 340—Electronics 3
T.A.M. 221—Resistance of Materials 3	E.E. 341—Electronics Laboratory 1
T.A.M. 223—Resistance of Materials Laboratory 1	Nontechnical electives ³ 3
<i>Total</i> 18	<i>Total</i> 19

Third Year—Illumination Engineering Option

First Semester	Second Semester
E.E. 260—Fundamentals of Illumination 3	Arch. 217—Architecture and Civilization of the Americas to 1870 ⁴ 2
E.E. 320—Circuit Analysis 4	E.E. 322—Circuit Analysis 4
E.E. 321—Circuit Laboratory 1	E.E. 323—Circuit Laboratory 1
Math. 345—Differential Equations and Orthogonal Functions 3	E.E. 340—Electronics 3
Psych. 100—Introduction to Psychology ⁴ 4	E.E. 341—Electronics Laboratory 1
T.A.M. 221—Resistance of Materials 3	E.E. 361—Elements of Illuminating Engineering Design 4
T.A.M. 223—Resistance of Materials Laboratory 1	Physiol. 101—Mammalian Physiology ⁴ 3
<i>Total</i> 19	<i>Total</i> 18

Fourth Year—Power Engineering Option

First Semester	Second Semester
E.E. 268—Principles of Illumination 2	E.E. 292—Seminar 1
E.E. 290—Seminar 0	E.E. 338—Electrical Power Apparatus 3
E.E. 336—Electrical Power Apparatus 4	E.E. 339—Electrical Power Apparatus Laboratory 1
E.E. 337—Electrical Power Apparatus Laboratory 2	M.E. 203—Power Plant Equipment 3
E.E. 347—Industrial Electronics 4	Technical electives ³ 5
E.E. 378—Fundamentals of Power Transmission 3	Nontechnical electives ³ 3
Nontechnical electives ³ 3	<i>Total</i> 16
<i>Total</i> 18	

Fourth Year—Illumination Engineering Option

First Semester	Second Semester
Arch. 218—Architecture and Civilization of the Americas and Europe since 1870 ⁴ 2	E.E. 292—Seminar 1
E.E. 290—Seminar 0	E.E. 332—Electrical Machinery 3
E.E. 330—Electrical Machinery 3	E.E. 333—Electrical Machinery Laboratory 1
E.E. 331—Electrical Machinery Laboratory 3	E.E. 364—Illumination Design and Economics 4
E.E. 347—Industrial Electronics 4	E.E. 365—Illumination Design Laboratory 1
E.E. 362—Principles of Illuminating Engineering 4	E.E. 366—Illumination Sources 4
E.E. 363—Illumination and Photometry Laboratory 1	Mktg. 373—Sales Management ⁴ 2
Mktg. 272—Industrial Selling 3	<i>Total</i> 16
<i>Total</i> 18	

Fourth Year—Communication Engineering Option

First Semester	Second Semester
E.E. 290—Seminar 0	E.E. 292—Seminar 1
E.E. 330—Electrical Machinery 3	E.E. 332—Electrical Machinery 3
E.E. 331—Electrical Machinery Laboratory 1	E.E. 333—Electrical Machinery Laboratory 1
E.E. 349—Electron Tube Circuits 5	E.E. 355—Fields and Waves 4
E.E. 353—Radio Circuits 4	Technical electives ³ 3
Technical electives ³ 3	Nontechnical electives ³ 6
<i>Total</i> 16	<i>Total</i> 18

¹E.E. 334 and 335 to be omitted by students in the communication engineering option.

²E.E. 351 to be omitted by students in the power engineering option.

³All electives to be chosen from the lists approved by the head of the department.

⁴These courses will be waived for students in advanced military, in which case one hour of approved elective will be added.

1961 Curriculum in Electrical Engineering
For the Degree of Bachelor of Science in Electrical Engineering

First Year

First Semester	Second Semester
Chem. 102 or 103—General Chemistry ¹3 or 4	Chem. 104—Chemistry of the Metallic Elements ¹4
G.E. 100—Engineering Lectures0	G.E. 102—Engineering Geometry3
G.E. 101—Engineering Graphical Communication3	Math. 133—Calculus3
Math. 123—Analytic Geometry ²5	Physics 106—General Physics (Mechanics)4
Rhet. 101—Rhetoric and Composition3	Rhet. 102—Rhetoric and Composition3
Physical Education1	Physical Education1
Military (men)1	Military (men)1
<i>Total</i>16 or 17	<i>Total</i>19

