HIGH IMPACT UNDERGRADUATE RESEARCH
A New Model for Mentoring from Freshman to PhD

Message from Department Chair
Honored Alumni
Research Highlights
Increasing the value of the educational experience we offer to our students remains one of our most important department objectives. Naturally, critical factors that contribute to this value include quality learning experiences, an up-to-date curriculum, and a dedicated well-qualified faculty. However, in the short term, a key contributor to the perceived value of a degree is the reputation of the university, college, and department. One popular measure of department standing is the *U.S. News and World Report* ranking derived from a survey in which college deans and department chairs rate each of the 300+ undergraduate programs in the nation. In recent years, the Brigham Young University (BYU) Electrical and Computer Engineering (ECEn) Department has been ranked as high as 68 in this survey.

The following graph shows key annual data associated with the BYU ECEn Department compared with the average of the corresponding data from 11 departments that are ranked from 43 to 55 in the survey*. The data reveals that while we have a smaller-than-average faculty size, we award a significantly larger-than-average number of undergraduate degrees, underscoring our focus on undergraduate education. Despite this emphasis, however, our performance in external research funding and number of graduate degrees awarded per faculty member is comparable to the average performance of the control group. In addition, our average of approximately five peer-reviewed publications per faculty represents strong approval by the scholarly community of our research results.

As you explore this issue of *ece@byu*, you will find highlights of several current activities that demonstrate our commitment to high-quality undergraduate student mentoring and world-class research. I am confident that you will conclude as I have that because of the dedication of students, staff, alumni, and faculty, the department is moving in the right direction and continuing to provide an environment where students can flourish and creative ideas can develop into significant scientific contributions.

Sincerely,

Michael A. Jensen  
Department Chair

*These universities are: Boston University, Iowa State, Rutgers, UMass (Amherst), Notre Dame, Case Western Reserve, Northeastern, Vanderbilt, Michigan State, Oregon State, and University of Rochester. (Data taken from ASEE 2007 Profiles of Engineering and Engineering Technology Colleges.)
Randy Mooney (MSEE 1987) is an Intel Fellow and director of I/O research in Intel's Microprocessor Technology Lab, part of Intel's Corporate Technology Group. After earning a bachelor's degree in engineering technology from Weber State University, he joined Signetics Corporation in Orem, Utah. While at Signetics, he completed an MSEE degree at BYU. Randy joined the Supercomputer Systems Division of Intel (Hillsboro, OR) in 1992, working on the Teraflops program. He was responsible for developing the physical layer signaling solution for a machine containing 9600 Pentium Pro processors. He and his team developed a technique termed “Simultaneous Bidirectional Signaling” for use on all of these various connections. This technique enables transmission of data in both directions on a wire simultaneously, thus solving the bandwidth problem for this machine with a 2X reduction in the number of pins and wires required for the interconnects. This machine was the first computer to break the teraflops barrier and was patented and later used for early Intel Itanium–based systems.

Randy then worked on interconnects for volume microprocessor platform applications. He developed electrical solutions for a "backside bus" for Intel's Pentium II microprocessors. They developed a circuit that is now standard on all high-speed interfaces at Intel. This work helped to establish the viability of the Intel Xeon line that followed. Randy then worked on high-speed circuits and interconnects to convert all of Intel's busses from standard operation at hundreds of megabits per second to giga-bits per second. The first buss to use this work was PCI-express, with others to follow. Randy’s team has demonstrated busses with speeds of up to 20Gb/s using standard CMOS processes and microprocessor platform interconnects. This work is industry-leading with results published at top conferences such as ISSCC.

Randy's current focus as a chief scientist in Intel's Circuit Research Lab continues to be bandwidth solutions for microprocessor platforms. He has expanded his work to include future solutions for memory, power delivery, and influencing the direction for the lab's other programs in high-speed, low-power circuits. As a result of Randy's work at Intel, he is an inventor or co-inventor on 70 patents and has authored or coauthored more than 25 technical papers. Through these efforts he has been instrumental in driving consolidation of Intel's microprocessor platform interconnect road map.

Alumni News

Tim Hollis (PhD 2007) came to BYU after earning a BSEE degree from the University of Utah in 2003. During his time as a graduate student studying signal integrity for high-speed digital interfaces, he also completed summer internships with both Intel’s Circuit Research Laboratory (Hillsboro, OR) and Micron Technology, Inc. (Boise, ID).

