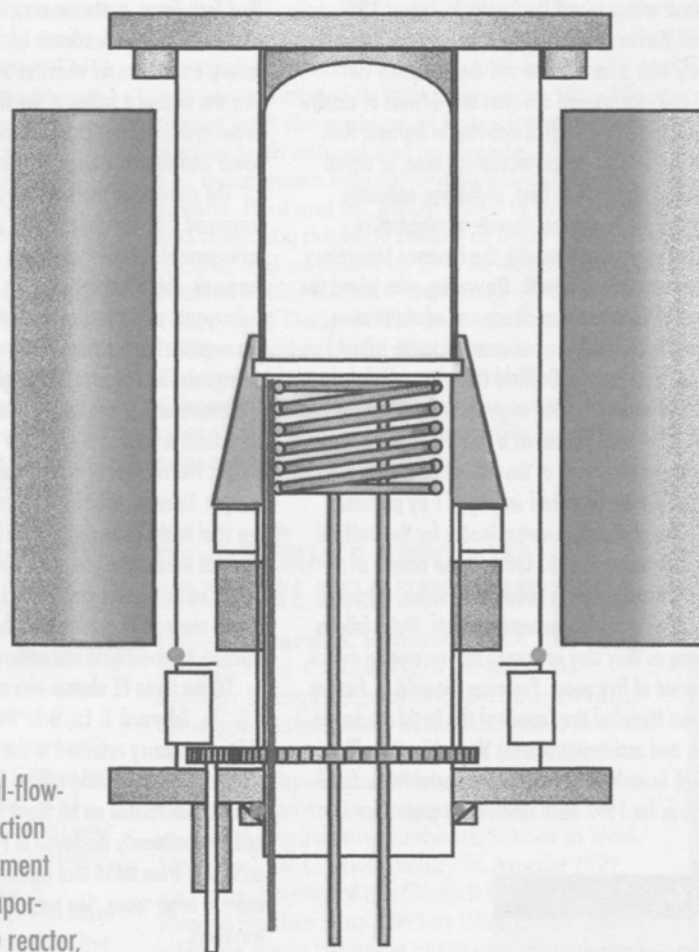


# CONNECTIONS

A Report from the School of ELECTRICAL ENGINEERING • Cornell University

## SEMICONDUCTOR RESEARCH

in the School  
of Electrical Engineering



This sketch of a vertical-flow-modulation epitaxy reaction cell, the operational element of an organometallic vapor-phase-epitaxy (OMVPE) reactor, illustrates one of several types of complex mechanisms used by members of the semiconductor research group in the EE School to fabricate the tiny devices that are pertinent to their work in submicron and nanometer technology. The reactor grows structures of semiconductor materials in layers that approach the diameters of atoms by means of deposition from chemical vapors. Recently, professor Dick Shealy's group has used this and related equipment for a first-time demonstration of submicron pattern resolution in a crystal growth and connection system, a typical example of research that contributes to the development of improved electronic and optoelectronic devices. Plans for the projected Duffield Hall project include expanded instructional facilities and significant extension of the capabilities of this and related semiconductor research in the EE School, and in the entire university scientific community. (Sketch courtesy of Dick Shealy and Joseph Smart.)

This seventh edition of *Connections* features the challenging research of our semiconductor and nanotechnology groups, relates the history of semiconductor technology in the EE School, and considers the impact of Duffield Hall on the future of these technologies in the EE School. 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

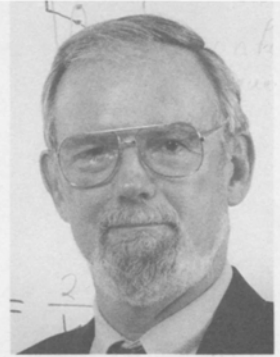
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### In this Issue

Report from the Director	2
Enrollment Statistics	2
Faculty Highlights	3
Newcomers to the EE School	4
Semiconductor Technology in the EE School	5
Semiconductor Research and Graduate Education	9
A Potential Semiconductor Breakthrough	10
Duffield Hall Impacts	11
Nanotechnology Display	14
Recent Faculty Accomplishments	17
Funds and Grants	18
Chris Pottle Retires	20
Report on EE Astronauts	21
A Distinguished EE Alumnus	22
H.C. Torng Honored by Intel	22
New Dual EE/MS&E Major	22
Staff News	23
New "Connection-Machine" Project	23
More Tales from the Past	24
Positive Feedback	26



# REPORT FROM THE DIRECTOR



JAMES S. THORP

For several years a vigorous recruiting program has been in progress in the EE School to fill vacancies created by regular and phased retirements of faculty members and the recent loss of some of our young professors to industry. In the past three years we have hired eight new professors, three of whom came to the school in the past year. Assistant professors **Edwin C. Kan** and **Bradley A. Minch**, B.S. '91, both of whom joined the faculty in August 1997, and assistant professor **Kevin T. Kornegay**, who joined in January 1998, will work closely with other members of the EE faculty concerned with research and instructional activities in the fields of materials and circuit devices related to projected activities in Duffield Hall. We are still recruiting in the information-technology area, in digital systems, and in the circuit and devices field. In the non-academic sector, we wish **Betty (B.J.) Bortz**, our former administrative manager, all success in her new position with the Newman Laboratory of Nuclear Studies, and welcome **Diane K. Downing**, who joined the EE School in December 1997 as our new director of administration. (See page 4 for biographical sketches of newcomers to the school.)

Plans are under development for Duffield Hall, now scheduled to be occupied in 2002. The east end of the engineering quadrangle adjacent to Phillips Hall has been chosen as a tentative site for the new building. The aims and objectives of the Advanced Science and Technology Initiative (ASTI) are described on page 11 by professor **Clifford R. Pollock**, the academic program leader for the Duffield Hall Project Management Team. In 1997 Clif was also named a Stephen H. Weiss Presidential Fellow in honor of effective, inspiring, and distinguished teaching of undergraduate students. Weiss fellows carry their titles as long as they stay at Cornell and receive an award of \$25,000 over a period of five years. Professor **Donald T. Farley** received the Geophysics Medal of the Council of the Royal Astronomical Society of London, and assistant professor **Venu Veeravalli** was awarded the 1996 IEEE Browder J. Thompson Memorial Prize. Excellence in Teaching Awards for 1997 were received by professors

**Michael C. Kelley** and **Paul M. Kintner**, associate professor **Zygmunt J. Haas**, and assistant professor **Sheila S. Hemami**. Other EE faculty members in the news included professor **H.C. Torng**, who received the first Intel Academic Research Fellow Award in a ceremony in December in Ithaca, associate professor **Yu-Hwa Lo**, whose work on universal substrates was featured in an article in the *New York Times*, professor emeritus **Herbert J. Carlin**, who delivered the 1997-98 Academic Address at Isik University in Istanbul, Turkey, and professor emeritus **Simpson (Sam) Linke**, M.E.E. '49, who was named a fellow of the IEEE "For a lifetime of dedication to power-system education and leadership in the development of electric-power and electric-energy systems."

The current job market for our graduates is exciting for all concerned. The anecdotes about salaries, signing bonuses, and special arrangements for working hours are becoming more unbelievable by the week. This alluring recruiting climate, however, has created an unfortunate side effect on our tuition income and budget because of the negative impact on students with particular interests in the Master of Engineering Program. Although M.Eng. graduates are just as much in demand as B.S. graduates, a senior with a fantastic job offer in hand finds it hard to think about an M.Eng. degree (or even an M.S./Ph.D.). The number of students applying for graduate school is down sharply. Since we believe electrical engineers with advanced training are vital to the profession, we are seeking help in convincing more students to consider graduate school. The EE School Web page is being upgraded into an interesting and provocative format that we hope will attract students to graduate study and will also encourage high school students to investigate our undergraduate programs.

Of the three EE alumni who are astronauts—**Daniel T. Barry**, B.S. '75, **Edward T. Lu**, B.S. '84, and **Jay Clark Buckey**, B.S. '77—Dan Barry returned to the campus on October 7, 1997, and presented an interesting talk on his experiences in orbit. The EE banner Dan carried on his flight has been placed in a sturdy frame and is prominently displayed in Phillips 101 together with an official certificate from NASA that confirms the banner's flight of 3.7 million miles in outer space. See page 21 for more details on our space travellers.

The EE School has become the recent beneficiary of a portion of the estate of the late **Roswell C. VanSickle**, M.E. '23, E.E. '24. The sum of \$150,000 will be used to provide the school with laboratory equipment for educational purposes. A similar amount, also to be used for laboratory equipment, will be received by the School of Mechanical Engineering. EE alumni will be interested to learn that Ros VanSickle's late widow, Olive Tjaden, Arch. '25, left her estate for the renovation of Tjaden Hall, formerly Franklin Hall, the first home of the EE School.

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

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## ENROLLMENT AND GRADUATION STATISTICS

### Undergraduate Program

year	sophomores	juniors	seniors	degrees
95-96	120	116	104	117
96-97	138	128	109	115
97-98	132	169	111	•

### M.Eng. (Electrical) Degrees

August	January	May	Total
50	12	53	115
50	22	42	114
29	7	•	•

• Not available at press time.

### M.S./Ph.D. Program

year	applicants	admissions	total enrollment	degrees
95-96	462	15	112	20 Ph.D.s 8 M.S.s
96-97	493	19	108	24 Ph.D.s, 6 M.S.s
97-98	429	•	•	•

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 has increased moderately, the M.Eng. (Elec.) program has decreased significantly and M.S./Ph.D. enrollment has also decreased significantly.



**"It is not an exaggeration to state that Duffield Hall will provide the first suitable laboratory space for my work since I came to Cornell."**

—Joseph M. Ballantyne

## JOE BALLANTYNE IS NEW DIRECTOR OF CNF

Professor **Joseph M. Ballantyne**, Ph.D. '64 (MIT), director of the Semiconductor Research Corporation (SRC) Interdisciplinary Program on Microscience and Technology at Cornell, was named the Lester B. Knight Director of the Cornell Nanofabrication Facility (CNF) in January 1998, succeeding professor **Noel C. MacDonald**, who is on leave of absence in Washington, D.C.

An EE faculty member since 1964, Joe was the founding director in 1978 of the National Research and Resource Facility for Submicron Structures (the predecessor of CNF), was director of the EE School from 1980 to 1984, and served the university as vice president for research and advanced studies from 1984 to 1989. His research interests focus on the synthesis and characterization of III-V compound materials for application in optical devices, and on the design, construction, and testing of optoelectronic devices and circuits. Joe is a fellow of IEEE, has over 200 research papers and conference talks, and holds several patents.

The potential impact of Duffield Hall on the EE School and on future research in the semiconductor and optoelectronic fields is well expressed in Joe's following comments: "Because my work has strong processing and materials components, I have used wet chemistry, clean space, and toxic materials from the beginning of my research. It is not an exaggeration to state that Duffield Hall will provide the first suitable laboratory space for my work since I came to Cornell. Duffield Hall will allow its occupants to grow and process semiconductor materials in a safe environment and one that provides convenient access to the variety of utilities necessary for this work. Since semiconductor materials are at the core of all the devices in electronics and optoelectronics that will be used in future information-processing systems, the new facility will allow Cornell researchers and students to keep pace with continuing rapid advances in this field."

## PAUL KINTNER APPOINTED EE ASSOCIATE DIRECTOR

Professor **Paul M. Kintner Jr.**, B.S. '68, physics (Rochester), Ph.D. '74, physics of the northern lights (Minnesota), became associate director of the EE School on July 1, 1997 succeeding professor **Clifford R. Pollock** '81 (Rice). Paul came to Cornell in 1976 as a research associate in the space-plasma group, became a senior research associate and lecturer in 1978, joined the EE faculty as an assistant professor in 1981, became an associate professor in 1985, and was promoted to full professor in 1991. His research is concerned with the problem of how electromagnetic and electrostatic signals, both natural and manmade, affect the exchange of energy and momentum in collisionless plasmas, especially Earth's plasma. Paul and his group make *in situ* measurements of electric and magnetic fields by means of high-altitude balloons, sounding rockets, and satellites. In 1996 he developed and offered a new course EE 485, Global-Positioning-System Theory and Design. Paul is a senior member of IEEE, a member of the American Geophysical Union, and has served on the Arecibo Advisory Committee and NASA's Management Operations Working Group. He has published 105 papers in his fields of interest.

PAUL M. KINTNER



## DAVE HAMMER APPOINTED GRADUATE FIELD REPRESENTATIVE

Professor **David A. Hammer**, Ph.D. '69, applied physics, the J. Carlton Ward Professor of Nuclear Energy Engineering, became coordinator of graduate studies in the EE School in 1998, succeeding professor **Charles E. Seyler Jr.**, Ph.D. '75, physics and astronomy (Iowa). Dave transferred from the Program in Nuclear Science and Engineering to the EE School in 1995. He joined the Cornell faculty in August 1977 and was director of the Cornell Laboratory of Plasma Studies from 1985 to 1995. His research interests are in the areas of plasma physics and controlled thermonuclear fusion. Dave is a fellow of the American Physical Society and of the IEEE, has published over 130 papers, and holds one U.S. patent.

Dave's research on the production of compact x-ray sources by means of x-pinch is described in the 1997 issue of *Connections*. Since the small size and high intensity of these sources make them suitable for submicron lithography, Dave and his group have conducted studies to understand the physics of the x-pinch and to optimize it for this application. Although this lithographic process could be valuable in projected solid-state nanotechnology studies, Dave believes that his principal contact with the work of Duffield Hall will be in the guidance of graduate students who will be concerned with studying plasma processing methods for nanotechnology.

JOSEPH M. BALLANTYNE



DAVID A. HAMMER



## EDWIN C. KAN

B.S. '84 (National Taiwan University), M.S. '88, Ph.D. '91 (University of Illinois at Urbana-Champaign), all in electrical engineering, joined the EE School faculty in July 1997 as an assistant professor. At UIUC he was a graduate teaching and research assistant from 1986 to 1988 and a graduate research assistant from 1989 to 1991. From 1992 to 1993 he was a senior computer-aided design (CAD) engineer with Dawn Electronic Technologies, and a research associate from 1993 to 1997 at Stanford University. There, he worked on next-generation technology CAD (TCAD) 1-2-3D tool development employing object-oriented and parallel design principles, TCAD model hierarchy for supporting system designs, validation and calibration of TCAD tools, compact models for circuit simulation and design, and microelectromechanical systems (MEMS) modeling.

Edwin teaches very-large-scale-integrated (VLSI) digital circuit and device design and directs his research toward modeling and fabrication of nanometer-scale devices with emphasis on TCAD tool development and model-based process control. He has over 46 publications in his fields of interest. His personal hobbies include reading, basketball, table tennis, and enjoyment of fine music.

Since semiconductor-technology research and development has become very capital-intensive in industry, it is almost impossible for small-group university researchers, especially new ones, to afford the titanic cost of maintaining a state-of-the-art fabrication line. Edwin believes the fabrication facility planned for Duffield Hall represents a collective effort that will counter this deterrent to university research, offer great opportunities for interdisciplinary collaboration, and provide newly established researchers with easy and practical access to process and metrology equipment and to the experts in their use.



## DIANE K. DOWNING

B.S. '93, education (Cornell), joined the School of Electrical Engineering in December 1997 as director of administration. She has had 22 years of experience at Cornell as an academic administrative business manager with skills in project management, human resources, computer expertise, financial management, and public affairs and development. Prior to her present position she was an administrative associate for 13 years with the

Department of Computer Science, a non-academic administrator for the Department of Mathematics for seven years, and a member of the Human Resources and Payroll Implementation Team of Project 2000 for the past two years, a collective background that bodes well for her success in the EE School. Diane is an accomplished vocal artist, well-known locally for her past performances with the Ithaca Opera Association, the Cornell Savoyards, and the Ithaca Community Chorus. Diane and her husband, William, are avid sailors who take their boat, *Cypraea*, out on Cayuga Lake, and occasionally on Lake Erie, when time and weather permit.



## KEVIN T. KORNEGAY

B.S. '85, with honors (Pratt Institute), M.S. '90, Ph.D. '92 (University of California at Berkeley), all in electrical engineering, joined the EE School

faculty in December 1997 as an assistant professor. From 1985 to 1986 he was a member of the technical staff of AT&T Bell Laboratories, followed by a six-year Bell Labs cooperative research fellowship while he was a graduate student at Berkeley. From 1992 to 1994 he was a research staff member at IBM Research in Yorktown Heights, New York, served as an adjunct professor of electrical engineering at Polytechnic University in Brooklyn, New York, from 1993 to 1994, and was an assistant professor in the School of Electrical and Computer Engineering at Purdue University from 1994 to 1997.

Kevin teaches metal-oxide-semiconductor (MOS) VLSI design, wide-bandgap devices and circuits, and smart-power electronics, and conducts research in similar areas as well as in computer-aided design for VLSI circuits. He has numerous journal and conference publications in his fields of interest, has filed for one U.S. patent, and is the recipient of three awards during his recent teaching career. Kevin is a member of Tau Beta Pi, Eta Kappa Nu, a senior member of IEEE, and serves on several IEEE committees. His personal hobbies include golf, cycling, reading, computer games, and jazz.

