CONNECTIONS

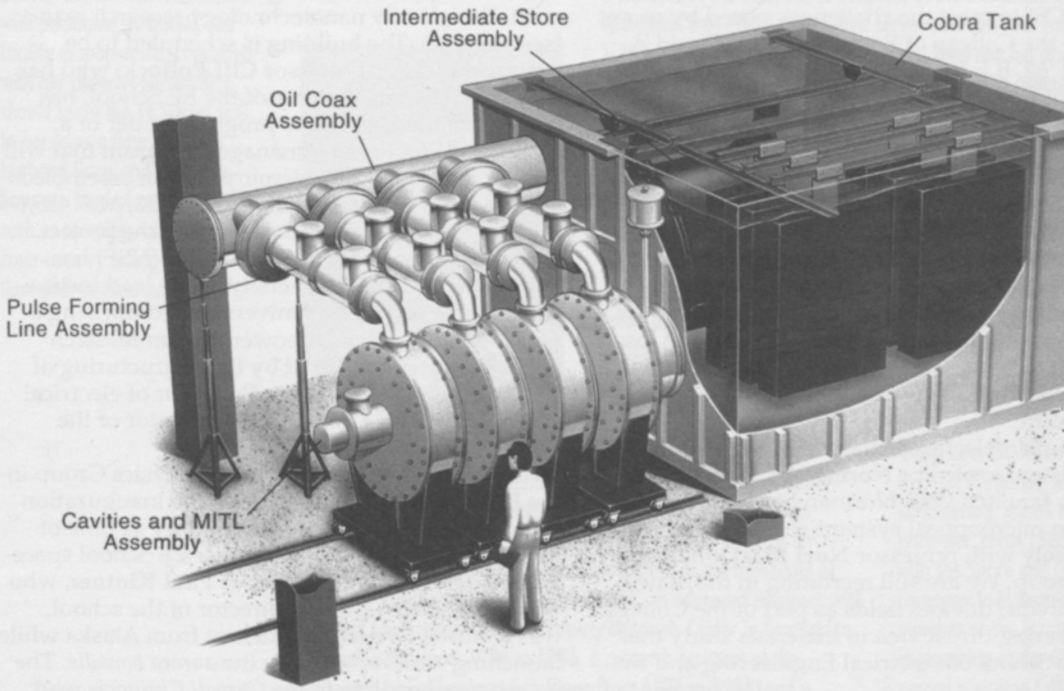
A report from the School of ELECTRICAL ENGINEERING • Cornell University

Plasma-Physics Research in the School of Electrical Engineering

This sixth edition of *Connections* features the challenging research of our Plasma-Physics Research Group, relates the history of plasma studies in the EE School, and considers the impact of these studies on controlled thermonuclear fusion research and high-power microwave generation. The "Positive Feedback" section contains news of recent alumni activities. Other items of interest to alumni are listed in the table of contents below. Please fill out the information coupon on the last page of this newsletter, and clip and mail it to us. We want to hear what you are up to.

Simpson (Sam) Linke, editor

SPRING 1997



Cornell/Sandia COBRA Accelerator

This sketch of the new Cornell Beam Research Accelerator (COBRA) displays one of several pulsed-power devices employed in plasma-physics research performed by the Plasma-Physics Research Group in the EE School and by members of the Cornell Laboratory of Plasma Studies. COBRA, funded by the U.S. Department of Energy's Sandia National Laboratory, is the latest in a series of high-voltage, high-energy intense electron and ion-beam sources that have been developed at the Mitchell Street and Upson Hall laboratories over the past thirty years for use in studies related to thermonuclear fusion, high-power microwave production, x-ray lithography, and associated plasma-physics topics. COBRA is designed to produce single 40-nanosecond ion-beam pulses at 4 MV and 200 kA to determine if focused intense ion beams can develop sufficient power density to replace lasers for pellet ignition in inertial-confinement fusion studies. (Photo courtesy of Sandia National Laboratory and John Greenly.)

In this Issue

Report from the Director

James S. Thorp

A review of major events in the EE School for the past year indicates that faculty recruiting continues to be an important activity. In keeping with the recruiting initiative in information technology that I outlined in last year's report, we have added two new faculty members in that area, associate professor **Stephen Wicker** and assistant professor **Venugopal Veeravalli,** both of whom joined the faculty in July 1996. When the one remaining line in the area is filled, our EE information-technology group will consist of the three new members and professors **Chris Heegard, Zygmunt Haas,** and **Sheila Hemami,** who will join with faculty members of the Department of Computer Science (CS) to meet the challenges posed by recent grants to the College of Engineering by **David A. Duffield** '62, B.E.E. '63, M.B.A. '64, president and founder of PeopleSoft, Inc., and the GTE and AT&T Foundations in support of interdisciplinary efforts in telecommunications and information technology. Faculty members in both departments are cooperating in development of a new "virtual laboratory" with the gift from PeopleSoft. This lab will consist of two components, one for EE in Frank H. T. Rhodes Hall (the former Engineering and Theory Center building, recently renamed in honor of the retired Cornell president) and the CS unit in Upson Hall, both to be joined by a fiberoptics connection, with wireless links between the two units planned for the future.

In the microelectromechanical systems (MEMS) area, assistant professor **Norman C. Tien** joined the faculty in January 1997. Norman has a particular interest in microoptical systems research and will work closely with professor **Noel MacDonald**'s MEMS group. We are still recruiting in the materials and circuit/devices fields as part of the College of Engineering thrust area in materials study that spans the School of Electrical Engineering and the Department of Materials Science and Engineering. In the non-academic sector, we are fortunate in obtaining the expert managerial services of **Betty (B.J.) Bortz,** who joined the EE School in August 1996 as administrative manager. (See page 3 for biographical sketches of the newcomers to the school.)

Cornell University has formally announced that two initial generous grants from EE alumni **Dwight C. (Bill) Baum** '36 (see page 26) and David A. Duffield (see page 27 will allow construction of the new engineering building I mentioned last year. The building will be called Duffield Hall and will house the Advanced Science and Technology Initiative (ASTI) facility that will provide specialized instruction and laboratory space for the School of Electrical Engineering, the Materials Science Center, the Cornell Nanofabrication Facility, the School of Applied and Engineering Physics, and multidisciplinary nanotechnology research teams (see page 22). The building is scheduled to be occupied in 2001. Professor **Clif Pollock,** who has been the associate director of the EE School, has been appointed academic program leader of a College of Engineering management team that will further develop the academic program assembled by professor **Lester Eastman,** B.E.E. '53, M.S. '55, Ph.D. '57, during the initial stages of the project.

The National Science Foundation (NSF) has established Cornell University as the lead institution in a consortium of universities comprising a new national center for power-system research focused on issues created by the restructuring of the electric-utility industry. Professor of electrical engineering **Bob Thomas** is the director of the center (see page 28).

Members of the Space-Plasma Physics Group in the EE School will participate in the inauguration of the upgraded Arecibo Observatory in June of this year (see page 19). In another EE School space-related development, professor **Paul Kintner,** who will be the next associate director of the school, was featured live on the Internet from Alaska while launching a rocket to study the *aurora borealis*. The newspaper headline in the *Cornell Chronicle* read "Rocket scientist goes on-line" (see page 28).

The EE School is one of the units in the university to be subjected to a newly instituted "program review" in the fall of 1997. This year has been designated as a period for self-study. Planning activities required for the review will involve various standing faculty committees and ad-hoc groups, along with the EE Advisory Council. We are also engaged with the Chalmers Institute in Sweden and the Eidgenössiche Technische Hochschule (ETH) in Switzerland in a "benchmarking" study that is concerned with similar planning.

—James S. Thorp
Professor and Director
School of Electrical Engineering

Enrollment and Graduation Statistics

Undergraduate Program

year	sophomores	juniors	seniors	degrees
94–95	125	112	110	106
95–96	120	116	104	117
96–97	138	128	109	•

M.Eng. (Electrical) Degrees

August	January	May	Total
57	19	55	124
50	12	53	115
50	22	•	•

• Not available at press time.

M.S./Ph.D. Program

year	sophomores	juniors	seniors	degrees
94–95	556	13	117	20 Ph.D.s 7 MS.s
95–96	501	14	109	26 Ph.D.s 9 MS.s
96–97	138	128	109	•

NOTE: Undergraduate students now affiliate with the EE School when the first term of sophomore math and physics is completed.
These figures indicate that over the past three years, the undergraduate program is stable, the M.Eng. (Elec.) program has increased moderately and M.S.-Ph.D. enrollment has not changed significantly.

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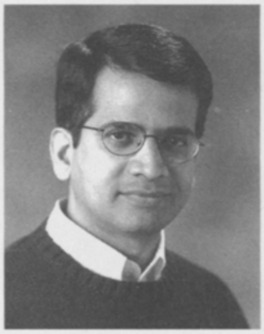
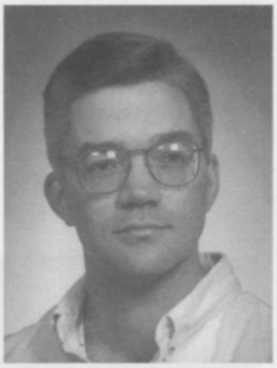
Newcomers to the EE School

Betty (B.J.) Bortz
joined the School of Electrical Engineering in August 1996 as administrative manager. She brings with her over twenty-six years of diverse administrative experience, all of which has been in the sciences. Her most recent positions, prior to joining EE, were in the School of Chemical Engineering and the Laboratory of Nuclear Studies, both at Cornell. Her experience with personnel, financial, and facility management, combined with her cheerful personality, should serve the EE School well. In her leisure time, B.J., her husband Gary, and their two boys are fond of outdoor sports such as camping, canoeing, and cross-country skiing—when time and weather permit.



Venugopal V. Veeravalli
B.S. '85 (IIT, Bombay), M.S. '87 (Carnegie-Mellon), Ph.D. '92, (Illinois, Urbana-Champaign), all in electrical engineering, joined the EE School faculty in July 1996 as an assistant professor. After serving as a postdoctoral fellow in 1992–93 at the Division of Applied Science at Harvard University, Venu was an assistant professor of electrical engineering at CUNY in 1993–94, and a visiting assistant professor of electrical engineering at Rice University from 1994 to 1996. From the summer of 1995 to the present he has been a consultant and instructor to Northern Telecom in Richardson, Texas, and has also consulted with RSI Medical Research, Inc., in Galveston, Texas. He is a member of the IEEE, the co-recipient of the 1996 IEEE Browder J. Thompson Best Paper Award, and serves as a reviewer for two *IEEE Transactions* and other publications. Venu teaches and conducts research in wireless communications, detection and estimation theory, and information theory. Current topics of research include cellular CDMA (Code Division Multiple Access) network design, sequential code-acquisition techniques for CDMA systems, handoff and power-control algorithms for wireless networks, decentralized dynamic decision making, and coding-spreading tradeoff issues in CDMA multiuser detection systems. He is the author of over thirty journal and conference papers. Venu is particularly enthusiastic about his research, and that of his colleagues in the EE School, with mobile communications: the ability to maintain "seamless communication." His leisure activities include camping and biking when time permits.

Norman C. Tien
B.S. '81 (Berkeley) engineering physics, M.S. '84 (Illinois, Urbana-Champaign), Ph.D. '93 (California, San Diego) both in electrical engineering, joined the EE School faculty in January 1997 as an assistant professor. He was a research assistant at the University of Illinois at Urbana-Champaign in 1983–84, an advanced engineer with Polaroid Corporation Microelectronics/Materials Center in Cambridge, Massachusetts, from 1984 to 1986, a research assistant at the University of California at San Diego from 1986 to 1993, and a postdoctoral research engineer at Berkeley from 1993 to 1996. He became inspired to seek a career in academia when he was a lecturer in electrical engineering at Berkeley during 1995–96, and progressed toward that goal as a visiting assistant professor in electrical engineering at Cornell in the 1996 fall term. Norman teaches and conducts research in microelectromechanical systems (MEMS) for radio-frequency circuits and optoelectronics. He has a particular interest in research on silicon surface micromachining for microoptical systems, the creation of an "optical bench on a chip." Development of this advanced technology for silicon integrated circuits would allow many large, bulky, and expensive mechanical systems to be miniaturized, reduced in cost, and enhanced in performance, thereby leading to previously unforeseen products. Norman is a member of the IEEE and the author of over twenty-six journal articles and conference papers in his research areas. His leisure interests include any racquet sport, skiing, and movies, but family duties with two youngsters have set these activities aside for the present.



Stephen B. Wicker
B.S. '82 (Virginia), M.S. '83 (Purdue), Ph.D. '87 (UCLA), all in electrical engineering, joined the EE School faculty in July 1996 as an associate professor. From 1983 to 1987 he was a subsystem and system engineer with the Space and Communications Group of the Hughes Aircraft Company in El Segundo, California. From 1987 to 1996 he was a member of the faculty of the School of Electrical and Computer Engineering at the Georgia Institute of Technology. In 1992 he was named a visiting fellow of the British Columbia Advanced Systems Institute. He is a senior member of the IEEE, a member of the IEEE Communications, Information Theory, and Vehicular Technology Societies, and was elected to the Board of Governors of the IEEE Information Theory Society in 1996. Stephen teaches and conducts research in wireless information networks, digital communication systems, error-control coding, and cryptography. His research has focused on the development and application of advanced technologies for data links and multiple-access protocols in wireless networks. Stephen is the author of *Error Control Systems for Digital Communication and Storage* (Prentice Hall, 1995) and is co-editor of *Reed-Solomon Codes and Their Applications* (IEEE Press, 1994). He is the author of over eighty journal articles and conference papers, and is the editor for coding theory and techniques for the *IEEE Transactions on Communications*. He is a member of Eta Kappa Nu, Tau Beta Pi, Sigma Xi, and Omicron Delta Kappa (a national leadership/scholastic honorary society). His leisure activities include reading philosophy and history, skiing, and speed running.

The Development of Plasma Studies in the EE School

In his book *A History of Cornell,* **Morris Bishop** described early electric lighting on campus powered by "electricity delivered . . . to two arc lights, the wonder of the countryside and indeed of the engineering world." A footnote attributed to professor **Charles H. Hall,** Class of 1886, adds: "A tower attached to Sage Chapel gave shelter to a buzzing and sputtering open-arc lamp . . . The arc jumped back and forwards along the edges [of the irregular electrodes] from one point to another of approximate contact. Polychromatic flames resulted, startling to behold." The first electrical device displaying the phenomenon now known as "plasma" had arrived at Cornell.

Some years later, when series ac arc lamps became the standard for street lighting, professor **Vladimir Karapetoff** added an arc-lamp experiment to his electrical laboratory course, as outlined in his *Electrical Laboratory Notes,* published in 1906. Kary favored the dc arc lamp and wrote the following footnote in his text: "In a recently proposed system, ordinary alternating current is *converted into direct current* by means of a mercury-vapor rectifier and used for series direct-current arc lamps. This system apparently has good chances for success, although the mercury rectifier has not yet had a sufficient practical test as to its reliability." His later courses included studies of more advanced mercury-vapor rectifiers.

Above, Figure B. Professor **Paul Ankrum**'s electronic regulator for the dc generator. The two glass tubes are grid-controlled mercury-vapor thyratrons in a full-wave rectifier circuit.

Left, Figure A. The full-wave mercury-arc rectifier in action. The intense glow at the bottom of the glass chamber is caused by the "cathode spot" on the mercury pool. Professor **L. A. Burckmyer** is at the rear with assistant professor **Joe Logue** at left.

Eventually, mercury-arc rectifiers and other gas-discharge tubes became sufficiently well-developed to engage the attention of several EE faculty members in studies related to electrical-discharge phenomena. Courses on power-electronics and control based on these devices were established by professors **B. K. Northrop** and **Walter Cotner.** Alumni of the early years of this electronics laboratory may recall an experiment with the demonstration model of a mercury-arc full-wave rectifier shown in Figure A. In 1944, professor **Paul Ankrum** used controlled mercury-vapor thyratrons in his design and construction of electronic regulators for the two large dc generators that supplied power to the machinery laboratory in Rand Hall and later in Phillips Hall (see Figure B), and included the study of gas-discharge tubes in his electronics courses in the EE School. Professors **Everett Strong** and **Casper Cottrell** examined plasma characteristics in Cooper-Hewitt lamps, mercury-vapor lamps, and fluorescent lamps in their research on illumination systems, and professor **True McLean** conducted experiments for many years with a heavy-duty six-phase mercury-vapor ignitron power rectifier. Professor **Stanley Zimmerman** used his multimillion-volt surge generator in the Mitchell Street High-Voltage Laboratory to produce massive electrical discharges while testing power-utility equipment with artificial lightning bolts. Professor **Nelson Bryant** investigated plasma phenomena in a unique design of a controlled mercury-vapor rectifier that, unlike standard thyratrons, allowed current to be cut off at any point in the conduction period.

