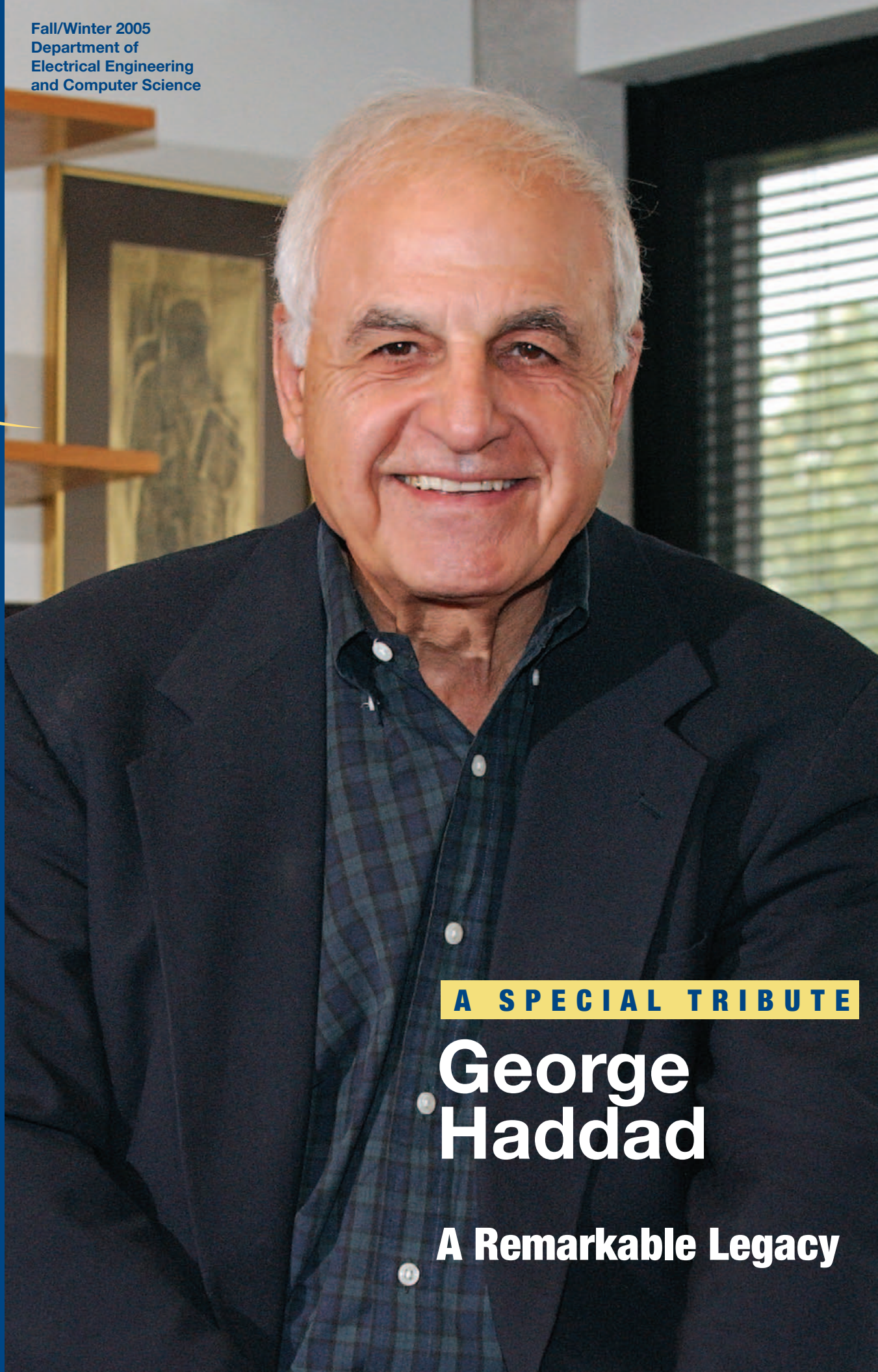


Fall/Winter 2005  
Department of  
Electrical Engineering  
and Computer Science



THE UNIVERSITY OF MICHIGAN

EECS  News



**A SPECIAL TRIBUTE**

**George  
Haddad**

**A Remarkable Legacy**

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## Electrical Engineering and Computer Science

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# A Message from the Chair



Greetings. As I write this, our students have returned to the University of Michigan and the fall term is about to begin. Excitement abounds, but it is tempered by awareness of the massive destruction brought about on the Gulf Coast by Hurricane Katrina. The University of Michigan is seeing the effects directly as numerous students and faculty from the affected region are making arrangements to enroll or visit the U-M for at least the fall term. This disaster has many lessons. Among them is that technology alone is

insufficient to maintain a safe, productive, and vibrant society. We all have witnessed that there is a finer line than we may have thought between the richest nation in the world and some of its third-world neighbors. I don't pretend that there is any way to avoid natural disasters, but the wake of Katrina is one more reminder that we live in a highly complex world where social, technological and political factors are heavily intertwined. Although Katrina is an extreme example, those who are best prepared to contribute to our world have the ability to go beyond "book learning" and display leadership in uncertain environments with teams of other people. In this EECS News, I think you will see evidence that at the University of Michigan we are preparing our students for this role.

It is our faculty who prepare our students. The programs of three of our most distinguished faculty are highlighted in this issue. First is George Haddad, who has just retired after an unparalleled career in research, administration (two terms as department chair), and education. I could go on and on about George's unique and lasting contributions to EECS, his leadership skills, and his terrific personality. However, this story is told later on pp. 4-10, so enjoy. George has my heartfelt congratulations for a well-deserved retirement, but the best news is that he is maintaining his research and service ties to EECS. The other two eminent faculty who are featured are Pallab Bhattacharya, who holds the Charles Vest University Professorship, and John Hayes, who holds the Claude Shannon Professorship. The write-ups, beginning on pages 11 and 14, describe their cutting-edge research programs in optoelectronics and computing, respectively.

This year we are pleased to welcome five new faculty to the department. We have done much to shore up our activities in electromagnetics, with the addition of Eric Michielssen who has joined us as a full professor from the University of Illinois, and Anthony Grbic, who will be joining us in January from the University of Toronto. Domitilla Del Vecchio is arriving as an assistant

professor in the control systems area from the California Institute of Technology. We have two new additions in the nanoscience area at the assistant professor level: Wei Lu from Rice University and P. C. Ku from Berkeley.

The EECS Alumni Society is soliciting volunteers for two initiatives. First, they are seeking mentors for current students and for recent graduates. Second, they are hoping to recruit EECS alumni to participate in the recruitment of new students to the College of Engineering at Michigan. Neither of these activities is time-consuming. Both can be rewarding. See the instructions in this newsletter to sign up. Also, you are invited to join in on the EECS alumni activities on Friday, October 7 and the CoE tailgate preceding the Homecoming Football Game on Saturday, October 8. Please contact Catharine June for further information ([cmsj@eecs.umich.edu](mailto:cmsj@eecs.umich.edu)).

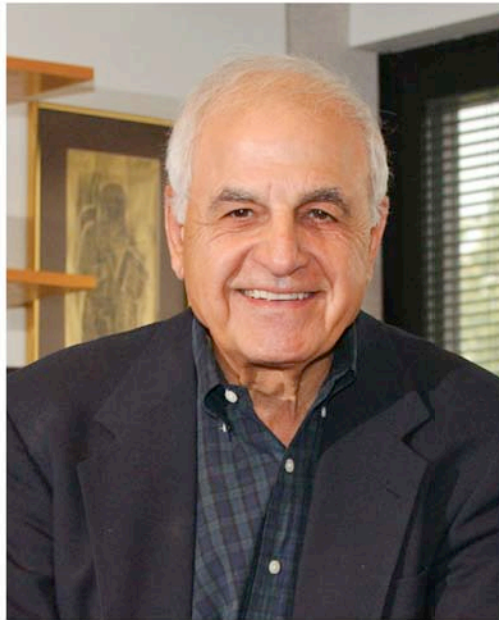
The EECS Department is extremely grateful for the support provided by corporations, foundations, alumni, and friends. This generous assistance is especially needed as we complete the new Computer Science and Engineering Building, undertake the expansion of our clean room (Michigan Nanofabrication Facility) and begin renovation of the EECS building. Exciting naming opportunities exist with each of these projects. Please contact me if you would like to participate. Ford Motor Company has been one of our most loyal corporate sponsors over the years. Please see p. 27 to learn more about the close association of Ford with EECS at the University of Michigan.

I would like to close by stating that we are as proud as ever of our students. You can read about some of their many activities in this newsletter. The victory of the U-M student team in the North American Solar Car Challenge deserves special mention. The design and construction of their solar car, Momentum, was an enormous challenge, as were the logistics for the competition itself. Racing from Austin, Texas to Calgary, Alberta, the team successfully overcame a series of unforeseen obstacles. It was a delight to track the team's progress over the web via GPS, and to see them in the lead in the final minutes of the race on the last day. One-third of the engineering students on the team are from EECS and one of the two faculty co-advisers is our own Professor Brian Gilchrist. The team now enters the international competition in Australia. When one witnesses the hard work and ingenuity put forth by this team, and by the student teams from the other competing universities, you can't help but conclude that our future is in good hands.

A handwritten signature in black ink that reads "Dave".

David C. Munson, Jr.

## George Haddad: A Remarkable Legacy



**George I. Haddad, Robert J. Hiller Professor**

George I. Haddad became an emeritus professor this past May, 2005 - leaving a remarkable legacy of achievement and leadership in research, teaching, service and administration that spans nearly half a century. Originally from Lebanon, Haddad came to the University of Michigan in 1952, and has been here ever since. With numerous opportunities to go elsewhere, he has remained true blue, stating, "I love Ann Arbor, I love Michigan. The University of Michigan is in my blood."

### **Early Career**

George enjoyed his time as an undergraduate student. "I belonged to a fraternity, and had lots of very good friends that I'm still in touch with. After receiving my bachelor's degree in 1956, I went to Motorola in Chicago for 3-4 months, and then decided I wanted to go back to school."

After receiving his master's degree, Haddad was convinced to stay at Michigan for his PhD by renowned professor and chair, William Gould Dow (1895-1999), who recognized his gift for communication and encouraged him to remain at Michigan. So he stayed, and upon graduation, Dow (chair of the department 1960-65) hired him as an assistant professor in 1963.

When his thesis advisor, Joseph Rowe, became department chair, he tapped Professor Haddad to

become Director of the Electron Physics Laboratory (EPL) in 1968. This was a very challenging time for the lab, and Professor Haddad immediately showed the resourcefulness, vision, persistence and care for faculty and staff that would mark his entire career.

Haddad's first responsibility as lab director was the difficult task of laying off several individuals who could no longer be supported, and also to reduce the level of graduate student support because the government had ceased to fund microwave tubes, which was the mainstay of the laboratory research at that time. George vowed that he would never again have to let an individual go due to lack of funding. Betty Cummings, then secretary to Professor Haddad, recalls the many hours he spent on the phone with colleagues and granting agencies to ensure the future of the lab. He did receive significant funding in the area of solid-state electronics, he hired key faculty member Professor Ken Wise (Director, NSF Engineering Research Center for Wireless Integrated MicroSystems) in 1974, and said "we rebuilt the whole place, and it's been growing ever since. We never had to lay off another person."