Kevin feels that the addition of Duffield Hall to the EE School and the College of Engineering will provide additional incentive for him to continue his research in wide-bandgap semiconductors and smart-power electronics, and believes the new facility will also enable him to attract the best and the brightest students and postdoctoral research associates.



## BRADLEY A. MINCH

B.S. '91, electrical engineering, with distinction (Cornell), Ph.D. '97, computation and neural systems (California Institute of Technology), joined the EE School faculty in July 1997 as an assistant professor. Brad teaches in the areas of analog and digital VLSI circuit design. He has a wide range of research interests in related fields including design of analog and digital integrated-circuits, development of "smart" electronic interfaces for microelectromechanical systems (MEMS) sensors, and implementation of low-power, low-voltage, adaptive analog signal-processing systems with floating-gate transistors in standard complementary metal-oxide-semiconductor (CMOS) processes. He is also interested in building silicon models of neural computation. He is a member of Tau Beta Pi, Eta Kappa Nu, Phi Kappa Phi, and the IEEE, with submembership in the Circuits and System Society, the Electron Devices Society, and the Education Society. He has 20 publications in his areas of interest. His hobbies include reading, origami, and an occasional game of chess.

Brad is excited at the prospect of the completion of Duffield Hall. He believes this state-of-the-art instructional and research facility will promote interdisciplinary research and teaching endeavors, and will also give students in the EE School the opportunity to become familiar with the fabrication of microelectronic and MEMS circuits in a hands-on environment.





# SEMICONDUCTOR TECHNOLOGY IN THE EE SCHOOL

**A**s a teenager in Riverdale, New York, **Dwight C. (Bill) Baum '36** used a hand-wound inductance coil, an adjustable capacitor, an antenna, and a galena (lead sulfide) semiconductor rectifier to tune in radio broadcast stations of the early '20s. With this "cat whisker" detector and a set of earphones, Bill got loud and clear reception from WJZ and WEA in New York City, WOR in New Jersey, and the 50-kW "Nation's Station," WLW, in Cincinnati, Ohio. Recollections of this early application of semiconductors and a longtime fascination with the potential of these remarkable materials inspired Bill's recent generous support of instructional facilities for solid-state nanotechnology in Duffield Hall.

The advent of vacuum-tube receivers in the early radio-broadcast years soon relegated crystal detectors to the status of curiosities as the electronic age came into being and radio studies became significant components of electrical engineering curricula. In the EE School, radio-communication courses were initiated in the mid '20s by professors **William C. Ballard** and **True McLean**, followed in succeeding years by the development of standard and advanced courses in electronic-circuit design and analysis by professors **A. Berry Credle '30**, **Howard G. Smith '30**, and others. Since these early courses were primarily concerned with the application of vacuum tubes in appropriate circuits, Professor Ballard developed a companion course in vacuum-tube technology together with a semiprofessional laboratory for the design and construction of

vacuum tubes. Under the direction of professors Ballard and **Walter R. Jones**, this laboratory, shown in Figure A, was housed for many years in the basement of the Franklin Annex, behind Franklin Hall, and was moved to the fourth floor of Phillips Hall in 1955. Faculty and student interest in the behavior and characteristics of electronic devices was further enhanced by the Signal Corps Tube Analysis Program (SCTA) established in the EE School in 1951. This three-year undergraduate research activity, also located in the Franklin Annex basement and directed by Professor Jones, was concerned with analysis of vacuum-tube failures in equipment used by all of the armed services during World War II. From 1951 to 1953, professor **Paul D. Ankrum** used his text *Basic Electronics* in a fall-term course in electronic tubes, circuits, and vacuum-tube characteristics.

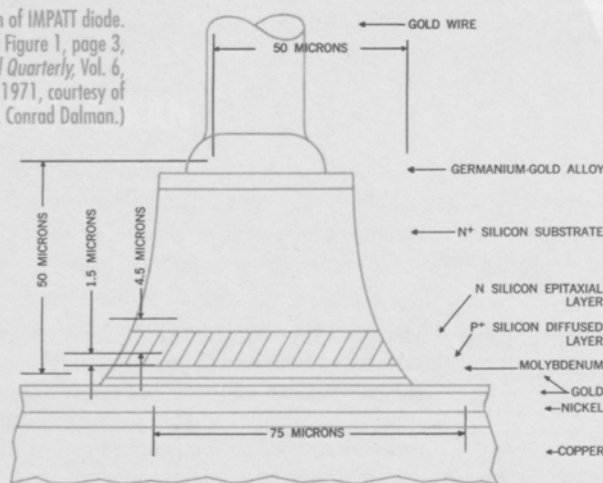
In fall 1953, course EE 4529 Transistors was offered in the EE School for the first time. Professor **Clyde Ingalls** taught the course jointly with professor of physics **Robert L. Sproull**, and Professor Ankrum conducted a companion laboratory in the Franklin Annex basement (a truly versatile location!). The course description read, "This course treats the motion of electrons and holes in semiconductors and gives the physical basis of transistor action and semiconductor rectification." In the light of his later contributions to semiconductor research in the EE School, it is interesting to note that professor **Lester F. Eastman '53**, a graduate student in EE at the time, was a member of that class. When Paul Ankrum returned from his sabbatical leave in 1957–



Figure A. The vacuum-tube laboratory in Phillips Hall in 1955. Assistant professor Les Eastman is second from the right.



Figure 8. Diagram of IMPATT diode.  
(Adapted from Figure 1, page 3,  
*Engineering: Cornell Quarterly*, Vol. 6,  
No. 2, Summer 1971, courtesy of  
Charles A. Lee and G. Conrad Dalman.)



58, he took over EE 4529, added a second course in 1961, and taught the sequence as Semiconductor Electronics I & II for many years. Paul became recognized as a pioneering teacher in his specialty and in 1970 published a textbook, *Semiconductor Electronics*, that became a standard in the field.

In the early '60s the study of electron-device characteristics in the EE School was transferred almost completely from vacuum tubes to semiconductors, but the solid-state devices available at that time were limited to audio and radio-frequency applications. Professor **G. Conrad Dalman**, who came to the EE School in 1956, began to apply his expertise in microwave electronics to semiconductors. In 1959 he joined with Les Eastman, now an associate professor, to introduce physical electronics into the curriculum.

They formed a new academic division, Electronics and Microwaves, that was concerned with the study of solid-state devices operating at very high frequencies. The vacuum-tube laboratory and associated courses were removed from the curriculum in 1961 and replaced by Dalman at the senior and graduate levels with two new courses, EE 4526, Electron Dynamics, and EE 4527, Microwave Electronics. Assistant professors **Lee A. MacKenzie** '56 and **A. Scott Gilmour Jr.** '54 joined Dalman and Eastman in the preparation of EE students for careers in research, analysis, and engineering design in the fields of vacuum, gaseous, and solid-state electronics at high frequencies. Eastman developed a new course, Introduction to Electronic Engineering, on electron flow in vacuum, semiconductor, and ionized gases, and professor **George Wolga** '53 initiated EE 4531, Quantum Electronics, a course that was later required in the EE curriculum as EE 306 for many years. In 1964, a graduate course in physical and microwave electronics included topics on materials science in electrical engineering for the first time, and the course EE 4651, Advanced Physical Electronics, and a laboratory course on vacuum and physical electronics were first offered in 1965.

The establishment in 1963-64 of the two major divisions in the EE School, Systems and Electrophysics, brought several new faculty members with interests in physical electronics. Professor **Joseph M. Ballantyne** (semiconductors, optical materials and devices) and professor **Chung L. Tang** (lasers and quantum electronics) both arrived in 1964.

Professor **Charles A. Lee** (physical electronics and semiconductors) joined the faculty in 1967 and brought his expertise in semiconductor fabrication techniques to the EE School. Professor **Ross A. McFarlane** (quantum electronics and molecular spectroscopy) joined in 1969, and professor **Jeffrey I. Frey** '60 (microwave semiconductor devices and methods) came in 1970. Semiconductor technology at the academic level was now firmly established in the EE School.

## The New Semiconductor Electronics

Several industrial laboratory breakthroughs in physical electronics occurred in the '50s and '60s. Germanium transistor operation at 800 MHz was first demonstrated in 1956 by Charles A. Lee, then of Bell Labs. Further transistor development concentrated on silicon technology and radio-telephony applications (at 100 MHz) until in 1963 J. B. Gunn, a physicist at IBM, found that compound-semiconductor crystals of gallium arsenide (GaAs) are capable of producing oscillations at very high frequencies. This discovery created a new field in compound-semiconductor electronics. In 1965 the microwave avalanche transit-time diode proposed by W. T. Read was fabricated by Charles A. Lee while both scientists were at Bell Labs. The "Gunn effect" diodes, coupled with this new diode, gave promise of great reductions in size and weight of all microwave electronic equipment that heretofore had depended on bulky vacuum tubes and associated power-supply gear. Possibilities were opened up for miniaturization of airborne and satellite communications systems, radar and navigational aids, and many earthbound instrumentation systems. In 1964, Jack S. Kilby and Richard F. Stewart of Texas Instruments, Inc., were awarded patents on semiconductor integrated circuits, a development that allowed a 100-to-1 reduction in the size of conventional transistor circuits, even in those early years, and launched the "chip revolution."

In 1967, John A. Copeland of Bell Labs devised and published a computer simulation of the limited-space-charge accumulation (LSA) oscillator that appeared to show promise for pulsed-power generation of microwaves by means of compound-semiconductor circuitry. In that same year Hooper and Lehrer of IBM fabricated a microwave metal-semiconductor field-effect transistor (MESFET) that had been proposed by Carver Mead of Cal Tech in 1966. The MESFET stimulated the development of microwave transistor structures that have replaced the Gunn and avalanche diodes in the majority of current microwave applications.

Early research in the EE School that would eventually be influenced by these industrial discoveries consisted of studies of vacuum-tube microwave systems, and semiconductor research was confined to circuit applications of silicon transistors. Under the direction of professor Conrad Dalman, Lee Mackenzie completed his doctoral research in 1961 on noise in self-excited microwave oscillators, and A. Scott Gilmour Jr. studied the velocity distribution in velocity-modulated electron beams for his Ph.D. thesis in 1962. In a 1964-65 sabbatical year at the RCA Sarnoff Laboratory, Les Eastman studied compound semiconductors such as GaAs and re-



turned to Cornell to establish research in the EE School on these materials. He was particularly interested in developing high-pulsed-power microwave devices. In 1966, prior to Copeland's publication, **W. Keith Kennedy Jr.** '65, one of professor Les Eastman's graduate students, operated GaAs devices at Cornell in the LSA mode, and as part of the research for his doctoral thesis obtained pulsed high power at microwave frequencies in 1968. This research required GaAs crystals of extremely high quality and special techniques for the fabrication of the associated electronic circuits. The execution of Keith's experiment involved major experimental effort and the able assistance of technicians **Jack Berry** and **Paul Lumbard**.

In the early '70s, professors Lee and Dalman began to apply the revolutionary discoveries of Gunn and Read to the study of solid-state devices composed of semiconductors such as gallium arsenide and silicon, which can, under certain conditions, generate or amplify electrical signals at microwave frequencies at high power and efficiency, broad bandwidths of energy transmission, and low operating noise levels. The tiny dimensions and the complex structure of such compound semiconductor electronic devices are well illustrated in the sketch of an impact-ionization avalanche transit-time (IMPATT) diode shown in Figure B.

During the next five years, professors Ballantyne, Dalman, Eastman, Frey, Lee, McFarlane, and Tang developed small individual laboratories in Phillips Hall, including a rudimentary clean room, to conduct research in their specific areas of interest. It soon became clear, however, that successful expansion of physical-electronics research would require development of materials-science expertise in the fabrication of integrated circuits and the new compound semiconductors, and would necessitate greatly expanded space for experimental facilities. Since the Materials Science Center on campus exhibited limited interest in semiconductor technology at the time, a decision was made to establish a suitable laboratory within the EE School. With financial assistance provided by dean of engineering **Edmund T. Cranch** '45, and matching funds from several industries, a professional "clean room" was constructed on the fourth floor of Phillips Hall. Pertinent equipment, either purchased by Cornell or obtained as donations from industry, included instruments for photolithography techniques, a scanning optical microprobe for analysis of semiconductor materials and devices, and an electron-beam evaporation system used for fabrication of components from material grown by liquid-phase epitaxy (the sequential deposition of patterned thin-film layers of a crystalline substance on a base composed of a different crystal).

Starting in 1972, this facility experienced five years of intensive development of semiconductor research in the EE School. Faculty members from Applied and Engineering Physics and from Materials Science and Engineering made significant contributions, and the facility attracted widespread interest from representatives of industrial laboratories and the National Science Foundation (NSF). As shown in Figure C, visitors to the facility were required to wear protective garments in order to

maintain the integrity of the clean room.

Although the major focus of semiconductor research at Cornell during the '70s was on microwave and optical semiconductor devices, emphasis was broadened to include integrated-circuit (IC) science and technology concerned with the fabrication of thousands of tiny transistors assembled and connected together to form complete circuits on single postage-stamp-size silicon chips. Professor Jeffrey Frey was an early leader in establishing courses in the EE School in this field. This very-large-scale-integrated-circuit (VLSI) technology had developed to the point where an individual transistor on a chip was beginning to approach one-millionth of a meter (one micron) in size, with promise of submicron dimensions on the horizon. Unfortunately for the future of university studies in this new and exciting field, research on such very small structures required expensive high-technology experimental equipment that was well beyond typical university research budgets. In recognition of this problem, NSF held a series of regional workshops in 1976 on the feasibility of establishing a national laboratory that would provide facilities for constructing and analyzing patterns with submicron dimensions. Soon afterwards, proposals were invited for the establishment of a center that would meet these goals.

A proposal was prepared at Cornell and submitted to NSF in 1977 under the direction of professor Ballantyne, with the assistance of EE professors Dalman,

Eastman, Frey, Lee, McFarlane, and Tang, and with the cooperation of faculty members from the School of Applied and Engineering Physics, the School of Chemical Engineering, the Department of Chemistry, the Department of Materials Science and Engineering, and the Department of Physics. In competition with most of the major

research universities in the country and leading government and nonprofit laboratories, Cornell was selected as the host institution with an initial five-year, \$5 million grant. A distinguishing feature of the Cornell proposal, unique among its competitors, was an emphasis on the application of submicron structures in many branches of technology. This firm commitment to interaction between disciplines continues to this day. With Joe Ballantyne as acting director, the National Research and Resource Facility for Submicron Structures (NRRFSS) was established on campus in 1977 and opened its facilities to academic investigators and others in the scientific community across the country.

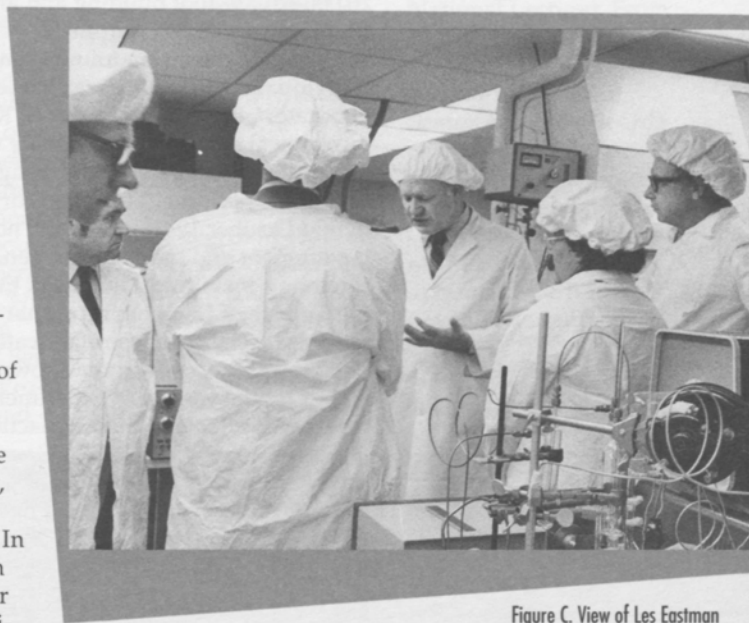


Figure C. View of Les Eastman and visitors in the Phillips Hall clean laboratory. (Photo courtesy *Engineering: Cornell Quarterly*, Vol. 12, No. 4, April 1978.)



## Toward Nanotechnology Research

*I am grateful for interesting discussions with Joe Ballantyne, Conrad Dalman, Les Eastman, and Charles Lee, all of whom were most helpful in providing information on the development of semiconductor technology in the EE School.*

—Sam Linke  
Professor Emeritus  
Electrical Engineering

Phase I of the NRRFSS development program was conducted on the fourth floor of Phillips Hall in space that was renovated for installation of new equipment, and in the existing clean room. An immediate task involved the acquisition of special equipment that would allow semiconductor research in major technological areas, including pattern generation, pattern replication, materials preparation of thin films using epitaxy systems, doping techniques using diffusion and ion-implantation systems, device processing, and device and structure analysis. In 1978 professor of electrical engineering **Edward D. Wolf**, formerly of Hughes Research Laboratories, an expert on submicron technology and surface chemical physics, was named director of NRRFSS and began planning Phase II of the new facility.

