Summer 2004

WIMS WORLD

University of Michigan | Michigan State University | Michigan Technological University

Director's Message

Fall is here, and the fifth year of our Wireless Integrated MicroSystems Engineering Research Center (WIMS ERC) has begun. It will be an important one for our testbeds, which represent "grand challenges" in every sense of the word. The neural testbed is attempting to build nothing less than an electronic interface to the central nervous system. With it we hope to revolutionize our understanding of the brain and develop prosthetic devices to treat some of mankind's most debilitating disorders. Our environmental testbed is paving the way toward the distributed monitoring of air quality for pollution control and homeland defense. I am now convinced that the micro gas chromatograph—the heart of this testbed—will perform better than we ever dared hope, and in many respects better than its macro counterparts.

This fall I am teaching the seminar course "Societal Impact of Microsystems." It examines some of the critical challenges we face as a global society—clean air, clean water, sufficient energy, adequate food, security, and others. These are challenges we must somehow meet during the decades ahead—decades that will frame the careers of the students we are now training. Population growth is exacerbating these problems, and I am reminded of a comment that Intel's Craig Barrett made when he visited us last spring. He pointed out that a third of the world's population, Russia, India, and China, entered the competitive marketplace during the past decade. As these countries undergo growth and industrialization, and as other countries follow suit, the strains on global resources will be extreme. Technology has played a role in getting us into this situation, and the question now is whether it can also provide the tools to get us out.

Many people today expect that it will—that today's problems will, in many cases, be solved tomorrow. They expect we will be able to do things better in fifty years than we can today, just as we can do things better today than we could fifty years ago. That certainly has been the case in information processing, communications, and health care. It is a premise of this Center that microsystems will lead the way in grappling with many of the new challenges we face. But this faith in technology is a relatively recent development and is not universally shared.

This year marks the 200th anniversary of the Lewis and Clark Expedition. In many ways (including its relative slice of the Federal budget), that adventure was equivalent to the Apollo program that took us to the moon. It was a "grand challenge." But Stephen Ambrose, in his book *Undaunted Courage*, points out that at that time there was no expectation that technology was poised to make things better. "It seemed unlikely that one nation could govern an entire continent. The distances were just too great. Americans lived in a free and democratic society, but a society whose technology was barely advanced over that of the Greeks. . . . A critical fact in the world of 1801 was that nothing moved faster than the speed of a horse. Nothing had ever moved faster, and, as far as Jefferson's contemporaries were able to tell, nothing ever would. . . and except on a racetrack, no horse moved very fast. Road conditions in the United States ranged from bad to abominable." But he goes on to point out that "only sixty years later, Americans could move bulky items in great quantity farther in an hour than Americans of 1801 could do in a day, whether by land or by water. This great leap forward in transportation in so short a space of time must be reckoned as the greatest and most unexpected revolution of all—except for the transmitting of information." We can still appreciate the sense of magic that must have greeted the telegraph. As we develop microsystems technology today, we engineers must make sure it solves the problems that confront us without creating others. We truly have some grand challenges ahead, and the students we are training are going to meet them. As we start our fifth year, I am more grateful than ever to those who are helping us move forward, and especially to our industrial partners in this great adventure.

Ken D. Wise

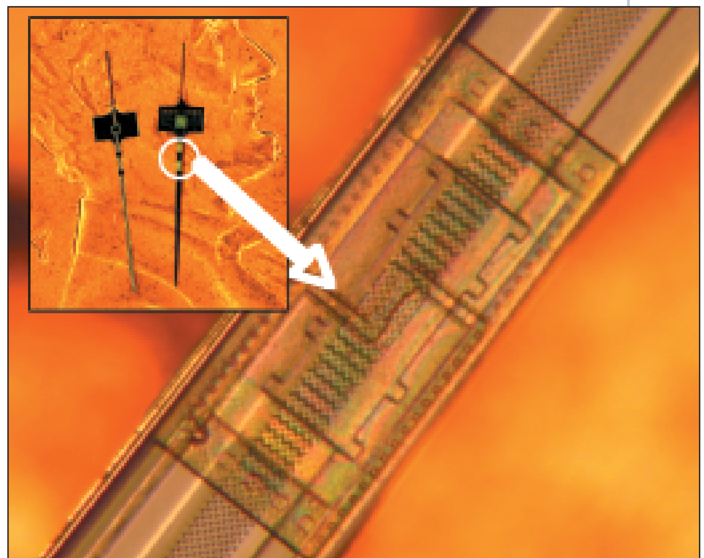
Director, Engineering Research Center for Wireless Integrated MicroSystems