In the decade of the '50s, EE faculty interest in traditional plasma devices declined as controlled solid-state rectifiers gradually superseded thyratrons and ignitrons in power-electronics circuits, and the High-Voltage Laboratory was decommissioned. During this period, however, space-plasma physics began to engage the attention of several EE faculty members, who formed a research group in that discipline. Development of the significant

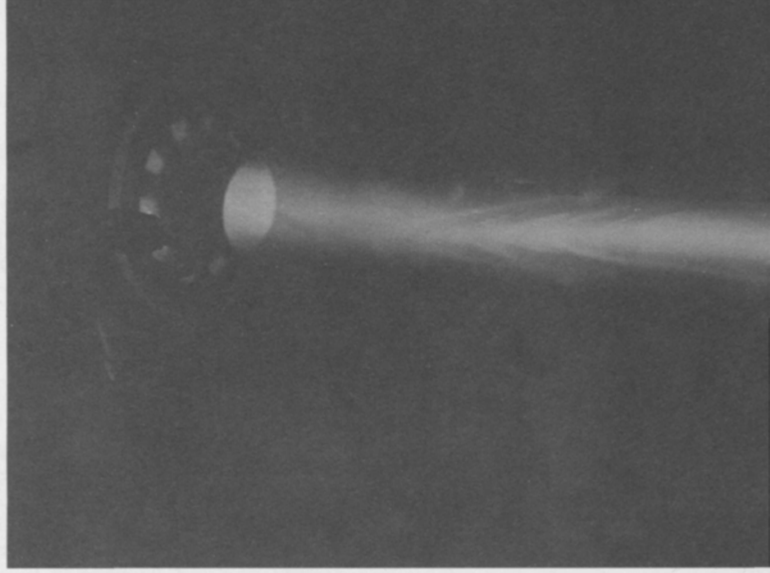


Figure D. Photograph of one of the first relativistic electron beams injected into a plexiglass "drift tube." The beam lasts for only 50 nanoseconds but is intense enough to activate the film.

research in this area of plasma studies was detailed in the 1995 issue of *Connections.*

In the early '60s, professors **Conrad Dalman** and **Lester Eastman** began plasma-related research on a unique Penning-discharge device involving the interaction of an electron beam in a travelling-wave tube containing hydrogen gas at reduced pressure, professors **Sam Linke** and **Ravi Sudan** investigated arc characteristics in vacuum circuit breakers, and Sudan also directed research on the physics of electric discharges in vacuum.

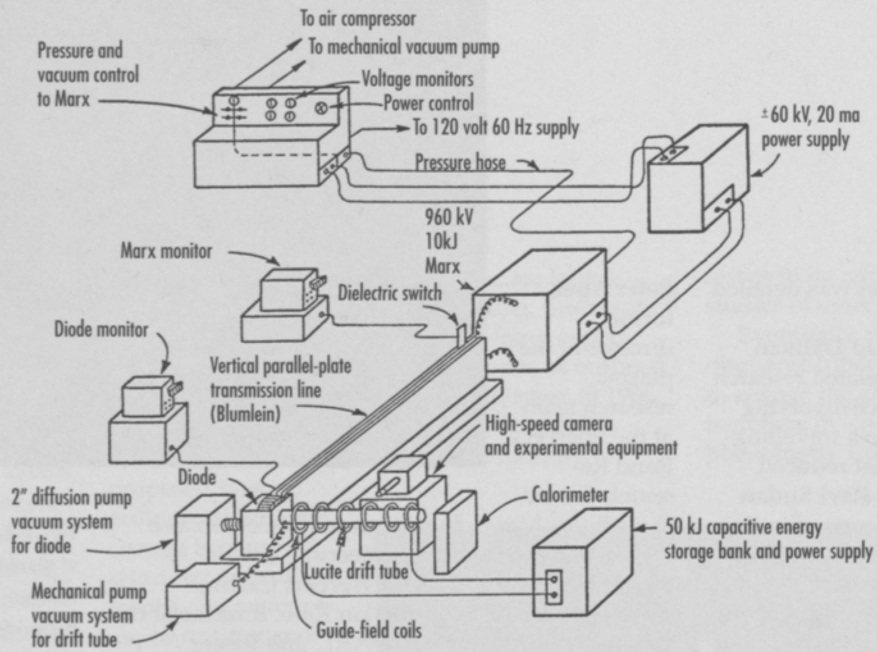
Linke and Sudan, together with visiting scientist Fred Depping from Germany, had established their vacuum-arc research in a limited space in a first-floor laboratory in Phillips Hall. Initiation grants from the National Science Foundation supported two graduate students, **B. L. Rao** and **F. J. Gonzales-Perez,** and allowed development of modest experimental equipment augmented by components that were begged and borrowed from other facilities in the school. In 1964–65, Ravi Sudan began offering two senior and graduate-level courses in plasma physics, professor **John Nation** joined the EE faculty after having performed plasma-related research in England and Italy for several years, and the large open area in the former high-voltage laboratory building on Mitchell Street was converted into an energy-research facility with a large enclosed laboratory space, staff offices, a conference room, and an adequate power-supply system. When the renovations were completed, the vacuum-switch project was moved to the Mitchell Street laboratory since the Phillips Hall facilities were found to be inadequate for an experiment that required controlled pulses of high voltage, high current, and strong magnetic fields.

New Electron- and Ion-Beam Program

Several events in 1966 stimulated development of a new program of plasma research in the EE School. Professor Ravi Sudan was on leave at the International Center for Theoretical Physics in Trieste, Italy, and at Princeton University, developing theoretical skills that were eventually to lead to his award in 1989 of the James Clerk Maxwell Prize in Plasma Physics. Professor **Edwin Resler,** director of the Graduate School of Aerospace Engineering at Cornell, arranged an agreement with the EE School and the Naval Research Laboratory (NRL) in Washington, D.C., for use of the Mitchell Street Laboratory on a joint project. Shortly thereafter, **Peter Auer,** former director of the plasma research team at the Sperry Rand Research Center in Sudbury, Massachusetts, came to Cornell as a professor of aerospace engineering, and, in cooperation with professor **Herbert Carlin,** director of the EE School, Alan Kolb, director of the Plasma Physics Division of NRL, and Resler, established a joint program with Cornell, the University of Maryland, and NRL for funding and three-way sharing of plasma-physics research. The university members were to perform basic research to complement the more applied research conducted by NRL. The initial charge to the EE School was to engage in studies of high-voltage pulsed power, and the production of intense relativistic electron beams, with eventual application to the defense sciences, thermonuclear fusion power, and research in directed-energy phenomena.

When the Cornell/Maryland/NRL project began, pulsed-power technology was in its infancy, commercial high-voltage, high-current electron-beam generators of the necessary power (~100 GW) and short pulse duration were nonexistent, and the collective pulsed-power expertise of the newly formed EE plasma group was at the beginner's level. In order to launch the program and acquaint the group's faculty members and their graduate students with the techniques required for the design and construction of the necessary test equipment, Alan Kolb arranged for J. C. (Charlie) Martin, from the Atomic Weapons Research Establishment (AWRE) in England, to come to Cornell for a week-long tutorial. Charlie was the acknowledged world expert on pulsed power, a firm proponent of the "build it yourself from available parts" engineering philosophy, and a stimulating instructor. Before his return to England he invited members of the group to visit his laboratory to experience his technical developments at first-hand. Professor **David A. Hammer,** who at that time was a graduate student in the School of Applied and Engineering Physics (AEP), took advantage of Charlie's offer, spent several weeks at AWRE and returned to the campus with a 500 kV pulse transformer that he had built under Charlie's guidance. Iron was not used in the construction so Dave, as reported later by Peter

Figure C. Diagram of the components of the first accelerator built in the Mitchell Street Laboratory. The Blumlein line was insulated with Mylar™ sheets and distilled water. (Diagram by Sam Linke, *circa* 1969.)



Auer, was able to board the plane with the relatively small (~40-pound) device as a piece of carry-on luggage wrapped in a Union Jack! The transformer was used in flashover testing and calibration in the laboratory and served as an effective model for low-cost construction of pulsed-power circuitry.

By mid-1967, members of the EE plasma group at the Mitchell Street Laboratory had made significant progress on the preliminary design of a pulsed-power accelerator based on Charlie Martin's suggestions, a 60 kV dc power supply from the recently completed vacuum-switch program was available for use on the new project, and sixteen 0.05 microfarad, 100 kV coaxial-type capacitors (originally from a controlled-fusion experiment in a United Kingdom laboratory) had been donated by the Sandia National Laboratory through the good offices of NRL. Construction of the accelerator began in late autumn 1967 under the direction of George Herbert, one of Charlie Martin's engineers from AWRE. The sixteen capacitors were formed into a Marx surge generator in which the capacitors were to be charged in parallel at 60 kV by the power supply and discharged in series by means of spark gaps to form a ten-kilojoule pulse at 960 kV in about one microsecond. The Marx pulse was then used to charge a pulse-forming transmission line known as a "Blumlein line" (after its inventor) to create a high-voltage pulse of approximately 50-nanosecond duration across a special evacuated diode consisting of a field-emission cathode and a thin aluminum-foil anode. In the diode the emitted electrons, accelerated to relativistic velocities (up to 85 percent of the speed of light), would penetrate the foil anode and emerge into a cylindrical plexiglass "drift tube" to form an intense electron beam of from 50 to 100 kiloamperes. The essential elements of the accelerator are shown in Figure C together with ancillary components added during the conduct of more advanced experiments at a later date.

George Herbert returned to England after a six-week stay in Ithaca and was replaced a few months later by Philip Champney, also from AWRE. The first relativistic electron beam was achieved at approximately 6:00 p.m. on January 5, 1968. A photograph of a typical electron beam in a drift tube is shown in Figure D on page 5.

Following this successful establishment of the first electron-beam accelerator in a university facility in the world, the Mitchell Street Laboratory entered into a productive era of research and development. Modifications to the initial configuration, addition of controlled magnetic field-coils, acquisition of high-speed oscilloscopes installed in suitable double-screened rooms, and high-speed photographic equipment were incorporated into the facility by John Nation, AEP professors **Hans H. Fleischmann** and **Merrill L. Andrews,** AEP graduate student Dave Hammer, EE graduate students **Jack Clark, John Bzura, Bill Glock,** electrical engineers **Michael Ury** '64, **James Ivers,** and technician **Joseph Sanford.** Their subsequent investigations won the approval of Alan Kolb and his colleagues at NRL, thereby assuring continued funding. The electron-beam program stimulated several EE and AEP faculty members to consider similar pulsed-power techniques for the production of intense ion-beams. From 1973 to 1976, Ravi Sudan and AEP postdoctoral fellow **Stanley Humphries, Jr.,** developed a method for the generation of intense ion beams and were granted a patent for their process. To this day, ion-beam technology is playing a major role in controlled themonuclear research.

"The thirty years of plasma research in the EE School and in LPS since the launching of that first relativistic electron beam have resulted in significant contributions that may lead to the realization of fusion power."

Toward Fusion-Power Research

The Laboratory of Plasma Studies (LPS) was established in 1967 as an interdisciplinary center to coordinate College of Engineering plasma research in the Schools of Applied and Engineering Physics, Electrical Engineering, and Mechanical and Aerospace Engineering. Peter Auer was named director of LPS at its inception and Sam Linke was appointed assistant director the following year. The first major task of the new center was to assemble a core faculty in plasma studies and to seek adequate funding for research from federal, state, and nongovernmental agencies. Fortunately, the New York State electric utilities and the Edison Electric Institute provided much-needed financial support during this critical start-up period. LPS assumed management of the Mitchell Street laboratory and eventually established additional experimental facilities in Upson Hall to meet the research needs of new faculty members.

With the cooperation of deans **Andrew Schultz** and **Edmund Cranch,** Peter was instrumental in bringing several senior faculty members with expertise in thermonuclear fusion to the college. In 1967, three appropriate candidates were recruited from the General Atomics Division (GA) of the General Dynamics Corporation in San Diego, California: **Norman Rostoker** was named the IBM Professor of Engineering and chairman of the School of Applied and Engineering Physics, **Charles Wharton** was appointed professor of electrical engineering, and **Hans Fleischmann** joined the AEP faculty as an associate professor. In 1968, **Arthur Kuckes** joined the AEP faculty as a full professor.

Several younger plasma specialists came to Cornell in those formative years. After seven years at NRL, Dave Hammer returned to Cornell as an associate professor in nuclear science and engineering, and in 1996 became a member of the EE faculty. In 1968, **Edward Ott** joined the EE School as an assistant professor. **Bruce Kusse,** an LPS research associate in 1970, joined the AEP faculty in 1971 as an assistant professor. **Richard Lovelace,** Ph.D. '70, was an LPS research associate in 1970 and became an assistant professor in AEP in 1972. **Charles Seyler, Jr.,** joined the EE faculty as an assistant professor in 1981.

In close cooperation with other LPS groups, EE faculty members associated with plasma studies entered upon a productive period of research that continues to the present time. Following initial work on space-plasma physics, Ravi Sudan spent a second sabbatical year with NRL in 1970–71 and returned to the campus to launch a long-term program of research on intense ion-beam technology and associated theoretical studies of charged-particle beam behavior with Richard Lovelace and Edward Ott. John Nation has been concerned throughout his career at Cornell with ways to apply intense relativistic electron-beam technology to the generation of high-power microwave pulses for Department of Energy applications, and to powering high-energy accelerators. During his tenure at Cornell, professor emeritus Chuck Wharton concentrated his research initially on techniques for heating plasmas in fusion reactors, with particular attention to the application of high-energy electron beams for that purpose, and later to high-power microwave generators. In his years at Cornell as a professor of nuclear science and engineering, and more recently as a professor of electrical engineering, Dave Hammer has been concerned with the development of intense pulsed light-ion-beam generation technology for light-ion fusion reactors, and optical and x-ray diagnostics for ion diodes and z-pinches. Until his transfer in 1984 to the space-plasma physics group, Charles Seyler worked with Ravi Sudan on fusion-related research. Before transferring to the University of Maryland in 1980, Ed Ott worked with Ravi Sudan on theoretical studies of plasma behavior. Over the years, professor **Richard Liboff** has complemented these faculty investigations with his theoretical studies of the kinetic theory of plasmas. EE professors **George Wolga** and **Chung Tang** were active participants in early research on lasers and quantum electronics sponsored by LPS.

The thirty years of plasma research in the EE School and in LPS since the launching of that first relativistic electron beam have resulted in significant contributions to the effort that may eventually lead to the realization of fusion power and other areas such as high-power radars and new, more powerful accelerators and x-ray sources. The centerfold of this newsletter displays some of the remarkable devices that have been developed and used in this research. Activities of individual members of the EE Plasma-Physics Research Group are described in articles that appear elsewhere in this newsletter.

—Sam Linke
Professor Emeritus
Electrical Engineering

The EE Plasma-Physics Research Group

The Plasma-Physics Research Group in the School of Electrical Engineering consists of three full professors, **David A. Hammer, John A. Nation,** and **Ravindra N. Sudan,** visiting scientists and research associates affiliated with the Laboratory of Plasma Studies (LPS), and associated graduate students. AEP professor **Bruce R. Kusse,** director of LPS, and his graduate students conduct their research in close collaboration with the EE Group. Experimental facilities were gradually developed in the Mitchell Street Laboratory and in Upson Hall by these experimenters together with EE professor emeritus **Charles B. Wharton** and AEP professor **Hans H. Fleischmann.** In addition, Ravi Sudan together with former EE professor **Ed Ott,** professor **Charles E. Seyler, Jr.,** and AEP professor **Richard V. E. Lovelace** conducted their theoretical studies of plasma behavior with the aid of the Cornell supercomputer facilities. EE professors **George Wolga** and **Chung Tang** were active in early laser and quantum electronics research under LPS sponsorship.

In earlier years, Chuck Wharton conducted plasma research in Upson Hall and applied his extensive expertise in plasma diagnostics to characterize the behavior of magnetically confined plasmas heated to high temperatures by injection of high-power electron beams into the plasma. He also investigated fundamental problems of beam-wave interactions in high-power microwave systems. Hans Fleischmann engaged in early relativistic electron-beam research in the Mitchell Street Laboratory, particularly in the production of electron rings that can serve as scalable test models for the more powerful ion-ring compact toroids used in alternative plasma-confinement concepts. Hans achieved a major breakthrough in electron-beam research by demonstrating magnetic-field reversal in electron rings.

The principal areas of EE plasma-physics research are described in the following three articles.