Initial designs involved construction of a fourth-floor addition to the south wing of the building but that plan was abandoned when tests indicated the presence of excessive vibrations that could not be tolerated by the ultra-sensitive instruments destined for installation in the facility. The solution was to erect a completely new building adjacent to Phillips Hall, with massive separate foundations for instrument rooms, special high-purity air conditioning, attention to reduction of electromagnetic interference from external sources, and other necessary special-service facilities. The \$3.85 million, 20,000-square-foot building and an additional \$5 million worth of equipment were made possible by generous gifts from foundations, industry, and individuals. The facility was named the Knight Laboratory in honor of **Lester B. Knight Jr.**, '29, a mechanical engineering graduate who was the major donor of funds for the design and construction of the building. The laboratory was dedicated in mid October 1981 with many notables from government and industry in attendance at the ceremony, including **Thomas E. Everhart**, dean of the College of Engineering at that time, who himself is a specialist in microfabrication technology. The central processing area shown in Figure D illustrates the variety of experimental equipment that was available in the new facility.

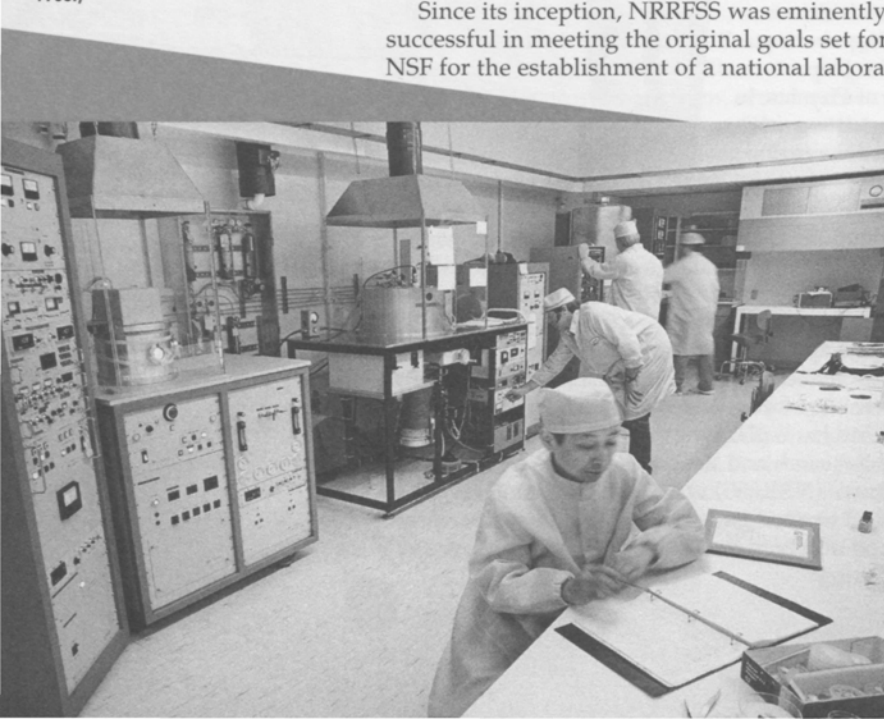
Since its inception, NRRFSS was eminently successful in meeting the original goals set forth by NSF for the establishment of a national laboratory

for research in submicron structures. The facility served scientists and engineers from universities and governmental and industrial laboratories in this country and abroad, and indeed set a standard for the development of similar centers at other institutions. In addition to long-term funding from NSF, other federal agencies and industrial concerns provided support for general research, seed money for special projects, and equipment for the laboratory. In 1977 Les Eastman founded the Joint Services Electronics Program (JSEP), which provides support from the U.S. Army, Navy, and Air Force. Les was director of the program for ten years, followed by the current director, professor **J. Peter Krusius**, who joined the EE faculty in 1981. Professor Joe Ballantyne established the Program on Submicrometer Structures (PROSUS) in 1978 to provide U.S. industries with a "window" into Cornell research in the fields of submicrometer and semiconductor science and technology. In 1982 the Semiconductor Research Corporation (SRC), a cooperative organization of leading U.S. semiconductor, computer, and telecommunication industries, designated Cornell as one of the first "centers of excellence" for research on VLSI circuits. The SRC Program on Microscience and Technology at Cornell was organized to promote an expansion of knowledge in this field, to provide for the training of new researchers, and to foster interaction among industrial and academic researchers. The first director of the program was professor Jeffrey Frey, followed later by professor **Noel C. MacDonald**, who had joined the EE faculty in 1981. Professor Joseph Ballantyne is the current director of SRC.

At the time of the tenth anniversary of the establishment of NRRFSS in 1987, the principal thrust of semiconductor research on miniaturization of structures had entered the nanometer regime. Consequently, the name of the organization was changed to the National Nanofabrication Facility (NNF). In subsequent years, nanotechnology research emerged as the major concern at NNF, broadly applied within the EE School and across other disciplines. In EE, major research in silicon VLSI, microwave and optical devices has been further enhanced by recent development of the microelectromechanical systems (MEMS) program. (See the 1994 *Connections* for a description of MEMS research.)

In 1995 several universities with nanofabrication facilities were formed into the National Nanofabrication Users Network (NNUN). In order to reflect Cornell's membership in NNUN, the name of the facility was changed once again, to the Cornell Nanofabrication Facility (CNF). Following professor Ed Wolf's retirement as director of NNF in 1988, professor **Harold G. Craighead**, Ph.D. '80 (physics), was named the first Lester B. Knight Director of the Laboratory in 1989. He was succeeded by professor Noel MacDonald in 1995, and professor Joseph Ballantyne became the current director in 1998. Articles that appear elsewhere in this newsletter describe activities of individual members of the semiconductor research group in the EE School. Past and present investigations are summarized in those reports, and plans are suggested for future research that will be coordinated with the Advanced Science and Technology Initiative (ASTI) projected for Duffield Hall. ■

Figure D. The NRRFSS central processing area in Knight Laboratory. (Photo courtesy of *Engineering: Cornell Quarterly*, Vol. 18, No. 1/2, Autumn 1983.)







*Directed by  
Lester F. Eastman*

Since the invention of the transistor in the mid '40s, and its extrapolation to practically every aspect of modern technology, silicon has been considered as the preeminent semiconductor material in use, best epitomized by the popular use of terms such as "silicon chip," and "Silicon Valley." The advent of compound semiconductors in the early '60s introduced a powerful new dimension to solid-state electronics that would find application in areas where the relatively low-frequency silicon devices could not function satisfactorily.

Compound-semiconductor research at Cornell has focused principally on gallium arsenide (GaAs) and related alloys with indium (InGaAs) and aluminum (AlGaAs). The work includes layered growth (epitaxial growth) of these compounds and their alloys, growth of heterojunctions (combinations of different compounds), and fabrication of structures for high-frequency, high-speed, solid-state devices suitable for microwave, millimeter-wave, high-speed logic, and high-speed optical applications.

The Cornell Nanofabrication Facility (CNF) is vital to the program because it has state-of-the-art equipment available for computer-aided design and can provide clean rooms with capabilities for fine-line electron-beam lithography. Additional facilities available to the program include clean-room space to house molecular-beam-epitaxy equipment, measurement capability for microwave, millimeter-wave, high-frequency, high-speed, and optical functions, and a liquid-helium photoluminescence system.

**Professor Lester F. Eastman**, known worldwide for his contributions to the development of compound-semiconductor materials, high-speed devices and circuits, has conducted research in those areas since 1965, and has organized related conferences and workshops at Cornell and elsewhere. In 1977 he joined other Cornell faculty members in obtaining funding and founding the National Research and Resource Facility for Submicron Structures (now CNF).

Also in 1977 he founded the Joint Services Electronics Program at Cornell and

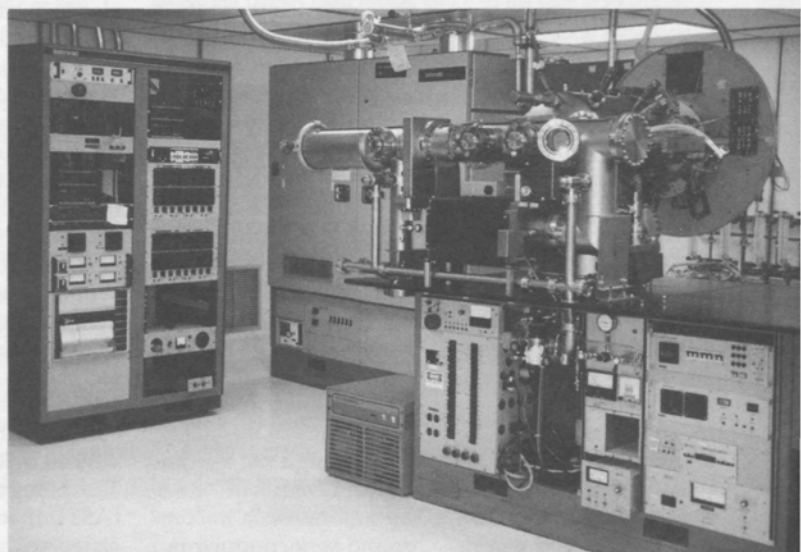
directed the program until 1987. His research group investigates molecular-beam epitaxy, microwave transistors, high-speed semiconductor lasers, high-frequency photo receivers, and fundamental phenomena in compound semiconductor quantum electron and optical devices. He joined with others at Cornell to develop a large effort in high-frequency/high-speed optoelectronics, and recently led the effort to establish a large multidisciplinary university research initiative (MURI) at Cornell to study gallium-nitride high-power microwave amplifiers.

Les obtained a B.S. degree in 1953, a M.S. degree in 1955, and a Ph.D. degree in 1957, all in electrical engineering at Cornell University. He joined the EE faculty in 1957 and is also a member of the graduate fields of Applied Physics and

of Materials Science. His first sabbatical leave in 1964-65 was spent at the RCA Sarnoff Laboratory where he became interested in compound semiconductors. During 1978-79 Les was on leave at MIT's Lincoln Laboratory and spent another leave in 1985-86 at the IBM Watson Research Laboratory. Starting in 1978, he served for ten years as a member of the U.S. Government Advisory Group on Electron Devices and in 1983 was the IEEE Electron-Device-Society National Lecturer. From 1987 to 1993 he was a member of the Kuratorium (Visiting Senior Advisory Board) of the Fraunhofer Applied Physics Institute in Freiburg, Germany.

He has been a fellow of IEEE since 1969, was appointed the John L. Given Foundation Chair Professor of Engineering at Cornell in January 1985, became a member

Figure A.  
A molecular-beam-epitaxy (MBE) machine in the newly renovated clean room in Phillips Hall.





of the National Academy of Engineering in 1986 and a member of the Electromagnetic Academy in 1990. He has received several awards in the compound-semiconductor field including the Heinrich Welker Medal and Annual Award of the International Symposium on Gallium Arsenide and Related Compounds in 1991 for his "contributions to the development of ballistic electron devices, planar doping, buffer layers, and AlInAs/GaInAs/InP heterostructures," the Alexander von Humboldt Senior Fellowship in 1994, and the Aldert van der Ziel Award in 1995. Les has been a consultant for several industries, was a founder in 1985 of Northeast Semiconductors, Inc., in Ithaca, New York, and served as chairman of the board of directors of that company until 1993. Currently he is the chairman of the Advisory Committee for the Materials Science Research Center of Excellence at Howard University.

A major thrust of compound-semiconductor research at Cornell has been concerned with improving the performance of electronic devices by decreasing the transit time of electrons in the device, either by decreasing the size of the structure so the electrons have shorter distances to traverse, or using materials such as gallium arsenide that have better electron-transport properties. Both approaches have been used successfully by Lester's group. In early work, a GaAs logic was developed that achieved a switching-speed record of 15 picoseconds and world-

record gains in transistor current and power at frequencies up to 150 GHz and 250 GHz, respectively. After initiating the concept of ballistic electrons, the group developed GaAs devices with submicrometer dimensions that allow electrons to approach this limit. Ballistic electrons can reach speeds that are four to eight times greater than electron speeds in larger structures where collisions limit their performance. In consequence, it is now possible to study the characteristics of submicrometer-sized field-effect and bipolar transistors that operate at much higher frequencies than were possible in previously developed devices. Other more recent work has been involved with improving the frequency response of devices composed of complex compound semiconductors such as aluminum-gallium-nitride (AlGaN) and gallium-indium-arsenide (GaInAs). Particular attention has been given to the development of high-electron-mobility-transistors with characteristics initially caused by modulation-doping, and very recently found to result from piezoelectric effects on strained layers of material grown on unstrained layers by molecular-beam-epitaxy (MBE) equipment such as shown in Figure A on page 9. Because of their capacity for ultra-low-noise amplification at high frequencies, these new transistors have potential applications in radio astronomy, satellite communications, and radar.

Although the technological benefits of Cornell research in compound semiconductors

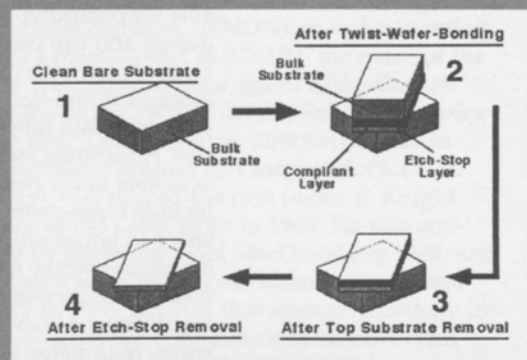
are well documented, the benefits to graduate education are equally impressive. To date, Les has directed the doctoral studies of 101 graduate students during his career at Cornell, as well as many masters candidates and undergraduates, all of whom have distinguished themselves in academia and industry. Les takes pride in reporting that of his Ph.D.s, 16 are members of college faculties in the U.S.; three are professors in Denmark, Japan, and Korea; one is president and CEO of a prominent electronics firm in the U.S.; one, a former director of the Los Alamos National Laboratory, is now an assistant director of the FBI; one is president of a large firm in Sweden; six are IEEE fellows; two are patent lawyers; two have also obtained M.B.A. degrees; 12 are women; and five are under-represented minorities.

Capabilities for future graduate study will be further enhanced by the new Molecular Beam Epitaxy Laboratory that has been installed in Phillips Hall in renovated space formerly occupied by the early submicron clean-room facility (see Figure A). Senior research associates **William J. Schaff** '78, Ph.D. '84, and **David W. Woodard**, Ph.D. '79, will direct the activities of the MBE laboratory for their ongoing research in compound semiconductors and for instruction of students in materials-processing techniques, thereby adding a significant component to the Advanced Science and Technology Initiative (ASTI) that will be associated with Duffield Hall.

## A POTENTIAL SEMICONDUCTOR BREAKTHROUGH

A possible technique for the manufacture of completely new classes of optoelectronic and microelectronic devices has been demonstrated by associate professor of electrical engineering **Yu-Hwa Lo** and his research group including **E. Felix Ejeckam**, Ph.D. '97, **Shanthi Subramanian**, Ph.D. '96 (materials science and engineering), EE doctoral candidate **Matthew Seaford**, and colleagues at Sandia National Laboratory.

The group has developed a "compliant universal substrate" that may make it possible to grow pure single crystals of any semiconductor material on a given semiconductor base. If the new approach can be reduced to economic practice, it will be possible, for example, to grow a thin film of gallium arsenide on a silicon substrate, a process that cannot be achieved easily with current techniques. In the Cornell technique, an ultrathin film is twisted slightly and bonded to the substrate thereby creating a new substrate with a flexible or compliant surface that allows growth of any crystalline material (see diagram). This effect is known as a "twist boundary," in which crystal materials are bonded by angular misalignment, a phenomenon that is not completely understood at present. The discovery has potential for the creation of a new generation of semiconductors that may be applied to lasers, detectors, sensors, computer chips, compact disks, and many similar devices.



A schematic of the formation of a compliant universal (CU) substrate. (Diagram courtesy of Yu-Hwa Lo and CNE.)



# DUFFIELD HALL IMPACTS

The proposed configuration and potential impact of Duffield Hall on teaching and research in the EE School are described in the following series of articles about several professors from among those in the semiconductor research group who will be directly affected by the Duffield project. The research of professor **Joe Ballantyne**, director of CNF, and that of three new members of the faculty, **Edwin Kan**, **Kevin Kornegay**, and **Bradley Minch**, will also be profoundly affected by the new facility (see pages 3 and 4 for their comments). The presence on the faculty of professor **Lester Eastman** and associate professor **Alfred Phillips Jr.** and their expertise in semiconductor growth processes and semiconductor theory, respectively, will be of great value to all participants in the project.