### **Early Research**

Haddad's research is focused on microwave devices, and finding ways to get them to generate the highest frequencies possible at relatively high power levels and efficiencies. As a master's student, he built the first X-Band traveling wave maser in the world. Masers, which preceded lasers, were used for low noise amplifiers in such applications as receiving signals from satellites.

His PhD work focused on microwave tubes, which quickly turned to Impact Ionization Avalanche Transit-Time (IMPATT) and GUNN diode transfer electron solid-state devices. The book *Avalanche Transit Time Devices*, which he edited in 1971, contained contributions from the most prominent people in the field at that time, and became a standard reference in the field. His move from tubes to solid-state devices, combined with his charge as EPL director, led Haddad to build up the area of microwave solid-state devices and integrated circuits. Michigan has remained a leader in these fields for over forty years.

### **Chair of ECE and EECS, 1975-1986**

Professor Rowe left the University in 1974, and Haddad was again named to take over his position,

this time as chair of the department. As with the EPL, he took over at a time of reduced resources. Adding to this difficulty was the fact that, due to the popularity of Electrical and Computer Engineering, enrollment began to rise sharply, almost doubling in the years 1975-80. Classes on central campus were overloaded, morale was suffering, and the EE departmental ranking by the National Academies in 1978 was 13 in the nation - not good enough for George. In addition, very few faculty positions were available due to the state economy.

The department underwent sweeping changes during the 1980's - most of them initiated, planned, and executed with Haddad at the helm. These changes included the new EECS building on North Campus, which housed a state-of-the-art Solid-State Electronics Laboratory, the hiring of several dozen faculty, the formation of the EECS Department from three entities, and a virtual explosion of new research centers and funding. This was accomplished through vision, planning, and hard work.

George credits Jim Duderstadt, Dean of the College of Engineering between 1981-86 (and later President of U-M), Chuck Vest, Associate Dean for Academic Affairs (and later Dean and Provost at U-M and President of MIT), and Dan Atkins, Associate Dean for Research (and later Dean of the School of Information), for their exceptional support and leadership during these formative years.

Haddad recalls that when the Solid-State Electronics Laboratory was built, the facility was empty, and in need of extraordinarily expensive equipment to outfit. He and Wise assisted Duderstadt and Vest in writing a successful proposal to the State of Michigan, which established the Research Excellence Fund. A significant portion of this fund went to the department, and contributed to the excellent facilities in the SSEL, the Radiation Laboratory, and the Optics Laboratory - facilities that exist to this day. In addition, significant funding was devoted to machine intelligence and robotics activities.

Duderstadt called Haddad's accomplishments extraordinary, and added, "Even while providing such extraordinarily strong leadership, George Haddad maintained a world-class research program, which brought in many millions of dollars, produced outstanding graduate students, and contributed greatly to the nation. The University will long bear the imprint of his achievements and his leadership."

The current EECS Department was formed during these exciting times. In 1984, three distinct yet related entities merged: the former College of Engineering, Electrical and Computer Engineering (ECE) Department, whose roots go back to the

original Electrical Engineering Department in 1895; the College of Literature, Sciences & the Arts, Computer and Communication Sciences Department (CCS), which was formed in 1967; and the Computer Information and Control Engineering (CICE) graduate program. The merger was primarily a response to the disparate manner in which computer science and engineering was taught throughout the University, and the desire to improve the national standing of the department, particularly in Computer Science and Engineering (CSE).

It was a remarkable achievement to bring together three fairly distinct academic cultures and help them to coexist within a completely new environment. The new EECS Department merged about 35 faculty from ECE, 10 from CICE, and 8 from CCS. In addition, the very first year of the new department, fall of 1984, 14 new faculty were hired. During this time, Professor Haddad relied on his trusted associate chairs, Tom Senior, Keki Irani, and Dave Neuhoﬀ, to handle significant administrative responsibilities.

Tom Senior, associate chair for the Electrical Engineering division during this time, said "You don't think of the things you have to do when you completely change a department, which we did." He recalls the summer of 1984 when he and Haddad completely reorganized every course in the new department - each course was systematically numbered by topic and level, while many were eliminated or restructured. "He was the right person at the right time for this department," said Senior. "George was able to direct and oversee enormous change in a remarkably smooth and effective manner."

Keki Irani, associate chair for the CSE division during the merger, is happy to still call George, "a very good friend of mine. Working for him, I never felt that I was serving a boss. I was just helping a friend. One thing that impressed me most about George was that he was always fair. He was capable of objectively evaluating a person or a situation and acting accordingly."

Dave Neuhoﬀ, associate chair for the new Systems Division, had an important role in defining the new organization. As he recalls, "We merged ECE with CCS to form EECS, nearly doubled the faculty, dramatically increased salaries,

*"The University will long bear the imprint of his achievements and leadership"*

James Duderstadt



**Dedication of the EECS Building in 1986**

reconstituted the graduate programs, substantially enlarged funded research and PhD production, and moved to North Campus. As an associate chair, I was an intimate observer of George's steady hand on the helm throughout this period. We owe most of EECS's present strength to the developments that he led in that period."

At the same time, Professor Haddad improved the climate for faculty in significant ways, making it possible to divide their time more equally between

teaching and research. He changed the teaching load from two courses per term plus one lab, to one course per term for those doing significant research. He and Duderstadt ensured that faculty would receive a portion of the money that was generated by overhead on their research, an issue he advocated during his tenure on the U-M Research Policies Committee ('76-'79). He also successfully lobbied for faculty to take three month summer salaries from their research grants in order to continue their research during the summers.

# George I. Haddad

'52: Enrolls at U-M

'60-'63: Instructor

'70: ASEE Curtis W. McGraw Award

'63: Assistant Professor

'72: IEEE Fellow

'65: Assoc. Professor

'77: MTT Society, Dist. Service Award

'69: Professor

'78: EPL be

Director, EPL

Ch

1955

1960

1965

1970

1975

19

'56, '58: BSE, MSE EE

'63: PhD, EE

'68-'71: Editor, IEEE Trans. On Microwave Theory and Tech.

'68-76: Admin. Comm., IEEE Society on Microwave Theory and Tech.

'73-'76: U-M Comm. on the Economic Status of the Faculty

'76-'79: U-M University

'81

1975

1997

Research Funding	\$2 M	\$35.8M
Faculty (35 ECE/9 CICE)	44	89
PhD's Graduated	7	66
Graduate Students	212	650
Undergraduate Students	709	772

EE Dept.

ECE Dept.  
(1971)

### Chair to CHFM

Once the move from East Engineering on Central Campus to the EECS Building on North Campus was accomplished in 1986, Haddad stepped down as chair, only to jump right into leading a major program, while also fulfilling the duties of director of the SSEL. Saying that "lady luck was on our side,"

Haddad became aware that the Department of Defense was establishing the University Research Initiative (URI) to create major research centers at universities. After writing a successful proposal, he and a team of more than 12 faculty established the Center for High Frequency Microelectronics (CHFM). Funded at \$15M for the initial five-year period, with an additional \$5M from the state, the CHFM essentially doubled the research funding in the department.

## 50+ years at U-M

'85: CoE Research Excellence Award

'91: Robert J. Hiller Chair Professor

'86: U-M Distinguished Faculty Achiev. Award

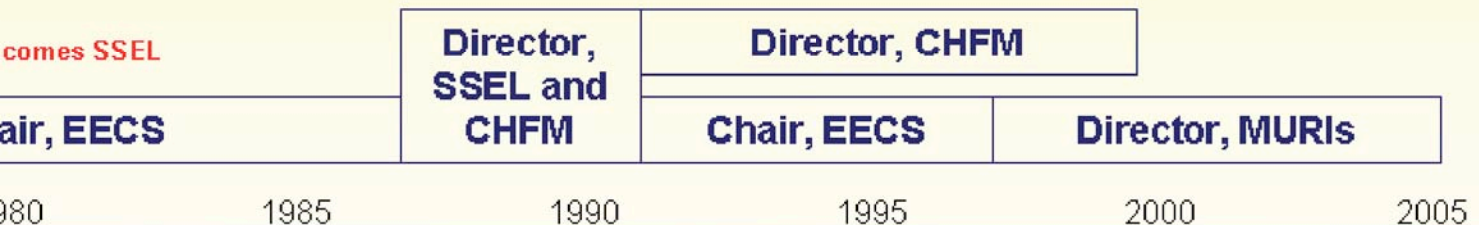
'94: Member, National Academy of Engineering

'88: CoE Attwood Dist. Achiev. Award

'96: IEEE MTT Society, Dist. Educator Award

'00: IEEE Millenium Medal

'05: Retirement and Symposium in honor  
of George I. Haddad



and Techniques

'86: EECS moves from East Engineering on Central Campus to North Campus

Theory and Techniques

Status of the Faculty

Research Policies Committee

'84: U-M Comm. on Honorary Degrees

'88-'91: U-M University Budget Priorities Committee

'88-'92: Hewlett-Packard Laboratories Research Board

'90-'92: U-M Provost Advisory Committee on Excellence

'91-'93: U.S. Army Science Board

**EECS Dept.**  
**(1984)**

'96-'99: U-M Technology Mngmt. Office, Advisory Board

'96-'00: NRC Advisory Comm. for the Army Research Lab.

'96-'99: Electronics Peer Committee: NAE

'01-'04: U-M Henry Russell Lecture Comm.

"With the CHFM, we started a major effort to make the fastest transistors in the world," said Haddad. "We had a great program based on III-V semiconductor materials for very high frequency applications ranging from microwave frequencies up to optical frequencies. We did work in microwave integrated circuits, high frequency transistors, optoelectronic integrated circuits, nanoelectronic devices and circuits – the whole gamut."

The CHFM opened new research avenues for graduate students, including state-of-the-art millimeter wave integrated circuits, sub-0.1-micron field-effect transistor technology, advanced epitaxial growth technologies, optoelectronic devices and integrated circuits, and quantum-based electronic devices and circuits. The ability Michigan now had, with the SSEL, to produce microwave integrated circuits led to the first university courses on the subject. In addition, the Center's pioneering efforts in quantum-based electronic devices and systems put Michigan at the leading edge of technology that even now, nearly two decades later, remains at the forefront of engineering research. Throughout its 12-year history, the CHFM trained hundreds of students, many of whom became leaders in the field either in industry or academia.

George credits his very good friends and colleagues Pallab Bhattacharya, Dimitris Pavlidis, Jasprit Singh, Duncan Steel, and Roberto Merlin for their key roles in making the program in compound semiconductor materials and devices for high frequency electronics and optoelectronics one of the best in the world. George stated that "this research, coupled with the outstanding research of Ken Wise, Khalil Najafi, and Rich Brown on Integrated Sensors and Circuits based on silicon micro-electro-mechanical systems (MEMS) technology, made the SSEL the laboratory to emulate at other major universities."

Drawing on the solid foundation of the SSEL and CHFM, Haddad recalls that thereafter, "every year for about 10 years we established a major center or program. It was a very exciting time." These included the Center for Space Terahertz Technology (Fawwaz Ulaby, director), the Center for Ultrafast Optical Sciences (CUOS, Gérard Mourou, director), the Center for Display Technology and Manufacturing (DTM), the Center for Neural Communication Technology (CNCT, Ken Wise and Dave Anderson), several centers in optoelectronics (Pallab Bhattacharya), and several multi-investigator, multi-disciplinary (MURI) programs.