His duties at Micron consist of input/output circuit design and signal integrity analysis for multi-Gigabit/second/pin memory interfaces. In addition, he often consults on projects assigned to other design teams, including recently redesigning integrated circuit packaging for Micron’s high-end DDR3 parts. He has been engaged as a member of various JEDEC task groups and has contributed to the development of the DDR4 and GDDR5 (5Gb/s graphics DRAM) standards, as well as the development of Micron proprietary tools and methodologies for increasing the accuracy and realism of high-speed circuit simulations.

Since joining Micron in March of 2006, he has filed 24 patents related to his work. Tim has been invited to speak at several technical gatherings including giving presentations on high-speed signal integrity for the 2008 Micron Knowledge Forum, signal modeling techniques for the Engineering Leading Edge Program, and consecutive presentations at Micron’s 2007 and 2008 Strategic Technology Forums (attended by the top 100 technical leaders in the company), where he was asked to forecast signal integrity challenges along Micron’s current road map and offer solutions for maximizing performance with minimal cost and complexity. While at Micron he has continued to publish his work externally in leading IEEE journals.

Schuyler Shimanek (BSChE 1984, MSEE 1988) has been a process engineer for Signetics (1984–1992), an IC design engineer for Philips Semiconductors (1992–1997), and is now a design engineer for Xilinx, Inc. His CMOS design experience extends from 1 micron gate lengths at Signetics down to 65 nanometer gate lengths at Xilinx.

Schuyler holds 14 U.S. patents with several others pending for his innovative designs. He was a keynote speaker at the 1998 IEEE Custom Integrated Circuit Conference, Programmable Logic Section. While at Philips, he was the coinventor of the CoolRunner CPLD family of devices and was awarded EDN's Innovation of the Year for Digital ICs in 1996. The CoolRunner Product was among Philip's portfolio of “green products” instrumental in gaining the 1998 World Environment Center (WEC) Gold Medal for International Corporate Environmental Achievement. He was also a finalist for EDN's Innovator of the Year Award. He is currently a member of Xilinx's Architecture Team, which is responsible for developing next generation FPGA architectures.
Early research experiences can be transformative and often drive undergraduate students toward graduate work and leadership in their respective fields. BYU’s high-caliber students are well suited for such independent work and often go on to earn advanced degrees (BYU now ranks No. 10 in terms of alumni earning PhDs). The Electrical and Computer Engineering Department has a long history of employing undergraduate researchers, but most were simply hired to work alongside graduate students when projects needed more manpower and when students had the necessary technical backgrounds. However, in the last five years, several faculty-sponsored programs have emerged that are dedicated specifically to developing undergraduate researchers. One of the most visible is IMMERSE (Intensive Mentoring and Micro-Electronic Research for Students in Engineering), which was initiated in 2002 by Professors Aaron Hawkins and Stephen Schultz.

One of the unique aspects of IMMERSE is that students are hired as early as their sophomore year and have frequent one-on-one contact with faculty and graduate student mentors. Mentors teach technical concepts and outline research activities that are experimental in nature and utilize BYU’s cleanroom facility. IMMERSE also prepares students for graduate school and careers by providing training on technical speaking and writing.

After six years of refining IMMERSE, its founders have identified three factors for a successful undergraduate research program:

1. Involve students early in their academic career. “Real research takes time, and students need a couple of years of consistent involvement before they can really contribute,” says Schultz.

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**IMMERSE By the Numbers**

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<th>IMMERSE Students Since 2002</th>
<th>61</th>
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<tr>
<td>Percentage of Students Publishing a Technical Paper</td>
<td>80</td>
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<tr>
<td>Number of Technical Papers with IMMERSE Authors</td>
<td>70</td>
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<tr>
<td>Percentage of IMMERSE Alumni Pursuing Graduate Degrees</td>
<td>75</td>
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2. Create a specific mentoring organization. “We treat IMMERSE as an independent entity that requires a critical mass of about 15 students, including more experienced students that can help train younger ones,” says Schultz.

3. Intimate faculty involvement. “Faculty advisors have to put in the time and creativity, coming up with projects undergraduates can work on. And you can’t just give a student a problem and leave them alone for four months, hoping they will solve it. There can be a lot of initial hand-holding,” cautions Schultz. “Although I’ve heard some colleagues worry that this kind of effort might water down their research efforts, I really believe IMMERSE makes me more productive and my research better.”