## Duffield Hall Project Elements

**Directed by Clifford R. Pollock**

Duffield Hall will be the university center for nanotechnology, an emerging discipline that is pushing research in many fields such as electrical engineering, biology, mechanical engineering, and chemistry. Current nanotechnology research is spread across campus in facilities that were not designed for the extreme precision and cleanliness required for this research. Duffield Hall will provide the state-of-the-art facility needed to work at nanometer dimensions and will provide an interactive, multidisciplinary facility that will foster intellectual collisions between researchers in these different fields.

Schematic design of Duffield Hall is just beginning, with construction scheduled to start in the fall of 1999, and move-in planned for February 2002. A team of Cornell architects, engineers, and faculty members (led by professor Clif Pollock) is working with architecture firm Zimmer, Gunsul, and Frasca of Los Angeles to design the structure. The proposed site for the building is to the west of Phillips Hall, in the engineering quadrangle. Duffield Hall will be a mixture of central facilities and individual laboratories. The building will have approximately 50,000 net square feet of space.

The Cornell Nanofabrication Facility will anchor Duffield Hall's central laboratories with 11,000 net square feet of clean-room and nanofabrication facilities for investigations ranging from semiconductor-device fabrication to biological template structuring. The Cornell Materials Science Center will occupy approximately 4,000 net square feet for microscopy and various other high-spatial-resolution characterization equipment. Approximately 1,900 net square feet of space will be devoted to instructional laboratories, and 18,000 net square feet of laboratory space will be available to individual research groups.

Professor **Clifford R. Pollock**, Ph.D. '81 (Rice), the Ilda and Charles Lee Professor of Engineering, was appointed in 1997 as the academic program leader of the Advanced Science and Technology Initiative (ASTI) for the Duffield Hall Project Management Team. Clif joined the EE faculty as an assistant professor in 1983, was promoted to associate professor in 1987, and became a full professor in November 1993. He was one of the first recipients of the National Science Foundation Presidential Young Investigator Awards, and has received five Excellence in Teaching Awards in the EE School. His research centers on the development of tunable solid-state lasers applied to problems in ultrashort pulse generation, and optical-fiber devices. Clif is a fellow of the IEEE, has published over 65 papers and holds five patents in his fields of interest.

CLIFFORD R. POLLOCK



CHUNG L. TANG

## Femtosecond Lasers and Other Ultrafast Semiconductor Devices

**Directed by Chung L. Tang**

Professor Chung L. Tang, the Spencer T. Olin Professor of Engineering, received the B.S. degree from the University of Washington at Seattle in 1955, the M.S. degree from the California Institute of Technology in 1956, and the Ph.D. degree from Harvard in 1960, all in electrical engineering. Following a year as the John Parker Traveling Fellow from Harvard at the Technical University in Aachen, Germany, he became a research staff member, and later principal research scientist, in the Research Division of the Raytheon Company. He joined the Cornell EE School faculty as an associate professor in 1964, was promoted to full professor in 1968, and became the Olin professor in 1985. He is also a member of the Cornell Materials Science Center.

During sabbatical leaves he has been a visiting professor and consultant at several universities and laboratories in the U.S. and abroad. Chung edited the volume on quantum electronics in the *Methods of Experimental Physics* series and was coeditor of the volumes on nonlinear optics in *Treatise on Quantum Electronics*, both published by Academic Press. He was an associate editor of the *IEEE Journal of Quantum Electronics*, and an associate editor of *Optics Letters*. He has over 250 publications in his areas of research interest and holds a number of U.S. patents that have resulted in successful commercial products. In 1996 he was presented the Charles Hard Townes Award by the Optical Society of America. He is a member of the National Academy of Engineering, a fellow of the American Physical Society, the American Optical Society, and the IEEE, and a member of Phi Beta Kappa and Tau Beta Pi.

The objective of Chung's research program is to search for and study new optical materials and processes that are suitable for application in the generation, modulation, and detection of electromagnetic radiation from the infrared to the ultraviolet. Emphasis is on lasers, optoelectronic devices, and nonlinear and coherent optical processes. Current research projects include femtosecond sources and ultrafast processes, femtosecond laser studies of ultrafast processes in compound semiconductors, and optical switching and two-mode bi-stability in semiconductor lasers.

Chung comments, "The planned Duffield Hall facilities should help greatly in our research efforts in the optoelectronics area. The new microfabrication capabilities, processing and characterization





laboratories, wet chemical laboratories, and other pertinent resources will allow us to develop, study, and evaluate new device and system concepts that may impact on future information technology. These facilities will also be vitally important for the education and training of students to meet the needs of society in the future."

## Nanostructure Fabrication and Characterization

**Directed by Noel C. MacDonald**

Professor Noel C. MacDonald received the B.S. degree in 1963, the M.S. degree in 1965, and the Ph.D. in 1967 from the University of California at Berkeley, all in electrical engineering. Following a year as an acting assistant professor at Berkeley, he became a member of the technical staff at the Rockwell International Science Center in 1968. He joined Physical Electronics Industries, Inc., as an entrepreneur, instrumentation engineer, and manager in 1970. After the company was taken over by Perkin-Elmer Corporation, he remained with that organization until 1983 in management positions that included a period as general manager of the Physical Electronics Division. He attended the Harvard Business School's Program for Management Development in 1980.

In 1984 he joined the Cornell EE School as professor of electrical engineering and director of the Semiconductor Research Corporation's Program on Microscience and Technology at Cornell. In 1989 he began a five-year term as director of the School of Electrical Engineering. Noel received the 1973 Victor Macres Memorial Award of the Electron Probe Analysis Society of America and an IEEE Young Engineer of the Year Award in 1975. He serves

on the Semiconductor Manufacturing Technology (SEMATECH) University Advisory Board, the International MEMS Steering Committee, and the Advisory Board for the International Symposium on Electron, Ion, and Photon Beams (EIPB). He has 126 publications in his areas of research interest and holds 25 U.S. patents. He is a fellow of the IEEE and a member of Sigma Xi, the American Vacuum Society, the Electrochemical Society, the Materials Research Society, and the American Physical Society.

The goal of Noel's research is to better understand the physical limits for fabrication, integration, characterization, and inspection of nanostructures. As a specialist in electron-beam technology,

with emphasis on microelectronic applications, he was instrumental in combining Auger electron spectroscopy with scanning electron microscopy in the development of the scanning Auger microprobe. He is interested in the ultimate spatial limits for fabricating, probing, and modeling nanometer-size electronic and mechanical structures. Consequently, research projects that address the generation and application of focused electron beams for nanofabrication, along with computer simulation and modeling, are included in his program. Research subjects include fabrication of nanometer-scale electron devices and nanomechanical structures for information storage, vacuum microelectronics, electron-beam microinstrumentation for lithography and characterization, electron-beam time-resolved probing of integrated circuits and nanostructures, electron scattering and energy dissipation in solids, electron-beam lithography, and nanosensors. An example of a typical nanostructure is shown in Figure A.

The potential of Duffield Hall on nanotechnology in the EE School is well expressed by Dr. **Hercules P. Neves**, visiting scientist, who is directing the work of the group while Noel is on leave in Washington, D.C. "The interdisciplinary character of nanotechnology poses serious challenges because of the diversity of activities that encompass the work. The physical proximity of laboratories of diverse fields is no longer sought as mere convenience; it has become a crucial requirement for the advancement of emerging technologies. In addition, the closer interaction between researchers will most certainly lead to a cornucopia of new ideas and alliances. The Advanced Science and Technology Initiative (ASTI) that will be housed in Duffield Hall is the culmination of this important mission."

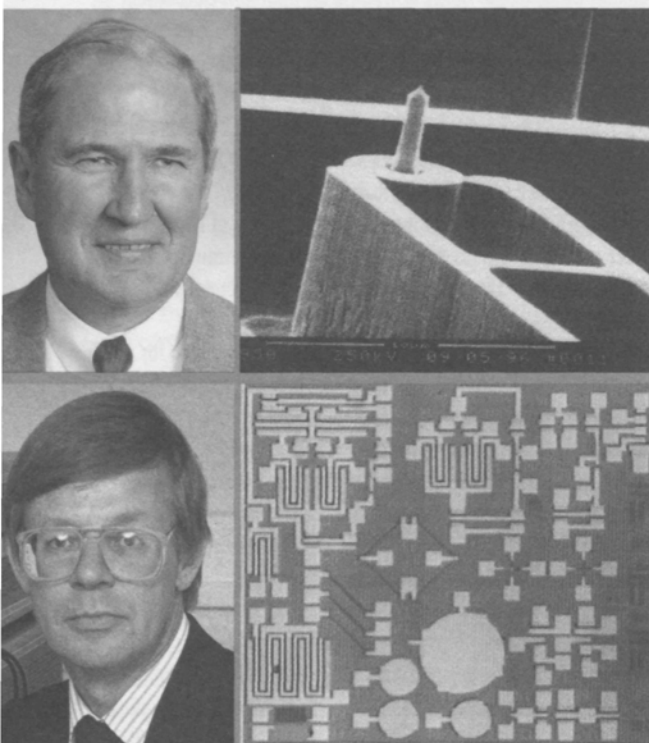
## Nanoelectronic and Optoelectronic Devices

**Directed by J. Peter Krusius**

Professor J. Peter Krusius received the Diploma Engineer degree in 1969 (electrical engineering), the Licentiate of Technology degree in 1972, and the Ph.D. degree in 1975 (both in electron physics), all from Helsinki University of Technology in Finland. Following receipt of his doctorate, he did research on semiconductor physics for two years at the University of Dortmund (West Germany) Institute of Physics, and as a docent at the Helsinki University of Technology Electron Physics Laboratory from 1977 to 1979. Peter was a Fulbright fellow at the Cornell School of Electrical Engineering and the National Submicron Facility from 1979 to 1980. He joined the EE School faculty as an associate professor in 1980 and was promoted to full professor in 1987. During the 1988-89 academic year he was on sabbatical leave at the T. J. Watson Research Center of IBM, and in 1995 he was a visiting professor at the Royal Institute of Technology in Stockholm, Sweden. At present, he is the director of the Cornell Joint Services Electronics Program and the director of the Cornell Electronic Packaging Program. Peter is editor-in-chief of the *IEEE Transactions on Components, Packaging and Manufacturing Technology—Advanced Packaging*, has authored more than 200 technical articles, and has

Top, Figure A. The tip on the end of the beam in this MEMS structure fabricated by Professor MacDonald's group is about 20 nanometers in diameter and can image and move individual atoms. These structures are used in micro scanning tunneling microscopes and in dense data-storage applications. (Photo courtesy of Noel C. MacDonald.)

Bottom, Figure B. Micrograph of a die from a MOS/MEMS wafer fabricated by Professor Krusius's students. Wafer diameter is 75 mm, die size is about 3.5 mm x 3.5 mm, probe pads are 150  $\mu\text{m}$  x 150  $\mu\text{m}$ , and the minimum feature size is 10  $\mu\text{m}$ . (Photo courtesy of J. Peter Krusius.)





written more than 10 invention disclosures or patent applications. He teaches micro/nanofabrication, electronic packaging, device physics, and VLSI and circuit design. He is a member of the IEEE and the American Physical Society.

Peter's current research interests are in three major areas: (1) nanoelectronic devices with minimum features less than 100 nm, nanofabrication characteristics of nanoelectronic devices/circuits in the silicon-materials system with applications to logic and analog VLSI, massively parallel systems, artificial neural nets, quantum-coupled systems, and ultra-large-scale integrated circuits, (2) advanced electronic packaging including development of new designs, connections, packages, and architectures for electronic systems with an emphasis on compact, high-density, mixed-signal systems, and (3) optoelectronic devices and optical coupling between high-speed semiconductor lasers and detectors, and light coupling between optoelectronic devices for optical links and interconnects.

His research group is exploring the materials, fabrication, characteristics, and integration of nanometer-scale complementary metal-oxide semiconductors (CMOS). These devices will have 30 nm minimum feature sizes and lead to densities of more than 100 million transistors per square centimeter. Micrometer-scale silicon circuitry (shown in Figure B) is currently fabricated at the CNF in outdated 1980s-level clean rooms. Peter comments, "With the opportunity to move this research into new state-of-the-art clean-room facilities in Duffield Hall, a new era for nanoelectronics can begin. Ultimately operating in Duffield Hall, my group plans to reach system-level device counts comparable to the number of neurons in the human brain."

## Fabrication of Complex Crystalline Structures

Directed by J. Richard Shealy

Associate professor J. Richard Shealy received the B.S. degree from North Carolina State University in 1978, the M.S. degree from Rensselaer Polytechnic Institute in 1980, and the Ph.D. degree from Cornell University in 1983 (all in electrical engineering). Following completion of his doctoral study, he held a dual appointment as a research associate at Cornell and as a principal staff scientist at General Electric Company. In 1983 he cofounded and has since chaired the biennial international workshop on organometallic vapor-phase epitaxy (OMVPE), a technique used for growing semiconductor crystals. He joined the Cornell EE School faculty in 1987 as an assistant professor, was promoted to associate professor in 1991, and was appointed director of Cornell's Optoelectronics Technology Center in 1993. Dick has been recognized for excellence in undergraduate teaching and has received two awards for contributions to the EE School curriculum. During a sabbatical leave in 1994, he started interactions on materials growth with the University of California at Santa Barbara, Hughes Research Laboratories, and several corporations in California. He has published more than 100 technical papers, has served as a

reviewer for several technical journals, has chaired sessions at many conferences, and has consulted with the General Electric Research Laboratory and a number of industrial corporations. Dick is a member of IEEE, Eta Kappa Nu, and the Materials Research Society.

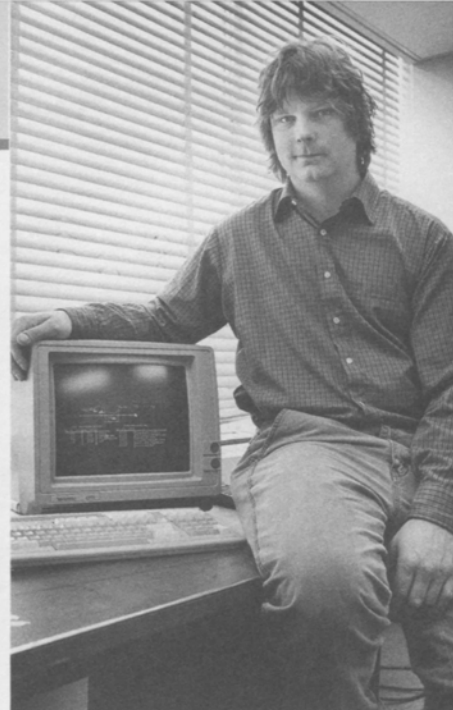
Dick's research interests include advanced epitaxial deposition processes for compound semiconductor materials and structures, high-performance infrared and visible optoelectronic-device diodes, and structural analysis of semiconductor structures. Among experimental techniques for the fabrication of complex crystalline structures with unique semiconducting properties, OMVPE is used to produce compound-semiconductor configurations with dimensional control on the atomic scale. These structures will result in new materials for high-efficiency lasers in both the infrared and the visible regions, and for ultra-high-speed transistors. As the technology progresses, these techniques will be used to produce integrated optoelectronic circuits for applications including communications and remote sensing.

At the present time the OMVPE laboratory is located off-campus near the airport; students and faculty members in the research group are therefore relatively isolated from activities in the central campus. Dick expects that Duffield Hall will bring a consolidation of effort between his activities and those of other units of the university who are engaged in related research. The new building will introduce definite advantages through clustering of research tools, establishment of central storage space and support services, and coordinated control of the laboratory work environment. Dick believes that one of the major benefits of Duffield Hall would be the elimination of the current unwieldy "satellite" status of his graduate students.