### Back to the Chair's Office

In the midst of running the CHFM, Haddad was asked again to chair the department in 1991.

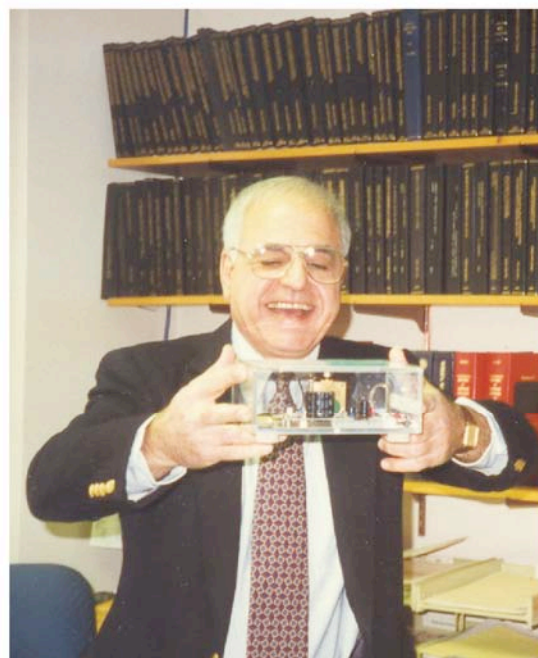
Rather than a time of rapid expansion and growth, it was now a time for management of existing resources, and maintaining the momentum gathered during the previous decade. Haddad adapted to these new circumstances, revealing a keen ability to handle financial issues. His many years managing the EPL, SSEL, CHFM and a wide variety of smaller grants served him well, as did his work on important University committees, in particular the Economic Status of the Faculty ('73-'76) and the University Budget Priorities Committee ('88-'91).

Virginia Wait, administrative manager for the department since 1989, said that "George understood the administrative systems better than anyone else I had ever worked with. He knew what could be accomplished, and what you needed to do to accomplish it."

Among these accomplishments were the continued hiring of excellent faculty, a continual acceleration of research funding, and PhD student production that reached an all-time high. Haddad stated that he is grateful for great support from the College of Engineering during these years, through Dean Peter Banks, and associate deans Erdogan Gulari, George Carignan, and Bill Martin.

Haddad created an environment in which faculty and staff alike could thrive, and feel appreciated. Pallab Bhattacharya, professor in SSEL, came to Michigan in 1984. He said, "George provided faculty an environment to work unfettered – the room to grow and to realize our dreams. This was crucial for our success."

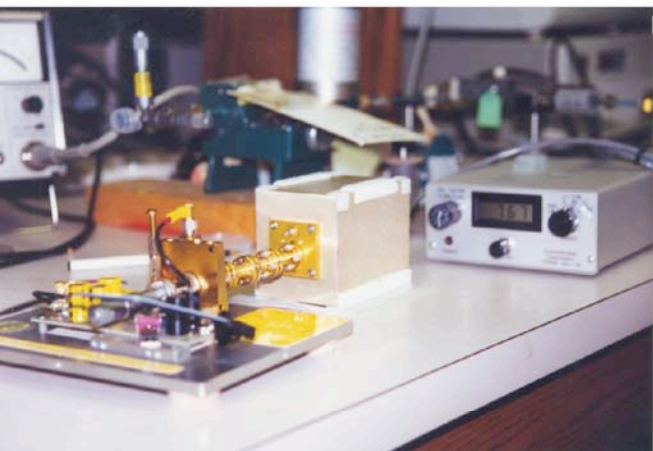
"A great department cannot exist without great staff," says Haddad. Assisting him in his role as department chair at different times, he is always quick to praise Betty Cummings (SSEL Administrative Manager), Wait, and Karen Liska (EECS Human Resources Coordinator) for their excellent and dedicated service to the EECS Department. Liska stated that George "set the tone in the department for past and future generations of staff to make this department what it is, in an atmosphere that continues to promote and perpetuate excellence." George also freely praises



**202 GHz GaAs TUNNETT diode oscillator - presented by Dr. Heribert Eisele to Prof. Haddad on the occasion of his 60th birthday. This oscillator yielded two separate world records for TUNNETT diodes, one in April 1995 and another in October 1998.**

the excellent leadership of his associate chairs during these years: Kang Shin, Dave Anderson, Toby Teorey, and Pramod Khargonekar.

His final report on the status of the department in 1997 showed a very strong department, both in national rankings and in fiscal health. The timeline on pp. 6-7 shows the growth in research funding, number of faculty, PhD students graduated, and enrollment of graduate students from the time that George first became chair in 1975, to when he left in 1997, having served nearly 19 years in that office. It became time to turn his attention again to research.



### Continuing Research

As before, just as Haddad would step down as chair, he and several other faculty members were awarded a large grant, this time a Multidisciplinary University Research Initiative (MURI) to study Low Power/Low Noise Electronics. This continued research begun under the URI program, as well as new areas in microwave MEMS, and a focus on wireless communications. George worked with Linda Katehi (now Dean of Engineering at Purdue), Gabriel Rebeiz (now at UC-San Diego), and Clark Nguyen (currently on leave serving with the US Defense Advanced Research Projects Agency) on some of these new areas. "My own work has always been on the devices themselves, ranging anywhere from microwave frequencies to terahertz and optical frequencies. The last major program I have right now is to develop terahertz sources to be used for chemical and biological sensing. The terahertz frequency range is still unexplored territory."

The best devices for generating significant power levels to reach the high terahertz frequencies are still IMPATT diodes, and close derivatives such as Tunnel Transit Time (TUNNETT) and GUNN devices.

"Even though I have done a great deal of research on various electronic and optoelectronic devices, my last graduate student thesis is similar to my first one," explains Haddad, "in trying to extend the frequency range of these devices up into the terahertz frequencies. We have devices that generate enough power for the lower frequencies, and devices that generate significantly higher levels of power at the infrared and optical frequencies. The goal is to build solid-state devices which we can use to detect the molecular activity in the terahertz range, which lies in the middle of these lower and higher frequencies." He is continuing this research in cooperation with two research scientists who have worked with him for many years, Jack East and Heribert Eisele (now at the University of Leeds). He says, "both have been a real asset to the department, and have helped a great deal over the years."

### The Great Communicator

Haddad's special gifts as a communicator were recognized early on by William Gould Dow. As Dow described in a letter written in 1963, he would often bring external visitors to various labs in the department. When he would stop by and ask Haddad about his activities, "[George would] undertake a fine description of what he was doing, tailored precisely to the degree of sophistication or lack thereof the visitor possessed. I just listened with admiration." He had this same effect on students.

Without exception, his students praise his ability to make complex topics comprehensible. Paul Greiling, Director and Manager, Microelectronics Laboratory, Hughes Research Laboratories, Inc., received his BSE, MSE, and PhD degrees at U-M, and studied under Haddad. He stated that Haddad's "enthusiasm for the subject matter was contagious and his popularity as a teacher convinced many students to pursue solid state microwave devices as a major field of study at Michigan. Over the last 20 years I have interviewed and hired many of Professor Haddad's students. Without exception, he trains and graduates students who are equal to, or superior to, those coming out of any other University."

A gifted teacher can alter a student's entire future. Robert J. Trew, Department Head of Electrical and Computer Engineering at North Carolina State University, and former Director of Research for the Department of Defense, stated that as a first year graduate student, "standing in the hall before George's class became a turning point in my career. I became intrigued by the material he was presenting on the blackboard. I subsequently enrolled in his class, from which he

*"Students,  
Students, and  
Students!"*

recruited me as a graduate student, and I have never looked back.”

Haddad has been very involved in the Microwave Theory and Techniques Society (MTTS) throughout his career. He served as Editor of the IEEE Transactions on MTT for three years, and served on the Administrative Committee for eight years, as well as on a variety of other committees. He has involved all of his students in the professional society – Bob Trew has served as president.

The students were, and still are, Haddad’s most precious concern. In writing the annual report on the status of the department in his last year as chair, he stated that the most important product of the department is: “Students, Students and Students!” He trained and graduated 57 PhD students, and still maintains close contact with many of them. He is only a bit chagrined that some have retired before he did!

### **A Leader with Vision and Integrity**

Being an effective chair can be part visionary, leader, administrator, salesman, spokesman, caring father. Haddad was all of these. He took on the role of “Father of EECS” in a natural way. Having “grown up” in the department, receiving his BS, MS, and PhD degrees all in EE, he was called to be department chair twelve years after being hired as an assistant professor, and he was instrumental in the formation of the current EECS Department.

“George is the renaissance patriarch of the EECS Department,” said Ulaby, EECS professor and VP for Research at U-M. “He shaped its identity, hired half of its faculty, and propelled it into one of the very top departments in the country.”

“He had just the right combination of long range vision for the institution, a tremendous sense for recruiting top talent, and an abiding faith in his people that made him such a successful leader of the EECS Department,” said Pramod Khargonekar, EECS Chair following Haddad, and now Dean of the College of Engineering at the University of Florida.

Trust is critical to be an effective leader, and Haddad’s honesty was unquestioned. This has instilled great loyalty in others, whether they worked with him one year, 10 years, or 40 years. Kang Shin, hired by George 23 years ago, said, “I admire him in many ways, but his straightforwardness and fairness stands out. He set a very high standard.”

Rich Brown, who was hired by George in 1985, served as interim chair, and is now Dean at the University of Utah, said, “George has been the greatest advocate a faculty member could hope to have. He was a creative and bold leader, who made the changes needed to make EECS one of the top

departments in the world. He was always willing to use his own resources and connections to build infrastructure that enabled the work of others.”

Haddad created an environment within the department that is very supportive of each individual, while encouraging excellence at all times. He pays special tribute to Betty Cummings, who worked for him in some capacity for close to 40 years. “I don’t know what I would have done without Betty,” said Haddad.

Cummings’ words are echoed in those of many others: “He knew that the success of either the lab, or the department, lay in the individual success of everyone in it – and whether you were a senior or junior faculty member, or staff member, he promoted your success. This has made individuals extremely loyal to Haddad. Even those who work for him for a short period of time garner tremendous respect for his leadership, his vision, and his ability to move things forward, all with a great sense of humor.”

“I’m very fortunate to have been able to work with so many great people over the years,” reflects Professor Haddad, “most of whom I hired,” he adds with a chuckle. “It’s been a great journey.” When asked what he is going to do now –aside from continuing his research and service activities, he said, “I’m going to have a good time – I’ve always had a good time.”

*The editor greatly appreciates the many voices who contributed to this article, and regrets not being able to print each comment received.*

**“It’s been a great journey”**

**George Haddad**

## Pallab Bhattacharya:

The Race is On! Quantum Dot Technology Leads the Pack



**Pallab Bhattacharya**  
Charles M. Vest Distinguished University Professor, and  
James R. Mellor Professor of Engineering

Pallab Bhattacharya, professor in the Solid-State Electronics Laboratory (SSEL), is a sprinter, pushing himself and his research group to be the best in the world in new technologies and device performance, and a long-distance runner – relying on a strong foundation while continually replenishing his reserves to continue the race. His work involves the conception and realization of synthetically modulated semiconductor structures, and nanophotonic devices, placing his work in the field of science now known as nanotechnology. He has been working in this field for close to three decades.