The results from IMMERSE have been impressive in terms of both research and student experiences. “We put a lot of emphasis on publishing a scientific paper during a student’s time with IMMERSE, and the majority of the students actually do publish before they graduate—something remarkable for undergraduates,” remarks Hawkins. Three-quarters of IMMERSE students also go on to graduate school; many pursuing PhDs. “When the program got started I don’t think we envisioned just what kind of effect it would have on the student psyche. Maybe the best aspect of this program is when we watch a kid go from just looking for a steady job to wanting to earn a PhD or to revolutionize the world,” says Hawkins.

As IMMERSE has developed, it has also emphasized outreach to the engineering community and potential future students. Examples include developing a class aimed at recruiting new students into electrical and computer engineering (www.et.byu.edu/groups/newstudent), building hallway displays demonstrating engineering concepts, and teaming with BYU’s multicultural program to introduce visiting high school students to basic engineering (www.ece.byu.edu/ugresearch/soar.phtml). IMMERSE also develops two major online resources: the Web page homes for BYU’s cleanroom (www.ee.byu.edu/cleanroom) and photonics labs (www.ee.byu.edu/photonics). These sites offer reference materials, tutorials, calculators, and equipment operating instructions and were put together entirely by IMMERSE students. Combined, these sites receive almost 100,000 hits per month worldwide and have become some of the most referenced resources in the fields of microfabrication and photonics.

Hawkins and Schultz are quick to point out that a program like IMMERSE could not run without financial support. “Unpaid internships just don’t work out in engineering,” says Schultz. IMMERSE was started with an initial grant from BYU’s research office, with money coming from university donors. Current IMMERSE funding comes from a continuing BYU grant, external research contracts including undergraduate specific supplements from the National Science Foundation, and more recently the Micron Foundation. “Micron used to fund scholarships for our department, but they’ve decided the money is more effective when directed at IMMERSE. Sort of the ‘teach a man to fish versus giving him a fish’ model,” says Hawkins.

Watch for a documentary on the IMMERSE program to be released this fall on BYU-TV. For more general information, visit the IMMERSE Web site at www.ee.byu.edu/ugresearch. To help expand the IMMERSE program, you can contribute financially by visiting www.ee.byu.edu/ugresearch/contribute.phtml.

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Jeff Maas began with IMMERSE in early 2005 as an EE undergrad. Jeff attributes his desire for graduate studies to the program. “IMMERSE helped me to realize my potential in electrical engineering. I was able to learn beyond the textbook. IMMERSE gave me the chance, early in my career, to know what kind of results hard work and ‘loving what I do’ can bring. This program seeded the desire to learn, an important link to my success in graduate studies.” Jeff is currently a PhD student at Purdue and credits the technical papers he published as an undergraduate with helping him get into that program.

Seth Lloyd received his undergraduate degree from BYU in electrical engineering and mathematics. Seth is currently pursuing a PhD in Electrical Engineering at Stanford University. He is working on fiber-optic gyroscopes using a photonic crystal fiber-sensing coil. Seth said of his experience, “IMMERSE was a fantastic chance to get my feet wet and use all the theory that I was learning in my coursework. My undergraduate work with fiber sensors has now carried over to my graduate research in fiber gyroscopes. There’s no question that the experience I gained in IMMERSE was a huge factor as I moved on to graduate school.”
Imagine taking a drop of blood from your finger and putting it in a handheld device that in a few minutes gives a comprehensive report on the state of your health, including any cancer or precancerous trends that may be present in your body. Dr. Greg Nordin and his students in the Nano and Micro Devices research group are working on a new sensor technology to enable such handheld medical diagnostic devices, as well as on compact, integrated sensors for a host of other applications, including chemical and biowarfare agent detection, environmental monitoring, and industrial process control.

Their new sensor platform is based on arrays of chemically sensitized microcantilevers on a small silicon chip. Each microcantilever has a length comparable to the diameter of a human hair and is sensitized to detect a specific target molecule. When target molecules are present, the microcantilever undergoes a minute deflection that is sensed by light traveling in waveguides on the chip. The deflection sensitivity is much smaller than a nanometer—typically in the 10s of picometer range. The result is a tiny, exquisitely sensitive chemical detector. Putting several hundred of these on a single chip results in broad spectrum sensors that have high sensitivity and specificity toward a large suite of target molecules. The particular set of target molecules is completely flexible and is determined by how each microcantilever in the array is sensitized.