Second Year

First Semester	Second Semester
Math. 143—Calculus5	Econ. 108—Elements of Economics3
Phycs. 107—General Physics (Heat, Electricity, and Magnetism).....4	E.E. 250—Introduction to Circuit Analysis ¹5
Speech 101—Principles of Effective Speaking3	E.E. 251—Circuit Laboratory ¹1
T.A.M. 154—Analytical Mechanics (Statics and Dynamics)4	Phycs. 108—General Physics (Sound, Light, and Modern Physics)4
Physical Education1	Math. 345—Differential Equations and Orthogonal Functions3
Military (men)1	Physical Education1
<i>Total</i>18	Military (men)1
	<i>Total</i>18

Third Year

First Semester	
E.E. 229—Electric and Magnetic Fields	3
E.E. 322—Circuit Analysis	4
E.E. 330—Magnetic Circuits and Transformers	3
E.E. 331—Magnetic Circuits Laboratory	1
E.E. 340—Electronics	3
E.E. 341—Electronics Laboratory	1
M.E. 202—Thermodynamics	3
<i>Total</i>	18

Second Semester	
E.E. 323—Circuits Laboratory	1
E.E. 332—Electrical Machinery	3
E.E. 333—Electrical Machinery Laboratory	1
E.E. 342—Advanced Electronics	3
E.E. 343—Advanced Electronics Laboratory	1
E.E. 350—Transmission Lines	3
Phys. 383—Atomic Physics and Quantum Theory for Engineers	3
Electives ²	3
<i>Total</i>	18

Fourth Year

First Semester	
E.E. 352—Electromagnetic Fields	3
Met. E. 384—Properties of Solids	3
Electives ²	13
<i>Total</i>	19

Second Semester	
E.E. 288—Economic Aspects of Engineering	3
Electives ²	15
<i>Total</i>	18

¹New freshmen entering in the first semester of 1961 or transfer students eligible to enter the junior courses in the first semester of 1963 will take E.E. 250 and 251. Students entering the second-semester sophomore courses prior to the second semester of 1963 will follow the curriculum of the 1960-61 catalog.

²Of the thirty-one hours of electives required in the third and fourth years, twelve must be technical, nine social science or humanities, five nontechnical, and five either technical or nontechnical. Students should consult the departmental list of approved courses for nine hours of social science or humanities electives. Advanced military courses may be substituted for five hours of nontechnical electives. Suggested technical electives other than electrical engineering courses are Math. 315, 317, 327, 343, 346, 363, Phys. 381.

1973 Curriculum in Computer Engineering
For the Degree of Bachelor of Science in Computer Engineering

First Year

First Semester	Second Semester
Chem. 101—General Chemistry 4	Chem. 102—General Chemistry 4
Eng. 100—Engineering Lecture 0	Math. 130—Calculus and Analytic Geometry 5
Math. 120—Calculus and Analytic Geometry 5	Phycs. 106—General Physics (Mechanics) 4
Rhet. 105—Principles of Composition 4	Humanities or social sciences elective ¹ 3
Humanities or social sciences elective ¹ 3	<i>Total</i> 16
<i>Total</i> 16	

Second Year

First Semester	Second Semester
C.S. 101—Introduction to Automatic Digital Computing 3	E.E. 244—Electrical Engineering Laboratory I 2
Math. 140—Calculus and Analytic Geometry 3	E.E. 260—Networks I 3
Phycs. 107—General Physics (Heat, Electricity, and Magnetism) 4	Math. 345—Differential Equations and Orthogonal Functions 3
Electives ¹ 6	Phycs. 108—General Physics (Wave Motion, Sound, Light, and Modern Physics) 4
<i>Total</i> 16	Electives ¹ 4
	<i>Total</i> 16

Third Year

First Semester	Second Semester
E.E. 229–Introduction to Electromagnetic Fields 3	E.E. 249–Digital Systems Laboratory 2
E.E. 340–Electronics 3	Math. 361–Theory of Probability or E.E. 266– Probabilistic Methods in Electrical Engineering 3
E.E. 290–Introduction to Information Processing 3	E.E. 391–Boolean Algebra and Switching Theory 3
Math. 319–Applied Modern Algebra 3	C.S. 201–Machine Language and Systems Programming I 3
E.E. 310–Systems I or E.E. 262–Networks II 3	E.E. 380–Pulse and Digital Circuits or E.E. 342–Advanced Electronics 3
<i>Total</i> 15	Elective ¹ 3
	<i>Total</i> 17

Fourth Year

First Semester	Second Semester
Electives ¹ 14	Electives ¹ 14

¹Forty-seven hours of electives to be selected by the student in consultation with his adviser, apportioned as follows:

-Twenty-three hours of technical electives as follows: 14 hours (not including other requirements) must be chosen from a departmentally approved list of technical courses for the computer engineering program. Nine hours may be chosen from other technical areas.