## Optoelectronic Materials and Devices

Directed by Yu-Hwa Lo

Associate professor Yu-Hwa Lo received the B.S. degree from National Taiwan University in 1981, the M.S. degree in 1986, and the Ph.D. in 1987 from the University of California at Berkeley (all in electrical engineering). Following completion of his doctoral studies he joined the technical staff of the Laboratory of Solid-State Science and Technology at Bellcore, where his research focused on semiconductor lasers and optoelectronic integrated circuits for fiberoptic communication. He joined the Cornell EE School faculty in 1991 as an assistant professor, was promoted to associate professor in 1996, and was the recipient of the **Michael Tien '72 Excellence in Teaching Award** in the same year. During a sabbatical leave of absence in 1997, Yu-Hwa edited a special edition of *Proceedings of the IEEE* on optoelectronics technologies. He has published about 150 papers in the general area of compound semiconductor materials and devices, authored one book



J. RICHARD SHEALY

**"A new era for nanoelectronics can begin. Ultimately operating in Duffield Hall, my group plans to reach system-level device counts comparable to the number of neurons in the human brain."**

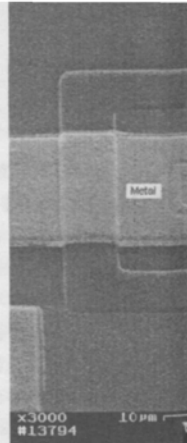
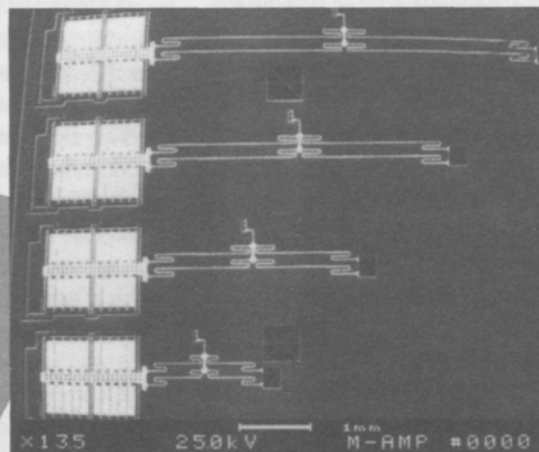
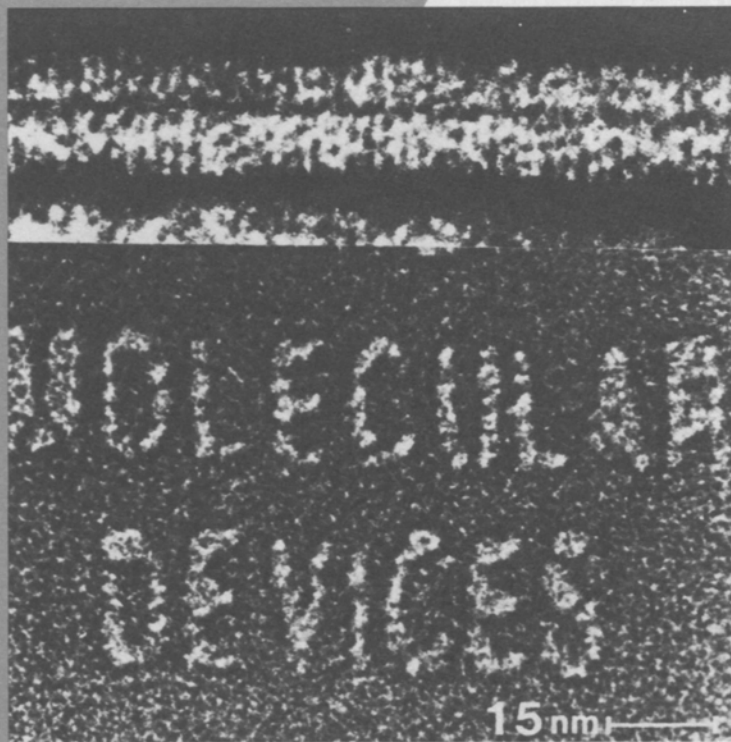
—J. Peter Krusius

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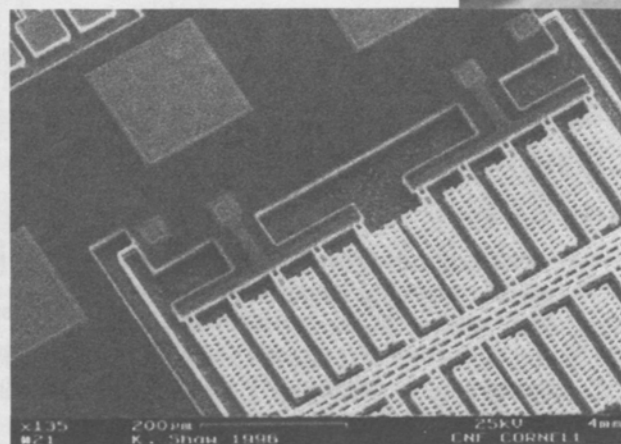
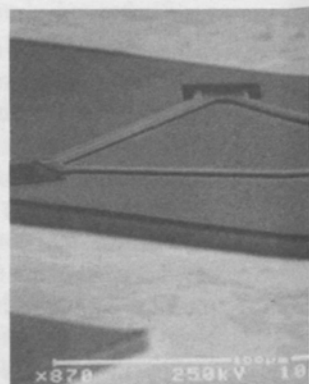


# It's a Small World!

**Nano**, from the Greek *nanos*—meaning “dwarf,” one billionth or  $10^{-9}$

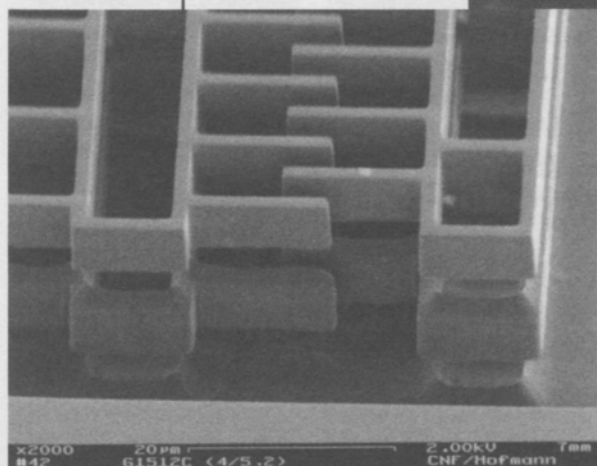
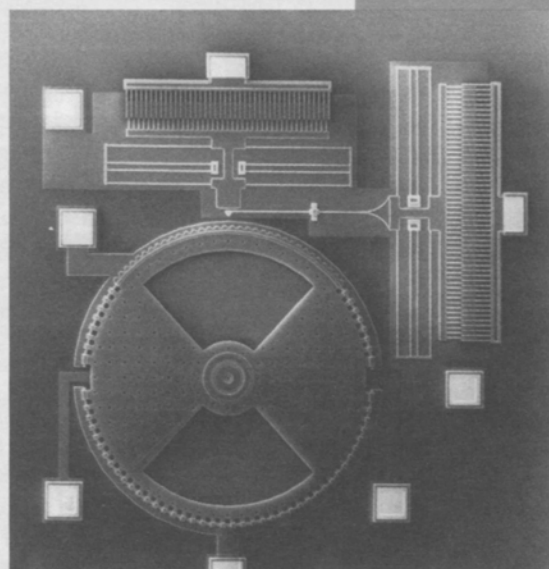
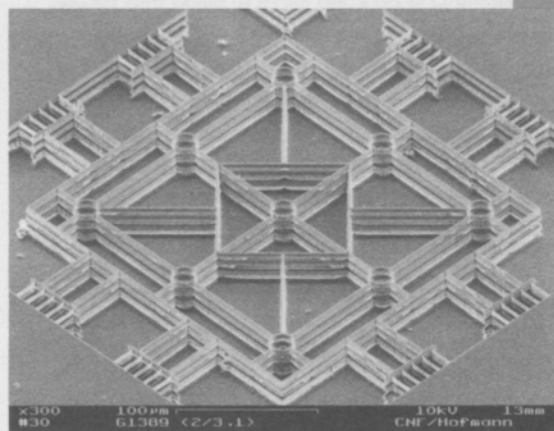
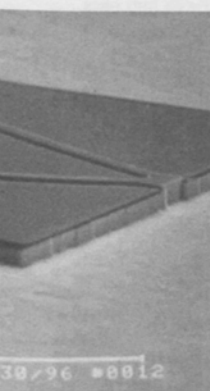
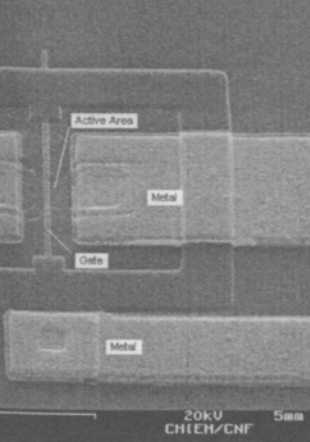


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**1.** This electron-beam etching, made in 1981 by professor **Michael S. Isaacson** of Applied and Engineering Physics, was the smallest manmade pattern at that time. The letters vary from six to nine nanometers in width, small enough to print the *Encyclopedia Britannica* on a postage stamp. (Photo courtesy of *Engineering: Cornell Quarterly*, Vol.16, No. 2, Autumn 1981.)

**2.** The microactuators shown in the photo have demonstrated quasi-static displacements of up to 55 mm, based on a novel quasi-buckling method that overcomes inherent instabilities of conventional techniques. The method is applicable to virtually any process, such as surface machining. (Photo courtesy of Noel C. MacDonald.)

**3.** The complementary metal-oxide semiconductor (CMOS) device shown in this sample scanning electron microscopic (SEM) image has a dimension of 60 nanometers in the active region. This advanced gate/channel structure has a 4 nm-thick  $N_2O$  gate dielectric. (Photo courtesy of J. Peter Krusius.)

**4.** The MEMS circuit in the lower right-hand portion of the photo is shown directly connected to an integrated circuit (IC). Use of a novel single-crystal-silicon reactive etching and metallization (SCREAM) process allows MEMS circuits to be built on the wafers of standard mass-produced ICs. (Photo courtesy of Noel C. MacDonald.)

**5.** The triangular-shaped waveguide ring laser in this photo, complete with smooth and vertical mirrors, was fabricated from compound semiconductors by a dry etching process. Semiconductor lasers have the high spectral purity and low noise required by modern optical communications systems. (Photo courtesy of Joseph M. Ballantyne.)

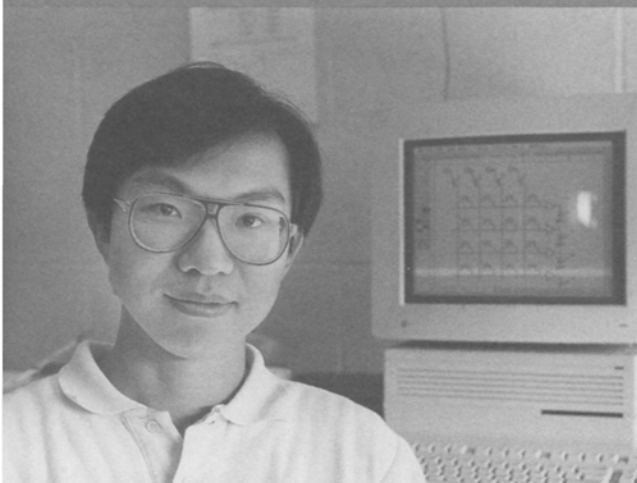
**6.** This micromachined structure is an array of entire electron guns on a single silicon substrate. The stacked disks in the photo are integrated high-aspect-ratio single-crystal electrostatic lenses that focus the emitted beams. The silicon field emitters (with tip radii of <20 nanometers) on the substrate within each lens are not visible in the display. (Photo courtesy of Noel C. MacDonald.)

**7.** The electrostatic comb-drive MEMS actuator in this photo is a linear motor composed of interspersed capacitor plates fabricated from silicon by micromachining techniques. The structure has an upper and a lower set of plates to improve linear movement. One application of these tiny devices is as an accelerometer used to activate automobile safety air bags. (Photo courtesy of Noel C. MacDonald.)

**8.** The disk of this micromotor-driven MEMS capacitor has a diameter of 300 mm. The top plate rotates with respect to the stationary bottom plate. This device is a micro version of the adjustable capacitors used in typical radio sets. (Photo courtesy of Norman C. Tien.)

The photographs of the microdevices in this display were obtained through the courtesy of CNF and the able assistance of Melanie Clair Mallison, Wolfgang Hofmann, Hercules Nevis, and Lynn Rathbun.





Yu-Hwa Lo

chapter, and has been awarded several patents. Yu-Hwa is a senior member of the IEEE and a member of the Optical Society of America.

Yu-Hwa's research interests are primarily in semiconductor materials and processing, semiconductor lasers, optoelectronic device integration, high-bandgap semiconductor devices, and surface micromachining in microelectromechanical systems (MEMS). His group has been collaborating extensively with industrial research laboratories, government laboratories, and research teams at other universities, on work including pseudomorphic structures for the U.S. Navy, surface-emitting lasers and integrated nanomechanisms for optical terabit information storage for the Advanced Research Projects Agency (DARPA), and near- and mid-infrared detectors for the Jet Propulsion Laboratory. His research is also funded by the National Science Foundation and the Air Force Office of Scientific Research. Recently Yu-Hwa and his group demonstrated for the first time and have applied for a U.S. patent on a unique approach to the achievement of a "universal substrate," on which a crystal of any material can be grown. (See page 10 for additional details.)

Since Yu-Hwa's research is focused on semiconductor material and device processing, in the near future he plans to put efforts into material growth and MEMS. As a very heavy user of the CNF facility and the optoelectronics laboratories at Phillips Hall, he has found a pressing need for more quality lab space than is available today. He expects Duffield Hall to provide solutions to these critical needs for lab space and expansion of lab equipment. Specifically, there will be room for an organometallic vapor-phase-epitaxy (OMVPE) reactor that he will acquire for his material and device research. The new facility will also provide space for more chemical hoods and custom-designed equipment that is pivotal to his research. The proposed upgrade of the CNF facility will be particularly important for his MEMS and optoelectronics-device research. Yu-Hwa comments, "The presence of Duffield Hall will also greatly improve our recruitment of graduate students so we will all have better chances to work with top-notch students, which is, of course, the key for success in our research."

## Wireless and Optics Applications

Directed by Norman C. Tien

Assistant professor Norman C. Tien received the B.S. degree in engineering physics from the University of California at Berkeley in 1981, the M.S. degree from the University of Illinois at Urbana-Champaign (UIUC) in 1984, and the Ph.D. degree from the University of California at San Diego in 1993, both in electrical engineering. He was a research assistant at UIUC from 1983 to 1984, a process development 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 lecturer and postdoctoral research engineer at Berkeley from 1993 to 1996. He joined the EE School faculty in January 1997 as an assistant professor. Norman teaches and conducts research in microelectromechanical systems (MEMS) for radio-frequency circuits and optoelectronics. He is a member of IEEE and the author of more than 27 journal articles and conference papers in his research areas.

Norman's research interests are in the development of silicon microelectromechanical systems (MEMS), including the design and fabrication of microactuators, microsensors, and micromechanical structures and systems, with a particular interest in actuated mechanical structures for wireless communication systems and optoelectronics. As a postdoctoral research engineer at Berkeley, he helped build a new MEMS program to develop free-space-actuated microoptical systems on silicon using surface micromachining. This work on the design, fabrication, and characterization of polysilicon motor-driven micromirrors led to his current interest in the creation of "optical benches 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.

Much of Norman's work is done in the Cornell Nanofabrication Facility (CNF). His research requires the full suite of silicon-fabrication equipment from photolithography to reactive-ion etching to thin-film deposition of metals and semiconductors. In the course of creating MEMS for the applications of interest, novel semiconductor-fabrication techniques are often developed. One of the primary reasons Norman chose to come to Cornell was the availability of the superb resources of the CNF. Now he expects the addition of Duffield Hall and its state-of-the-art clean-room facilities will be of even greater benefit to his research. Norman comments, "MEMS is a field that straddles the boundaries of many areas, and the interdisciplinary emphasis of Duffield Hall will be an additional asset."



NORMAN C. TIEN



# RECENT FACULTY ACCOMPLISHMENTS

Note: Most of the listed awards were announced at the College of Engineering Fall 1997 Awards Ceremony and Faculty Reception on September 23, 1997.

• Professor **Joseph M. Ballantyne** (optoelectronic devices and materials), director of the Semiconductor Research Corporation (SRC) interdisciplinary Program on Microscience and Technology at Cornell, and director of the Cornell Fabrication Center (CNC), has discovered that direct-bandgap material on GaP substrates is actually composed of small islands, or quantum dots, that have an ordered structure. Joe and his group were successful in making electrically pumped light-emitting diodes in this new material. He has completed the first finite-element simulations of the electromagnetic fields in asymmetric, stepped, dielectric waveguides and verified that these structures show asymmetric reflectivity, a feature that is useful in unidirectional ring lasers. A patent was filed on this advance. The first diode-ring lasers operating at 1.3  $\mu\text{m}$  wavelength were constructed and showed very pure spectral output. During a six-month sabbatical leave at the University of California at San Diego (UCSD) in La Jolla, California, Joe coordinated the preparation of a white paper on diode-ring lasers and light-emitting materials for optical communication on silicon chips, and with his students submitted several papers for publication that report their new results. This research is also being carried forward in collaboration with Cornell professor **Peter Krusius** and about 20 faculty members from Cornell and UCSD. New collaborations on optical devices and materials

have also been initiated between Professor Ballantyne's group and those of professors Charles Tu and Paul Yu at UCSD.

• Professor **Toby Berger** (information theory and communications), the J. Preston Levis Professor of Electrical Engineering, has developed a mathematical theory of information handling by living systems. It combines ideas from information theory, chemical thermodynamics, biology, and neurobiology to provide a unified quantitative description of sorting and signaling of information within an organism that explicates the several similarities and the key differences between interorganism and intraorganism communication and signal processing.

• Associate professor **Adam W. Bojanczyk** (computer engineering, parallel architecture, and algorithms for signal and image processing) has developed software tools for automatic benchmarking and modeling of parallel radar signal-processing hardware/software systems.