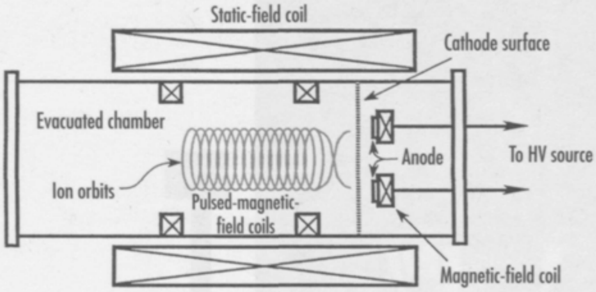
Ion Beams for Fusion Studies

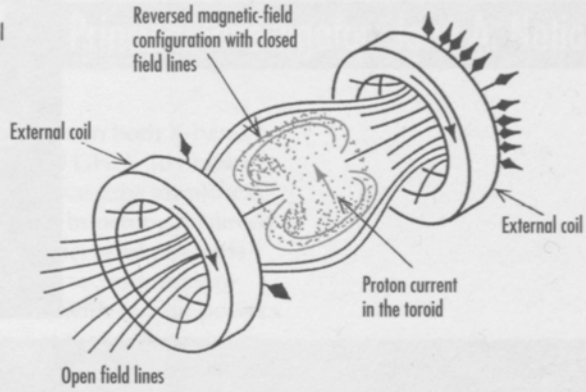
During the thirty-year existence of plasma-physics research in the EE School, one of the primary goals of the plasma group has been to make significant contributions to thermonuclear fusion research. The early mastery of pulsed-power technology and the resulting experiments with intense electron beams were noteworthy achievements toward this objective and provided the essential elements for the theoretical calculations and physical development of the next logical step: the production of intense ion beams. The resulting major ion-beam experiments conducted over the years in the Upson Hall laboratory have caused Cornell to become recognized as one of the world's leading centers of research in intense ion-beam physics, and one of the few places where significant experimental research in both magnetic and inertial fusion is being performed.

Principal Investigator: Ravindra N. Sudan

The ion-beam laboratory now consists of two large machines devoted to fusion research. The Field-reversed Ion-Ring Experiment (FIREX), funded by the U.S. Department of Energy (DOE), is designed to create an intense ion ring to act as a new "bottle" for magnetic confinement of plasmas. The Cornell Beam Research Accelerator (COBRA), also funded by DOE through Sandia National Laboratories (see cover page), will investigate possible advantages of replacement of laser beams with intense ion beams for inertial confinement of plasmas.

Professor **Ravindra N. Sudan** is a widely recognized leader in research in all aspects of plasma physics applied to space and solar physics, controlled thermonuclear fusion, plasma stability, nonlinear interactions in plasmas, intense laser-plasma interaction, solitons, plasma turbulence in the equatorial electrojet, solar coronal heating, and the physics of intense relativistic electron beams and intense ion beams. Following undergraduate and graduate study in India, Ravi obtained the Ph.D. in electrical engineering from Imperial College, University of London, in 1955 and after several years in industry, joined the EE faculty in 1959. His initial field of research was in electrical





machines and power systems, but his interests changed sharply in the period 1960–62 towards plasma physics and controlled thermonuclear fusion. His first work in this new area was the independent discovery in 1963 of the "whistler instability," which subsequently was shown to be the physical mechanism causing very-low-frequency radio emissions from the magnetosphere. Ravi became a full professor in both electrical engineering and applied and engineering physics (AEP) in 1968, and in 1975 he was named the IBM Professor of Engineering at Cornell.

From 1975 to 1985 he was director of the Cornell Laboratory of Plasma Studies (LPS). In 1984–85 he joined professor of physics **Ken Wilson** to found the Cornell Theory Center and was the deputy director of that facility from 1985 to 1987. He has held visiting appointments in plasma and fusion physics in England, Italy, and the United States; has been an invited lecturer in the Soviet Union, France, West Germany, and Japan; and has chaired several international conferences. He has served as head of the theoretical plasma-physics section at the U.S. Naval Research Laboratory, and is a consultant to a number of other government, industrial, and university laboratories. He has been on the editorial boards of several technical journals and is co-editor of Volumes I and II of the *Handbook of Plasma Physics.* His many awards include the James Clerk Maxwell Prize in Plasma Physics by the American Physical Society in 1989, and the Gold Medal in Physical Sciences of the Academy of Sciences of the Czech Republic in 1994. At present he is chairman of the Plasma Science Committee of the National Research Council, and is a fellow of APS, IEEE, and AAAS. Ravi has published over 225 papers with his students and colleagues.

The FIREX and COBRA projects at Cornell use intense ion-beam accelerators that are current versions of pulsed-power systems that have been under cooperative development between DOE's Sandia National Laboratory and Ravi and his associates at Cornell for nearly twenty-five years. Initially, the successful electron-beam accelerator described on page 6, and the subsequent more-advanced devices built in the Mitchell Street Laboratory, prompted consideration of a possible intense-ion-beam accelerator based on similar technology. In principle, just as negatively charged electrons are drawn from the cathode of the field-emission diode in the accelerator, positive ions could be obtained from the anode of the diode. Analysis of this conjecture, however, revealed two major difficulties. One was that unlike field-emitted electrons drawn from a metallic cathode, impractically high electric fields must be applied in order to extract ions from a metallic anode. The second problem was the poor efficiency of the projected diode. Even if ions could be extracted from an anode surface, almost all of the diode current would be due to electrons emitted from the cathode because their mass is so much smaller than that of ions. However, a theoretical calculation by Ravi Sudan and Richard Lovelace showed that introduction of a magnetic field in the diode gap would prevent emitted electrons from reaching the anode. In 1973, initial experiments by postdoctoral fellow **Stanley Humphries, Jr.,** demonstrated that the ion-source problem could be solved without the presence of a magnetic field. Protons and other ionic species could be obtained from ionized plasma layers created on the surfaces of non-metallic anodes that flash over when high-voltage pulses are applied across the diode gap. Subsequent experiments also verified the Sudan/Lovelace magnetically insulated diode concept. Sudan and Humphries were granted a U.S. patent for both diode types in 1976. This technology was adopted soon thereafter by the Naval Research and Sandia Laboratories, and by investigators in Germany, Japan, and the Soviet Union. Today, the magnetically insulated diode is the device most commonly used in this country and abroad to produce intense ion beams for research and applications.

In 1981 the joint program with Sandia National Laboratory allowed acquisition of a light-ion (LION) fusion facility based on the Cornell ion-beam technology. This machine, rated at 2 MV, 400 kA and 40 nanoseconds (ns) (nearly a trillion watts of power in 40 billionths of a second) served for about a decade as an ion-beam research tool in LPS for experiments on generation of intense ion beams

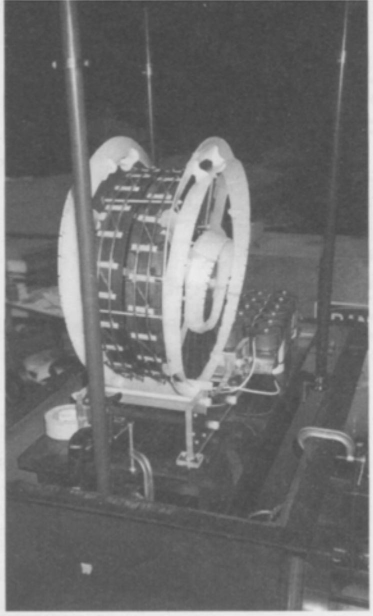
continued on page 21

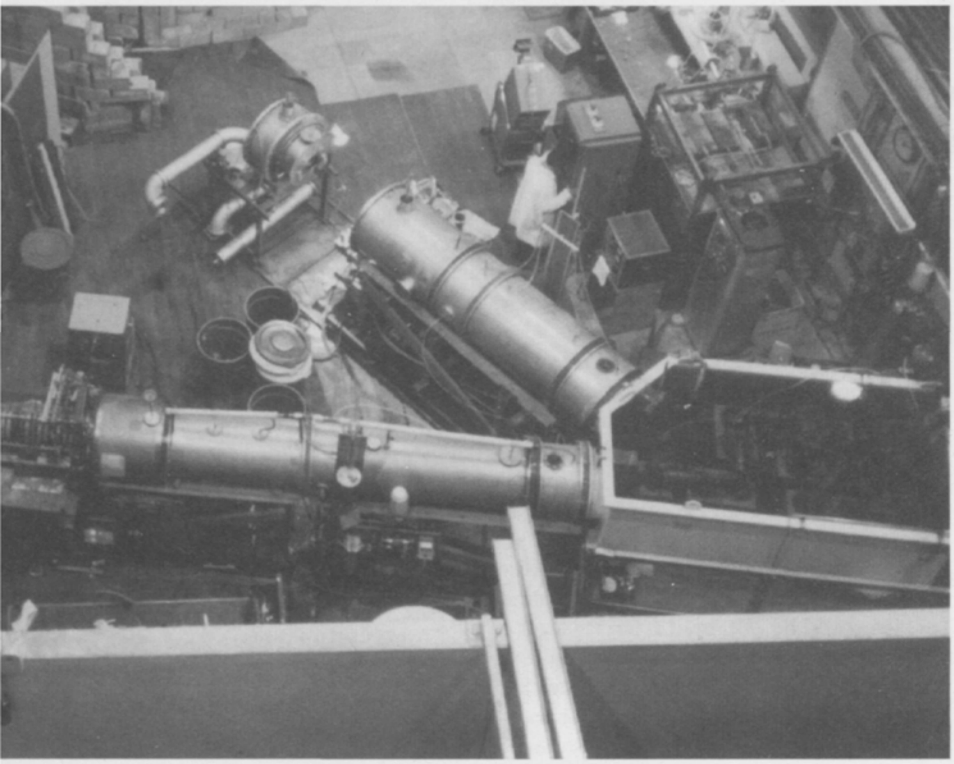
Top, Figure A. The ion-ring experiment. In this apparatus, a magnetic field causes an intense proton beam (injected by the high-voltage pulse source) to rotate around the field lines, thereby producing a rotating proton beam or ion ring. An increasing magnetic field (a magnetic mirror) reflects most of the protons back toward the injector, where they encounter and are trapped by a pulsed magnetic-mirror field that is generated after the initial passage of the ion ring.

Bottom, Figure B. The basic concept of a compact toroid. The plasma is magnetically confined in a doughnut-shaped ring that is kept in place by a simple axial magnetic field. (Adapted from H. H. Fleischmann, "Compact-Toroid Fusion and High-Energy Particle Rings," *Engineering Cornell Quarterly,* vol. 22, no. 1, Autumn 1987).

Diagrams courtesy of David A. Hammer and *Engineering Cornell Quarterly,* vol. 22, no.1 (Autumn 1987).

High-Power Microwave Research





Above, Figure A. General view of the Mitchell Street high-power microwave laboratory. An early version of a cylindrical large-scale pulser is shown in the foreground adjoining a similar partially dismantled device. The oil-filled Marx generator tank is at lower right.

Top, Figure B. This view of the new experimental pulser dislays a prototype of the ferrite-core step-up transformer assembly in early stages of construction. The overall completed assembly will have a volume about 60 times smaller than that of a cylindrical pulser.

In 1969, following the production of the first relativistic electron beams by the pulsed-power facility in the Mitchell Street Laboratory, preliminary diagnostic experiments confirmed a conjecture that the beams could be used as sources of powerful microwave radiation. In the same year, the first experiment to demonstrate the generation of ultra-high power-source pulses using pulsed-power technology occurred at Mitchell Street. The subsequent long-term program of research on intense electron beams and applied electrodynamics has established Cornell as a major contributor to the technology of high-power microwave generation. The principal research effort is devoted to the generation of high-power microwave pulses, with applications to accelerators and high-power radars.

Modern high-energy accelerators, such as the Stanford Linear Collider, use klystron-generated radio-frequency waves interacting with electromagnetic waves in a waveguide configuration to accelerate electrons and positrons. Proposed increases in microwave power and frequency for next-generation electron-positron colliders, advanced radar, and other future applications, will require ever-increasing powers at higher frequencies that may introduce significant difficulties such as r-f breakdown in microwave source and accelerator cavities. High-power microwave research at Cornell concentrates on new classes of traveling-wave-tube amplifiers. In the recent past, r-f sources coupled with pulsed-power-driven electron beams propagating in traveling-wave-tube configurations have been operated in the Mitchell Street Laboratory at x-band frequencies (8–12 GHz) and at microwave output-power levels of the order of 80 megawatts (MW). In current research, an earlier large and bulky accelerator is being set aside in favor of a smaller, more compact device that uses a ferrite-core transformer to raise pulse-line voltages to the necessary levels. This accelerator has been operated at 500 MW at a voltage of 500 kV. The device will be used for high-power microwave-source research at 35 GHz with the hope of achieving r-f conversion efficiencies of at least 40 percent.

Professor **John A. Nation** is a respected leader in the field of high-power microwave generation who has earned particular recognition for his work on the study of pulsed electron-beam interactions in traveling-wave tubes. Throughout his career in the EE School he has been concerned with investigation of the physics of intense electron and ion beams, and with development of appropriate diagnostics to measure their characteristics. Following important

Principal Investigator: John A. Nation

contributions to the establishment of the early relativistic-electron-beam research at Cornell, he recognized the potential of the beams for microwave generation, and over the years has designed and built several pulsers that have contributed to the evolution of his current research.

John obtained the B.Sc. degree in 1957, and the Ph.D. in plasma physics in 1960, both from the University of London. Following completion of his doctoral work he spent a year and a half at the Comitato Nazionale per L'Energia Nucleare laboratory in Frascati, Rome, where he worked on a theta-pinch fusion device. In 1962 he joined the staff of the Central Electricity Generating Board Research Laboratories in Leatherhead, England, and remained there until 1965, when he joined the EE faculty at Cornell as a visiting assistant professor; he became an associate professor in 1972, and was promoted to full professor in 1978. From 1975 to 1984 he served as assistant director and then associate director of the Cornell Laboratory of Plasma Studies, and was director of the School of Electrical Engineering from 1984 to 1989. In 1973–74, he was a senior visiting fellow with the Scientific Research Council in London, and has taken sabbatical leaves at the University of London, the École Polytechnique, the Academia Sinica, and the European Organization for Nuclear Research (CERN). He was awarded the IEEE Centennial Medal in 1988. He has been a consultant in plasma physics with several institutions, including the Naval Research Laboratory in Washington, D.C., and with the Los Alamos National Laboratory in New Mexico. John is a fellow of both the IEEE and the American Physical Society.

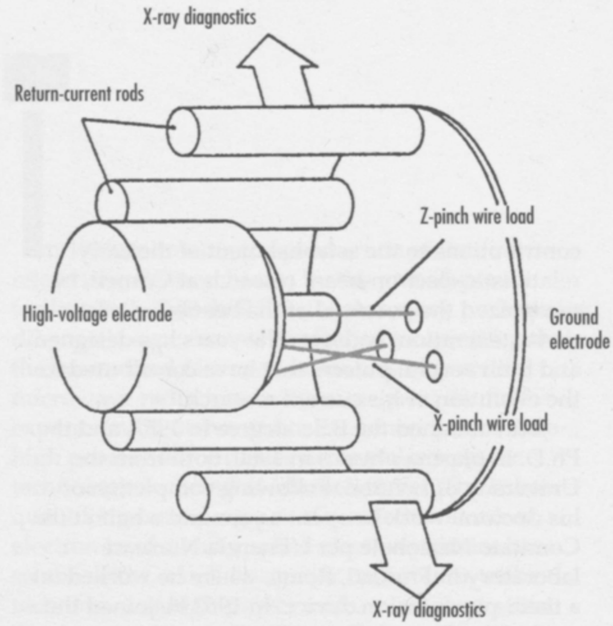
Charged particles are accelerated in modern high-energy devices such as linear accelerators by feeding radio-frequency waves via microwave circuitry into high-energy electron and positron beams that are propagating in a suitable waveguide. Particle acceleration is achieved by designing the waveguide to allow the phase velocity of the wave to match the velocity of the electron/positrons so that particles traveling with the wave can continuously extract energy from the electromagnetic wave. Thus the high power from a high-current, low-energy electron beam, say in a klystron, or traveling-wave tube, is transformed to produce the low-current, high-energy beams of the accelerator.

The present class of microwave devices under development for this purpose by John Nation and colleagues **Graham Kerslick, Jim Ivers, Shahid Naqvi, Cz. Golkowski** and their associates is directed to the study of high-efficiency microwave sources in both X-band (8–12 GHz) and Ka-band (26.5–40 GHz). To obtain high efficiencies the traveling-wave-tube amplifiers are built in sections with optimal bunching achieved in a high-phase-velocity first section and power is extracted in a low-phase-velocity second section. Overall efficiencies of 50 percent with output powers of about 200 MW are expected at the lower frequencies, and 40 percent efficiency at 100 MW is expected in the Ka-band experiments. Modern-day accelerators will require powers of order 100 MW/m length and hence will require several thousand compact, reliable, and efficient microwave sources.