Professor Bhattacharya joined the EECS Department in 1984, and was instrumental in establishing The University of Michigan as a premier institution in optoelectronics research. He has made fundamental contributions in the area of compound semiconductor materials, and uses this knowledge to build novel and state-of-the-art optoelectronic and electronic devices.

### Self-Assembled Quantum Dots

Using molecular beam epitaxy (MBE), Bhattacharya grows materials atom by atom. It takes significant resources to do this work. At an initial cost of about

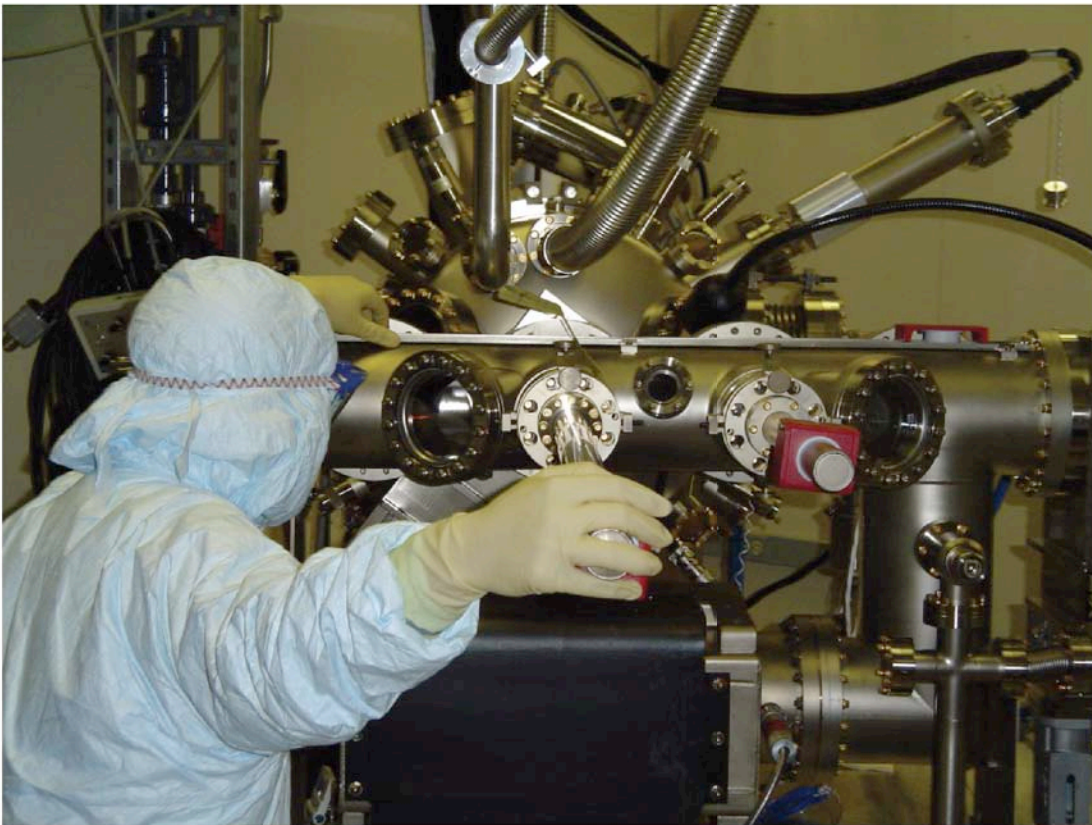
\$1M per MBE system, each system then requires \$100K in annual maintenance costs. Bhattacharya once had four in his research group, and now maintains two, having given one each to former student and now colleague in the SSEL, Professor Jamie Phillips, and to Professor Rachel Goldman, collaborator in Materials Science and Engineering (MSE).

Much of Bhattacharya's groundbreaking research is founded on his accidental realization of a new technique for growing unique semiconductor structures in 1988. Prior to this, his group was creating quantum wells using MBE technology. Quantum wells are formed in semiconductors by having a specific material, like indium gallium arsenide, sandwiched between two layers of another material, like gallium arsenide. An unexpected result occurred in the lab after increasing the concentration of indium in one of the materials, so that instead of having flat planar structures, the indium gallium arsenide began to coalesce into three-dimensional structures, more like pyramids, or islands. They did this naturally, and therefore came to be known as self-assembled quantum dots.

The first paper to provide a quantitative understanding of the formation of quantum dots appeared in 1988, resulting from the collaborative work of Bhattacharya and Jasprit Singh, professor in SSEL. This paper has been cited repeatedly for its early and foundational work in quantum dots. Paul Berger, now on the faculty at Ohio State University, was a member of Bhattacharya's group who conducted the experimental work behind the paper. He recalls the extreme novelty of their early work, saying "it took the rest of the research community seven years to catch up to what we were doing."

To learn more about these semiconductor nanostructures, Bhattacharya collaborated with colleagues, namely Rachel Goldman, associate professor in MSE, Ted Norris, professor in the Center for Ultrafast Optics (CUOS), Brad Orr, professor of Physics, and Jasprit Singh. "Without the great work done by Goldman, Norris, Orr, and Singh, I wouldn't have been able to do what I'm doing now," he said.

Bhattacharya and his group were among the first to report room temperature operation of a quantum dot laser in 1996. Since then, they have done pioneering work in the development of high-



This molecular beam epitaxy system grows semiconductor materials and devices atomic layer by layer in the Michigan Nanofabrication Facility.

performance quantum dot lasers, which currently outperform any other semiconductor laser. He paved the way during the late 1990s for research into quantum dot infrared photodetectors with high temperature operation, research that continues today. In 2000, Bhattacharya began exploring the application of quantum dots to the emerging field of spintronics – where the spin of electrons and holes in semiconductors can be exploited for communication and computing applications. He and his students recently reported a new material – diluted magnetic quantum dots – formed by selectively incorporating manganese atoms in the self-assembled islands. These quantum dots display magnetism at room temperature. Using these materials, Bhattacharya and his students recently realized and reported the first spin-laser, which will be able to transmit more information with less power consumption. In fact, Bhattacharya's Distinguished University Professorship Lecture, to be hosted by University President Coleman on April 4, 2006, will be entitled, "From Pigeons to Spin-polarized Lasers: Carriers of Information Through the Ages."

Bhattacharya received several awards in recognition of his research on quantum dot lasers, including the IEEE Paul Rappaport Award (1999), shared with his co-authors for their 1999 paper, the Nicholas Holonyak, Jr. Award from the Optical

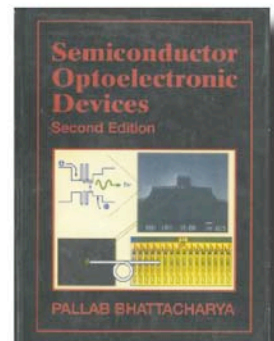
Society of America (2002), and the International Quantum Devices Award (2003).

For his contributions to the design and development of high-performance integrated photoreceivers, work that was published in 1996 and which represented a decade of research, he was awarded the 2000 SPIE Technology Achievement Award, and the 2000 IEEE (LEOS) Engineering Achievement Award. Virtually all contemporary high-performance photoreceivers use the integration technique pioneered by Bhattacharya and his co-workers, and it is expected that these photoreceivers will eventually be used in every optical fiber communication link.

### The Group That Does Everything

The study of material growth and characterization, and the transference of this basic research to actual devices, are areas of research that are rarely pursued by the same individual. Professor Bhattacharya does both.

His students have benefited from this great breadth. Phillips said, "One thing I learned by being in his group is something about everything. Usually in this work you have two distinct groups, the materials group, and the device group. Not many people do both – but to really make an impact, you need to understand both areas." Bhattacharya credits Phillips, who was placed at the intersection



The basic technology behind the 16-channel photoreceiver pictured on the cover of his textbook, now in its second edition, was developed at U-M by Bhattacharya and his group. It is the first multichannel photoreceiver to come out of a university, and similar systems are in use in industry today.

of both areas, with pioneering the development of quantum dot photo infrared detectors while still a student.

Bhattacharya's recent work in quantum dot infrared photo detectors has attracted the interest of Lockheed Martin, as well as the federal government. He takes great satisfaction in developing a novel technology to the point where devices based on it are finding viable applications. "We are making focal plane arrays in our lab for Lockheed Martin to couple them to readout circuits. Similar to the lasers, they are being produced commercially."

### **The Drive For Success**

Bhattacharya drives himself and inspires his students to conduct world-class research. He expects much from his students, because he knows they can do it. "What brings me to this department every morning are my students. They are the single most important factor in my work here," said Bhattacharya. "My students work hard because they are excited about what they do. They are doing forefront research, and are in the middle of worldwide competition. That's their driver – new ideas."

The productivity of Bhattacharya and his students is truly remarkable; he has written 450 journal publications, and given more than 75 invited and plenary talks, 300 conference presentations, and nearly 100 seminars, presented all over the world. His students graduate with extensive experience in presentations, writing, and interactions with colleagues around the world, as well as training in time management skills.

Adrienne Stiff-Roberts, now assistant professor at Duke University, said that "learning time management, working at an intense level while managing my work, has been very helpful." She felt that Professor Bhattacharya prepared her well to become a faculty member. Significantly, half of his 56 PhD students have followed the path of academia.

### **The Future is Now: Silicon and Sensors**

Bhattacharya continues to find new applications using MBE technology. The most exciting current research involves silicon photonics – transmitting information on a silicon chip, or between chips, by light. Moore's law, that predicts the doubling of the number of transistors on a chip every 18 months, is pushing the computer industry to seek out technologies with significantly different physics than is currently used. As Bhattacharya explains, "there are miles and miles of interconnects on a chip, whether they are aluminum, or copper, or gold. This ultimately creates a bottleneck. There are problems

with crosstalk, heating, and propagation delay. The wisdom is to use optical interconnects to transmit information on a single chip, or between chips.

This means putting photonic devices on a silicon chip." However, silicon is not known to give out light. With Bhattacharya's entry into this new line of research, employing quantum dot technology, this is changing.

"One of the most exciting results we've received recently is that we now have good quantum dot lasers grown directly on silicon," says Bhattacharya. Working with his students, and Professor Pipe of Mechanical Engineering, he expects to achieve results others will have to follow. "The race is on to develop real light sources on silicon, and we've done that." His focus now is on increasing the reliability of a silicon-based laser that is compatible with CMOS processing. It should be no surprise that Bhattacharya already knows how to do that. It's just a question of time.

One of Bhattacharya's newest avenues of research is in the area of photonic crystal quantum dot devices, which has applications in the field of quantum computing, and sensing. He states with excitement, "these photonic crystals can be used in all kinds of sensors - beautiful nanosensors. The sensors will be very small, and highly sensitive to a variety of gases and fluids. They will be competing head on with the best sensors out there today."

If we can glean one thing from the way Bhattacharya works, we can safely say, "The race is on."