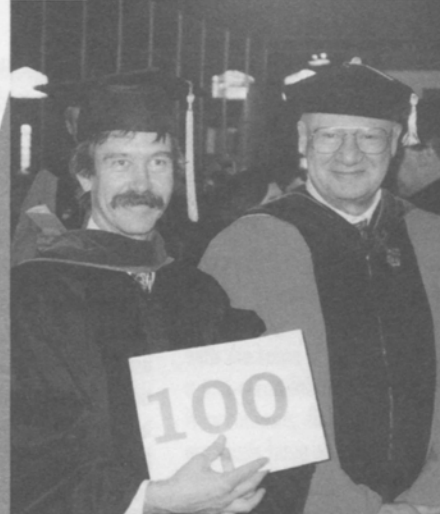
• Associate professor **Hsiao-Dong Chiang** (analysis and control of nonlinear systems with applications to electric-power networks) developed a comprehensive methodology for calculating available transfer capability of large, interconnected power systems. This methodology not only satisfies the static and dynamic security constraints but also is in compliance with the Federal Electric Regulatory Committee's Orders 888 and 889. Hsiao-Dong

spoke at the EE Colloquium on November 11, 1997, on the topic "Direct Stability Analysis of Large-Scale Power Systems: Theory, Computation, Applications and Extensions."

• Associate professor **David F. Delchamps** (control and system theory) has moved his research program in intelligent and hybrid dynamic systems in some interesting new directions over the last year. Such systems mix continuous and discrete variables, and often have massively parallel and/or "connectionist" architectures along with event-driven dynamics. He has come to recognize the central importance of evolutionary computational approaches, including genetic algorithms, to the modeling, analysis, and control of such systems. Current research that applies dynamical systems techniques to problems in cognitive science has also begun to play an important role in his investigations.

• Professor **Lester F. Eastman** (compound semiconductor materials, devices, and circuits), the John LaPorte Given Professor of Engineering, announced that the multidisciplinary university research initiative (MURI) with which he is associated was awarded a \$1M/year contract by the Office of Naval Research, effective September 1, 1996. The award is based on research on gallium nitride high-power microwave amplifiers involving a new state-of-the-art frequency response of modulation-doped field-effect transistor (MODFET) power gain to 100 GHz. Lester was honored

At the 1997 Commencement exercises, Glenn Martin is proud to be Professor Eastman's 100th Ph.D. student.



at the 129th (1997) Cornell Commencement Ph.D. Recognition Ceremony for the graduation of his 100th Ph.D. student, **Glenn H. Martin** (see photograph).

• Professor **Donald T. Farley** (radiowave and upper-atmospheric physics) had four papers on ionospheric plasma instabilities published, as well as a book chapter on radar scattering. He received the 1997 Medal for Geophysics from the Council of the Royal Astronomical Society of London (this was a total surprise for Don, since he is not an astronomer!).

• Professor **Terrence L. Fine** (information theory, inference and decision making in the presence of uncertainty) reports that his most important research contribution in the past academic year is the development of probabilistic analyses and approaches to such optimization algorithms as steepest descent to make them better suited to the design of neural networks.

• Associate professor **Zygmunt J. Haas** (wireless communication and networks, mobile systems) introduced the course Wireless Reconfigurable Networks, concerned with the study of fast, self-reconfigurable communication networks that operate without fixed infrastructure. He has developed efficient and robust routing protocols, medium-access

control schemes, and a distributed mobility management protocol for this type of network. These networks can be applied in both military and commercial applications such as tactical communications, rescue missions, wall-free classrooms, and exhibitions and presentations. Zygmunt was a 1997 recipient of a **Michael Tien ('72) Excellence in Teaching Award**.

• Professor **David A. Hammer** (plasma physics, controlled fusion, intense ion beams), the J. Carlton Ward Professor of Nuclear Energy, developed an x-ray imaging method for use on high-peak-power experimental devices at the Sandia National Laboratories in Albuquerque, New Mexico. He described the new Sandia z-pinch machine in the January 17, 1998, issue of *Science News*. Dave also developed, together with professor **Dieter Ast** of the Department of Materials Science and Engineering, an interdisciplinary systems-engineering design course (MSE 448), in which the students had to design a plasma-etching system. Dave is on sabbatical leave during the 1998 spring term with Applied Materials, Inc., in San Francisco, California.

• Associate professor **Chris Heegard** (communication, information, and coding theory) spoke at the EE Colloquium on October 21, 1997, on the topic



"Turbo Coding." He is on a leave of absence during the 1998 spring term with the Alantro Company, in Santa Rosa, California.

- Assistant professor **Sheila S. Hemami** (application-specific compression techniques for packet networks, networking aspects of visual communications, and multirate coding and transmission) received a National Science Foundation Faculty Early Career Development Award in support of research on "Robust Visual Communications for Packet Networks," a continuation of her Department of Energy-sponsored work to enable universal access to visual communications. She is a recipient of a 1997 **Michael Tien** ('72) Excellence in Teaching Award, is a Lilly Teaching Fellow for 1996-98, and holds an Eastman Kodak Company 1997 Term Professorship. In the past year, Sheila has collaborated with the psychology department in developing a perceptually based image-compression algorithm that offers scalability as well as being psychovisually optimal.

- Professor **C. Richard Johnson Jr.** (adaptive control and signal processing) has devoted several years of effort to characterization of the applicability domain of—and construction of a design methodology for—blind linear equalization of communication channels via the standard algorithm currently used in practice. These efforts have reached fruition as evidenced by invitations to compose overviews for a broad audience, including a request for a paper for a special issue of *Proceedings of the IEEE*. The manuscript of that article was submitted in May 1997.

- Professor **Michael C. Kelley** (upper-atmospheric and ionospheric physics) has been a leader in the effort to create a new observatory in the Canadian Arctic that has led to a line item in the president's budget and is part of the National Science Foundation's Major Research Expenditure account. His contributions included authorship of the original scientific rationale, "A Polar-Cap Observatory: The Next Step in Upper-Atmospheric Science," stewardship of the Polar-Cap Observatory Steering Committee, and presentation of congressional testimony on the project in April 1997. His comments on the complexity of space were quoted in the February 10, 1998, issue of *Science Daily Online*. Mike was the recipient of the 1997 **Robert '55 and Vane '57 Cowie** Excellence in Teaching Award, and recently became a senior member of the IEEE.

- Professor **Paul M. Kintner** (atmospheric plasma physics) presented six colloquia/seminars on the Global Positioning System (GPS) and completed GPS scintillation campaigns in Peru and Alaska in the past year. Paul was the recipient of the 1997 **Douglas Whitney '61** Excellence in Teaching Award.

- Associate professor **Ronald M. Kline** (history of technology and electrical engineering), director of the Sue and **Harry E. Bovay Jr.** ('30) Cornell Program on History and Ethics of Professional Engineering, published three articles on the history of the automobile and electric light and power in the rural United States. He also organized a panel discussion at Cornell on the topic "Ethical Issues of the Internet."

- Professor **J. Peter Krusius** (solid-state electronics, semiconductor devices and systems, and electronic packaging), director of the Cornell University Electronic Packaging Program, was appointed in the fall 1997 term as principal investigator of a National Science Foundation \$1 million three-year program to design and construct a novel fabrication and characterization tool for industry that will be capable of interconnecting integrated circuits with at least 10 times as many connections as can be done with today's most powerful computer chips.

- Professor **Richard L. Liboff** (physics of microsemiconductor devices and solid-state plasmas) has uncovered a break in the second law of thermodynamics. He has shown that this law is not valid in general for idealized, irreversible processes. In technology, a residual resistivity at 0° K temperature was discovered for pure monovalent metals due only to electron/phonon interactions. The third edition of his textbook *Introductory Quantum Mechanics* was published in February 1998 by Addison-Wesley Longman. This text has been widely adopted both in the U.S. and abroad. The second edition of his textbook *Kinetic Theory: Classical, Quantum, and Relativistic Descriptions* was published in March 1998 by John Wiley & Sons.

- Associate professor **Yu-Hwa Lo** (optoelectronic materials and devices, and integrated optoelectronic circuits) has received worldwide attention for his invention of an innovative technique, a compliant universal substrate that enables growth of many new semiconductors with qualities unachievable before. Yu-Hwa has repeatedly set world records in device performance with his research on long-wavelength vertical-cavity surface-emitting lasers, devices that have important applications in optical communication.

- Professor **Noel C. MacDonald** (microelectromechanical and nanoelectromechanical systems) and his research group have fabricated and characterized a new microelectromechanical actuator with an integrated sensor for nanometer-scale information storage. An array of 144 devices on a silicon chip was fabricated to demonstrate a packing density of 2,500 devices/cm<sup>2</sup> of silicon. For a 10 nm x 10 nm bit size, the potential storage density for the 2,500 devices/cm<sup>2</sup> array is 10<sup>14</sup> bits/cm<sup>2</sup>. Noel is on a leave of absence in Washington, D.C., with the Defense Advanced Research Projects Agency (DARPA) as director of the Electronics Technology Office.

- Professor **Paul R. McIsaac** (microwave theory and techniques) was concerned with the study of the scattering matrix associated with the abrupt junction between two uniform waveguides. The two waveguides must have closed boundaries and contain reciprocal media, but they may be inhomogeneous and have any cross section. In particular, Paul explored the restrictions placed on the junction scattering matrix produced by the symmetry properties of the two waveguides.

## EE School Research Funding

Total research funds expended in 1994-95	\$11,848,956
Total research funds expended in 1995-96	\$12,921,520
Percent increase	9.05 %
Total research funds for 1996-97 (as of June 30, 1997)	\$13,857,387
Percent increase	7.24 %

In addition, approximately \$300,000 has been received by the EE School in the past academic year in support of faculty research and special projects from Eastman Kodak, Hughes Aircraft, Intel Foundation, Lutron Foundation, Motorola, and PLT Technology. These generous grants from corporations and foundations, coupled with equally commendable gifts from many individuals, aid the recipients in their teaching and research and make it possible for the EE School to establish and maintain a leading edge in the discipline.



• Professor **John A. Nation** (electromagnetic fields and waves) visited the Institute of Applied Physics in Nizhny-Novgorod, Russia, under a joint grant with the U.S. Civilian Research and Development Foundation for the Independent States of the Former Soviet Union (the SOROS Foundation). Two members of the institute will visit Cornell for two months during the 1998 fall term.

• Professor **Thomas W. Parks** (signal theory and digital-signal processing) is on sabbatical leave during the 1998 spring term as a visiting scientist with the Imaging Science Division of Eastman Kodak Corporation in Rochester, New York. His main activities center around digital photo-finiting. Tom predicts that all film turned in for developing will soon be scanned and processed digitally, with implications for improved use on the World Wide Web and other exciting applications.

• Associate professor **Alfred Phillips Jr.** (quantum mechanical devices, optical switches, and process modeling) has obtained empirical confirmation of his field-effect transistor theory for MOSFETs, MESFETs, and MODFETs. He has also generalized the coupled-partial-differential equation diffusion model to account for all known low-energy processes in semiconductors.

• Professor **Clifford R. Pollock** (lasers and optoelectronics), the Ilda and **Charles R. Lee** ('61) Professor of Engineering, and academic program leader of the Advanced Science and Technology Initiative (ASTI) for the Duffield Hall Project Management Team, completed his three-year term as associate director with the major academic task of coordinating the EE School undergraduate program. Clif is one of the recipients of a 1997 Stephen H. Weiss Presidential

Fellowship, which recognizes the importance of undergraduate teaching. In research, he is beginning to redirect his activities toward fiber optics, and has also been consulting at Corning, Inc. During the summer of 1997 and for the 1997 fall term, Clif was on sabbatical leave with the Corning, Inc., Sullivan Park Research Facility, in Corning, New York.

• Professor **Christopher Pottle** (computer engineering, parallel processors, VLSI technology), working with three excellent honors-program students (one in the Department of Computer Science), has completed a thorough reworking of the homegrown design tools used in course EE 475, Computer Structures. The first is CURTAIL (the Cornell Register Transfer Language—Varian & Brown), and the second is Microbox III, the digital system testbed that no longer requires a digital I/O board in a PC, but operates over a standard serial link.

• Associate professor **Anthony P. Reeves** (parallel computer systems, computer-vision algorithms) initiated a new collaboration with the faculty in the Department of Radiology at the Cornell Medical College. Established medical-imaging research is enhanced with the multidimensional computer-vision capabilities developed in the School of Electrical Engineering for Tony's research program. A first project focuses on early repeat computer-tomography (CT) imaging for the diagnosis of lung cancer. Two papers on three-dimensional image processing of CT scans of pulmonary nodules, and a research proposal have already been submitted as a result of this collaboration. During his sabbatical leave in the 1997–98 academic year, Tony has been interacting with the Cornell Medical College and with the Woods Hole Marine Biology Laboratory.

• Professor **Charles E. Seyler Jr.** (space-plasma physics, physics of relativistic electron beams), coordinator of graduate studies in the School of Electrical Engineering, participated in the development (with professor **Jim Thorp**) of a globally distributed electric-power-system model utilizing partial differential equations. The model may ultimately provide a basis for continent-wide power-system control. Charles received the 1997 Ruth and Joel Spira Excellence in Teaching Award.

• Associate professor **J. Richard Shealy** (development of compound semiconductors) has discovered a new process for the synthesis of advanced semiconductor materials that allows the direct patterning of the crystal growth using ultraviolet (UV) laser stimulation. The ability now exists to produce three-dimensional crystal structures with submicron resolution.

• Professor **Chung L. Tang** (lasers, optoelectronic devices, nonlinear and coherent optical processes), the Spencer T. Olin Professor of Engineering, developed the first broadly tunable femtosecond optical parametric oscillator that can operate in the mid-infrared to 5.4 microns. Chung is continuing his research in Ithaca, New York, while on sabbatical leave during the 1998 spring term, and will spend a few weeks at the Laboratoire D'Optique, C.N.R.S., École Polytechnique, Orsay, France, and will visit laboratories in Italy.

• Professor **Robert J. Thomas** (control techniques for large-scale networks, analysis of microelectromechanical systems) completely revamped course EE 215, Electrical Systems Laboratory, and chaired the committee whose recommendation for major structural changes to the EE curriculum was adopted by the faculty.

Bob also continues as director of PSERC, the National Power Systems Center, established by the National Science Foundation.

• 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 director of the School of Electrical Engineering, has demonstrated a method of synchronizing two chaotic nonlinear electric-field-driven microactuator systems (fabricated using a unique single-crystal silicon MEMS process developed at Cornell by professor **Noel MacDonald's** group). One chip, the modulator and transmitter, includes a nonlinear oscillator and a sensor (pressure, acceleration, sound, vibration) along with minimal electronics for chip integration, interrogation, and/or transmission. A second chip incorporates an "identical" nonlinear MEMS voltage tunable oscillator, and a demodulator. Several parameters may be modulated and estimated concurrently, resulting in simultaneous multiple access of a single channel. This network forms a basis for simultaneous multiple access of a single channel, a parameter division multiple access (PDMA) communication system. Jim is the recipient (together with S. Tamronglak, S. H. Horowitz, and A. G. Phadke) of the IEEE PSRC Prize Paper Award for 1996, for the paper "Anatomy of Power-System Blackouts: Preventive Relaying Strategies."

• Professor **Hwa C. Torng** (computer architecture applied to design of intelligent communications networks) was named the first Intel Academic Research Fellow "for his contributions to the state-of-the-art in high-speed instruction decoding and execution." H.C. was also

the recipient of the 1996–97 Faculty of the Year Award of the IEEE Cornell Student Branch, and the Golden Core Member Award of the IEEE Computer Society. H.C. reformulated course EE 230, Introduction to Digital Systems, into EE 231, an engineering distribution course with the same title, and EE 232, a one-credit laboratory course. New contents, flexibility, and emphasis have enhanced the appeal of the courses to more engineering students, and laboratory loads for the fall and spring semesters can be balanced since both courses are offered each term.

• Assistant professor **Venugopal Veeravalli** (wireless communications, detection and estimation theory, and information theory) developed a new graduate course, EE 596, Mobile Communications Systems, that provides students with the fundamental tools required for the design and analysis of modern communication systems. In research, he conducted a capacity versus coverage analysis for cellular-code-division multiple-access (CDMA) systems. In November 1997, Venu was the recipient of an Early Career Award from the National Science Foundation.

• Associate professor **Stephen B. Wicker** (wireless information networks, digital communications systems, error-control coding, and cryptography) has made significant progress in developing a flexible lower-layer architecture for wireless multimedia systems. He has also developed collaborative projects with the Department of Computer Science, acquired funding, and developed new classes, all within the framework of a Wireless Multimedia Center. Steve has been elected to the Board of Governors of the IEEE Information Theory Society, to serve from 1996 to 1999. ■



## CHRISTOPHER POTTLE RETIRES

**C**hristopher Pottle, a member of the EE School faculty for 36 years, will become professor emeritus on July 1, 1998.

Chris received the B.Eng. degree in electrical engineering from Yale University in 1953, worked for a year with the Sperry Gyroscope Company as an assistant project engineer, and spent two years in the U.S. Army at the Ballistic Research Laboratory in Aberdeen, Maryland, before starting graduate study in 1956 at the University of Illinois at Urbana, where he was a research assistant until he received the M.S. degree in electrical engineering in 1958. He spent the next year as a Fulbright scholar at the Max Planck Institut für Physik, in Munich, Germany, returned to the University of Illinois as an instructor, obtained the Ph.D. degree in electrical engineering in 1962, and received an immediate appointment at Urbana as an assistant professor. Chris joined the EE School faculty at Cornell in the fall of 1962 as an assistant professor, was promoted to associate professor in 1966, became a full professor in 1979, and will retire as professor emeritus in 1998.