The pulsed-power devices that have been developed and operated in the Mitchell Street and Upson Hall laboratories over the years used high-voltage sources derived from Marx generators composed of large banks of capacitors enclosed either in tanks of mineral oil or in chambers filled with a compressed-gas insulator, sulfur hexafluoride (SF_6) (see Figure A). The need for smaller, compact, high-repetition-rate, high-powered microwave sources for use in applications such as airborne radar and hospital procedures has stimulated John's group to develop a new pulser configuration. Energy from a 50 kV Blumlein line is fed into a step-up ferrite-core transformer to achieve the necessary high voltage for the electron beam that is driving the traveling-wave tube. An experimental unit based on this design has a 12:1 step-up transformer ratio and operates at 500 MW, 500 kV, and 400 ns (see Figure B). A smaller pulser with a 4:1 step-up ratio operates at 50 MW, 100 kV, and 250 ns to test the performance of diodes fitted with ferrite cathodes. A particular feature of this latter arrangement is the use of a thyratron in the transformer switching circuit—an interesting combination in which a state-of-the-art plasma experiment depends on an "old-fashioned" plasma device for its successful operation!

John's research is funded by the U.S. Department of Energy and the Air Force Office of Scientific Research through the Multidisciplinary University Research Initiative (MURI) program on High-Power Microwave Sources. It is interesting to note that John also has collaborative programs with Dr. Levi Schächter of the electrical engineering department at the Technion in Haifa, Israel, and the Institute of Applied Physics, in Nizhniy-Novograd, Russia, funded by the U.S. Civilian Research and Development Foundation for the Independent States of the former Soviet Union (the SOROS Foundation).

Studies of Pulsed Compact X-Ray Sources



Although production of intense ion beams for fusion research is the principal incentive at Cornell for the use of pulsed-power technology, the powerful yet compact modern pulsers now available in laboratories at Cornell and elsewhere also make research possible in other areas such as the creation of pulsed, bright, small-size extreme ultraviolet and soft x-ray radiation sources; development of x-ray sources for imaging; application of compact x-ray sources to high-resolution lithography, proximity printing microlithography, and x-ray crystallography; studies of plasma spectra, plasma instabilities, energy flow, and radiation; and design of experiments that permit access to the hot, dense region of plasma-parameter space without necessity for large-scale experiments.

Principal Investigator: David A. Hammer

Exploding-wire techniques are most commonly used to produce compact radiation sources by means of pulsed-power generators. A “z-pinch” is produced when a thin metallic wire placed between the anode and cathode of a pulser diode vaporizes and turns into a plasma as a 100–350 kA, 100 nanosecond (ns) current pulse is applied. The resulting exploding plasma is turned around and imploded (pinched) along the axis of the wire by compression from the self-magnetic field of the current in the plasma. Small bright spots of high temperature and high density form along the wire and emit intense bursts of soft x-rays. In a similar manner, an “x-pinch” event occurs if two or more crossed wires that touch at an intersection point are pulsed in the diode. Since the bright spots occur in the intersection region, the x-pinch is a point source of intense soft x-rays.

Professor **David A. Hammer** has been at the forefront of development of pulsed-power technology since its inception in the EE School. In applications to controlled fusion, he has studied intense ion-beam generation technology and physics, and intense ion-beam propagation and focusing in vacuum, in gases, and in plasmas. Together with graduate students and collaborating scientists, he has pioneered research and development on the generation of pulsed, compact soft-x-ray radiation sources for various applications, has initiated research on advanced electro-optical instruments to study the properties of dense plasmas without perturbing them, and has developed new diagnostic techniques for dense plasmas using these methods.

Dave received the B.S. degree in physics in 1964 from the California Institute of Technology, and the Ph.D. in applied physics in 1969 from Cornell University. He worked at the Naval Research Laboratory in Washington, D.C., from 1969 to 1976, was a visiting associate professor (part-time) at the University of Maryland from 1973 to 1979, and an associate professor at UCLA in 1977. He joined the Cornell faculty in August 1977 as an associate professor in the Nuclear Science and Engineering Program, and became a full professor in 1984. He was appointed the J. Carlton Ward Professor of Nuclear Energy Engineering in 1991, and transferred to the School of Electrical Engineering in July 1995. He served as director of the Cornell Laboratory of Plasma Studies from 1985 to 1995, and was a visiting senior fellow at Imperial College, London, in 1977, in 1983–84, and again in 1991.

He has been a consultant to several corporations and government laboratories, and was a member of the Inertial Confinement Fusion (ICF) Advisory Committee of the U.S. Department of Energy from 1993 to 1995. He is also a member of JASON, a group of academic scientists that advises several U.S. government agencies on

Figure A. Wire load on the pulser showing a single-wire z-pinch on the axis between the pulser diode electrodes, and a two-wire x-pinch placed in parallel for x-ray backlighting of the z-pinch. The electrode gap length is 29 mm. (Diagram adapted from *Physics Review Letters*, vol. 71, number 23, 6 December, 1993, p. 3806, courtesy of David Hammer.)

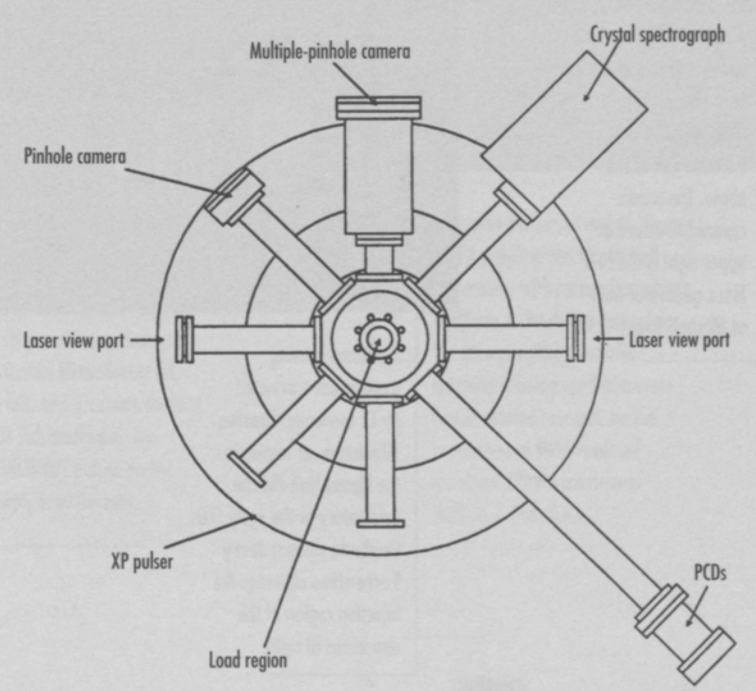
national security issues. Dave is a fellow of IEEE and of the American Physical Society (APS). Currently, he serves as a member of the Executive Committee of the University Fusion Association, and as an associate editor of *The Physics of Plasmas*. He was a member of the Executive Committee of the Plasma Physics Division of the APS from 1988 to 1990, and a member of the Executive Committee of the Plasma Science and Applications Committee of IEEE from 1994 to 1996. He was also a divisional associate editor of *Physical Review Letters* from 1989 to 1991. He has authored or co-authored about eighty articles that have appeared in refereed journals, and about fifty that have been published in conference proceedings, mostly on the technology, physics, and applications of intense charged particle beams and plasma radiation sources. Dave holds a patent on the x-pinch x-ray source for application to lithography in microelectronics manufacturing.

The ability to readily produce pulsed, compact soft x-rays in the laboratory has allowed Dave Hammer and his associates to conduct an ongoing program of research that seeks to characterize the dynamics and basic atomic physics of the plasmas and ancillary electron and ion beams that are formed during x-pinch and z-pinch events. Experimental structures that are similar to the arrangement shown in Figure A have been used to examine and compare radiation from x-pinches and z-pinches using a variety of thin wires such as aluminum, copper, magnesium, tungsten, and tantalum, at diameters of from 5 to 100 microns (10^{-3} mm), and anode-to-cathode gap lengths of 10 to 30 mm. The nature of the studies has required the development of complex diagnostic instrumentation and procedures, as illustrated in Figure B.

For a given pulser, the magnitude of the current drawn by the wire load in an x- or z-pinch experiment depends on the inductance match between the pulser and the load. A typical wire load across the diode electrodes may have had an inductance as low as 10 nanohenries (nH) compared to a power-feed inductance of 100 nH in early experiments conducted with the LION pulser described on page 9; currents were therefore limited to 450 kA. Similar early experiments with the GAMBLE II pulser at the Naval Research Laboratory (NRL) in Washington, D.C., were performed with currents up to 1 MA since the internal inductance of that pulser is 40 nH. In order to upgrade the current levels available from LION, Dave's group designed and built the XP pulser, a relatively inexpensive device with an internal inductance of 40 nH. Subsequent experiments were conducted with XP, rated at 50 kV, 550 kA, and 100 ns.

Compact x-ray sources produced by the x-pinch range from 1.4 keV to more than 10 keV in line radiation from a variety of wire materials. The small size and high intensity of these sources make them suitable for applications requiring high spectral and spatial resolution such as x-ray backlighting for images of z-pinches and other x-pinches, and for submicron lithography. The latter application is of particular interest to the microelectronics industry due to demands from circuit designers for increasing the number of features that can be placed on a single printed-circuit chip. The corresponding decrease in feature size requires high-resolution lithographic techniques that require soft x-rays of the type available from x-pinches. Dave and his group conducted studies to understand the physics of the x-pinch and to optimize it for this application. A small engineering company in Ithaca has built a high-repetition-rate pulser capable of 40 pulses per second, together with a synchronized wire puller, as a prototype of an x-ray source for microlithography.

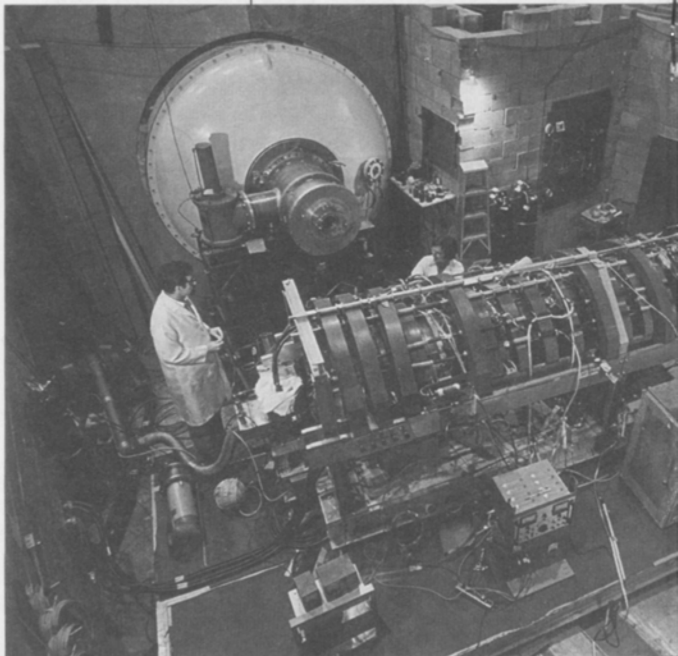
Figure B. Diagnostics for x-pinch and z-pinch studies on the XP pulser. The instruments marked PCDs refer to photoconducting diodes. (Diagram from Figure 2.7 of the doctoral thesis *An Experimental Study of the Dynamics of X-pinch and Z-pinch Plasmas*, by D. H. Kalantar, p. 17, Cornell University, 1993. Reprinted with permission of the author.)



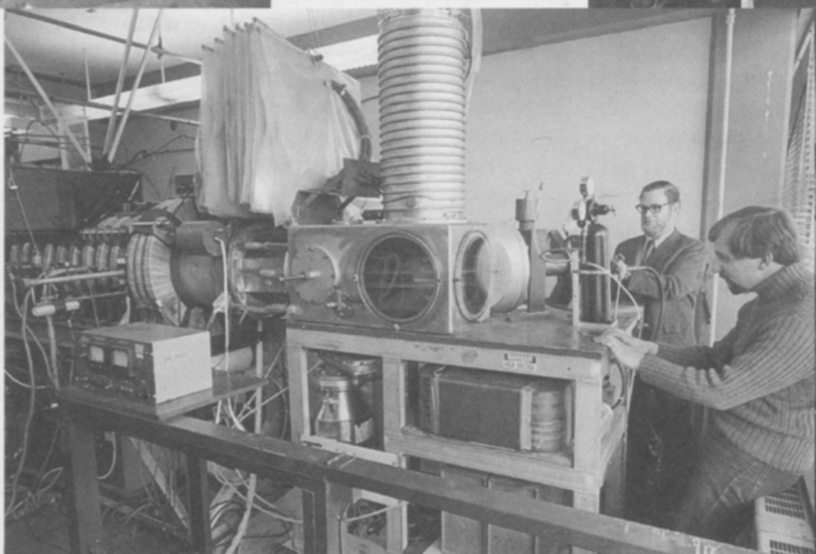
This photograph collection displays the remarkable pulsed-power devices (pulsers) developed in the plasma-studies laboratories through the years.

Pulsers

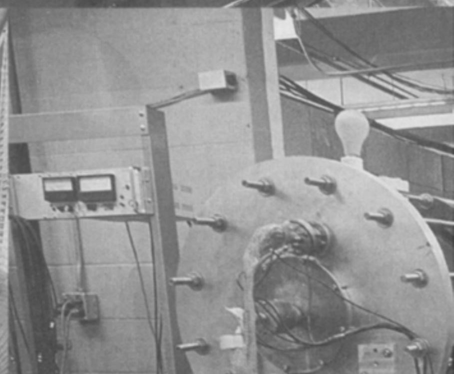
An electron-ring experiment conducted by AEP professor **Hans Fleischmann,** at left, in the Mitchell Street Laboratory in the mid '70s. The apparatus used a 5-MeV electron-beam generator and a large vacuum tank containment vessel surrounded by magnetic field coils. Professor Fleischmann used several versions of this machine to conduct many experiments with field-reversing electron rings.



Two early pulsers (*circa* 1968) are shown in the Mitchell Street Laboratory. The first Blumlein line built in the lab is shown at the top of the photo. A relativistic electron beam is visible in the long plexiglass drift tube seen at the extreme left of the photo. The plastic-covered structure at upper right is the first Marx generator built at Mitchell Street.

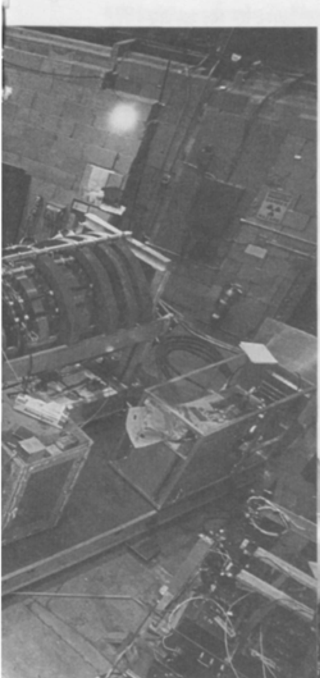


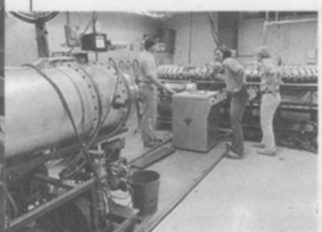
A plasma-heating experiment conducted by EE professor **Charles Wharton,** at center, in the Upson Hall Plasma Laboratory in the early '70s. Graduate student **Jerry Ferrentino** observes the injection region of the apparatus at right.



A cylindrically focussed ion-beam experiment conducted by EE professors **Ravi Sudan,** at right, and **Dave Hammer,** at center, and performed by graduate student **Michael Greenspan** in the Upson Hall Laboratory in the late '70s. The NEPTUNE pulsed-power supply was used for this investigation.