-Eighteen hours of humanities and social sciences from the college-approved list.

-Six hours of free electives, to be selected in accordance with the regulations of the college.

1973 Curriculum in Electrical Engineering
For the Degree of Bachelor of Science in Electrical Engineering

First Year

First Semester	Second Semester
Chem. 101—General Chemistry4	Chem. 102—General Chemistry4
Eng. 100—Engineering Lecture0	Math. 130—Calculus and Analytic Geometry5
Math. 120—Calculus and Analytic Geometry5	Phycs. 106—General Physics (Mechanics)4
Rhet. 105—Principles of Composition4	Humanities or social sciences elective ¹3
Humanities or social sciences elective ¹3	<i>Total</i>16
<i>Total</i>16	

Second Year

First Semester	Second Semester
C.S. 101—Introduction to Automatic Digital Computing3	E.E. 260—Networks I3
Math. 140—Calculus and Analytic Geometry3	E.E. 244—Electrical Engineering Laboratory I2
Phycs. 107—General Physics (Heat, Electricity, and Magnetism)4	Math. 345—Differential Equations and Orthogonal Functions3
Electives ¹6	Phycs. 108—General Physics (Wave Motion, Sound, Light, and Modern Physics)4
<i>Total</i>16	Electives ¹4
	<i>Total</i>16

Third Year

First Semester		Second Semester	
E.E. 229—Introduction to Electromagnetic Fields	3	E.E. 245—Electrical Engineering Laboratory II	2
E.E. 290—Introduction to Information Processing	3	Electives ¹	13
E.E. 340—Electronics I	3	<i>Total</i>	15
Electives ¹	6		
<i>Total</i>	15		

Fourth Year

First Semester	Second Semester
Electives ¹	Electives ¹
15	15

¹Sixty-five hours of electives are to be selected by the student, in consultation with his adviser, apportioned as follows:

-Forty-one hours of technical electives as follows: Two semester hours of advanced electrical engineering laboratory courses, to be selected from a departmentally approved list. Twenty-four semester hours of electrical engineering courses, to be selected from a departmentally approved list. Fifteen semester hours of technical electives to be selected from a departmentally approved list, at least 12 of which must be in areas outside electrical engineering. The courses selected to meet the preceding requirements must include at least four of the following seven courses: E.E. 262, 266, 350, 342, 330, 310 and Physcs. 383 or E.E. 344, or equivalent. Although it is recommended that all seven of these courses be taken, only four of the seven are required.

-Eighteen hours of humanities and social sciences from the college-approved list.

-Six semester hours of free electives, to be selected in accordance with the regulations of the college.

1989-91 Curriculum in Computer Engineering
For the Degree of Bachelor of Science in Computer Engineering

First Year

First Semester	Second Semester
Chem. 101—General Chemistry4	Chem. 102—General Chemistry4
Eng. 100—Engineering Lecture0	Math. 132—Calculus and Analytic Geometry II*3
Math. 120—Calculus and Analytic Geometry I*5	Phy. 106—General Physics (Mechanics)*4
Rhet. 105—Principles of Composition4	Humanities or social sciences electives ¹5
Humanities or social sciences elective ¹3	<i>Total</i>16
<i>Total</i>16	

Second Year

First Semester	Second Semester
C.S. 121—Introduction to Computer Science* ²4	ECE 244—Electrical Engineering Laboratory I*2
Math. 242—Calculus of Several Variables*3	ECE 270—Introduction to Circuit Analysis*4
Phy. 107—General Physics (Heat, Electricity, and Magnetism)*4	ECE 290—Introduction to Computer Engineering*3
Electives ¹5	Math. 285—Differential Equations and Orthogonal Functions*3
<i>Total</i>16	Phy. 108—General Physics (Wave Motion, Sound, Light, and Modern Physics)*4
	<i>Total</i>16

Third Year

First Semester	Second Semester
ECE 229–Introduction to Electromagnetic Fields 3	ECE 312–Computer Organization and Design 4
ECE 249–Digital Systems Laboratory 2	ECE 319–Applied Modern Algebra 3
ECE 291–On-Line Computing 3	Math. 361–Introduction to Probability Theory I or E.E. 313–Probabilistic Methods of Signal and System Analysis 3
ECE 340–Solid State Electronic Devices 3	ECE 342–Electronic Circuits 3
ECE 309–Signal and System Analysis 3	C.S. 225–Data Structures 3
Electives ¹ 2	<i>Total</i> 16
<i>Total</i> 16	

Fourth Year

First Semester	Second Semester
Electives ¹ 16	Electives ¹ 16

¹Electives totaling 47 hours are to be selected by the student in consultation with his or her adviser, apportioned as follows:
 -23 hours of technical electives, including 15 hours chosen from a departmentally approved list of technical courses for the computer engineering program
 -18 hours of humanities and social sciences from the college-approved list
 -6 hours of free electives, to be selected in accordance with the regulations of the college.
²The alternate for C.S. 121 is C.S. 101 and C.S. 122, with 7, instead of 8, hours of electives from other technical areas.
 *A 3.25 rule course.