Chris's career at Cornell has been devoted to teaching, research, and service to the EE School and the College of Engineering during a long and fruitful career in the field of computer applications. Following his first assignment as successor to professor **Bill Erickson** in the service course for non-electrical engineers known as "Horse Racing for Non-Horses," he offered the first computer programming course taught in the school. Soon afterwards, he joined with then-professor of industrial engineering **Richard Conway** '53, Ph.D. '58, professor of mathematics **Robert Walker**, and others, as the EE representative in the formation of the Department of Computer Science. This cooperative activity between the two departments exists to the present day and is being enhanced by the cur-

rent support in the College of Engineering for interdisciplinary efforts in telecommunications and information technology.

In the early '70s Chris introduced computer concepts into the required junior courses in electrical signals and systems in the EE School, and was instrumental in obtaining a PDP/11, the top-of-the-line minicomputer of the time. The system allowed a computer to be applied for the first time as an educational tool in the required junior laboratory course EE 316 and also served as a valuable aid to early computer research in the school. Chris created and developed a popular new course, EE 424, Computer Methods in Electrical Engineering, developed new computer experiments for EE 315 and EE 316 (Super Labs), and, with professor **Jeffrey Frey** '60, established the first project-oriented course at Cornell in the design of very-large-scale-integrated (VLSI) circuits. Over the last several years, he taught EE 475, Computer Structures, and EE 476, Digital System Design Using Microcontrollers, the latter a complete redesign of the microprocessor course previously taught by professor emeritus **Norman Vrana**, M.E.E. '51.

In addition to those academic duties, Chris served a four-year term as associate dean for computing in the College of Engineering, spent one semester as the associate dean for undergraduate affairs, was a member of the International Engineering Committee for the college, and was chairman of the computer-engineering area of the EE School. During his career at Cornell, he directed the Ph.D. research of 15 graduate students, wrote more than 75 publications, and was an active class advisor.

Chris was a Fulbright fellow in 1966-67 at the University of Erlangen-Nuremberg, Germany, where he lectured on state-variable techniques for linear systems and found to his surprise that this material was not widely used by his colleagues in Germany. On his first sabbatical leave, in 1970-71, he served as a full-time special research consultant at the IBM Watson Research Laboratory, in Yorktown Heights, New York, and was a part-time consultant there during the following year. In 1977-78 he held a full-time position as resident program professor with the General Electric Company, in Schenectady, New York, and in 1983-84 he was a visiting professor in the Department of Electrical Engineering at Carnegie-Mellon University. He has also been a consultant with Bell Telephone Laboratories, Leeds and Northrup Company, the General Motors Corporation, in Warren, Michigan, and Digicomp Corporation of Ithaca, New York.







## REPORT ON EE ASTRONAUTS

Chris is a senior member of IEEE, a member of the Association for Computing Machinery, and a member of the American Association for the Advancement of Science. He is a member of Tau Beta Pi, Sigma Xi, Eta Kappa Nu, Phi Kappa Phi, and Pi Mu Epsilon (mathematics honorary society), and is listed in *American Men and Women of Science*.

Chris's research was motivated by the enormous potential for the fabrication of special-purpose electrical systems, now rendered technically feasible by the rapid development of VLSI technology, as well as by the requirements this technology puts on computer tools used in the design of VLSI systems. He has been a leading proponent of the parallel-processing technique: direct implementation of time-consuming computer algorithms in parallel VLSI hardware. Economical custom VLSI design demands an array of tools (computer programs) to aid in a design process that will provide accurate simulation of eventual circuit behavior. Chris has been working in the simulation area since 1965, when he developed a widely distributed program called CORNAP, a pedagogical tool that tied circuit-theory and state-space concepts together with modern numerical methods.

His interest in dynamic-system simulation generated considerable collaboration with the Cornell Program in Power-Systems Engineering, especially in those areas requiring computer analysis of electric-utility systems operating under certain faulted conditions—a situation referred to as “transient stability.” The specific task was the development of a transient-stability simulator that would run in real time; that is, the computer-generated waveforms would be on the same time scale and identical to those that occur on real power systems, a goal long sought by power engineers. A real-time simulator could be used to train power-system dispatchers to carry out studies of “what-if” situations in the operational environment, and to allow system engineers to design and test digital equipment, such as protective relays, in a realistic, but off-line environment. Recently, the technology has become available to carry out such computations with the required speed. Chris's basic idea was to take advantage of parallel computer architecture in which the interconnection of special processors (for example, the transputer) has the same topology as the system to be simulated.

In retirement, Chris plans to leave technology for the present to concentrate on rehabilitation of an old family homestead in Maine, a 160-year-old structure that is in need of extensive modernization to allow comfortable year-round living. ■

Readers who access the revised EE home page ([www.ee.cornell.edu](http://www.ee.cornell.edu)) will find a prominent question: WHERE DO CORNELL EE'S END UP? followed by a picture of an astronaut in a space suit floating in space. This reply is no idle boast—three EE alumni have indeed been in orbit within the past two years, the third as recently as this spring.

**Daniel T. Barry '75** was a mission specialist 4 on the NASA STS-72 shuttle *Endeavor* flight, which lasted from January 11 to 20, 1996. On October 7, 1997, Dan returned to the campus and spoke about his flight in Phillips 101. “When I left Cornell,” he said, “I always hoped I would come back to give a colloquium in this room that I spent so much time in, and I hoped that it would be about flying into space.” The EE School banner that Dan took with him on his 3.7 million-mile journey is now framed and on display in Room 101. The nine-day flight, a cooperative venture between NASA and the Japanese Space Agency, included a retrieval of a Japanese satellite from its orbit, and Dan's participation in a six-and-a-half-hour space walk to test equipment that will be used in the construction of the International Space Station.

Another of our high-flying alumni, **Edward T. Lu '84**, was one of six mission specialists on the NASA STS-84 shuttle *Atlantis*, the sixth mission to rendezvous and dock with the Russian space station *Mir*. During the nine-day flight that began on May 15, 1997, Ed and his associates conducted experiments related to the effect of weightlessness on the human immune system. He was also one of the two crew members who had been trained for a space walk in the event of the need for emergency repairs. The flight went smoothly, however, so Ed had to be content with spectacular views of auroras glowing over both poles, and thunderstorms gathering over the Indian Ocean.

**Jay Clark Buckey Jr. '77, M.D. '81**, is the latest EE alumnus to travel in space. He served as a payload specialist on the NASA STS-90 shuttle *Columbia*, a 16-day Spacelab mission that was launched on April 17, 1998. Jay, an associate professor of medicine at Dartmouth-Hitchcock Medical School, participated in this mission to help investigate the effects of microgravity on the nervous system. He carried an EE School artifact into space: a hologram of the Samuel F. B. Morse instrument that on May 24, 1844, received the famous first long-distance telegraph message in the U.S.: “What hath God wrought.” The actual receiver is still in the possession of the Cornell College of Engineering.



# A DISTINGUISHED ALUMNUS IN SEMICONDUCTOR TECHNOLOGY



# W

Keith Kennedy Jr. received the B.S.E.E. degree in 1966, the M.S. degree in 1966, and the Ph.D. degree in 1968, all in electrical engineering, and all from Cornell University. From 1964 to 1968, while an undergraduate and graduate student, Keith studied microwave solid-state devices with a concentration on various modes of the Gunn effect, including gallium-arsenide technology.

This work resulted in a U.S. patent on a "Microwave Power Generator" granted in December 1969. After graduation he joined the Watkins-Johnson Company and from 1968 to 1971 led a team in the development and production of bulk gallium-arsenide X- and Ku-band electronically tunable oscillators. Following this success he directed the establishment of a thin-film fabrication facility that contributed to the company's competitiveness through continual advances in product performance and reductions in size and weight. From 1974 to 1978 he was manager of the Solid-State Division, served from 1978 to 1986 as vice president of the company's Devices Group, held a two-year appointment as vice president of shareowner relations and planning coordination, and was promoted in 1988 to his present position as president and chief executive officer of the company.

Under Keith's leadership, Watkins-Johnson has successfully made the transition from a defense-electronics company to become a high-technology growth business. In the mid-1980s under Keith's direction, the Devices Group initiated an enterprise to supply chemical-vapor-deposition equipment to semiconductor integrated-circuit manufacturers, a business that is now a major component of the company's revenue. The last unit of defense electronics was divested in 1997. At present he is guiding the company to use its core radio-frequency electronics skills in developing products for the wireless-communications market, an effort that has grown to be a significant amount of the company's continuing business.

Keith is a member of the board of directors of CNF Transportation, Inc. He serves on the boards of the Joint Venture Silicon Valley Network, the Silicon Valley Defense-Space Consortium, the California Chamber of Commerce, and the Santa Clara Valley Manufacturers Group. He is a member of the Executive Board of the Center for Quality Management-West. He has served on the Pacific Skyline Council of the Boy Scouts of America and on the Executive Committee of the NorCal Council of the American Electronics Association. He is a senior member of IEEE and a member of Phi Eta Sigma, Eta Kappa Nu, Tau Beta Pi, Phi Kappa Phi, and Sigma Xi. He has 13 publications in his fields of interest.

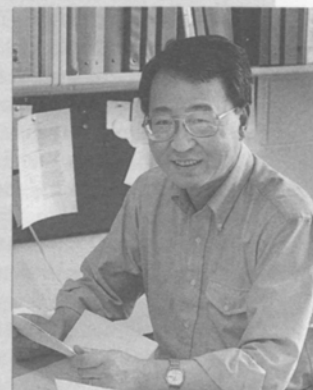
Keith writes that his Cornell EE education was an excellent preparation for his business career. His undergraduate classes trained him in the experimental method and provided the theory to design experiments effectively. His graduate study extended the theory in ways that allowed him to generate designs for new solid-state microwave devices.

We congratulate Keith on his distinguished career and wish him continued success in his management and direction of activities that are so vital to the further development of semiconductor technology. ■

## H.C. Torng Honored by Intel Corporation

Professor Hwa C. Torng, M.S. '58, Ph.D. '60, has been named the first Intel Academic Research Fellow "for his contributions to the state-of-the-art in high-speed instruction decoding and execution."

A plaque was presented to H.C. in a ceremony in Cornell's Biotechnology Building on December 2, 1997, by a group of Intel executives that included Justin R. Ratner '70, one of H.C.'s former students. In 1982, H.C., a



computer-architecture specialist, invented an ingenious computer chip that had the potential to greatly increase the speed of computer operations. Initially unacceptable by the industry because of the then-impossible requirement for 250,000 transistors on a single chip, the device has come into its own now that 7 or 8 million transistors can be incorporated into a similar space. In traditional computer operations, a microprocessor executes instructions in a rigid order. H.C.'s design allows a processor to sort out instructions by rapidly evaluating their relationships to one another so that certain

ones can be executed out of order without having to wait their normal turn. Cornell holds the patent on the invention and has licensed it to Intel for use in their Pentium® chips.

## New Dual EE/MSE Major Established

The School of Electrical Engineering and the Department of Materials Science and Engineering have established a new dual major for undergraduates in either department. The major will appeal primarily to EE students who plan to pursue a career in the chip-fabrication industry or are planning to continue on to graduate study in semiconductor processing or modeling. The major will be attractive to MSE students who are interested in solid-state materials tracks, or in the electronics industry. Alumni and prospective students who may be interested in this option can obtain additional information from a new Web page as follows:

[http://www.mse.cornell.edu/html/dual\\_major\\_-\\_ee.html](http://www.mse.cornell.edu/html/dual_major_-_ee.html)



**S**ally Bird, administrative assistant to the Space-Plasma Physics Group for the past ten years, has been appointed as administrative assistant to the EE faculty in Rhodes Hall to fill the vacancy left by Paula Solat's transfer to Phillips Hall. She will work as a team with **Tammie Van Buskirk**, and will continue to carry a core set of duties with the plasma group. **Jutta Brann**, accounts representative, joined the EE School in June 1997 to assume the position vacated by **John Crissey**, who has left Cornell and Ithaca for a career change. Prior to her present position, she was an accounts representative in the Department of Materials Science and Engineering for six years, following several years of accounting experience with a firm in Ithaca. Jutta received her high school and advanced education in Germany, took accounting and business courses in Tompkins Cortland Community College and BOCES, and says she likes university-type accounting and the opportunities it affords to interact with members of the college community. She enjoys her family and reading when time allows. **Melissa Fields**, programmer/analyst, joined the EE School in September 1997 to assume the position

vacated by **Bruce Fingerhood**, who left Cornell and Ithaca for a new career in Oregon. Before coming to the EE School she was in the library technical department in Olin Library for one year, after having spent eight years with the Technology Connection repair department (formerly under Cornell Information Technologies) as an office-systems technician. Melissa, a native of Ithaca and graduate of Ithaca High School, studied electronics technology for two years in Cayuga County College, in Auburn, before joining CIT. Melissa enjoys her family, flower gardening, snowmobiling, and is an avid country-music fan. **Albert Heidt**, research support specialist with senior research associate **Bill Schaff** in professor **Les Eastman's** group, joined the EE School in 1992. Prior to taking his present position, he was a research technician in Nuclear Studies for nine years with professor of physics (now emeritus) **Maury Tigner**, and others. Albert is a native of Dryden New York and a graduate of Dryden High School. His personal hobby is rebuilding antique motor cars. His current pride and joy is a 1949 TCMG that he has painted the famous British racing green. Albert competes for trophies with other

motor-car enthusiasts, and has shown his MG recently at Hershey, Pennsylvania, and Stowe, Vermont. **Paula Solat** was promoted to administrative assistant III in August 1997 and assumed the position in the director's office previously held by **Shelley Wright**. **Carol Webster** was appointed administrative assistant to third-floor faculty in Phillips Hall in June 1997. Before joining the EE School she was an allocations assistant for two years in the Theory

Center in Rhodes Hall, where she coordinated the review process of proposals for allocation of supercomputing resources. Prior to that position she was an administrative assistant in the Office of Sponsored Programs for eight years. Carol is a native of Ithaca, a graduate of Ithaca High School, and took business courses at Tompkins Cortland Community College. Carol enjoys her family and likes to play golf when time and weather permit. ■

## NEW "CONNECTION MACHINE" PROJECT

The National Science Foundation (NSF) has made a three-year \$1 million grant to the Electronic Packaging Program at Cornell for the design and construction of a precision interconnect cluster tool (PICT) that will be capable of connecting integrated circuits together with at least 10 times as many connections between chip, package, and circuit board as can be done with the most powerful computer chips available today.

This "connection machine" could allow industry by the year 2012 to develop microprocessors with as many as 7,000 connections, compared with about 500 connections that can be made at present, for example, by the Intel Pentium® II microprocessor chip. EE professor **Peter Krusius**, director of the Electronic Packaging Program, is principal investigator of the PICT project with professor **Che-Yu Li** of the Department of Materials Science and Engineering as co-principal investigator. Within the next decade such increased connection capability will be necessary for communication between individual computer chips that are projected to contain as many as 100 million transistors.

Peter comments, "We expect this research to provide new understanding of advanced concepts, new materials, novel processes, advanced structures, and reliability for many generations of future chip and package connections." The industrial advisory group of the project includes AMP, Inc. (the world's largest connector company), CVC, Inc. (a leading semiconductor equipment company), ESEC (a leading packaging and assembly equipment company), IBM, and Universal Instruments.



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. Further examples of the Matthews Criterion (see next page), as demonstrated at Cornell, are also of interest. We'll print 'em as space allows.

The story about professor **Malcolm McIlroy** '23 and his pipeline network analyzer in the last *Connections* brought forth some interesting recollections from **Bernard H. Rudwick**, M.E.E. '51. During his time in the EE School as a graduate student and instructor, Bernie got to know Mac and became very familiar with the analog model and its operation. Bernie writes:

You may recall the two former EE technical societies, AIEE and IRE, that were eventually combined into the present IEEE organization. When I was a grad student at Cornell the Ithaca Section of AIEE consisted of members from Binghamton, Corning, Elmira, and Ithaca. One of the regular monthly meetings of the Ithaca Section was devoted to the annual Cornell Student Paper Contest. In 1950 I presented a paper on system theory, the area of my thesis research, and was fortunate to take first place in the graduate-student contest. The prize was a certificate, \$25, and a trip to the forthcoming Regional Conference at Providence, Rhode Island, to represent Cornell at the regional paper contest. After the Ithaca contest was over, professor **Jack Tarboux**, Ph.D. '37, surprised me by saying, "Bernie, I think you should change the topic of your talk. The fellows who will be at the meeting are mostly power men and some old-timers who will find it pretty hard to follow you on system theory, although they will be polite enough. Why don't you tell them about McIlroy's analyzer and describe it as a good example of systems analysis." I was thunderstruck, to say the least, but after a few minutes of reflection decided his idea was a good one, and followed his suggestion. So I put together a second paper that described the pipeline analyzer as an excellent simulation of a complex, nonlinear liquid-flow design problem, difficult to solve mathematically, but readily amenable to system optimization by the resulting electrical

network. Professor Tarboux accompanied me on the drive to Providence, where we attended the regional conference together. My presentation of the new paper provoked many interesting questions from the group, particularly from members who were quite familiar with the application of analyzers to electric-power

networks. I have always been grateful to Professor Tarboux, who, by challenging me to expand my horizons, and suggesting a topic more suitable to the audience, allowed me to experience the satisfaction of a good performance. (Incidentally, this paper also took first place in the regional contest.)