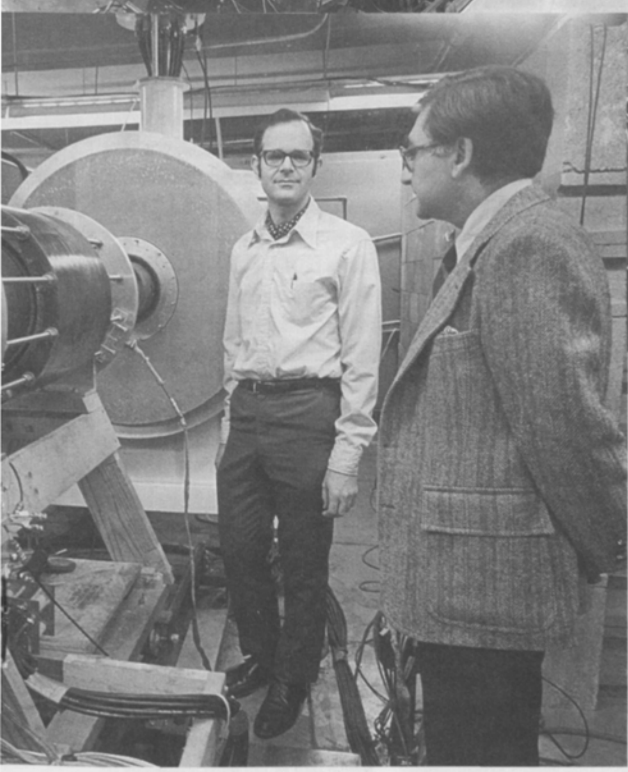
on Parade

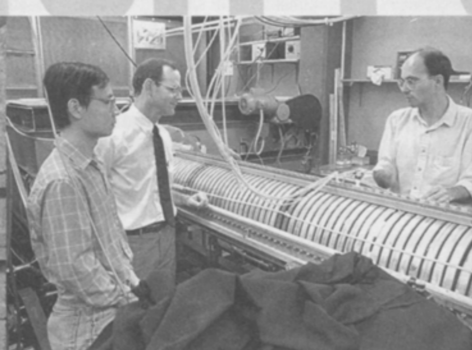




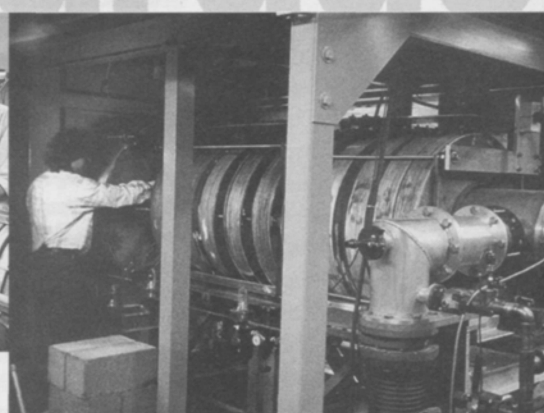
The "racetrack" experiment conducted by AEP professor **Bruce Kusse,** at left, (now director of the Laboratory of Plasma Studies) in the Upson Hall Laboratory in the late '70s. AEP graduate students **David Sing,** at center, and **George Proulx** investigated electron injection into a torus as part of their doctoral thesis research.

The diode of the Sandia/Cornell LION pulser is examined by AEP graduate student and laboratory engineer **Gary Rondeau.** Inertial-confinement experiments were conducted with this device in the Upson Hall Laboratory at about 1990.





This 2.5 meter–long apparatus was used in an ion-beam-plasma interaction experiment in Upson Hall in the mid '80s. Professor **Dave Hammer,** at center, is shown with postdoctoral associate **Niansheng Qi,** at left, and graduate student **Edl Schamiloglu.** The LONGSHOT pulsed-power supply is at the rear.



A view of the active end of the new FIREX pulser in the Upson Hall Laboratory with research associate **William J. Podulka** inspecting the structure. This powerful machine is being used in current fusion-related research on the production of field-reversed ion rings. (Photo courtesy of William J. Podulka.)

Note: Most of the listed awards were announced at the College of Engineering Fall 1996 Awards Ceremony and Faculty Reception on October 28, 1996.

• Professor **Joseph M. Ballantyne** (optoelectronic devices and materials), director of the Semiconductor Research Corporation (SRC) interdisciplinary Program on Microscience and Technology at Cornell, and his group for the first time have demonstrated two major advances in the growth of direct bandgap materials monolithic on silicon substrates. First, selective epitaxy can be used to create highly non-equilibrium conditions for the low-temperature nucleation and growth of low-defect-density GaP on silicon. Second, it is possible to grow a high-quality direct-bandgap pseudomorphic quantum well on gallium phosphide substrates. Taken together, these two advances should allow for the first reliable semiconductor lasers to be grown on silicon substrates, which will open up huge new applications for short-distance optical interconnections in computers. Joe is on a sabbatical leave of absence for the 1996–97 academic year with duties on campus to strengthen the SRC Center; he also plans to begin new research on wide-bandgap semiconductors, and visit several universities concerned with related research activities.

• Professor **Toby Berger** (information theory and communications), the J. Preston Levis Professor of Electrical Engineering, in conjunction with one Ph.D. student, approximately ten M.Eng. students, three undergraduate students, and one part-time research assistant, has developed CU2, an innovative software-only, corporate-quality, high-frame-rate, full-color, low-latency video conferencing utility for LAN/WAN environments. A patent application on the underlying technology was filed via Cornell Research Foundation, a UNIX™ simulation and a live demo in Apple's Quick-Time Conferencing have been produced, and a half-dozen conference papers concerning CU2 have been presented or submitted. Toby is on a sabbatical leave for the 1997 spring term at the University of Virginia in Charlottesville, where he will teach a graduate course and work in the Communications Laboratory in their electrical engineering department.

• Associate professor **Adam W. Bojanczyk** (computer engineering, parallel architecture, and algorithms for signal and image processing) and his graduate students have developed a portable parallel library for designing space-time adaptive processing applications.

• Associate professor **Geoffrey M. Brown** (concurrent systems, communications protocols, and hardware synthesis) in the fall 1996 term taught a new course, EE 491, Compiling Concurrent Programs for Reconfigurable Hardware. In the spring 1997 term, Geoff is on a leave of absence with the Hewlett-Packard Research Laboratory in Cambridge, Massachusetts, where he is working on advanced embedded controlled integrated circuits.

• Associate professor **Hsiao-Dong Chiang** (analysis and control of nonlinear systems with applications to electric-power networks) has been awarded a patent by the U.S. Patent Office for the invention "A Method for Preventing Power Collapse in Electric-Power Systems." He has also made patent applications for two additional inventions: "Boundary of a Stability Region Based on Controlling the Unstable Equilibrium Point (BCU) Classifiers for On-line Dynamic-Security Assessments of Electric-Power Systems," and "A Method for On-line Dynamic Contingency Screening of Electric- Power Systems." Hsiao-Dong has been named a fellow of the IEEE for "contributions to the direct methods to power systems stability analysis and to the development of nonlinear systems."

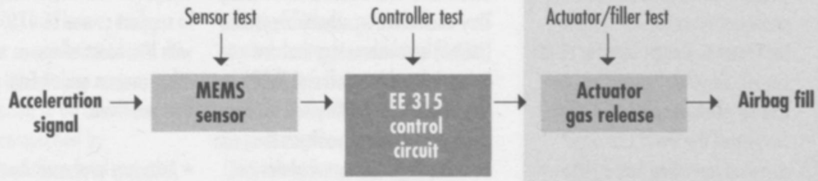
• Associate professor **Richard C. Compton** (millimeter and microwave integrated circuits) is leading a program in a collaborative effort with professor **Noel MacDonald** and Raytheon's Advanced Device Center in a first-of-its-kind project to build a pseudomorphic high-electron-mobility transistor (PHEMT)-based array that features microelectromechanical systems (MEMS) circuitry. As part of ARPA's Microwave Analog Front-End Technology (MAFET) program, Cornell has received a contract totaling nearly $3 million over two to five years. Rick is on leave in San Jose, California, during the spring 1997 term.

• Associate professor **David F. Delchamps** (control and system theory) and his students have begun investigating new approaches toward the modeling and analysis of hybrid dynamical systems. Such systems mix continuous and discrete variables, and often have massively parallel and/or "connectionist" architectures along with event-driven dynamics. Systems of particular interest are those whose states are, to a good approximation, discrete-valued quantities that evolve in continuous time. Goals include applying models of these types to problems in cognitive science and intelligent control-system design. Dave is on sabbatical leave for the spring 1997 term in Ithaca, where he is working full time on his research and finishing the second edition of his linear-systems-theory text.

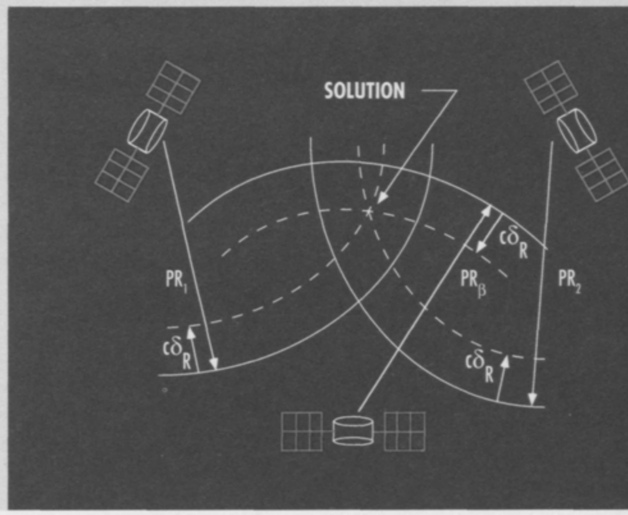
• Professor **Lester F. Eastman** (compound semiconductor materials, devices, and circuits), the John LaPorte Given Professor of Engineering, continues his phased retirement with teaching duties in the Fall term and research in the spring. A new state-of-the-art frequency response of 97.5 GHz for microwave power gain was obtained in an aluminum-gallium nitride-gallium-nitride (AlGaN/GaN)-based modulation-doped field-effect transistor. Lester received the Albert van der Ziel Award for 1996.

• Professor **Donald T. Farley** (radiowave and upper-atmospheric physics), following his sabbatical leave in 1995 as an Alexander von Humboldt Foundation Senior Scientist at the Max Planck Institute for Aeronomie in Germany, returned to teach undergraduate courses, introduced popular innovations in course EE 304, Electromagnetic Waves, and received the 1996 Stephen and Marilyn Miles Excellence in Teaching Award. Don also received the Council of the Royal Society of London Appleton Prize.

• Professor **Terrence L. Fine** (information theory, inference and decision making in the presence of uncertainty) developed two new algorithms for neural-network training. Both algorithms incorporate substantially more of the information developed in the course of training than any other algorithm, while controlling computation effort to match that of the most commonly used back-propagation algorithm. Terry received the Fiona Ip Li and Donald Li Excellence in Teaching Award in 1996.



Top left, Figure B. Block diagram of the circuitry used in the airbag-control project in course EE 315, Electronic Circuit Design. A "crash" was simulated by a controlled hammer blow on the MEMS sensor. (Sketch courtesy of Peter Krusius.)



Bottom, Figure A. An example from course EE 485 GPS, Theory and Design. This diagram demonstrates in two dimensions the uncertainty introduced by an inaccurate clock in GPS receivers. The navigation solution is found from intersecting circles with radii at measured distances, or pseudo-ranges (PR_i) from the satellites. The pseudo-ranges are measured using the GPS receiver clock and need to be corrected by the range equivalent of the receiver-clock offset ($c\delta_R$). By creating four equations, one for each of the three satellites and one for time correction, the GPS receiver can solve for the two positional variables (x,y) and the receiver clock offset (δ_R) to yield an accurate solution. (Sketch courtesy of Paul Kintner.)

• Associate professor **Zygmunt J. Haas** (wireless communication and networks, mobile systems) proposed and investigated a novel macrodiversity scheme for wireless cellular systems that he termed the Multiply Detected Macrodiversity. In this scheme, communication from a mobile unit is detected simultaneously by a number of base stations, with the results being post-detection combined. The scheme results in two to three orders of magnitude improvement in the bit error-rate, as compared with communications in the traditional cellular systems.

• Professor **David A. Hammer** (plasma physics, controlled fusion, intense ion beams), the J. Carlton Ward Professor of Nuclear Energy and a member of the EE Plasma-Physics Research Group, offered a new course, EE 482, Plasma Processing of Semiconductors. The course was instructive to both David and his students, and is likely to be followed soon by research proposals based on the course material.

• Associate professor **Chris Heegard** (communication, information, and coding theory) was on sabbatical leave for the 1995–96 academic year. During that time he was involved in the commercialization of a software package, DigComT™, which is used to analyze, design and verify digital communications systems under Matlab®. In addition he worked on a book, *The Tools of Digital Communications,* which is still in progress. With his graduate students he was involved in research on algebraic geometry coding and an exciting new area of research known as "turbo coding."

• Assistant professor **Sheila S. Hemami** (application-specific compression techniques for packet networks, networking aspects of visual communications, and multirate coding and transmission) has received DOE funding for research on visual communications for heterogeneous networks, research that enables universal access to visual communications through development of scalable, reconstructible image and video coding algorithms. Both scalable and reconstructible image-coding algorithms that provide superior visual performance to the current standard have been developed.

• Professor **C. Richard Johnson, Jr.** (adaptive control and signal processing) and his graduate students, as part of a research thrust in the characterization of the behavior of blind fractionally spaced equalizers, have created a Web site of field-measured received signals and data-based channel models from wireless and wired communication systems provided by industrial collaborator Applied Signal Technology of Sunnyvale, California. This work has the potential to become a widely adopted performance comparison tool. Rick received a Michael Tien Excellence in Teaching Award in 1996.

• Professor **Michael C. Kelley** (upper atmospheric and ionospheric physics) has made what seems to be the first detection of the Earth's dust layer using a combination of remote sensing via radar methods and *in situ* observations by a rocket-borne probe. The dust is thought to come from the ablation of meteors in the upper atmosphere. Although the existence of such a layer has important implications for the occurrence of very high altitude clouds and other phenomena, it has not been detected previously.

• Professor **Paul M. Kintner** (atmospheric plasma physics) created a laboratory course based on the Global Positioning System (GPS) that to the best of current knowledge is the first undergraduate course of its kind. An example of material covered in the course, EE 485, GPS Theory and Design, is shown in Figure A, which illustrates a correction procedure for the uncertainty introduced by inaccurate clocks in GPS receivers. *Geophysical Research Letters* will soon publish an issue containing a special section devoted to Paul's research in the previous academic year with the sounding rocket SCIFER.

• Associate professor **Ronald M. Kline** (history of technology and electrical engineering), director of the Sue and Harry E. Bovay Jr. Cornell Program on History and Ethics of Professional Engineering, revised two articles on the history of the automobile and electrical appliances for *Technology and Culture,* the international journal of the history of technology; had an article on the history of rural electrification accepted by *Public Understanding of Science*; and wrote two chapters for a book on the history of rural technologies.

• Professor **J. Peter Krusius** (solid-state electronics, semiconductor devices and systems, and electronic packaging), has been appointed as new director of the Cornell University Electronic Packaging Program following professor **Che-Yu Li** of the Department of Materials Science and Engineering. He has also been appointed as the new editor-in-chief of the *IEEE Transactions on Components, Packaging, and Manufacturing Technology—Advanced Packaging.* In the fall 1996 term, Peter supervised a novel airbag controller design project in course EE 315, Electronic Circuit Design. The students were given an accelerometer (a MEMS sensor) and an airbag filler module consisting of a rubber balloon, a pressurized nitrogen cylinder, a regulator, and a solenoid gas valve. They designed, built, and tested the control circuitry in a three-week project. A block diagram of the control circuitry is shown in Figure B.

• Professor **Richard L. Liboff** (physics of microsemiconductor devices and solid-state plasmas) has calculated the conditions for the irreversibility of a gas of inert atoms. Among other results, these criteria lead to the notion of a purely adiabatic wall. (Two such gases separated by an adiabatic wall exchange no energy.) Richard's findings were published in *Physics Letters* A204, 177, 1995. His new paper, "Maxwell's Demon and the Second Law of Thermodynamics," has just appeared in *Foundations of Physics Letters,* vol. 10, pp. 89–92, 1997.

• **Yu-Hwa Lo** (optoelectronic materials and devices, and integrated optoelectronic circuits) was promoted to associate professor on November 1, 1996. Yu-Hwa and his group demonstrated for the first time and have applied for a U.S. patent on a "universal substrate" on which a crystal of any material may be grown, a technique that will allow the manufacture of whole new classes of devices in optoelectronics and microelectronics. His group has also demonstrated a first-time use of micromachining technology to produce high-performance microoptic interferometers on silicon substrates, and have developed ultrahigh-sensitivity optical micromechanical sensors for nanometer motion detection and precision alignment. Yu-Hwa is on sabbatical leave of absence for the spring 1997 term. After several weeks at Sandia National Laboratory, he plans to return to Ithaca to work on his text and to edit a special issue of *IEEE Proceedings* on optoelectronics technologies.

EE Research-Funding Summary

Total research funds expended in 1993–94	$11,202,647
Total research funds expended in 1994–95	$11,848,956
Percent increase	5.77 %
Total research funds for 1995–96 *(as of June 30, 1996)*	$12,921,520

• Professor **Noel C. MacDonald** (microelectromechanical and nanoelectromechanical systems), the Lester B. Knight Director of the Cornell Nanofabrication Facility, and his graduate students have developed the world's smallest scanning tunneling microscope (micro-STM) using silicon micromachining processes developed at Cornell. The micro-STMs can be arrayed to make atom/molecular manipulators for information storage. These results have been published in *Applied Physics Letters* 67, Oct. 16, 1995. Noel has also introduced a new senior-level microelectromechanical systems (MEMS) course open to all seniors in science and engineering.