1989-91 Suggested Electrical Engineering Curriculum
For the Degree of Bachelor of Science in Electrical Engineering

First Year

First Semester	Second Semester
Chem. 101–General Chemistry ¹4	Chem. 102–General Chemistry4
Eng. 100–Engineering Lecture0	Math. 132–Calculus of Analytic Geometry II3
Math. 120–Calculus and Analytic Geometry I5	Phy. 106–General Physics (Mechanics)4
Rhet. 105–Principles of Composition4	Rhet. 133 ⁶ –Principles of Composition3
Humanities or social sciences elective ⁵3	Humanities or social sciences elective ⁵3
<i>Total</i>16	<i>Total</i>17

Second Year

First Semester	Second Semester
C.S. 101–Introduction to Computers for Application to Engineering and Physical Science3	ECE 244–Electrical Engineering Laboratory I2
Math. 242–Calculus of Several Variables3	ECE 270–Introduction to Circuit Analysis4
Phy. 107–General Physics (Heat, Electricity, and Magnetism)4	ECE 290–Introduction to Computer Engineering3
Sp. Comm. 101 ⁶ –Principles of Effective Speaking3	Math. 285–Differential Equations and Orthogonal Functions3
Humanities or social sciences elective ⁵3	Phy. 108–General Physics (Wave Motion, Sound, Light, and Modern Physics)4
<i>Total</i>16	<i>Total</i>16

Third Year

First Semester	
ECE 229—Introduction to Electromagnetic Fields	3
ECE 309—Signal and System Analysis	3
ECE 340—Solid State Electronic Devices	3
Math. 280 ⁴ —Advanced Calculus	3
M.E. 209 ⁴ —Thermodynamics and Heat Transfer	3
<i>Total</i>	15

Second Semester	
ECE 342—Electronic Circuits	3
ECE 343—Electronic Circuits Laboratory	1
ECE 350—Lines, Fields and Waves	3
ECE 313 ⁴ —Probabilistic Methods of Signal and System Analysis	3
ECE 330 ⁴ —Electromechanics	3
Math. 315 ⁴ —Linear Transformations and Matrices	3
<i>Total</i>	16

Fourth Year

First Semester	
Electrical engineering laboratory ²	1
Electrical engineering electives ³	6
C.S. 257 ⁴ —Numerical Methods	3
Physcs. 383 ⁴ —Atomic Physics and Quantum Theory	3
Humanities or social sciences elective ⁵	3
<i>Total</i>	16

Second Semester	
ECE 345—Senior Design Project Laboratory	2
Electrical engineering laboratory ²	1
Electrical engineering electives ³	7
Humanities or social sciences elective ⁵	6
<i>Total</i>	16

¹All courses shown without superscript letters are required.

²Electrical engineering laboratory elective to be selected by the student in consultation with his or her adviser from the departmentally approved list.

³Electrical engineering elective to be selected by the student in consultation with his or her adviser from the departmentally approved list.

⁴Suggested technical elective to be selected by the student in consultation with his or her adviser from the departmentally approved list. Of the 21 hours of technical electives needed, at least 12 hours must be from areas outside electrical engineering; at least 10 hours must be from 300-level courses; at least 9 hours must be from courses offered by the College of Engineering; at least one course must be from the departmentally approved list on nonelectrical engineering, engineering, science electives; and at least one course must be from the departmentally approved list of advanced mathematics courses.

⁵Social sciences and humanities elective to be selected by the student in consultation with his or her adviser from the college-approved list.

⁶Suggested free elective to be selected by the student in consultation with his or her adviser in accordance with the regulations of the college.