# John Hayes: Where EE and CS Converge: From the Early Microprocessor to Quantum Computing



**John P. Hayes**  
Claude E. Shannon Professor  
of Engineering Science

John Hayes, professor in the Advanced Computer Architecture Laboratory (ACAL), has led a career that has taken him from the early microprocessors to research in the futuristic field of quantum computing. His focus on fundamental principles in computer design and testing, and his ability to apply them to the newest technology available, has kept him at the frontier of computing research for nearly four decades.

"The first microprocessor chips were produced by Intel in 1971, which was the year after I got my PhD," recalled Hayes. He remembers when a single transistor (which is the basic component on a chip) was the size of today's chip, which now contains several hundred million transistors.

## Decades of Evolution

Hayes came to The University of Michigan in 1982 as a professor. This was just two years before the merger of the departments of Electrical and Computer Engineering, and Computer and Communication Sciences; he was placed on the merger committee right away. Hayes saw the benefits to merging the department, particularly with respect to his own work in Very Large Scale Integration (VLSI), which sits at the boundary of electrical engineering (EE) and computer science (CS). VLSI revolutionized the way computer chips were designed, accelerating the rate at which powerful new computer systems could be produced. "The evolution of technology has caused almost a convergence of technologies like computer architecture and electronics. For a student to learn computer design today, they must also learn something about electronics. It does suggest that there was wisdom in keeping EE and CS in the same department," reflects Hayes.

Once the department merged, it became evident to Hayes that a specialized lab in computer hardware was needed. He and others founded ACAL in 1985, which to this day serves as the focal point for interdisciplinary research into the theory, design, programming, and applications of advanced computer systems.

Hayes describes the 1970s as the age of the microprocessor, and the 1980s as the age of VLSI. During these years, Hayes' work focused on the synthesis and testing of conventional logic circuits. The 1990s ushered in the age of the internet and networking, prompting Hayes to expand his research into the area of networks of chips,

forming an extension of embedded systems. "The traditional embedded system is a single computer – it might sit inside your microwave oven to control all of its functions. A car has dozens of embedded computers, controlling things as complex as the engine and as simple as the gas tank. But increasingly, and I am doing some research in this area, there are applications where you could use a whole network of embedded processors talking to each other, sharing functions." With the advent of the 21<sup>st</sup> century, John's research interests have expanded to include quantum computing.

## Quantum Computing

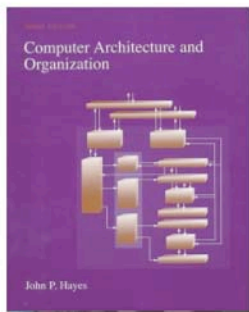
"Quantum computing is fundamentally different from classical computing because it's not just a new technology – it's a new type of computer science," explains Hayes. "Quantum computing is based on quantum mechanics, which is less familiar to computer scientists than to electrical engineers. It's another example of computer science coming back to electrical engineering in an unexpected way."

There are a few potential applications to quantum computing that make it an attractive area for research by computer scientists. These applications include the solving of difficult computing tasks such as factoring large numbers, and communication – including cryptography and encryption. "Quantum computers won't replace conventional computers, but they will probably supplement them in certain applications," said Hayes.

Hayes initiated the Quantum Circuits Group <http://vlsciad.eecs.umich.edu/Quantum/>, along with Professors Igor Markov and Yaoyun Shi, when his work in quantum computing began to be funded by the government. One of their tasks is to simulate quantum computers.

"Since it's very difficult to build any kind of quantum circuit," said Hayes, "it becomes important to be able to build it very efficiently, with as few components as possible." He explains that when building VLSI circuits, having even a few thousand transistors too many may not be noticed. But in the realm of quantum computing, where circuits are the size of atoms, it will become important to save even a few qubits (meaning quantum bits – the basic unit of quantum information).

With classical and quantum computers having completely different technologies, simulation is not a trivial task. "One of the great discoveries in recent years was that computation in the abstract has a



**Hayes has written three textbooks, including *Computer Architecture and Organization*, now in its 3<sup>rd</sup> edition, and two research monographs. His books have guided a generation of students through the general areas of digital logic and computer design.**

basis in classical physics. If you base computation on quantum mechanics, you get a new type of computation that is very different from any traditional type of computing. Everything operates at an atomic scale, and you only see this quantum phenomenon when you get down to individual atoms," explains Hayes.

When Hayes and his group turned their attention to reversible logic circuits, they found links to quantum computing, and wrote the innovative paper, "Synthesis of reversible logic circuits." This paper was co-authored by Markov, Vivek V. Shende (undergraduate student majoring in Math and Philosophy), and Aditya K. Prasad (BS CE '02), and received the 2004 IEEE Donald O. Pederson Paper of the Year Award. Reversible circuits are circuits that do not lose information (information-lossless circuits), implying no loss of energy. Reversible logic is thought to be the next logical step required to improve computer hardware performance.

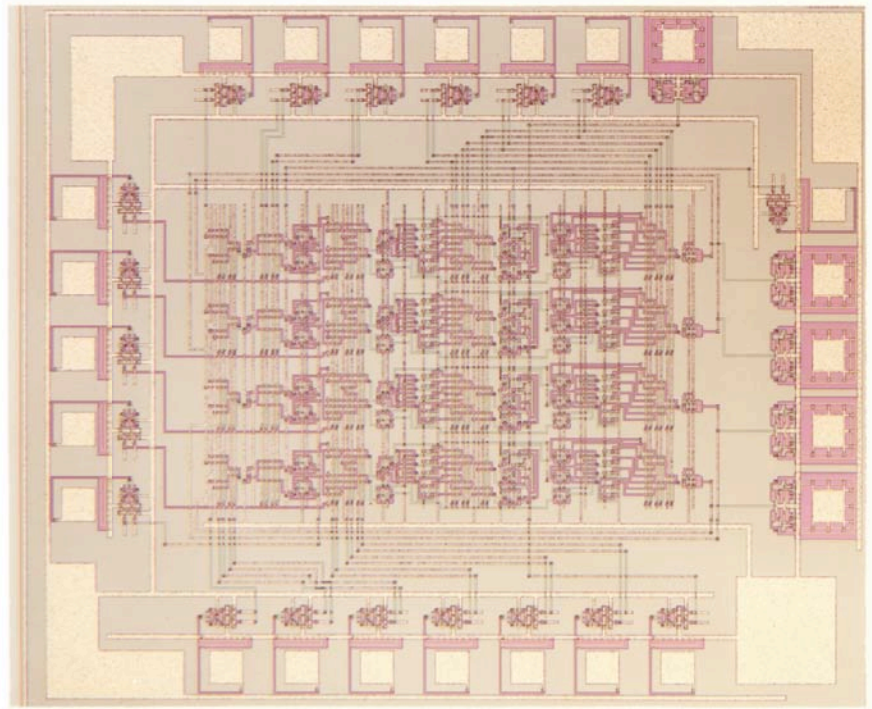
### A Vision for Student Involvement

Both Shende and Prasad were participants in the EECS summer research program. How does Hayes train undergraduate students to provide meaningful contributions to novel and challenging research? Markov said "John has a vision for what is achievable and what can be of interest to people in different fields. We selected a topic suitable for undergraduate students."

Current graduate student George Viamontes has also made significant contributions to the Quantum Circuits Group, even though he said, "when I first joined the group, I knew next to nothing about quantum mechanics. I now have several papers with John [Hayes] and Igor [Markov] about simulating quantum circuits and other quantum mechanical phenomena. Even though John's work is centered around hardware, my algorithmic and software development skills have also improved dramatically."

One of the projects Viamontes helped develop is the software tool called Quantum Information Decision Diagram (QuIDDPro), which is available from the group's web site. QuIDDPro is a high-performance quantum circuit simulator, used in national laboratories and universities throughout the world. It was developed by Hayes, Markov, and Viamontes. Markov said, "There are a number of commercial tools that companies sell for quantum circuit simulation, but this outperforms other tools out there."

Hayes trains his students in fundamental principles, which they can apply to any number of problems. One past student, John Shen, who received his BSE in electrical engineering at U-M before doing his graduate work with Hayes



at the University of Southern California, has made major shifts of research focus during his career (see the Alumni Notes). Shen stated "such changes keep my research work exciting and stimulating, and are made possible by the fundamental principles I learned years ago from John Hayes." After spending 18 years as a professor at Carnegie Mellon University, he is now Director of the Microarchitecture Research Lab at Intel.

**4-bit microprocessor chip designed by John Hayes and student T. Sridhar in 1980, using some of the earliest VLSI design software. This was also one of the earliest chips fabricated by The MOSIS Service, which is still used by EECS students to fabricate their chips.**

### A Vision for the Future

A recent project that was presented at the 2005 Design, Automation, and Test in Europe (DATE) conference and resulted in his most recent Best Paper award, grew from Hayes' work on quantum circuits. In fact, QuIDDPro was applied, with modifications, to a study of traditional digital circuits. An important application of the work deals with the destructive effects of radiation on digital circuits, causing significant errors. Learning how to deal with these effects will have relevance to space-born electronics, long flights at high altitudes, and human-implanted chips (such as pacemakers, blood sugar monitors, and drug injectors) that may be subject to higher levels of radiation during x-ray procedures and cancer treatments.

"John's work in computer engineering is building bridges between computer science and electrical engineering, between algorithm theory and physics," said Markov. "Vision and intuition is very important for this kind of research. We are getting results that weren't even considered five years ago."

For Hayes, whose interest has always been on the boundary of EE and CS, preparing for the future comes naturally.

## William Gould Dow Lectureship



Richard M. Karp, University Professor of Computer Science at Berkeley, was the invited speaker for the 2005 William Gould Dow Lectureship. In his lecture, "Computational Discovery of Genetic Regulatory Networks," Karp described how new biological insights can be gained by finding patterns in biological databases using combinatorial algorithms and statistical analyses. Karp has made many fundamental contributions to theoretical computer science, particularly in the area of algorithms, and recently in computational biology.

Among his many honors, Dr. Karp is a recipient of the U.S. National Medal of Science and the Turing Award (for his research in the theory of algorithms), and he is a member of the National Academies of Science and Engineering (NAS and NAE). He is a fellow of the Association for Computing Machinery, and the American Academy of Arts and Sciences.

## EECS Learning Center: Students Helping Students

The EECS Learning Center returned after a two year break, giving students enrolled in two core courses, EECS 206 (Signals and Systems I) and EECS 280 (Programming and Introductory Data Structures) the opportunity to seek assistance from highly accomplished student volunteers. Student members of Eta Kappa Nu, Tau Beta Pi, and the CSE Scholars were the primary tutors. The courses EECS 206 and 280 were selected based on the input given by a panel of undergraduate students.

Benjamin Sky actively sought to serve as a tutor in the center, saying, "I strongly feel that the EECS Department has provided excellent hardware in the infrastructure, and passionate heartware – through the people. I have gained tremendously from my experience thus far; it is only right to reciprocate and contribute back to the department, volunteering my time in an area that I love – EECS."

Dr. Karen Langona organized and oversaw the 2004-05 effort, and will continue in this role next year. She believes strongly in the need for readily available assistance for students. Langona said "it's a very positive experience for the students to have this kind of involvement with their peers." Sky agrees: "My experience as a tutor was simply fantastic. It has provided me with insights not just in tutoring, but also in the courses that I have taken through discussing concepts with my peers."