• Professor **Paul R. McIsaac** (microwave theory and techniques) explored the restrictions on the scattering matrix elements of microwave junctions whose port waveguides are helical structures. The difference in the characteristic symmetry of helical structures, compared to more commonly used waveguides and transmission lines, leads to different relationships between the scattering matrix elements for junctions containing either reciprocal or nonreciprocal media.

• Professor **John A. Nation** (electromagnetic fields and waves) and a member of the EE Plasma-Physics Research Group, reports successful accomplishment of a major improvement in the design of an output stage in a high-power microwave source. In the classroom, John extended the prior introduction of computer simulation into courses EE 303 and EE 304, Electromagnetic Waves and Fields I & II and received favorable student reviews.

• Professor **Thomas W. Parks** (signal theory and digital-signal processing) and his graduate students developed new algorithms for the design of multirate systems. Tom has established an arrangement with General Motors Corporation to study the application of signal-processing techniques to predictive maintenance of machinery. A gear box donated by GM has been fitted with accelerometers to facilitate the study. Tiny microelectromechanical systems (MEMS) accelerometers that are being devised by professor Noel MacDonald's laboratory will allow more precise measurements than can be made with conventional devices. This work has potential application to predictive maintenance of a large class of vibrating structures.

• Associate professor **Alfred Phillips, Jr.** (quantum mechanical devices, optical switches, and process modeling) is teaching a new course in the spring 1997 term, EE 498, Quantum Electronic Devices. The course is designed to be a preview of electronic devices that could replace complementary metal-oxide semiconductors (CMOS). It is also a course that considers quantum methods for future devices.

• Professor **Clifford R. Pollock** (lasers and optoelectronics) associate director of the School of Electrical Engineering and the Ilda and Charles Lee Professor of Engineering, led his group in the development of a new laser gain medium based on nanometer-sized crystals embedded in a polymer host lattice. This material has optical gain that is 10–100 times better than the gain available in commercial fiberoptic amplifiers, and opens the door to many new potential lasers and applications. Clif has been named a fellow of the IEEE for "development and application of tunable solid-state infrared lasers to spectroscopy, optical communication, and metrology." He has also been appointed the academic program leader of the Advanced Science and Technology Initiative (ASTI) for the Duffield Hall Project Management Team.

• Professor **Christopher Pottle** (computer engineering, parallel processors, VLSI technology) has successfully introduced a new Erasable Programmed Logic Device (EPLD) into course EE 475, Computer Structures. Since the updated Altera 5128 EPLD has considerably more functionality than the Altera 1810 EPLD, students may choose either device in accordance with their design-project needs. Chris has obtained over $16,000 in equipment from Intel Corporation to support course EE 476, Design with Microcontrollers, as well as other courses and M.Eng. projects that use them.

• Associate professor **Anthony P. Reeves** (parallel computer systems, computer-vision algorithms) and his group have conducted research in computer vision that has resulted in new techniques for extracting temporal motion features from image sequences and for processing probabilistic image sources. A new interactive vision system has also been developed for video-sequence image processing. Courses EE 547, Computer Vision, and EE 308, Fundamentals of Computer Engineering, have been extensively updated; all course materials are now available on the Web. In EE 308, the course material has been revised and labs have been rewritten to reflect experience gained from the first time they were given.

• Professor **Charles E. Seyler, Jr.** (space-plasma physics, physics of relativistic electron beams), coordinator of graduate studies in the School of Electrical Engineering, has developed, together with a Swedish collaborator, Jan-Erik Wahlund, a successful physical model that explains intense electric and magnetic-field phenomena in the upper auroral ionosphere associated with auroral magnetic storms. The model relates these electric field events to short-scale electron and ion energization that have been observed by satellite and sounding-rocket spacecraft.

• Assistant professor **Yosef Y. Shacham** (VLSI technology, nanoelectronics, and process integration) is on a personal leave of absence in Israel during the 1996–97 academic year.

• Associate professor **James R. Shealy** (development of compound semiconductors) and his students have developed two semiconductor processing methods for the first-time: one, a novel technique for synthesis of wide-bandgap nitride semiconductors for blue and green light-emitting diodes (LEDs) and lasers; and second, the combination of submicron lithography and crystal growth applied to an all-in-one process accomplished by stimulation of the crystal growth surface using deep ultraviolet radiation with holographic techniques. Dick received a Michael Tien Excellence in Teaching Award in 1996.

• Professor **Ravindra N. Sudan** (plasma physics), the IBM Professor of Engineering and a member of the EE Plasma-Physics Research Group, and his associates began experiments in February 1996 on the DOE-funded FIREX project to achieve field-reversed ion rings. Design and construction of FIREX started in August 1993. With visiting scientist **Yakov Dimant,** Sudan has developed a new theory for predicting laser pulse solitons (solitary waves) in a plasma at power levels above 10^{19} W/cm^2. A major advance has also been made in the theory of ionospheric turbulence that is similar in structure to fluid convection in porous media driven by temperature gradients. At present, Ravi is chairman of the Plasma Science Committee of the National Research Council. In June 1996, a report on the state of plasma science in the United States was presented to the council by a distinguished panel of scientists commissioned by the Plasma Science Committee.

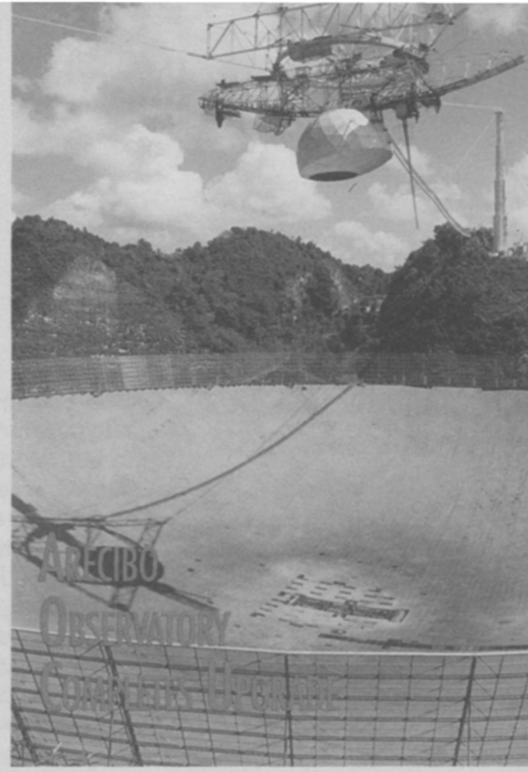
• Professor **Chung L. Tang** (lasers, optoelectric devices, nonlinear and coherent optical processes) the Spencer T. Olin Professor of Engineering, has developed the first femtosecond optical parametric oscillator operating in the mid-infrared to 5.2 microns. Chung has been named an Academician of the Academia Sinica of the Republic of China.

• Professor **Robert J. Thomas** (control techniques for large-scale networks, analysis of microelctro-mechanical systems) has developed a distributed Web-based platform for evaluating auction markets for a restructured electric-power industry. Following the work started during his sabbatical leave in 1995, Bob has continued as director of the Power Systems Engineering Research Center (PSERC) and has made significant progress on a new research area, namely, the integration of economics with power-system planning and operation in a restructured industry.

• Professor **James S. Thorp** (estimation and control of discrete linear systems as applied to control of electric-power networks), the Charles N. Mellowes Professor of Engineering and the director of the School of Electrical Engineering, has developed a technique for evaluating the influence of the electric-power-network protection system on transmission-system reliability.

• Professor **Hwa C. Torng** (computer architecture applied to design of intelligent communications networks) continues his work on ENGRD 231, Introduction to Digital Systems, with a radically new approach and scope. H.C. has completed his work as the program committee chair of the 25th International Conference on Parallel Processing. He reports that there were 272 papers submitted to the conference.

• Professor **George J. Wolga** (quantum and solid-state electronics) reports that his group's KCl:Li color-center laser measurement system went on-line at the focal experiment in Grumman Hall. Their U.S. Army's University Research Initiative (URI) work is now proceeding with experimental determination of temperature profiles in the after-flame region of the incineration of chemical-weapon stimulants.



Arecibo Observatory, the world's most sensitive radio-radar telescope, has just completed a major upgrade of its reflector system, radar transmitter, and other facilities. Conceived by EE professor **Bill Gordon,** the observatory began operations in 1963 and was first upgraded in 1974. It is located in Arecibo, Puerto Rico, and is operated by Cornell's National Astronomy and Ionosphere Center (NAIC) under a cooperative agreement with the National Science Foundation (NSF).

The brief account of progress on the second Arecibo Observatory upgrade in the 1995 issue of *Connections* mentioned a decade of modest participation by Cornell prior to the start of construction of this latest upgrade of the facility. EE professor emeritus **Tor Hagfors,** who was the director of NAIC during that period, writes to correct that statement and to give proper credit to the individuals who planned the upgrade:

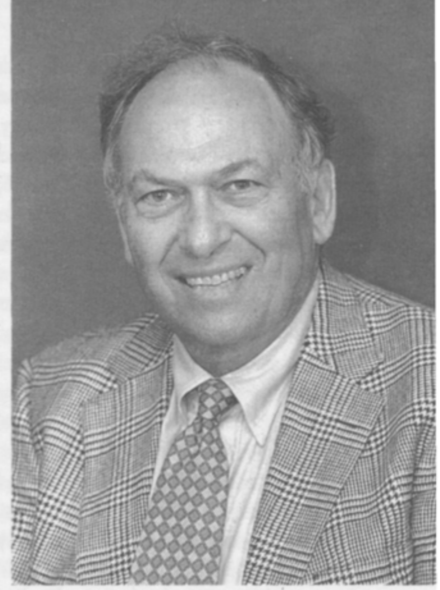
"To say that Cornell was not involved is blatantly wrong. Arecibo was indeed operated by the Cornell astronomy department for the NSF during that time, with an EE professor as director of NAIC and leader of the planning and design of the upgrading now in progress. The *Connections* article gave no credit for the upgrading to **Tommy Gold, Frank Drake,** nor me, when the ten years preceding the start of the upgrading were precisely the years when the plans were made, when the design occurred (with some of my previous grad students) of the feed, the ground screen, and other items now being implemented. Nor is any reference made to **Don Campbell,** who has delivered a titanic effort to implement the upgrading. At the time of 'modest participation,' we struggled very hard to raise the funds necessary to carry out the upgrading, and actually raised $23 million for that purpose."

The photograph is a view of the upgraded structure showing the screen on the perimeter of the bowl and the new Gregorian reflector in place. The editor regrets the omission of this important information and is grateful to Professor Hagfors for correcting the record. In the *Connections* article it was not made clear that the decade of modest participation referred to EE faculty members in the space-sciences group other than Professor Hagfors, and not to Cornell as a whole.

The inauguration of the improved facility is scheduled for Saturday, June 14, of this year at Arecibo. The preliminary list of speakers for the occasion includes: Hon. Pedro Rosello Gonzalez, governor of Puerto Rico, Dr. Neal Lane, director of the National Science Foundation, Dr. Hugh Van Horn, Division of Astronomical Sciences, NSF, Dr. **Hunter R. Rawlings III,** president of Cornell University, Dr. **Paul Goldsmith,** director of NAIC, Dr. **Donald Campbell,** associate director of NAIC, and other personages from NASA and astronomy-related groups at Cornell and elsewhere.

George Wolga Retires

In the past year, one member of the EE School faculty has retired. George Wolga was the guest of honor at a special retirement reception in the Phillips Hall Lounge on June 10, 1996. His biography follows.



George J. Wolga, a member of the EE School faculty for thirty-five years, became professor emeritus on July 1, 1996.

George received the B.S. degree in engineering physics (with distinction) from Cornell University in 1953, and the Ph.D. degree in physics from the Massachusetts Institute of Technology in 1957. During his eight-year residence at M.I.T. he was a research assistant in physics from 1953 to 1956, held a fellowship in 1956–57, was instructor in physics from 1957 to 1960, and an assistant professor in 1960–61. He joined the EE School faculty at Cornell in 1961 as an assistant professor of electrical engineering, and received a joint appointment as associate professor in electrical engineering and in applied and engineering physics (AEP) in 1964. He was promoted to professor in both EE and AEP in 1968, and retired as professor emeritus in 1996.

George's career at Cornell has been devoted to teaching, research, and service to the EE School and to the College of Engineering. He introduced quantum and solid-state physics and quantum electronics into the EE curriculum and research, and helped bring those fields to their present strong position. He taught undergraduate and graduate courses in physics, solid-state electronics, quantum electronics, and lasers and optical electronics, and has directed the research of many graduate students in these areas. His research interests have included excited-state spectroscopy, molecular physics, quantum electronics, molecular-energy transfer and relaxation, modern optical spectroscopic instruments, infrared tunable lasers and spectroscopy, processing of semiconductors, electroluminescent displays, and spectroscopic monitoring of combustion products.

He has served on many committees in the school and the college, including the EE Faculty Committee, and the EE Policy Committee that he helped to create. He served the College of Engineering as chair of the Dean's Oversight Committee for MBE and MOVPE, and chair of the Committee on Conflicts of Interest. He was active in the University Faculty Council of Representatives for several years, and also served on the University Commission on Undergraduate Education, and the University Laser Safety Committee. He was, for several years, the faculty coordinator of the new EE building committee. He is a past graduate field representative in AEP, and served as a member of the Executive and Steering Committees of the Laboratory of Plasma Studies. Along with these duties, he was an active class advisor throughout his career in the EE School.

In 1965–66 George received the Award for Excellence in Teaching from dean of engineering **Andrew Schultz, Jr.**, and was among the top 10 percent of the engineering faculty recommended for the Tau Beta Pi Teaching Effectiveness Award in 1974–75. He is listed in *Who's Who in America, Who's Who in Business*, and *Who's Who in the East*.

George has been a consultant with General Electric Company, Sylvania, U.S. Naval Research Laboratory, General Telephone and Electronics Corporation, Westinghouse Corporation, and ITEK Corporation's Applied Technology Laboratory. He is vice president of Lansing Instrument Corporation, a local company that he founded in 1964. In 1969–70 he was head of the Laser Physics Branch of the Naval Research Laboratory in Washington, D.C., and supervised the growth and redirection of that group. He has been a publication reviewer for the *Review of Scientific Instruments, Physical Review, Physical Review Letters, Applied Physics Letters*, and the *IEEE Journal on Quantum Electronics*, and is a member of the American Physical Society, IEEE, the Materials Research Society, and the Society of Information Display. George supervised the research of twenty-one Ph.D. students in the fields of electrical engineering, physics, and applied physics and has over eighty refereed publications in the fields of his research interests.

Since there were no modern physics courses taught in the EE School when George arrived at Cornell, his first academic assignment was to teach undergraduates in the physics department with professor **Diran H. Tomboulian** (who many older alumni may remember from their sophomore years). Shortly thereafter, he created and taught two new courses, EE 4531 and EE 4532, Quantum Electronics I and II, to graduate students, and started his first research project in the new field of lasers with funding by the Cornell Materials Science Center (MSC). George recalls that in this period he built the first ruby laser and HeNe laser at Cornell and demonstrated audio modulation of the beam to members of the Engineering Council, and at a meeting of professor **Bill Erickson**'s luncheon club, where his ability to stop the music by interrupting the beam with his hand was graphic proof that the process worked.

With additional support from MSC and ARPA, George moved on to molecular-laser research and built an early version of a CO_2 laser. In 1964, professor **Chung L. Tang** came to the EE faculty from Raytheon Corporation and joined George in advanced laser research that would eventually result in many significant individual contributions by both investigators. With Professor Tang on hand to teach quantum electronics, George developed EE 4411, Quantum Theory and Applications, and EE 4412, Solid State Physics and Applications, subsequently titled EE 407 and 408 for EE seniors, two courses that became required for seniors as part of the electrophysics stem of the EE curriculum. Subsequently, George developed EE 430, Introduction to Optical Electronics, with a laboratory component, that is still is being taught. Over the years, George's first courses in quantum and solid-state physics gradually moved from the senior to the junior year and eventually became EE 306, Fundamentals of Quantum and Solid-State Electronics, initially required of all EE upperclass students, and now offered as one of five required electives in the junior year, particularly for those students who wish to take upper-level courses in solid-state or quantum electronics. George taught EE 306 from its inception through 1994.

As soon as laser research started, George recognized the need for precise adjustment of laser-mirrors and invented and patented a gimbal/mirror mount, using a micrometer with magnetic coupling that provided the necessary adjustments without backlash. George founded the Lansing Research (now Instrument) Corporation to promote his invention and other devices, and thereby became the first professor in the College of Engineering to start a separate business.

While speaking of "career firsts," George maintains that he is the first professor in the history of the Cornell College of Engineering to regularly appear in the classroom without a tie and a jacket, and the first to install an air conditioner in the window of his office!