Appendix III. Recipients of the Distinguished Alumnus Award

1970

George C. Dacey, BS '42
Frank B. Doyle, BS '20
Gordon S. Heylin, BS '28
Everett S. Lee, BS '13
Julian Z. Millar, BS '23
Harold L. Olesen, BS '18

1971

Carl E. Asbury, PhD '38
John H. Bryant, PhD '49
Emerson A. Shultz, BS '31

1972

Charles V. Jakowatz, PhD '53
Walter E. Lotz, Jr., PhD '47
William A. Mann, BS '23

1973

Robert E. Fontana, PhD '49
Ray D. Kell, BS '26
Wendell J. Kelley, BS '49
Raymond D. Maxson, BS '21

1974

Edgar C. Chamberlin, Jr., BS '36
William C. Curtis, MS '35
Wallace A. Depp, MS '37

1975

Robert E. Finnigan, PhD '57
James Rod Johnstone, BS '33
Herbert A. Schulke, Jr., PhD '54

1976

William H. Christoffers, PhD '55
Maurice R. Eastin, BS '35
Albert R. Shiely, Jr., MS '47

1977

Kay N. Burns, PhD '52
O. Thomas Purl, PhD '55
Thomas M. Rienzi, MS '48
William A. Sink, BS '38

1978

Richard C. Becker, PhD '59
Richard A. Campbell, M.D. '50
Harry Charles F. Simrall, MS '39
Richard P. Wishner, PhD '60

1979

Lowell E. Ackmann, BS '44
William A. Blackwell, MS '52
Walter C. Kottemann, BS '47

1980

Albert R. Noland, MS '49
Joseph A. Saloom, PhD '51
Steven B. Sample, PhD '65
Robert S. Wiseman, PhD '54

1981

Norman R. Carson, BS '37
E. David Crockett, PhD '67
Robert C. Hansen, PhD '55
William E. Kunz, PhD '64

1982

Herbert M. Barnard, PhD '64
John J. Myers, PhD '59
Fred J. Rosenbaum, PhD '63
Joseph M. Wier, PhD '56

1983

Lionel Boulet, MS '47
Robert H. Brunner, MS '50
Shu-Park Chan, PhD '63

1984

Abraham MS Goo, BS '51
Edwin L. Hughes, MS '50
Robert M. Janowiak, BS '57
Lawrence W. Kessler, PhD '68

1985

Alfred Y. Cho, PhD '68
Donald J. Stukel, MS '62
Michael G. Tomasic, BS '66

1986

Jagdish K. Aggarwal, PhD '64
Kent M. Black, BS '62
Herbert Y. Chang, PhD '64
Kenneth A. McCollom, MS '49
Edward W. Springer, BS '47

1987

Richard D. Alberts, BS '47
Robert L. Barnett, MS '64
Leon O. Chua, PhD '64
Russell D. Dupuis, PhD '73
Franklin F. Kuo, PhD '58
Lynn E. Wolaver, MS '50

1988

Robert L. Carrel, PhD '61
Wai-Kai Chen, PhD '64
Carl J. Johnson, PhD '69
Robert J. Paluck, BS '69

1989

Daniel V. DeSimone, BS '56
Frank F. Fang, PhD '59
Se June Hong, PhD '69
Robert C. Mathis, MS '53
Peter W. Sognefest, MS '67

1990

Pallab K. Chatterjee, MS '74, PhD '76
Tatsuo Itoh, PhD '69
Robert R. Rankine, Jr., BS '58
Erlind G. Royer, PhD '70
Glenn H. Sherman, BS '68, MS '70,
PhD '72

1991

Algirdas Avizienis,
BS '54, MS '55, PhD '60
Newton A. Campbell,
BS '49,
Herman E. Koenig,
BS '47, MS '49, PhD '53
Milton E. Radant, BS '54, MS '56
Donald R. Scifres,
BS '68, MS '70, PhD '72
Curt Wittig, BS '66, MS '67, PhD '70

Appendix IV. Bibliography

Bibliographic details of publications listed in the text are given here for your information.