## St. George's Day



The EECS Department revived St. George's Day, April 18, 2005, when EECS faculty served lunch to nearly 800 EECS students. St. George's Day was started in 1987, after the department moved to North Campus from downtown. It's the department's way of saying thanks to all of the students, and is held on the last Monday of classes in the Winter term.

The faculty wish our graduating students the best - stay in touch! For those students still in the program, hang in there, your efforts will be rewarded!



## EECS Picnic

The Annual EECS Department Picnic was held June 24, 2005, at Independence Lake County Park. Highlights included excellent food, drink, and company, swimming, volleyball, face painting, the largest water balloon toss ever, and the awarding of numerous prizes. The tug of war was won in strong fashion by the heavyweights in ACAL. They will continue to hold the impressive department trophy for the next year.

## Faculty Promotions

**Achilleas Anastasopoulos**, assoc. prof. with tenure  
**Satinder Singh Baveja**, assoc. prof. with tenure  
**Lingjie J. Guo**, associate professor with tenure  
**Marios C. Papaefthymiou**, professor with tenure  
**Jignesh M. Patel**, associate professor with tenure  
**Dennis Sylvester**, associate professor with tenure  
**Kim A. Winick**, professor with tenure

## Research Scientist Promotions

Jamille Hetke, Associate Research Scientist

## HONORS AND AWARDS

### Departmental Awards



**HKN Professor of the Year**  
Peter Chen

## University of Michigan Awards

**2005 U-M Distinguished  
Faculty Award**  
Khalil Najafi



**2005 U-M Faculty Recognition Award**  
Kamal Sarabandi

**2006 U-M Henry Russel Award**  
Dennis Sylvester



## State of Michigan and National Awards



**Fellow of the Optical Society of America (OSA)**  
Kim Winick, "For seminal contributions to the field of passive and active glass and crystal integrated optics"

### NSF CAREER Award

Igor Markov, for his proposal entitled, "Spatial Optimization of Computing Systems"

**Governor's University Award for Commercialization Excellence**  
Farnam Jahanian

## Staff Awards

**2005 Distinguished Research Administrator Award**  
Kelly Cormier

# New Faculty



**Domitilla Del Vecchio**

Assistant Professor,  
ECE Division

Laurea, EE, University  
of Rome at Tor Vergata  
PhD, Control and  
Dynamical Systems,  
CalTech

Research Areas: Decision and Control Systems



**Eric Michielssen**

Professor, ECE Division

BS and MS, EE, Katholieke  
Universiteit Leuven  
PhD, EE, University of Illinois,  
Urbana-Champaign

Research Areas: Theoretical, computational and  
applied electromagnetics, antennas, high-speed  
circuits, fast mathematical algorithms.



**Anthony Grbic**

Assistant Professor,  
ECE Division

B.A.Sc. and M.A.Sc.,  
EE, University of  
Toronto, Canada  
PhD exp., EE,  
University of Toronto,  
Canada

Research Areas: Applied Electromagnetics,  
Microwave/RF Circuits and Electronics



**Pei-Cheng Ku**

Assistant Professor,  
ECE Division

BS, EE, National  
Taiwan University  
PhD, EECS, UC-  
Berkeley

Research Areas: Nanophotonics, Nanoelectronics



**Wei Lu**

Assistant Professor,  
ECE Division

BS, Physics, Tsinghua  
University  
PhD, Physics, Rice  
University

Research Areas: Nanoelectronics, Semiconductor  
Manufacturing, Solid-State Electronics

See Tony Fadell's advice for students in the Alumni Section of this newsletter.

## EECS Students Expand their Leadership Abilities Working in Team Projects

Students in the Department of Electrical Engineering and Computer Science participate in a variety of extracurricular activities that give them the opportunity to explore and develop their own interests while working in interdisciplinary teams of students. Here are some of the projects that involve our students.

### Solar Car *Momentum* Wins the Race

U-M's solar car race team, and their car *Momentum*, took first place in the 2005 North American Solar Car Challenge July 27, 2005. Team members build their cars from scratch to prepare for this bi-annual race, in existence since 1990. This is the fourth time Michigan has earned the National Championship.

Of the 21 team members from the College of Engineering, seven are EECS students: Mirai Aki, Jonathan Brown, Jeff Ferman, David Masselink, David Mazur, Brent Schwartz, and Robert Vogt. Vogt, Head Strategist and the only EECS graduate student on the team, is a four year veteran of the team who also runs a web hosting/consulting company, ArborHost.

EECS Professor Brian Gilchrist, faculty co-advisor to the Solar Car team, and his son were on hand to witness the race. Gilchrist said, "I am very proud of what the team accomplished, but even more so of what they learned! Over two years some 100+ students have been able to experience what it takes to develop a complete system from beginning to end! This is experience that would take years to obtain in industry."

The Solar Car team has earned the opportunity to participate in the 8<sup>th</sup> World Solar Challenge, Sept. 25 – Oct. 2, 2005 in Australia.



Photographer: Stefano Paltera/North American Solar Challenge

### Michigan Inspire

Multi-disciplinary teams of students from the College of Engineering, Art & Design, Architecture and Urban Planning, and Music worked together to create their vision of the Entertainment of Tomorrow. The CSE Scholars were one of several sponsors for Michigan Inspire, which was hosted Professor Elliot Soloway. EECS alumnus Tony Fadell (BSE CompE '91), was a special guest speaker.

Aeolian Dance Music was the winning team project. Elissa Karstu danced with pressure sensors attached to her outfit; the sensors were attached to a sound generator. As she danced, she caused the pressure on each sensor to change, which made music. The team consisted of Jonathan Dobbie (EECS), Elissa Karstu (Music), Toby Mitchell (Physics), Keith Pennington (Biomedical Engineering), and Amit Sachdev (Biomedical Engineering).

Dobbie designed the hardware, and together Dobbie, Mitchell, and Pennington, wrote the software. Dobbie said the project "was a wonderful chance to tinker and to deal with actual problems."



Jonathan Dobbie works on his project for Michigan Inspire

### Can Satellite Competition

Mustafa Rangwala, undergraduate student majoring in Electrical Engineering, was part of the team that took first place in the 2005 Can Satellite (CanSat) Competition. Students are required to write a mission proposal, document their design, build a CanSat (which contains a telemetry system and pressure and temperature sensors), and then launch the device to an altitude of one mile.

The U-M team consisted of students who participate in the Student Space Systems Fabrication Laboratory (S3FL). Rangwala became involved in the project after being accepted in the EECS Department's Summer Research Program with Professor Brian Gilchrist, who is a faculty advisor to S3FL. Rangwala contributed to the electrical components of the CanSat. This included helping to build the circuit boards and telemetry system, and integrating the microprocessor. Rangwala said he "enjoys working at S3FL. The people are very friendly, the work environment is relaxed and I learn a lot." He also likes that the projects are application oriented.

## Mars Rover Team Participates in the RASC-AL Forum

EECS Students Ilya Wagner and Chad Rowland enjoyed their experience as members of the interdisciplinary Mars Rover Team, which recently won second place in the Revolutionary Aerospace Systems Concepts – Academic Linkage (RASC-AL) Forum this past May, 2005, in Cocoa Beach, FL. At the RASC-AL Forum, student design teams present their research to peers, NASA, and industry.



**2004-05 Mars Rover Team: (l-r) Eric Nytko, Matthew van Kirk, Ilya Wagner, Prof. Nilton Renno Ph.D. (AOSS Dept), Christine Kryscio, Chad Rowland, Frantisek Sobolic.**

Rowland (BSE EE 2005), president of the winning team, was on the team since his freshman year, and said "Not only was it a lot of fun, it increased my skills in management, giving presentations, writing research reports, and team work. All are critical for success in the working world." Rowland is now in the Edison Engineering Development Program at General Electric Healthcare.

Wagner, a graduate student in Computer Science and Engineering, joined the Mars Rover Team in 2003 as an undergraduate student. Starting as a volunteer with no experience, he has worked his

way to being VP for Research, managing groups of students. "Good projects need a pool of students from a variety of disciplines," explained Wagner. "The project is a great way to be on the cutting edge of space exploration technology while learning to work with students of different majors at U-M. The team also helps students get in contact with industry and try on administrative responsibilities. I absolutely enjoy being on the team."

## Students Compete in EECS 511



**Jens Anders, Jae-sun Seo, Jongwoo Lee**

Graduate students Jens Anders, Jae-sun Seo and Jongwoo Lee took first prize in a contest of final projects held in EECS 511, Integrated Analog/Digital Interface Circuits, taught by Professor Michael Flynn. Their state-of-the-art data conversion circuit project was called, "A Logarithmic Pipeline ADC for Hifi Audio." Analog Devices donated \$1000 for their first place prize.

## STUDENT HONORS AND AWARDS

### MIT Lincoln Laboratory Fellowship

Nicholas Chang, PhD candidate in EE

### Semiconductor Research Corporation Fellowship

Scott Hanson, PhD student in EE

### Intel Foundation Ph.D. Fellowships

Sanjay Pant, PhD candidate in EE

Mark Ferriss, PhD candidate in EE

### International Union of Radio Science (URSI) Young Scientist Award

Amy Buerkle, PhD student in EE

Alireza Tabatabaenejad,

PhD student in EE

### 2005 Computer Science Alumnae of Michigan (CSAM) Scholarship

Joanna Borders, CS-ENG

Jill Dimond, CS-ENG

Jennifer Maertens, CS-ENG

## FOCUS ON OUR ALUMNI

### Tony Fadell: Mastermind Behind the Apple iPod, Offers Advice for Students



**Tony Fadell, BSE, Computer Engineering, 1991**

Tony Fadell started three companies before graduating from The University of Michigan with a BS in Computer Engineering in 1991. He went on to create another three companies before landing at Apple Computer, where he masterminded the Apple iPod, a tour-de-force in conceptualization, engineering, and production.

Digital audio players and MP3s existed on the market before the Apple iPod, but they were not very successful. Fadell changed that. "The big difference between iPod and the other MP3 players out there was it was pocketable, which is huge," said Tony. "All the others were big and bulky, the size of a large portable CD player. This one was the size of a deck of cards. Then, we made it so you could transfer the music very quickly to the device. You had to wait 24 hours for the others; we could do it in ½ hour. We devised an incredibly simple user interface, extended the life of the battery from about 3 to 10 hours, and finally, we had iTunes."

Fadell understands the needs of consumers, and can provide solutions very quickly. As an EECS student, he pursued his education with the same boundless energy, enthusiasm, and creativity that he now offers Apple Computer.

#### Student and Entrepreneur at U-M

Tony's preferred computing system was always an Apple, and as a student he owned an Apple II computer. The most advanced multimedia activity available on the Apple II at that time was some beeps and buzzes, but he knew there was more going on in the world of multimedia. "I thought maybe I could be the guy to help myself as well as the University get ahead and learn about these things. I made a sales pitch to Elliot [Professor Soloway] about getting the resources on campus so that both I, and the University, could learn about these things."

"Whatever it is, it sounds cool, go ahead and do it!" encouraged Elliot. Soloway was then working on multimedia teaching of children through handheld devices, so it was a perfect match. Fadell contacted industry and other funding sources to put together the Media Café. He and Soloway created the multimedia software program Mediatext, and together they started the company Constructive Instruments.