*That picture of the McIlroy analyzer, with its mat of plugged-in cables, reminded David J. Bechtold, E.E. '38, of his student days in professor L. A. Burckmyer's Rand Hall lab courses. Dave writes:*

Plug cables were used extensively in the labs at that time. Each week, we formed teams of three and proceeded to perform various experiments to determine the characteristics of performance, efficiency, etc., of motors, transformers, and similar gear. In each lab session, we connected up the test gear, meters, controls, etc., with *beaucoup* plug cables. We were cautioned never to close the incoming-power knife switch until the hookup was checked and okayed by professor Burckmyer. Now, Professor Burckmyer was very impressive to us students in that he always had an unruffled and rather awesome dignity and composure. He also exhibited great ability to eyeball those complex interconnected mats of cables and test gear and okay or correct them if needed. We even wondered to each other how he could do this so quickly. Was he maybe bluffing a bit at times?

You can guess the rest. One day we were at that required checkpoint with our setup maze of cables, the professor made his quick perusal and okay, turned away, and someone closed the switch. There was a remarkable explosion, a flash, and a mushroom cloud rose to the ceiling over our setup. No one was hurt, since the circuit breaker on the wall tripped instantly. The professor looked back and never batted an eye or lost his dignity. We quickly found the problem where, somehow, an extra cable had been plugged directly across the load side of the supply switch. The cable was ruined but nothing else had been harmed, so we went on and finished our tests of the day. To this day I do not know whether that culprit cable got there by pure accident or by somebody's design to try to embarrass us or test the professor's speedy checking skills. I suppose we'll never know. Better that way.

One other memory fragment about Professor Burckmyer was his articulate and precise way of speaking. It always stood out when he pronounced the word "syllable" as "sil-ah'-ble." Does anyone else remember that? Probably not, but we all remember him as a grand prof and the real gentleman that he was and as were all the other profs then and now, I'm sure. [Dave, your story is going to trigger a lot of memories—S.L.]

Mark Saturday, June 6, 1998, 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.



*Sam Linke reporting:* Some longtime EE alumni may have served as officers of the Delta Chapter of Tau Beta Pi during their undergraduate days in the '30s and '40s. If so, they probably had some communication with professor R. C. (Red) Matthews, the perennial national secretary of the society in those days. Red was professor of mechanical drawing and machine design at the University of Tennessee when professors such as yours truly (**Sam Linke**) and **Joe Rosson** were undergraduates there. He was a legendary character (perhaps the first cheerleader on the UT campus) who proclaimed once, in his hillbilly accent:

**"Engineerin' is doin'  
whut's gotta be done—an  
gittin' away with it."**

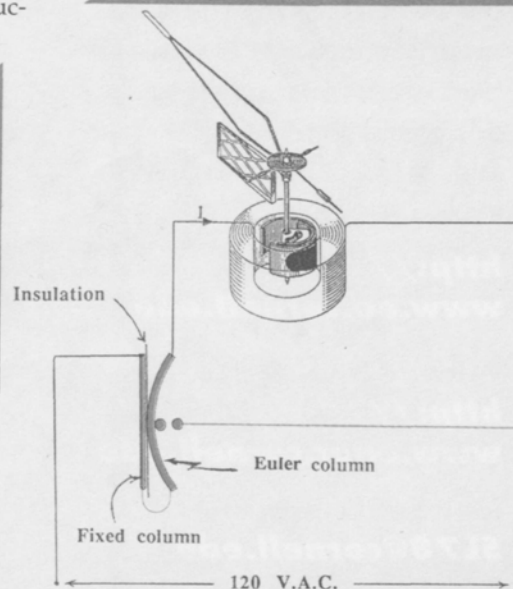
There are many examples of the "Matthews Criterion," and one that comes to mind is an engineering solution by Joe Rosson back in 1983 when the Data General Corporation donated a \$275,000 MV/8000 computer to the EE School. This new but already obsolete system was installed in Phillips Hall to serve several work stations in the building. Unfortunately, the required 208-volt three-phase four-wire grounded voltage supply for the machine was not available from the building mains, so special (and expensive) transformers were required to put the equipment into operation. Joe, as associate director of the EE School, always ran a tight ship, so he felt he could save a lot of money and time by building the transformers himself. Back in the early '60s, when Joe was in charge of the high-voltage ac-cable-insulation testing program at the High-Voltage Laboratory on Mitchell Street, the tests were conducted at 345 kV between cable conductor and ground with 1,000 amperes flowing in the conductor. Instead of the huge 345 MVA transformer that would have been required for the power source, a relatively modest-sized low-current transformer was used to supply the high voltage. For the high current, the cable ends were tied together to form a short-circuited secondary winding on a homemade transformer core with the primary winding connected to a controlled low-voltage source. Each core consisted of a 10-inch-thick laminated-iron torus with an outside diameter of about two feet. Joe brought three leftover cores to Phillips Hall, placed appropriate primary and secondary windings around each torus, and obtained the correct three-phase voltage source for the new computer, thereby eliminating a long wait for commercial transformers and getting the computer on-line at practically no cost. It was necessary to add several computer components to upgrade the MV/8000, but the power supply was up to the task and worked well for several years until the system was decommissioned in favor of the campus mainframe. Joe had learned his old professor's lesson well.

Here is still another example of the application of the Matthews Criterion: In the late '50s, the power and machinery laboratories in the EE School were under severe budget constraints, so great care was taken to minimize damage to the limited num-

ber of available instruments. Unfortunately, a student would occasionally connect an ammeter across the line. The resulting short circuit would blow a fuse or circuit breaker, but inevitably the meter pointer would be forcibly driven completely off-scale and the instrument would have to be sent off for repair. **John La Tour Jr.**, B.E.E. '58, M.E.E. '58, self-styled "man with an iron leg" because of his strong interest in the power field, was aware of this problem and, as part of his senior project, developed a bypass device to protect an ammeter during an accidental short-circuit event. Taking advantage of the well-known fact that two adjacent conductors will repel one another when they carry current in opposite directions, John envisioned that two thin flexible metallic strips, one of which was an Euler's column buckled in the second mode, separated by a thin strip of insulation and connected as shown in the figure, would do the job. After the necessary calculations, construction, adjustments, and trial runs, he demonstrated his design to his project advisor, professor L. A. Burckmyer. John said afterward that Burck's appreciative chuckle when he witnessed the successful operation of the bypass device was the only grade that he really needed.

Back in the days when I first came to Cornell in 1946, I was assigned to teach in the so-called service courses, designated by professor **Bill Erickson** as "Electrical Engineering for Non-Electrical Engineers." Since it was pretty obvious that EE was not the primary concern of most of those students even though the courses were required in their curricula, I tried to drum up some interest by giving an occasional lecture demonstration, generally on some offbeat topic that I hoped would remain in memory. For reasons that will be obvious, I tried the following stunt only once, but this story has always been one of my favorites. The subject of the lecture that day in Franklin 115 (for a bunch of chemical engineers) was the power transformer, its importance in power-distribution systems, its electrical behavior, and, of course, the details of its construction. A large gray-painted 25-kVA pole-top transformer tank with a cover was on the floor in front of the lecture table. After a considerable discourse on the amount of iron, copper, and insulating oil in the tank, and a supposition that it probably weighed 500 pounds, I casually picked it up and set it on the table. After some applause and a few hoots, I had to admit that the tank was a wooden model that weighed perhaps 20 pounds. I like to think those students never forgot that lecture.

—Sam Linke



The circuit of the bypass device is adapted from a sketch displayed in U.S. Patent 3,002,065, issued to John La Tour Jr. on September 26, 1961. The meter mechanism is adapted from Figure 17-19 (credited to Daystrom, Inc., Weston Instruments Division) in M. B. Stout, *Basic Electrical Measurements*, Second Edition, Prentice-Hall, Inc., Englewood Cliffs, N.J., 1960.



# ee ON-LINE NEWS

## New EE Web Page Is Now On-Line

The EE School Web page is in the process of being extensively modified with all planned changes to be completed by this summer. The current version contains a guide for enrolled and prospective students, an updated alumni section, and general information about the school and faculty. Check it out at:

[http://  
www.ee.cornell.edu](http://www.ee.cornell.edu)

The College of Engineering URL is:

[http://  
www.engr.cornell.edu](http://www.engr.cornell.edu)

E-mail address for *Connections* is:

[SL78@cornell.edu](mailto:SL78@cornell.edu)

## EE Alumni On-Line Database Changed

The EE "find file" established last year by the EE Master of Engineering Program, and described in the 1997 issue of *Connections*, has changed its URL. Alumni may visit the site by clicking on the ALUMNI DATABASE link of the main EE page URL, as follows:

[http://  
www.ee.cornell.edu](http://www.ee.cornell.edu)

## POSITIVE FEEDBACK

The Positive Feedback feature always triggers 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.

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.

• **Dwight C. (Bill) Baum '36** (senior vice president with Painewebber, Inc., in Pasadena, California) visited the campus in October 1997, discussed the potential of the Duffield Hall project with dean **John Hopcroft** and several EE School professors, toured semiconductor research facilities, participated in Cornell Council meetings, and spoke at a meeting of the Cornell Board of Trustees about his commitment to the project (see page 5).

• **David J. Bechtold '38** (retired from his many years of service as an electric-utility engineer with Pennsylvania Electric Company, and now living in Johnstown, Pennsylvania) writes that he is enjoying *Connections* and the memories the newsletter brings back of his days at Cornell. Dave remembers professor Victor Colby's abstract sculpture over the entrance to Room 101, and also describes a memorable experience in Rand Lab (see page 24).

**Max H. Kraus '49** (retired as president of Electro-Nite Company of Philadelphia and now living in Meadowbrook, Pennsylvania) attended a meeting of the Cornell Council in October 1997. During his visit to the campus he brought an artifact to the EE School historical collection: a 1940s-vintage multimeter housed in a handsome and sturdy wooden case.

**Donald D. Christiansen '50** (retired editor and publisher of *IEEE Spectrum* and president of Informatica, a consulting firm in Huntington, New York) edited the fourth edition of *The Electronic Engineers' Handbook*, published by McGraw-Hill in June 1997.

**Wilson Greatbatch '50** (inventor of the implantable cardiac pacemaker and holder of more than 150 patents) was featured this past summer in a PBS television special on the impact of the G.I. Bill of Rights on college education in the United States following World War II. Wilson described some of his experiences as an early participant in that historic and valuable program.

• **Bernard H. Rudwick, M.E.E. '51** (retired professor of Systems Engineering and Financial Management with the Defense Systems Management College in Washington, D.C., and a systems management consultant in the Washington area), writes that *Connections* brings fond memories of his days as a graduate student in Franklin Hall. Bernie relates an engaging story of his interactions with professors **McIlroy** and **Tarboux** (see page 24).

**Richard Bosshardt '52** (ex-Naval officer and board member of the Cornell Club of Switzerland) writes to congratulate his classmate **Les Eastman** on his further string of achievements, and expressed his great interest in professor **Paul Kintner's** new course, EE 485, GPS Theory and Design, as described in the 1997 issue of *Connections*.

**William E. Gordon, Ph.D. '53** (former Cornell EE professor and "father" of the Arecibo radar telescope), in an article in the November 1997 issue of *Air & Space Magazine* that discussed efforts to build the facility in Puerto Rico, wrote, "Forty years ago, I was just happy to get the dish!"

**Irwin M. Jacobs '56** (founder, chairman, and CEO of QUALCOMM, Inc.) has established the Joan and Irwin Jacobs Chair in Electrical Engi-



neering. Recruiting is in progress to fill this position with a new professor with research interests in the areas of wireless communications and digital systems.

• **John La Tour Jr.**, B.E.E. '58, M.E.E. '58 (consulting engineer with Economy Electric Company in Daytona Beach, Florida), recalls his stimulating interactions with Professor **Burckmyer** and provides details of an interesting invention that evolved from his EE Senior Project (see page 25).

**Abraham J. Osofsky** '58, M.S. '61 (consulting engineer, now living in Highland Park, New Jersey), attended the 1997 EE Reunion Breakfast and enjoyed chatting with his former professors and old friends.

**Peter H. Wolf** '58, M.E.E. '59 (Senior Judge of the Superior Court of the District of Columbia), also attended the Reunion Breakfast in June and enjoyed meeting old friends and recalling early days in Phillips Hall.

**Dwight J. (Jim) Baum** '65 (Investment Manager, Dwight Baum Investments in Pasadena, California) participated in the Cornell Council meetings in October 1997, and, together with Bill Baum, toured the semiconductor research facilities on campus.

**Neil J. A. Sloane**, M.S. '64, Ph.D. '67, reports that he is now with AT&T Labs Research in Florham Park, New Jersey.

**John J. Bzura** '66, M.E.E. '67, Ph.D. '71 (principal engineer with New England Power Service Company in Arlington, Massachu-

setts), writes that he was pleased with the 1997 *Connections* and the plasma-physics features. John was glad to see the old familiar names, and many of his memories of 1967 and onward at 509 Mitchell Street returned as he read the articles.

**Malvin C. Teich**, Ph.D. '66 (professor of electrical and computer engineering, biomedical engineering, and physics at Boston University), was named the 1997 recipient of the IEEE Morris E. Leeds Award for outstanding contributions to electrical measurement using infrared and nonlinear heterodyne detection. He received the award at the 1997 Lasers and Electro-Optics Society annual meeting on November 10, 1997, in San Francisco, California.

**Daniel T. Lee** '73 (supervisor and research manager with Hewlett-Packard Company) reported his new business address in Cupertino, California.

**John C. Belina**, B.S. '74, M.Eng. '75 (assistant director/lecturer, School of Electrical Engineering at Cornell), contributed Chapter 3 in the fourth

edition of *The Electronic Engineers' Handbook*, published by McGraw-Hill in June 1997.

**Jaclyn A. Spear** '74 (normally with the Westinghouse Savannah River Nuclear Site, in Aiken, South Carolina) spent the past year in Washington, D.C., on an IEEE Congressional Fellowship working for Rep. Lee Hamilton (D-IN) on the House International Relations Committee.

• **Daniel T. Barry** '75 (U.S. astronaut at NASA's Lyndon B. Johnson Space Center, in Houston, Texas) related his experiences on the space shuttle *Endeavor* at the EE Colloquium on October 7, 1997 (see page 21).

• **Jay Clark Bucky**, B.S. '77, M.D. '81 (U.S. astronaut at NASA's Lyndon B. Johnson Space Center, in Houston, Texas), was a payload specialist on the space shuttle *Columbia*, a 16-day Spacelab mission that lifted off April 17, 1998 (see page 21).

**Edward P. Einhart** '79 reports that he is president/electrical engineer of Industrial Control &

Electrical Design Corp., in Central Square, New York.

**Mark M. Gibson**, B.S. '84, M.Eng. '85 (member of technical staff at Hewlett-Packard's Microprocessor Technology Lab in Fort Collins, Colorado), spoke at the EE Colloquium on March 3, 1997, on the topic "Motivation and Design Approach for the 64-bit, IA-64 Instruction Set Architecture."

• **Edward T. Lu** '84 (U.S. astronaut at NASA's Lyndon B. Johnson Space Center, in Houston, Texas) served as a mission specialist on the space shuttle *Atlantis* that was launched in May 1997 on a nine-day mission that included a rendezvous and docking with the Russian space station *Mir* (see page 21).

**Tom Smith Tseng** '87 (assistant director of East Asia operations of Harvard University's development office) transferred to his present position in 1997

after eight and a half years in a similar post at Cornell. Tom writes that he is expected to travel to Asia four times a year. On July 1, he was in Hong Kong during the historic handover of the former British colony to the Chinese government.

**Bevan N. Das** '90 (graduate research assistant at the University of Illinois at Urbana) is completing his Ph.D. thesis on routing in ad hoc wireless networks.

**John Y. Cho**, Ph.D. '93 (research scientist at MIT), reports that he has left Arecibo, Puerto Rico, and is now living in Cambridge, Massachusetts.

**Alan F. Acker**, M.S. '96, reports that he has moved from Terre Haute, Indiana, to Torrance, California. ■

## A LINK BETWEEN ALUMNI

### AND THE SCHOOL OF ELECTRICAL ENGINEERING

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



## Eminent Professors' Fund

Six 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.

**CORNELL**  
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