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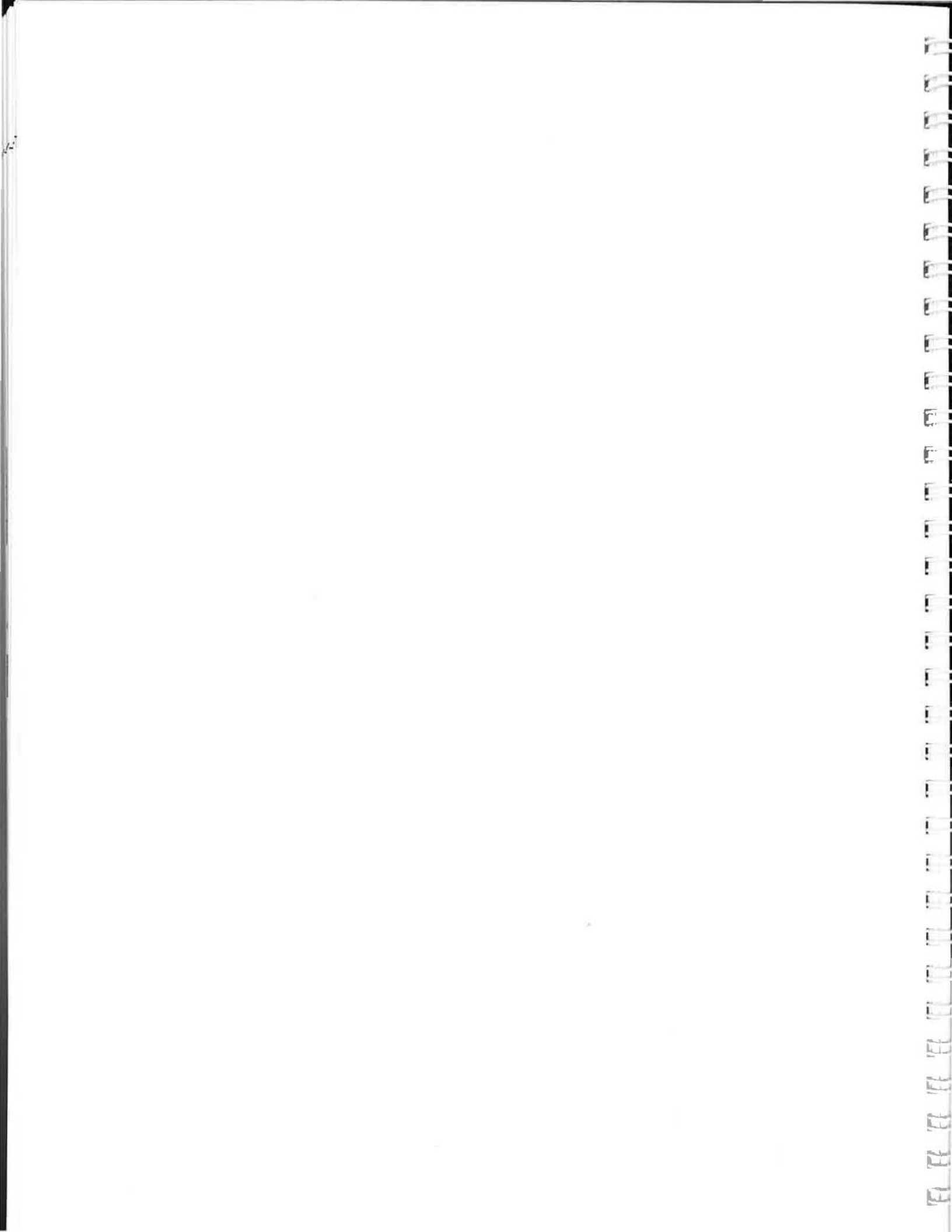
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