A further important aspect of the approach taken in Dr. Nordin's group is integrating a microcantilever array chip with microfluidics (lab-on-a-chip). The microfluidic layers include integrated fluid and control channels, valves, and pumps to precisely route small amounts of sample fluid and reagents on the chip. The end result will be a compact sensor that requires only tiny amounts of sample fluid (for example, a single drop of blood).

Dr. Nordin is currently collaborating with Dr. Adam Woolley in the Chemistry Department at BYU and with researchers at Pacific Northwest National Laboratory. His group at BYU includes Dr. Seunghyun Kim (research scientist) and five PhD, two MS, and two undergraduate students. His research funding includes a 5-year $1.6M grant from NSF, a 4-year $1.3M grant from DARPA, and $500K from the National Consortium for MASINT Research (NCMR).
Department Joins NSF National Research Center in Reconfigurable Computing

Dr. Brent Nelson is the center director for the BYU site of the National Science Foundation (NSF) Center for High-Performance Reconfigurable Computing (CHREC), a national research center focused on the development of reconfigurable computing technologies. The research center is a part of the NSF’s Industry/University Cooperative Research Center (I/UCRC) program, which brings together universities, government labs, and companies to promote the research and development of new advanced technologies. The center is a collaboration of four universities: BYU, the University of Florida (lead institution), George Washington University, and Virginia Tech.

The center’s research focus is on reconfigurable computing systems and technology such as FPGA-based computing platforms, design tools, and applications. For 2008, BYU researchers are focusing on four research projects. The first is the development of a reuse standard to facilitate the reuse of pre-existing circuit modules to increase FPGA-based design productivity. The second focuses on the use of other emerging technologies (such as GPUs and coarse-grain reconfigurable devices) as well as hybrid combinations of those devices in concert with FPGAs in systems. The third project focuses on the reliability of FPGA-based designs in space, where radiation-induced circuit upsets require the inclusion of redundant circuitry in the original design. The fourth project also focuses on reliability and FPGAs in space and involves creating a series of communication system designs to investigate application-level reliability techniques for those systems. The intent is to fly a series of such designs on the Los Alamos National Lab CFE satellite platform in the coming months for in-orbit testing and evaluation.

Funding for the center is provided by fees from the companies and government labs, who pay a yearly fee to be members of the center. In turn, they receive access to the research results carried out by the university research groups and additional opportunities for collaboration with center faculty and students. BYU faculty who collaborate on this project include Michael Wirthlin, Michael Rice, and Brad Hutchings. Almost 20 students are also involved in the center, performing research activities as a part of their MS and PhD thesis research. Members associated with BYU in the center include L-3 Communications, Lockheed-Martin Corporation, Los Alamos National Labs, National Instruments Corporation, NASA, Rincon Research Corporation, and Sandia National Labs. Inquiries from potential members are welcomed. More information on CHREC can be found at http://www.chrec.org or by contacting Dr. Brent Nelson (nelson@ee.byu.edu).
We express gratitude to generous alumni who donate to support our students. Over the years, we have received gifts ranging from $10 to more than $1,000,000. These funds are used to enhance the educational experience of both undergraduate and graduate students.

Donations to the department are used for three purposes:
1. Scholarship endowments
2. Endowed faculty chairs and university professorships
3. Capital equipment

The interest earned from scholarship endowments is used to provide scholarships and tuition credits to both undergraduate and graduate students in perpetuity. Scholarships are usually awarded competitively or according to criteria established by the donor. A tuition scholarship for one undergraduate student requires an $80,000 endowment. Funding a graduate fellowship in perpetuity requires approximately $500,000.

An endowed chair enables the department to hire an additional faculty member, who is usually an individual with considerable experience and expertise. Endowed chairs significantly raise the external visibility and stature of BYU and the department and can bless the lives of students for generations to come. A fully funded endowed chair requires approximately $5M.

A university professorship provides faculty members with funds that can be used for research assistants, travel to attend conferences, and other activities that enable high quality research in the department. Professorships raise the visibility and stature of BYU and significantly impact a faculty member’s ability to provide quality mentoring experiences to students. A fully funded university professorship requires approximately $1M.

The department currently has scholarship endowments totaling $1,400,000, one endowed chair, and one university professorship. Individuals or companies interested in donating to these funds or establishing an endowment or professorship should contact the department chair Prof. Mike Jensen at jensen@ee.byu.edu.