Tony then wanted to learn circuit design, so he and a partner in Los Angeles started the company ASIC Enterprises to create and manufacture a next-generation microprocessor for the Apple II. "It was a great way to learn. Learn by doing – that's my motto," he emphatically states.

#### Advice for Students

When asked what recommendations he would give today's students for getting the most out of their education, Tony said, "First, take as many project-focused classes as possible. You have to learn by doing. Second, combine those classes with one or more internships, especially where you will be able to work directly with a product. It's one thing to learn how to build something, and another to learn how to build it within a large team in a predictable manner over a period of time. You need to learn both project perspective and people perspective."

Working within a startup, and within a large company, are much different experiences, yet each can be very valuable. Fadell had both. When he joined Phillips, he had already started several companies and worked in a well-known startup, General Magic, where he gave himself the nickname, Silicon Sorcerer. At Phillips, he changed this to Chief (and Indian) Technical Officer. He explained, "I didn't want to be just the chief; I wanted to be known as the helper also."

Fadell compared working in a startup with a large corporation. "You learn a lot about engineering through startups. If you just want to be a super engineer, you can do that either in a startup or a larger company. To learn a lot about people and organizations, and predictable business – you have to be in a much larger organization. You then also understand the discipline it takes to become a big company, and what it means to *be* a big company."

#### Fadell Applauds Opportunities for Today's Students

Tony was a guest speaker, along with Elliot Soloway, at this year's Michigan Inspire program <http://www.michiganinspire.org>. He loved the team aspect of the program, the freedom students had to explore a topic of interest, and the contest. "There was engineering, there was technology – there was a marketing aspect to it, and a business aspect to it. I loved it because it was like a tiny little startup in some ways," said Fadell.

There were also important differences, noted Tony. "When you're in your own small company, people may think twice before even answering your questions. But when you're under the University banner, people will say, 'Sure, I'll help you.' Faculty, graduate students, or alumni are all willing to help – that's all great."

What can we expect next from Tony Fadell? "We have great products at Apple, and we're going to continue to surprise and delight you."

## Alumni Society President's Message: Mentoring EECS Students

Mentors... Werner Heisenberg had Neils Bohr, Andy Grove had Gordon Moore, and Nick Holonyak (inventor of the LED) had John Bardeen (co-inventor of the transistor). People often reach their highest potential by learning from the best that came before them.

So at a recent conference I attended, I was surprised to hear keynote speaker Jack Welch, former CEO of General Electric and top business guru, say "you shouldn't look for a mentor." What was he talking about?

During the question and answer part of Jack's talk, a young technology manager stepped up to the microphone and asked a simple question: "Should I be looking for a mentor?" Jack's full answer was, "you shouldn't be looking for one...you should be looking for ten!" And he's right.

After I graduated, I found that almost every one I met in my career had a special skill to offer – and I could continue my education by becoming a student of their ways. These resources are all around you, but the EECS Alumni Society would like to take it a step further. Once you graduate from EECS, you're a member of an elite and vast (16,500+ members) network of alumni for the rest of your life.

Furthermore, for those who haven't yet graduated, we alumni want to make sure you have access to the best resources – people resources – that are available.

The Alumni Society wants to encourage those willing to share their experience and knowledge to reach out to EECS students

and grads. We also want to make it easy for those seeking mentors to find the right one (or more than one) at the right time.

To find a mentor, or to become a resource for others, visit the EECS Alumni Society member page:

[www.eecs.umich.edu/eecs/alumnisociety/membership.html](http://www.eecs.umich.edu/eecs/alumnisociety/membership.html)

and follow the links to "Become a Mentor" or "Find a Mentor". There's also a mail-in form (<http://www.eecs.umich.edu/eecs/alumnisociety/alumni.pdf>) for those who prefer that route.

I hope to see you at the Michigan Engineering Alumni Weekend, October 6th through 8th - Go Blue!

Steve Schwartz  
President



Steve Schwartz and daughter Katie (class of 2025) at Camp Michigania

## Alumni Society Vice President's Message: Help Recruit the Best to Michigan



EECS alumni have the opportunity to help outstanding, newly admitted, high school students decide whether Michigan is the place to come for their undergraduate degree.

Once admitted to the College of Engineering, we want to make sure that those who choose Michigan, and those who choose a different school, do so for the right reasons.

We want to give these applicants

the chance to talk with a Michigan grad to answer their questions and address their concerns. Sometimes just the personal touch of showing interest in a student with a phone call is enough to tilt their decision in favor of Michigan.

EECS alumni are invited to contact these high school students. If you accept this opportunity, you will be provided the names of four or five students to contact in your area, an Alumni Student Recruitment Information Handbook, and suggestions to assist you in contacting these students. You will also be partnered with a current Michigan Engineering student to serve as a campus resource to assist you.

Alumni Recruiters are especially needed in:

- Florida
- Illinois
- Southeastern Michigan
- New Jersey
- New York
- Ohio
- Pennsylvania
- Texas
- Virginia

I have been a recruiter for the last four years. Recruiting is fun, requires little time, and really helps the College of Engineering get the best incoming class possible.

If you wish to volunteer, please contact:

Sharon Burch  
Director of Recruitment and Admissions  
Email: [sharbu@umich.edu](mailto:sharbu@umich.edu)  
Phone: (734) 647-7101

For additional information on alumni recruitment, please contact me at [dwalkconsult@SBCglobal.net](mailto:dwalkconsult@SBCglobal.net) or (248) 335-2229.

Don Walker  
Vice President

## 1940s



Frank Arams in 1944

Frank Arams (BSE EE '47) is pictured at the former West Engineering Building on Central Campus, in 1944, and 2004. The 1944 photo was prompted by the shortage of male students at the time; note the slide rule hanging from his pocket. Frank was Editor-in-Chief of the Michigan Technic, the publication of the College of Engineering, while he was a student. Arams went on to receive MS degrees in Applied Physics from Harvard and Business Management from Stevens Institute of Technology, and the PhD in Electrophysics from the Polytechnic University of New York. He was co-founder and VP of LNR Communications, Inc., manufacturer of microwave and satellite earth station equipment for data, voice, and video from 1971-2000. Prior to this time, he was Department Head for Electro-Optics at Airborne Instruments Laboratory. He published the book *Infrared to Millimeter Detectors*, and is currently working as a Patent Technical Expert and Management/Marketing/Proposal consultant. He has been a visiting lecturer at the U-M Summer Sessions, and would like to hear from his friends at: [tangle1345@ieee.org](mailto:tangle1345@ieee.org).



Frank Arams in 2004

Frank Arams (BSE EE '47) is pictured at the former West Engineering Building on Central Campus, in 1944, and 2004. The 1944 photo was prompted by the shortage of male students at the time; note the slide rule hanging from his pocket. Frank was Editor-in-Chief of the Michigan Technic, the publication of the College of Engineering, while

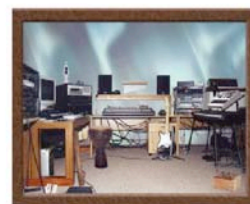
## 1970s

Mark S. Arams (BSE EE '78) is a Product Engineer for National Semiconductor Corp. (NSC) in Silicon Valley. His group specializes in chips that power portable products such as cell phones. He has worked for NSC for 25 years, 15 of them as a Process Engineer. Some of this time was spent working in a group that helped various fabs within the company improve their wafer sort yields. Mark has fond memories of Ann Arbor, and just started to return for regular visits with his Dad who also graduated from U-M (see Frank Arams '47). Mark says, "Ann Arbor has changed since I graduated in 1978, but it is great to walk around town and reminisce. Alice Lloyd Hall still has the same feel. Of course, going to a football game is always required when I visit."



John P. Shen (BSE EE '73) directs the Microarchitecture Research Lab at Intel with researchers located in Hillsboro, OR, Santa Clara, CA, and Austin TX. After receiving his U-M degree, he earned the MS and PhD degrees in

electrical engineering from the University of Southern California. He spent several years in the aerospace industry, and, until spring of 2000, was on the faculty of the Electrical and Computer Engineering Department at Carnegie Mellon University where he headed the Carnegie Mellon Microarchitecture Research Team (CMuART). John has published over 100 research papers in the areas of VLSI Design and Test; Fault Tolerant Computing; Computer Performance Evaluation; Instruction Level Parallelism; Superscalar Processor Design; Speculative and High-frequency Micro-architectures; and Thread-Level Speculation. He has just published a book called *Modern Processor Design: Fundamentals of Superscalar Processors* with McGraw-Hill.



Floyd Miller (BSE EE '78) works for Woodward McCoach, Inc., an electronic and software development firm in PA. He specializes in electronic and

computer circuit design, and device driver and software API design for communications

equipment. He is working with some of the people he started with in 1979, and stated, "when you enjoy your work and the people you work with, why tempt fate." Miller is an alumnus of the student radio station WCBN-FM and Eclipse Jazz, a student run organization that produced and promoted Jazz concerts. These days, Miller spends some spare time tinkering in his own music studio. You can hear his original music (and view his wife's artwork) at: [www.studiodust.com](http://www.studiodust.com).

## 1980s



Mitchell Abramson

**Jeff Abramson (BSE CE '89)** is a design engineer on the Pentium Pro (P6) design at Intel, and a former member of design management on the Pentium 4 design. After 11 years in design, he moved to system validation where he is currently managing the functional system validation for all desktop CPUs, with teams in Oregon, Sacramento, California and Penang, Malaysia. He also owns a business, Rainy Day Games, which has been a successful retail store for more than 6 years specializing in board games, puzzles, and other gaming products for all ages. Jeff is married to Nicole, and they have a son, Mitchell (see photo).

## 1990s



Madison Rose Kathleen Oh

**Allen J. Oh (BSE EE '93)** and his wife Tiffany are proud to announce that they have adopted their first child, Madison Rose Kathleen Oh. Madison recently celebrated her third birthday. The family lives in the Twin Cities area, where Allen works as a patent attorney at Moore, Hansen & Sumner in Minneapolis. His practice emphasizes client counseling and patent procurement for electronic and software inventions. Allen's technical interests include automotive technologies, wireless communications, medical devices, and computer hardware and software. He is actively involved with the American Intellectual Property Law Association



Kevin Rutkowski

**Kevin Rutkowski (BSE EE '94)** is a managing consultant in the department of Project Services for BORN, a national IT services firm. He consults in the area of software quality assurance, and also teaches software development at Capella University.

**Pete Staples (BSE EE '94)** is president and founder of Blue Clover Design, LLC, which specializes in product development. He worked as a systems engineer for Boeing Satellite Systems in El Segundo, CA for five years, where he designed advanced communication payloads and evaluated new business opportunities. His

final assignment there was in a leadership role on the multi-billion dollar Spaceway™ project. In addition to his work for Boeing, he has done projects for Hewlett-Packard (China), Techno-Sciences (USA), Clemson University, Telia (Sweden), the University of Michigan Medical Center, and Dow Chemical.

Pete holds an MBA from the Anderson School of Management at UCLA where he specialized in entrepreneurship. Twice he led teams to the semifinals in the Knapp New Venture Competition. He also received the Mitsui Fellowship for International Business and the Kauffman Fellowship for entrepreneurial research in China. Pete earned an MS in electrical engineering at Clemson University, where his research was focused on wireless networks. While at Clemson, he received the Harris Teaching Assistant of the Year Award.