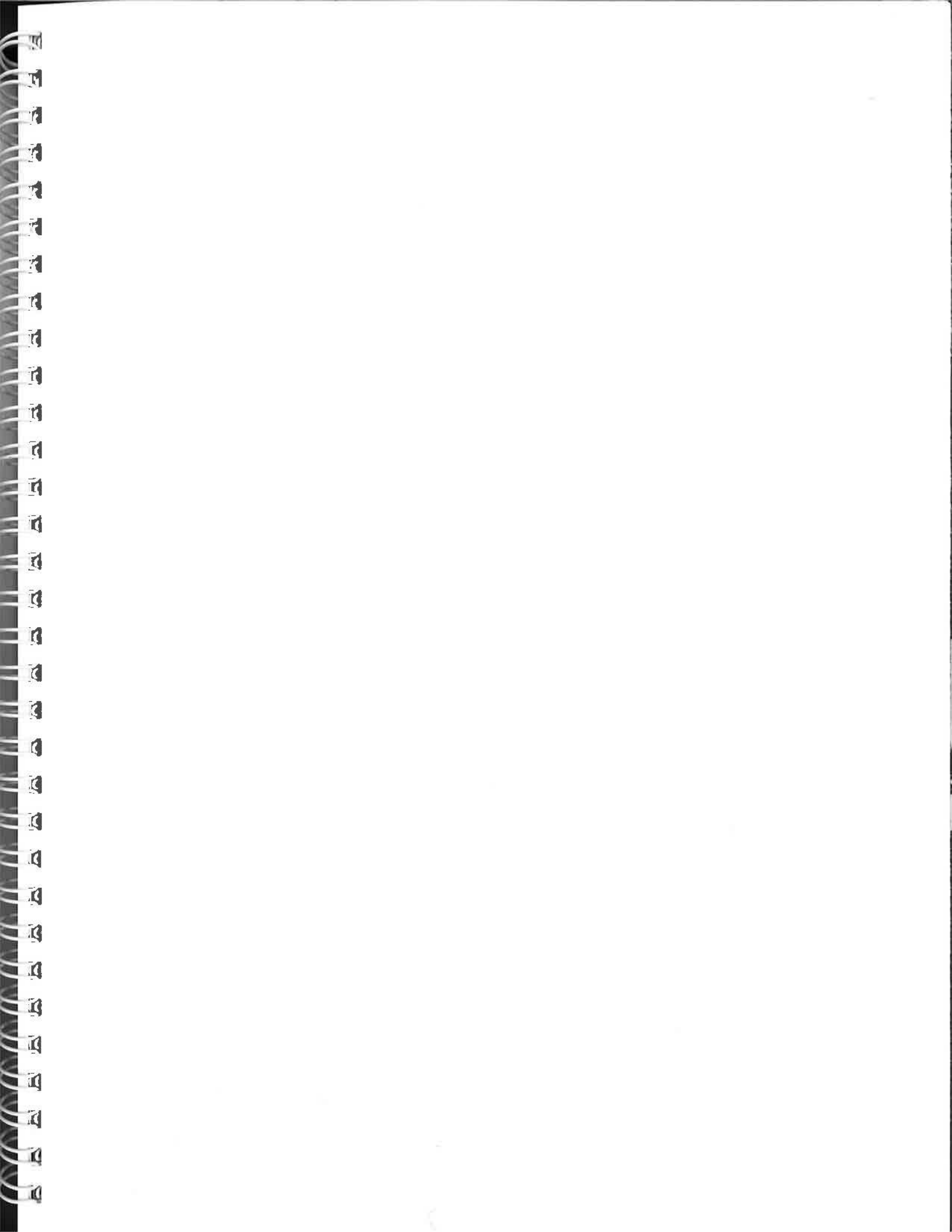
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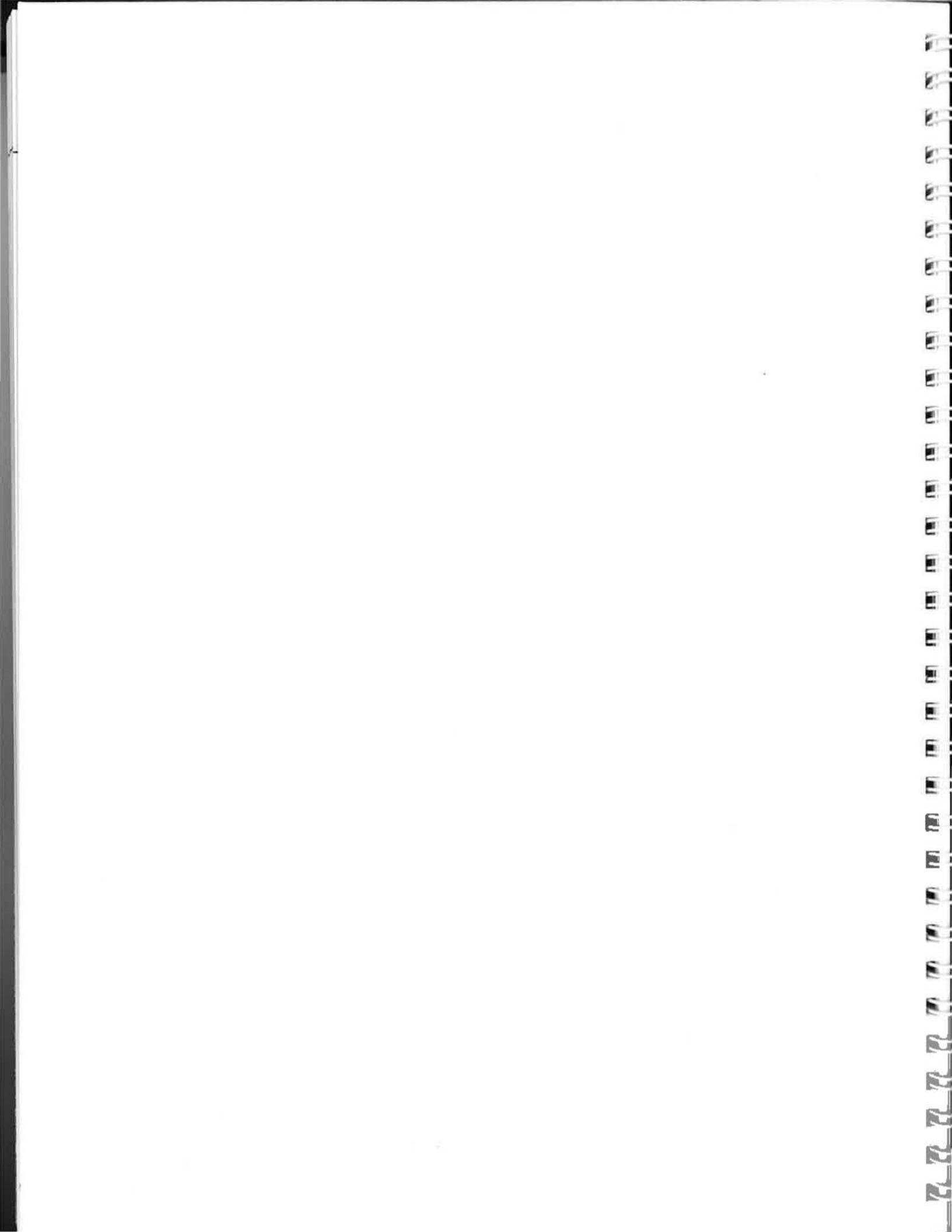