Through the years George's research has been sponsored by ARPA, AFOSR, U.S. Army, ONR, NSF, and the Cornell Materials Science Center. Most recently, George has joined with professor **Fred Gouldin,** of the School of Mechanical and Aerospace Engineering, in research on spectroscopic analysis of combustion products with application to pollution control of emissions from power-plant smokestacks and chemical-weapon incinerators. Their work has been sponsored by the U.S. Army as part of a multidisciplinary University Research Initiative (URI) grant to George, Fred, and colleagues in Applied Physics, Chemistry, and Mechanical and Aerospace Engineering. This work is continuing after George's retirement with a new grant from ONR.

Now in retirement, George continues this important research developing molecular gas tomography using tunable color-center lasers, a technique that may result in the development of stable devices that will be applicable for use in industrial environments. He also plans to pursue his favorite hobby of photography, and to engage in travel as time permits.

SUDAN, continued from page 9

in magnetically insulated diodes. A parallel research program on ion rings began in 1977, and by 1980, working with Ravi, professor **Dave Hammer,** graduate student **Phil Dreike,** and research associate **John Greenly** obtained ion rings in the laboratory with the NEPTUNE pulsed-power generator by injecting a proton beam across a transverse magnetic field of suitable length to cause the protons to rotate around the magnetic field lines (see Figure A on page 9). Ion rings can be important in fusion research if they are strong enough to produce magnetic-field reversal in a plasma so that the resulting compact plasma toroid would then remain in place within a simple axial magnetic field, as depicted in Figure B on page 9. Unfortunately, NEPTUNE, even in its highest power version of 550 kV, 250 kA, 100 ns (in an experiment called IREX, for ion-ring experiment) had insufficient energy output to inject the necessary number of rotating protons into an ion ring to create a fully reversed magnetic field around it.

The results obtained from the ion-ring experiments conducted for several years with these two pulsers allowed Ravi to convince the Department of Energy and the Sandia Laboratory to support construction of a new pulser at Cornell with substantially increased energy output. From 1993 to 1995, LION was enlarged into the FIREX device, rated at 1 MV, 800 kA, and 150 ns. The ultimate goal of FIREX is to produce the desired stable compact plasma toroid. Successful achievement of this objective would provide fusion researchers with a magnetic-confinement technique that is an alternative to the Tokamak configuration and potentially a more economically attractive reactor concept.

The COBRA device, rated at 4 MV, 200 kA, and 40 nanoseconds, will be used to investigate the physics issues that are crucial to determining whether single-pulse intense ion beams can be magnetically focused onto a target with the necessary power density required for pellet ignition in an inertial-confinement fusion experiment. Actual fusion-target experiments will not be conducted at Cornell. A diagnostic package for beam optics is under development to aid in the handling and focusing of the beam. Since inertial-confinement fusion by means of lasers will ultimately require large complicated and expensive apparatus, this research on substitution of ion-beams for lasers may result in more compact and possibly more economic fusion-reactor designs.

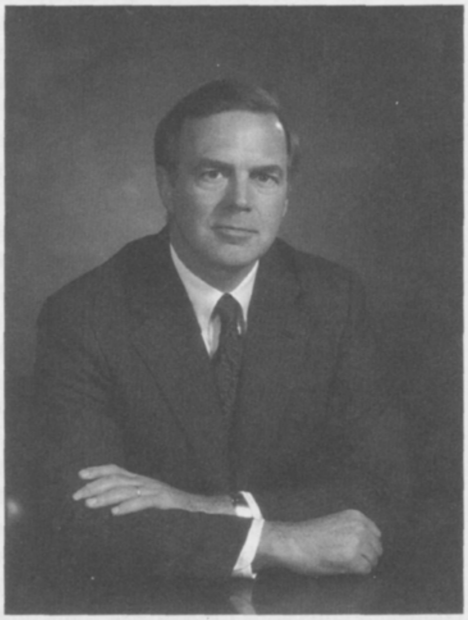
The editor is grateful for helpful discussions with Dave Hammer and John Greenly during Professor Sudan's illness.

A DISTINGUISHED PLASMA-PHYSICS ALUMNUS

Donald M. Kerr, Jr., received the B.E.E. degree in '63, the M.S. degree in '64 in electrical engineering, and the Ph.D. degree in '66 in plasma physics and microwave electronics, all from Cornell University. Following completion of his graduate studies he was employed at the University of California's Los Alamos National Laboratory for ten years conducting and leading research in high-altitude weapons effects, nuclear test detection, weapons diagnostics, ionospheric physics, and alternative-energy programs. From 1976 to 1979 he served in the U.S. Department of Energy (DOE), first in Las Vegas as deputy manager of the DOE Nevada Operations Office, and subsequently in Washington, D.C., as deputy assistant secretary and acting assistant secretary for defense programs, and later for energy technology.

Don received the DOE Outstanding Service Award in 1979, and in that same year he was appointed director of the Los Alamos National Laboratory, a position he held until 1985 when he became president and a director of EG&G in Wellesley, Massachusetts, with direct responsibility for optoelectronics products, security systems, electromechanical components, automotive testing, and government products and services. Following seven years with EG&G, he was a scholar in residence at the John F. Kennedy School of Government at Harvard University until January 1993, when he became corporate vice president and a director of Science Applications International Corporation in San Diego, California, with responsibility for the science and technology segment of the company.

In March 1996, Don assumed his present position as executive vice president, treasurer, and director of Information Systems Laboratories, Inc., in San Diego, California, an organization that provides engineering services with emphasis on advanced digital-signal processing techniques for sensor and telecommunications applications. Concurrently he serves as managing director of Resources Alternatives, Inc., in Washington, D.C., and La Jolla, California, a corporate-development firm specializing in energy utilization, environmental remediation, and strategic analysis for senior management.



DONALD M. KERR, JR.

Advanced Science and Technology Initiative Boosted by EE Alumnus

David A. Duffield, '62, B.E.E. '63, M.B.A. '64, founder of PeopleSoft Inc., has made a $20 million commitment to a new university facility, the Advanced Science and Technology Initiative (ASTI), to be built on or adjacent to the Engineering Quad in a structure, now in the early planning stages, that will be known as Duffield Hall. The grant supplements an earlier gift from **Dwight C. (Bill) Baum** '36, senior vice president of Painewebber, Inc.

Planned as one of the world's most advanced research centers for the characterization and diagnostics of materials and devices, the facility will provide specialized instruction and laboratory space for the School of Electrical Engineering, the Materials Science Center, the Cornell Nanofabrication Facility, the School of Applied and Engineering Physics, and multidisciplinary nanotechnology research teams. ASTI will launch major new instructional and research ventures in science and engineering, and provide state-of-the-art fabrication technologies for electronic and photonic devices, microelectromechanical systems (MEMS), advanced materials processing, and biotechnology devices. The new facility will focus research and instruction in important areas such as unique materials, optical communication links, better and faster information storage, miniature robots for probing at the atomic level, and devices for diagnostic or prosthetic applications that can be expected from miniaturization in biotechnology and bioengineering.

"Duffield Hall will enable Cornell to keep pace with the changing demands of interdisciplinary science and engineering required for education and research as we enter the next century and for the next twenty-five years," said **John Hopcroft,** the Joseph Silbert Dean of Engineering.

Last year, before the Duffield grant was announced, **Lester Eastman,** the John LaPorte Given Professor of Engineering, served as director of academic planning for a new project, called the Engineering Research and Instructional Facility (ERIF). For the ASTI project, professor of electrical engineering **Clif Pollock** has been appointed academic program leader of a College of Engineering management team that will further develop the academic program assembled by Les Eastman for ERIF. Site selection is currently underway and the conceptual-design phase will begin in fall 1997. Construction is anticipated to begin in the spring of 1999, and completion of the building is expected in 2001. Additional funding for the $40 million facility will be sought from private sources, including individuals, corporations, and foundations.

Don is a director of Resources for the Future, the NATO Atlantic Council, and KTAADN, Inc.; chairman of the Directorate of Central Intelligence's Nonproliferation Advisory Panel; and a member of the Defense Science Board and of the Corporation of the Charles Stark Draper Laboratory. He is also a member of advisory boards of the Sandia, Los Alamos, and Lawrence Livermore National Laboratories. He is a fellow of the American Association for the Advancement of Science, and serves on the Cornell University College Council and the San Diego Regional Technology Alliance Board. During his tours of duty with DOE and the Los Alamos National Laboratory, Don provided encouragement and support for the activities of the Cornell Laboratory of Plasma Studies that had direct bearing on the successes reported elsewhere in this issue of *Connections.*

We congratulate Don on his distinguished career and wish him continued success in his further management of these vital issues of national concern.

STAFF NEWS

Deborah Billups, administrative assistant to third- and fourth-floor faculty members since 1993, has left the EE School to take another position in the university. **Jessie Dimmick,** administrative assistant to professor **Noel MacDonald** and his group, joined the EE School in December 1996 after several months in a temporary position with the Cornell Nanofabrication Facility. Jessie obtained a B.S. degree from Paul Smith College in mathematics in May 1991, and also has an Associate in Business Administration degree from Geneseo College in Rochester. She is a native of the Ithaca area and enjoys her pastimes of reading and walking. **Susan (Sue) Drake,** executive staff assistant to director **Jim Thorp,** joined the EE School in November 1996 to replace **Mary Root,** who has relocated to Florida. Sue has been employed at Cornell for over seventeen years, with all of her previous positions having been in the Section of Ecology and Systematics in the Division of Biological Sciences where she was department secretary, and more recently, secretary to the chairman and administrative aide to the section. Sue is a native of the Ithaca area and now makes her home in Moravia, where she and her husband Terry are remodeling their old house. When time allows, Sue enjoys her hobbies of reading, and working with ceramics with a specialty in porcelain dolls. **Mukles Haddad,** office systems specialist in the EE School, over a period of six months prepared, tested, and installed the software for LabVIEW™, the control and data-acquisition system for the teaching labs, described in the 1996 issue of *Connections.* **William Mutch,** equipment technician in the EE School and a professional photographer, produced the cover photo and the Phillips 101 sculpture photo for this issue. **Beverly Phillips,** administrative assistant to associate director **Clif Pollock** and assistant director **John Belina,** joined the EE School in August 1996. Beverly has been employed at Cornell for seventeen years in the Intercollege Program in Archeology, where she was the administrative assistant to the department with principal duties given to assisting undergraduate and graduate students. Bev is a native of Ithaca, and enjoys boating and fishing in the area, reading, and traveling to North Carolina and Virginia to visit her sons and grandchildren. She also admits to being a golf fanatic. **Shelley Weight,** administrative assistant in the EE School since 1995, will be on maternal leave of absence this spring. **Tammie Van Buskirk,** administrative assistant to the EE faculty in Rhodes Hall, joined the EE School in October 1996 after three years as an administrative assistant in the Hotel School. Tammie studied business and information processing in vocational school. She is a native of Ithaca, and enjoys mountain-bike riding and horseback riding.

EE Alumni On-line Database Established

The EE Master of Engineering Program is developing an alumni database for the Web as a special student-directed project. The objective is to produce an EE "find file."

- All EE alumni are urged to submit the following personal data:
  - Name, class year, degrees, current position
  - Work and home addresses and telephone numbers
  - E-mail address (if available)
- Information may be sent directly to:

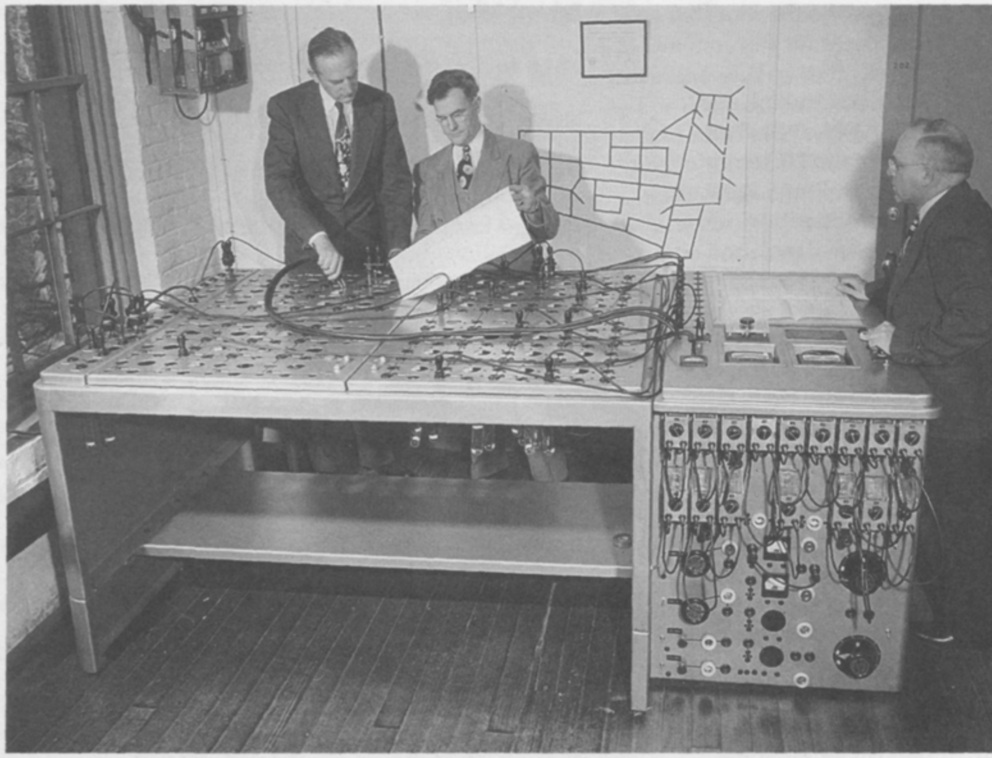
Web site:
http://www.meng.ee.cornell.edu/alumni.html

e-mail address:
meng@ee.cornell.edu

postal address:
Linda Struzinsky
Cornell University
222 Phillips Hall
Ithaca, NY 14853-5401

Please note that your personal information will be available to the general public through the Internet if you enter that information into the find file.

Professor **McIlroy** is shown at left operating his pipeline analyzer. Professor **J. G. (Jack) Tarboux** is at center and professor **Walter Jones** is at the right.



Your tales from the past are always welcome. Send us your favorite stories about professors, labs, classes, projects, stunts, or whatever else you think made the EE School a special place. We'll print 'em as space allows.

The 1996 *Connections* account of past activities and research in the electric-power field brought forth several comments from alumni who recalled their experiences in Franklin Hall and in the Rand Lab, as well as warm memories of their power professors. A particularly informative and interesting letter from **Robert C. Rustay** '50 describes some of his early work in the power field, and recalls his interactions with professor **Malcolm McIlroy** '23 and his novel pipeline analyzer. *Bob writes:*

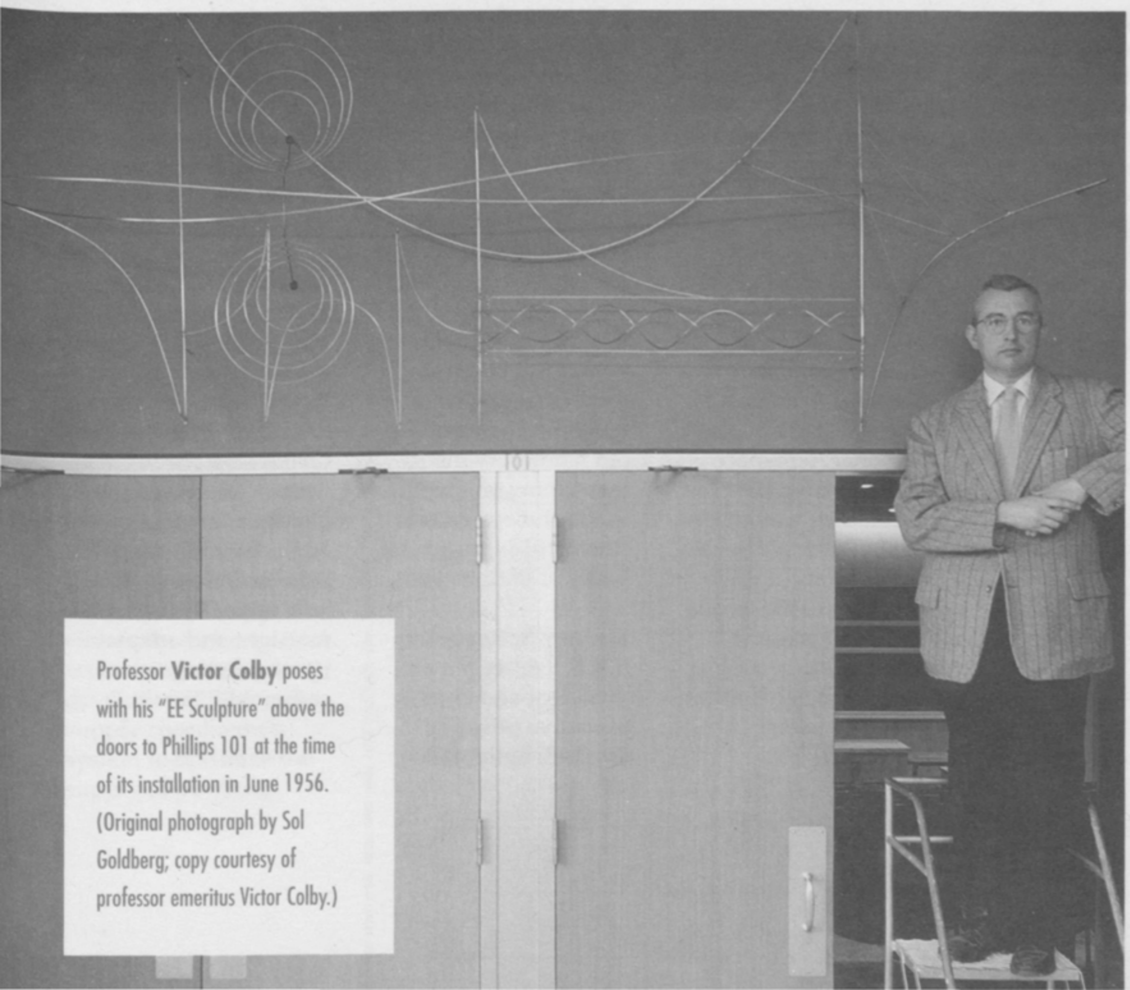
While working for the General Electric Research Laboratory, I was principal scientist on a project concerned with modeling and testing steady-state propagation on electrical distribution networks operating in a range of frequencies from 60 Hz to those commonly used for "carrier-current" signalling. The mathematical model was not only used for carrier-current propagation but also to examine the 60 Hz harmonic propagation. The basis of the model was a vector-matrix differential wave equation (for steady-state sinusoidal waveforms) and involved eigenvectors as "natural modes" which are mathematically decoupled from one another for sections of lines that are homogeneous. My recollection of this project reminds me that Professor McIlroy taught our course on symmetrical components for analyzing power systems before the days of either analog or digital-simulation techniques . . . to study the effects of various faults on electrical distribution systems.