## 2000s



Egor celebrates his birthday

**Egor Alekseev (MSE EE '00; PhD EE '00)** is engineering manager for Aeroflex/Inmet, in Ann Arbor. He is involved in all aspects of design, development, and support of high-frequency and high-power attenuators, bias tees, dc-blocks, adapters, equalizers and other microwave components.

**Tanay Bhatia (BSE CE '04)** is a software test engineer in the Data and Business Intelligence department of Microsoft, in Redmond, Washington.

**Farrokh Ayazi (MSE EE '97; PhD EE '00)** is

associate professor in the School of Electrical and Computer Engineering at the Georgia Institute of Technology. His current research interests are in the areas of low and high frequency micro and nano electromechanical resonators, RF MEMS, VLSI analog integrated circuits, MEMS inertial sensors, and microfabrication technologies. Prof. Ayazi is a 2004 recipient of the NSF CAREER award, the 2004 Richard M. Bass Outstanding Teacher Award, and the Georgia Tech College of Engineering Cutting Edge Research Award for 2001-2002.



**Eric Chmielewski (BS CS '00)** is a web and information systems developer for enrollment at Carnegie Mellon University. Before coming to CMU, he was a system analyst and programmer at Cornell University. Eric is currently working on a Masters of Science in Information Technology with a focus on information security assurance.

**Sébastien Fricker (MSE EE '02)** is an optics engineer at STIL (Sciences et Techniques Industrielles de la Lumière) in Aix en Provence, France.



**You!** - could have a story here about your time at U-M and after. We'd love to hear from you! Simply send a note to Catharine June ([cmsj@umich.edu](mailto:cmsj@umich.edu)).

#### Class of 1950-59

Franklyn J. Millhouse, '50, Dec. 11, 2004  
Henry J. Quint, '50, Dec. 21, 2004  
Leonard Dietch, '51, Oct. 22, 2004  
Lawrence J. Giacoletto, '52, Oct. 4, 2004  
Harold John Hansen, '52, Sept. 25, 2004  
Raymond E. Hoop, '52, Nov. 25, 2004  
Ernest H. Wakefield, '52, March 25, 2005  
Charles B. Sharpe, PhD, '47 and '53, Sept. 10, 2004  
Col. Robert A. Yoder, '55, Sept. 19, 2004  
Howard R. Ebersole, '51 and '57, Jan. 4, 2005

#### Class of 1960-69

Harold Sobol, PhD, '55 and '60, Sept. 22, 2004  
Leon J. Lockwood, '60, Nov. 5, 2004  
Bernard A. Wright, '60, Aug. 28, 2004  
Walter M. Nunn, Jr., '61, Nov. 3, 2004  
James R. Glasser, '60 and '62, Oct. 18, 2004  
Robert David Kalischer, '63, Aug. 27, 2004  
Dennis W. Fife, '60 and '65, April 28, 2005  
James Edwin Adair, '61, '63, and '68, July 28, 2005

#### Class of 1970-79

Ben Joseph Charboneau, '70, Dec. 22, 2004

#### Class of 1980-89

Matthew A. Dombrasusky, '82, March 21, 2005

#### Class of 1990-99

Kasra Barkeshli, '91, June 29, 2005

## IN MEMORIAM

#### Class of 1920-29

Hugh D. Stillman, '23, Feb. 2, 2005

#### Class of 1930-39

Arthur M. Schoen, M.D., '34, July 5, 2005  
Warren S. Mueller, '35, June 28, 2005  
Adolph Lovoff, '36 and '37, April 16, 2005  
Leslie M. Harris, Jr., '38, May 8, 2005  
G. Howard Carrothers, '39, Dec. 9, 2004

#### Class of 1940-49

Robert H. Jackson, '40, Feb. 14, 2005  
Charles V. Wadsworth, '40, Sept. 4, 2004  
Harold C. Petrowitz, '43, Sept. 30, 2004  
Donald Lee Davie, '45, June 24, 2005  
Albert Fink, '48, April 22, 2004  
Robert L. Wheaton, '48, Dec. 20, 2004  
Richard E. Batesole, '49, Jan. 6, 2005  
Lucien T. Finch, '49, Jan. 11, 2005  
Albert P. Haggerty, '48 and '49, March 20, 2005  
Bennett Hausman, Jr., '49, March 21, 2005

## Memorial Scholarship Fund Established

Arjun Chandran (MSE EE '99) passed away June 22, 2005 at the age of 29, in a tragic road accident, along with his mother and grandmother, while returning from Yosemite after celebrating his grandmother's 75th birthday. They were victims of an out-of-control car.

Friends of Arjun Chandran have established a Memorial Fund in his name that will provide scholarship money to a graduate student in EECS. Arjun studied Very-Large Scale Integration, commonly known as VLSI. After graduation, Arjun spent five years in microprocessor design at Sun Microsystems in Sunnyvale, California followed by a year in wireless processor design at Texas Instruments in Austin, TX. His team members at Sun and TI established the memorial fund.

If you would like to contribute to the endowment fund, you may use the enclosed donation form, and include a note on the form that the money is for the Chandran Memorial Fund.

For additional information about Arjun, see [rani-arjunchandran.blogspot.com/](http://rani-arjunchandran.blogspot.com/)



**Arjun Chandran and his mother, Rani Chandran**

# Thank You

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## THANKS TO OUR DONORS

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We would like to thank the following companies and individuals for their support of the Department through gifts of money and equipment during the past year. These gifts have enabled us to further the educational mission of the Department in a variety of ways, including: scholarships and fellowships to students; outstanding speakers featured at a variety of seminar series; faculty research; donated equipment and software that has been used for courses and research; outreach to the K-12 community, and our new CSE building and the Michigan Nanofabrication Facility expansion.

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### Industry and Foundations

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Ann & Robert H. Lurie Foundation  
Advanced Micro Devices  
Agilent Technologies  
Analog Devices  
Association For Computing Machinery  
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Cisco Systems  
Eaton  
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Ford Motor Company  
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Sandia National Laboratories  
Ten-Tec  
The Graham Foundation  
The P & G Fund  
Toyota Technical Center  
Verl J. Hawks Trust  
Wai-Tsin Change Trust  
Whirlpool

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### Individuals

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R. James Bennett	David & Nancy Munson
Frederick J. Beutler	Catherine G. Murphy
David E. Boundy	James M. Nichols
Ching-Tao Chen	Don E. Peck
Kelly A. Cormier	Leland A. Pickett
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Joseph L. Hoffman	Robert J. Trew, Jr.
Ernest S. Kuh	Daryl C. Weinert
Jack C. Kesterson	Marvin H. White
Brian R. Kotzian	David K. Wigton
Charles F. & Patricia L. Krumm	Donald W. Winfield
John Laird	Dawson Yee
Ned B. Lawrence	
Frederick J. Leonberger	
G. Robert Leopold	
Laura Marie Leventhal	
Jerry W. Levin	
Herman Lieberman	
Ronald J. Lomax	
Stanley T. Mendenhall	
Eiji Miki	

## LEADERS IN GIVING

### Focus on our Industrial Friends: Ford Motor Company

Ford Motor Company recently committed gifts of \$1 million dollars to the Computer Science and Engineering (CSE) Building, and \$650K to the Michigan Nanofabrication Facility (MNF). With these gifts, Ford is supporting two major capital investments that directly impact the quality of education for EECS students, while expanding the research capabilities of the faculty. The CSE Building will bring together CSE faculty and graduate students in one building, and will include computer and research labs, an auditorium, and space for student projects. The MNF expansion will provide additional cleanroom space while upgrading existing facilities, thus maintaining its status as a state-of-the-art, world class facility. The MNF is a member of the National Nanotechnology Infrastructure Network, and is a critical resource for research in MEMS and nanotechnology.

Ford's relationship with U-M has always been very strong across both the Ann Arbor and Dearborn campuses. Ford even donated generous funds and 210 acres of land to establish the U-M Dearborn campus, which opened in 1959. "Historically, U-M has been our number one source of engineering talent," said Ed Krause, Manager, Ford-University of Michigan Program Development, "and we have been the biggest single hirer of U-M engineering graduates in recent years."

Since 1989, Ford has encouraged cooperative research through the Ford University Research Program, or URP. EECS professors Jessy Grizzle and James Freudenberg have had projects sponsored by Ford. One such project resulted in the 2003 IEEE Control Systems Society "Control Systems Technology" award, shared by Jessy Grizzle, U-M Professor Jing Sun, and Jeffrey Cook, technical expert and project leader in the Ford Scientific Research Laboratory. The project, as stated on the award citation, was "the development of fuel-efficient and environmentally friendly automotive powertrains through innovative application of control theory." Students in EECS 461 (Embedded Control Systems) will benefit from Jeffrey Cook's experience when he teaches the course this fall.

Grizzle has greatly appreciated his long-term relationship with Ford, and found that his time as a faculty intern at Ford, even before he came to Michigan, complemented his natural theoretical abilities at the same time that it strengthened his undergraduate teaching. "The undergrads wanted to know more about how things were done in engineering practice than I could tell them," said



Grizzle. With the internship, "I was exposed to an amazing array of technological and societal issues faced in designing a product in the ultra-competitive, heavily-regulated industry that is automobile manufacturing." Professor Grizzle is the co-inventor of 15 US patents assigned to Ford Motor Company between 1992 and 2005.

Ford looks forward to expanding its relationship with EECS, and is already partnering with faculty in the areas of Artificial Intelligence (AI), namely Professor Michael Wellman, and Real-time Computing, with Professor Kang Shin. The AI project involves Ford sponsoring a team to enter an international research competition called the Trading Agent Competition, Supply Chain Management (TAC/SCM) game. The Ford/U-M team, called "GoBlueOval," is the top scoring team in a class tournament from Wellman's course, EECS 547 (Electronic Commerce).

On behalf of the faculty and students who will benefit from your continued intellectual involvement and financial assistance:

Thank you Ford – We Look Forward to Working With You!

**Ford personnel joined U-M President Mary Sue Coleman and former Dean of the College of Engineering Stephen Director at the MNF Groundbreaking ceremony April 15, 2005. From left: John LaFond, Paul Killgoar, Sue Cischke, Mary Sue Coleman, Stephen Director, Gerhard Schmidt, Charles Wu**

## Groundbreaking of the Michigan Nanofabrication Facility



Warren Welch, Khalil Najafi, Ann Lurie, Dean Stephen Director, President Mary Sue Coleman, Jerry Levin, Don Graham, David Munson



Groundbreaking of the Michigan Nanofabrication Facility (MNF) expansion took place April 15, 2005. Formerly known as the Solid-State Electronics Laboratory (SSEL), the MNF will have increased capabilities in the areas of semiconductor device and circuit fabrication, microsystems and MEMS technologies, nanotechnology, nanoelectronics, nanophotonics, and nanobiotechnology. SSEL still refers to the group of faculty who work with solid-state devices in their research. The existing facility will remain operational during construction.

The MNF is a member of the National Nanotechnology Infrastructure Network (NNIN), a network of facilities from 13 universities, supported by the National Science Foundation, whose mission "is to enable rapid advancements in science, engineering and technology at the nano-scale by efficient access to nanotechnology infrastructure."

### Electrical Engineering and Computer Science

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