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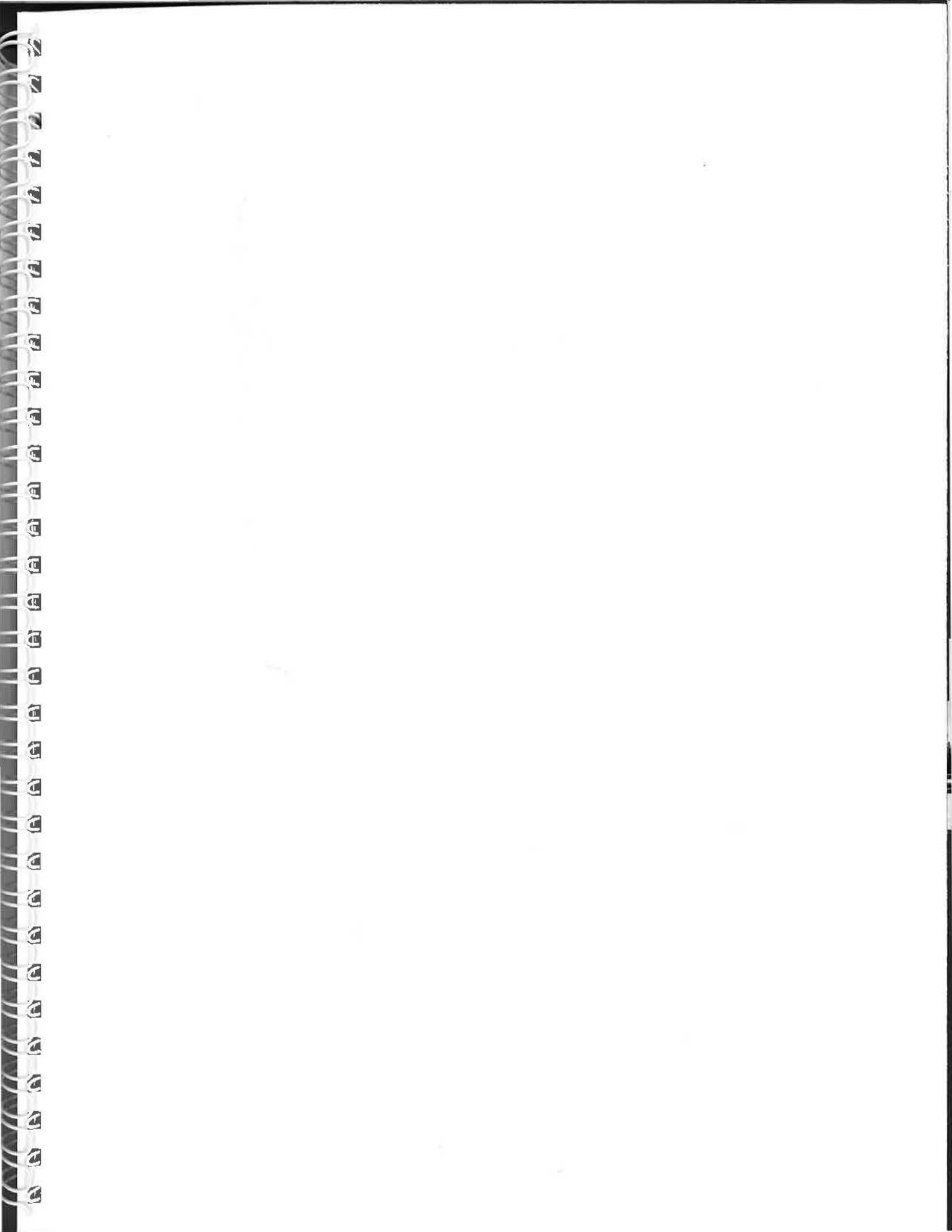
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