While in my senior year, I was given a small part-time assistantship with Professor McIlroy who was conducting a simulation of the water flow in the Winnipeg, Canada, mains under circumstances of heavy demand by fire-fighting pumpers. As I recall, Professor McIlroy's Ph.D. thesis at MIT involved the theoretical design and actual construction of a tungsten "filament" in an evacuated glass envelope (something like an incandescent bulb but at a much lower operating temperature) that would model the Darcy Law associated with pressure drop through a pipe as a function of the incompressible flow rate through the pipe. The idea behind this device was to take advantage of the very high sensitivity of tungsten resistivity to temperature, combined with the thermal-transfer characteristics (primarily convection and conduction) to obtain the Darcy mathematical function. As I recall, the pressure drop was proportional to a fractional-power exponent of the flow rate. Mac evolved a quantitative design procedure for selecting the various physical parameters to achieve the proportionality constant and nonlinear behavior for a variety of physical pipe sizes. I remember he had quite an inventory of these glass bulbs and a matrix connection arrangement that allowed modeling the principal features of the Winnipeg water distribution system. The pipeline analyzer demonstrated that a heavy fire-truck pumping load would create negative relative pressures in various parts of the system. [*Mac was able to simulate flow for water, natural gas, oil, and even traffic flow! Of course all such studies are being done by computer these days, but the device was excellent for providing instant visualization of incipient trouble spots in a system under study. The photo at left shows an early version of the pipeline analyzer at Cornell.—Ed.*]

How many EE alumni recall seeing the copper-wire sculpture above the entrance to Phillips Room 101 shown in below. When the new EE building was completed in 1955, dean **S. C. Hollister** commissioned Cornell professor of art **Victor E. Colby** to design and construct a work of art, pertinent to electrical engineering studies, to fill the empty space above the lecture-room doors. Victor examined some typical EE textbook illustrations of the time and composed the piece shown in the photo. Inevitably, time took its toll on the copper sculpture, and the damaged piece was removed from the space above the doors when the lecture room was refurbished last year.
A copy of this photograph will be placed in the University Archives so the sculpture will have its proper place in posterity.

The features on plasma studies in EE in this issue of *Connections* would not be complete without at least one story about how we were able to cope with minimum funding in the early days in the Mitchell Street Lab as we refined our "scrounging techniques." The old 60 kV dc power supply that we used in our earliest experiments consisted of a step-up transformer feeding a couple of large vacuum-tube diodes in a full-wave rectifier configuration terminated by two large oil-filled capacitors. At the end of an experiment, after the ac power to the rectifier was turned off, safety precautions made it necessary to remove the large residual charge on the capacitors by remote control. We rigged up a shorting bar with a rope and pulley arrangement that required some heavy contacts to take advantage of gravity when the control rope was released from its bindings. The problem was solved handily by means of two copper toilet-tank floats filled with concrete. On one occasion when the lab was being visited by dean **Andy Schultz,** we demonstrated the device, causing him to remark, "These EEs are really fast on their feet!"

—Sam Linke



Professor **Victor Colby** poses with his "EE Sculpture" above the doors to Phillips 101 at the time of its installation in June 1956. (Original photograph by Sol Goldberg; copy courtesy of professor emeritus Victor Colby.)

Eminent Professors' Fund

Five years ago, the EE School established the Eminent Professors' Fund to honor the memory of notable members of the EE Faculty of past years such as professors **Henry Booker, Nelson H. Bryant, L. A. Burckmyer, Walter W. Cotner, Casper L. Cottrell, Clyde E. Ingalls, M. Kim, Michel G. Malti, Malcolm S. McIlroy, Wilbur Meserve, True McLean, B. K. Northrop, Robert Osborn, Joseph L. Rosson, Howard G. Smith, Everett Strong, Joseph G. Tarboux,** and others whom alumni may recall. The objectives of the fund are twofold:

(1) to acquire specific grants to improve laboratory and research facilities in the EE School, and

(2) to establish endowments to provide ongoing financial support for undergraduate and graduate students.

The EE School has given high-priority status to the following activities:

- Establish an endowment fund to supplement the operating costs of the undergraduate computing center and the undergraduate teaching laboratory.
- Establish an endowment fund to provide financial support, on a yearly basis, for graduate and undergraduate students who serve as teaching assistants in our laboratories.
- Establish one-year fellowships to support professional-masters candidates for the M.Eng.(Electrical) degree.
- Establish a fund to support M.Eng.(Electrical) research projects.

Alumni who would like to contribute to the Eminent Professors' Fund should contact professor **James S. Thorp** in care of the School of Electrical Engineering, Room 224, Phillips Hall.

Positive Feedback

The last issue of *Connections* triggered a gratifying number of responses. We hope that this issue will stimulate even more returns of the coupon at the end of this newsletter. The dots (•) attached to some of the names in the following listing refer to respondents who are mentioned elsewhere in this issue. E-mail address for *Connections* is: *SL78@cornell.edu.* **Notice for Internet surfers:** on the World Wide Web, the EE home page may be found on our uniform resource locater (URL): *http://www.ee.cornell.edu.* The College of Engineering URL is: *http://www.engr.cornell.edu.* **Note:** Our alumni file is somewhat incomplete. If you know of EE alumni who are not receiving *Connections,* please urge them to send their names and addresses to Jeanne Subialka, Engineering Public Affairs, 248 Carpenter Hall, Ithaca, NY 14853-5401.

Larry Dwon '35 (retired from his many years of service as personnel director for American Electric Power Service Corporation in Columbus, Ohio, and now a consulting engineer in West Kill, New York) writes that he is enjoying *Connections* and recalling his long-time friends on the EE faculty. Larry, who has been active in Eta Kappa Nu (HKN) for many years, and wrote a history of the honor society in 1976, also reminds us that the year 2004 will be the 100th anniversary of this distinguished organization.

• **Dwight C. (Bill) Baum** '36 (senior vice president with Painewebber, Inc., in Pasadena, California) has made the first gift for the new facility to house Cornell's Advanced Science and Technology Institute (ASTI) (see page 22). On a recent visit to the campus, Mr. Baum was impressed with faculty and students who are working on molecular engineering and nanotechnology, and said, "It's very exciting to be in on the ground floor of a field that has such tremendous potential."

Wilson Greatbatch '50, inventor of the implantable cardiac pacemaker and holder of 150 patents, was awarded the 1996 Lifetime Achievement Award by the Lemelson-MIT Prize Program administered by the Massachusetts Institute of Technology. Wilson is a member of the National Inventors Hall of Fame, the National Academy of Engineering, and the National Aerospace Hall of Fame. His pacemaker was chosen by the National Society of Professional Engineering in 1983 as one of the ten greatest engineering contributions to society in the past fifty years.

• **Robert C. Rustay** '50 (retired and living in Schenectady, New York) writes that *Connections* brings back vivid memories of Franklin Hall and Rand Lab and of his professors in both buildings. In particular, he recalls that one of the assignments in his first basic EE course, taught by professor Everett Strong, was to design a circular electromagnet of the type used by junkyard cranes to lift scrap ferrous metal. Bob has also sent us an interesting recollection about professor Malcolm McIlroy and his pipeline analyzer (see page 24).

J. Eliot McCormack, Jr., B.E.E. '54 (professional engineering consultant in Valhalla, New York), writes that both he and his son **Scott E.,** B.S.E.E. '89, enjoy reading *Connections,* as does his classmate **Leon (Knick) Knickerbocker, Jr.,** B.E.E. '54, now retired in Skaneateles, New York. Eliot is certain that his fingerprints remain on some of the old laboratory instruments now on display in the showcases near Room 101 in the front lobby of Phillips Hall.

Rodney S. Rougelot, B.E.E. '56 (retired as president and chief executive officer of Evans & Sutherland Computer Corporation in Salt Lake City, Utah), has been named the 1997 recipient of the IEEE Judith A. Resnick Award "for pioneering contributions to space-flight simulation."

Robert Cohen, Ph.D. in E.E. '56 (retired as vice president of Mega Marine Structures, Inc., in Boulder, Colorado, and now active as an energy consultant), spoke at the Energy Engineering Seminar on March 27, 1997, on "Energy from the Oceans."

William J. Balet, Jr., '58 (executive director, New York Power Pool in Schenectady, New York) spoke at the Energy Engineering Seminar on October 3, 1996, on "Deregulation of Electric Utilities and Systems in New York State."

Randolph S. Little '62 (CPNI & Venture Manager, AT&T, Basking Ridge, New Jersey) writes that he found the 1996 issue of *Connections* "brought a new awareness of the history of electric-power engineering in the EE School, and with it a new appreciation for the foresight and adaptability of a distinguished cadre of EE faculty."

Alumni Breakfast

Mark Saturday, June 7, 1997, on your calendar for the annual EE alumni breakfast. The time is 7:45 to 9:30 a.m., and the place is the Phillips Hall Lounge. We hope you and your spouse will join other alumni and members of the faculty and staff for an event that is always a festive and memorable occasion.

• **David A. Duffield,** B.E.E. '63, M.B.A. '64 (president of PeopleSoft, Inc. in Walnut Creek, California), has made a $ 20 million gift to Cornell University to help fund the new facility that will house the Advance Science and Technology Initiative (ASTI). "I am very pleased to be able to share some of PeopleSoft's success with Cornell," said Mr. Duffield. "The education, both academic and social, that I received at Cornell enabled me to develop technical, analytical, interpersonal, and decision-making skills that have served me well as an entrepreneur and business person." (See page 22.)

Duy-Phuong Nguyen, M.Eng.(Electrical) '76 (large-systems hardware development with IBM in Poughkeepsie, New York), is on assignment to IBM in Boeblingen, Germany.

John E. Molinda '77 (senior energy consultant with Strategic Energy, Ltd., [SEL] in Pittsburgh, Pennsylvania) provides strategic planning consulting services to prepare electricity end users for retail competition, and develops SEL's power-supply coordination system to optimize the supply of power to aggregated retail loads in a competitive environment.

Jerry M. Woodall, Ph.D. '82 (the Charles William Harrison Distinguished Professor of Microelectronics at the School of Electrical and Computer Engineering, Purdue University), is the 1997 recipient of the Eta Kappa Nu Vladimir Karapetoff Eminent Members' Award for the invention of the GaAlAs/GaAs heterojunction, and for the invention, development, and realization of devices that use this materials system.

Masroor A. Khan '84 reports that he is now the director of project development with SYED BHAIS (Pvt), Ltd., in Lahore, Pakistan.

Talal Shamoon '85, Ph.D. '95 (scientist with NEC Research Institute in Princeton, New Jersey) has been appointed as a visiting scientist in the EE School for the 1997 spring term to work with assistant professor **Yosi Schacham**'s research group during that time. Talal spoke at the EE Colloquium on November 12, 1996, on "Secure Spread-Spectrum Watermarking for Multimedia." Illegal copying and transmission of image, audio, and video digital data can be prevented by insertion of a hidden tag (watermark) in the data.

John W. (Bill) Gnan '86 (senior electrical engineer with Sverdrup Facilities, Inc., in Orlando, Florida) writes that he is the project manager and electrical engineer of record for the design of the electrical systems for Jurassic Park—a dinosaur park scheduled to open at Universal Studios in Florida in 1999.

Tom Smith Tseng '87 (assistant director of the Cornell University International Affairs and Pacific Regional Office) is responsible for assisting the director in developing international ties to educational, private, and public institutions for the university. Tom was associate director of admissions in the College of Engineering at Cornell from 1989 to 1994.

Jennifer Truman Bernhard '88; Ph.D. '94, Duke University (assistant professor in the Department of Electrical and Computer Engineering at the University of New Hampshire in Durham, New Hampshire), reports that she is teaching and doing research into electromagnetic aspects of wireless communications.

Protima Banerjee '95 (with the Information Systems Leadership Development Program at Lockheed-Martin in Moorestown, New Jersey) writes that her current activities involve object-oriented design and development in database and systems integration.

Alumni: Please fill out this coupon for the "Positive Feedback" feature and return to: Sam Linke, Cornell University, School of Electrical Engineering, 204 Phillips Hall, Ithaca, NY 14853-5401; e-mail: *SL78@ee.cornell.edu*

Name: ______________________________ class year

Position title: ______________________________

I am employed by ______________________________

______________________________ street

______________________________ city state zip

My current activities are:

____

____

____

OPTIONAL:
I would like to explore possibilities in the following areas:

- ☐ Contributions to the Eminent Professors' Fund
- ☐ Contributions to the Joseph L. Rosson (Papa Joe) Memorial Fund
- ☐ Establishment of one-year fellowships for professional masters students
- ☐ Engineering Cooperative Program
- ☐ Job placement of Cornell EE School seniors or graduate students
- ☐ Other ______________

on-line

Live with a Rocket Launch

A Cornell rocket scientist, professor of electrical engineering **Paul Kintner,** provided the general public an opportunity to participate, by means of the Internet, in a NASA-sponsored scientific experiment as he and his colleagues launched a rocket about 620 miles into the upper atmosphere to gather data on the origin of the *aurora borealis*—the northern lights—and on the origin of the earth's radiation belt. Another part of the experiment, funded in part by the Office of Naval Research, was to test a Global Positioning Satellite (GPS) receiver.

In cooperation with NASA and a local science museum in Ithaca, Paul created a Web site for on-line live chats with members of the rocket crew on the launch pad as they prepared to blast off the 100-foot NASA PHAZE-II Black Brant-XII sounding rocket from Poker Flat, Alaska, about thirty miles north of Fairbanks. The chat room was arranged to allow participation by visitors to the Sciencenter in Ithaca as well as by visitors to any other science museum that had access to the Web. The successful launch occurred on February 10, 1997, at 5:17:15 GMT, and provided satisfactory data for all of the planned experiments. Unhappily, the chat-room exercise was not as successful. Several callers were able to get through to the launch pad, but apparently many others were unable to penetrate the intricacies of the Web. Paul feels that this first effort was a "shake-down cruise" and hopes to have better luck with another chat room on the occasion of his next rocket launch.

PSerc: New National Power Center

The National Science Foundation (NSF) has established Cornell University as the lead institution in a consortium of universities comprising a new national center known as the Power Systems Engineering Research Center (PSerc) for research on electric-power systems, including technical issues arising from the restructuring of the industry. In addition to Cornell, the consortium members include the University of California at Berkeley, the University of Illinois at Urbana-Champaign, the University of Wisconsin at Madison, and Howard University. The center was established three years ago with professor of electrical engineering **Robert J. Thomas** as director (see the 1996 issue of *Connections* for an initial description), and has recently been afforded national status by the NSF, with funding of about $200,000 per year for five years. PSerc is also supported by electric-utility companies, and the participating universities. More information is available on the Web at *http://www.pserc.cornell.edu/pserc.*

CORNELL UNIVERSITY

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