Inside

Research Highlights

World's Smallest Flowmeter

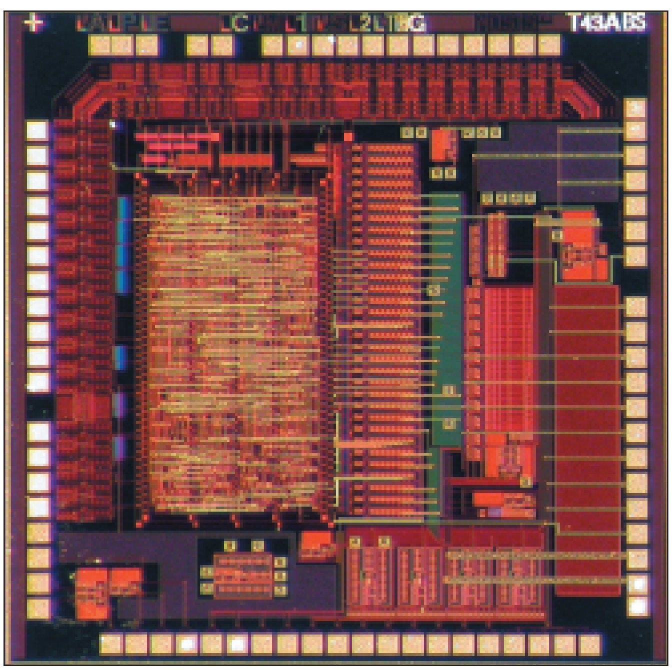
A new flowmeter developed at the University of Michigan represents a major step forward in instrumentation for neuropharmacological studies of the nervous system. The neural probes developed at Michigan have become widely used in neuroscience for studying the central nervous system at the cellular level. Past efforts to extend the electrical recording and stimulation capabilities of these devices into the chemical domain have produced process-compatible microchannels, shutters, and fluidic cables. Now, a pulsed thermal microflowmeter small enough to be integrated on the probe shanks has been demonstrated. Less than 50μm wide, the device meters doses of 100-500pL/sec while limiting any temperature rise in nearby tissue to less than 1°C. The flowmeters allow closed-loop control of in-vivo drug delivery.



An in-depth thermal flowmeter integrated on the shank of a neural probe.

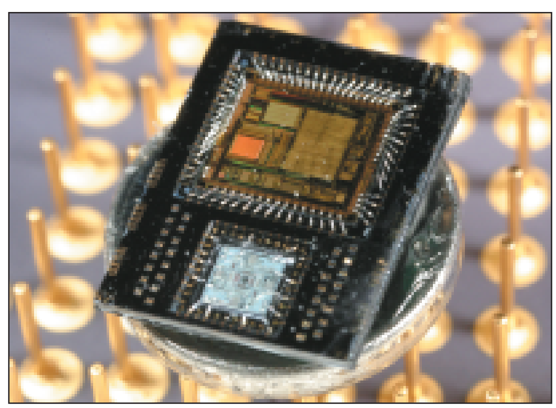
New Sensor-Interface ASIC for a 0.5cc Data-Gathering Microsystem

Fabrication and testing has recently been completed for a custom sensor interface circuit designed for use in a self-contained 0.5cc microsystem for environmental and biological data gathering. The ASIC works together with a mixed-signal microcontroller and flash memory chip to condition sensor data, convert it to digital format, and store it in a non-volatile memory. The chip, fabricated in AMI 0.5μm CMOS, includes a switched-capacitor charge integrator, multiple neural amplifiers, and a resistive readout circuit, so it is capable of interfacing with capacitive pressure, temperature, and humidity sensors as well as piezoresistive strain gauges and neural probes. To minimize power consumption, the ASIC puts each analog block into a sub-microwatt sleep mode when not in use, achieving an average analog power consumption of 15μW while gathering data at approximately 50Hz.



A sensor interface ASIC with neural amplifiers, capacitive readout, and on-chip calibration.

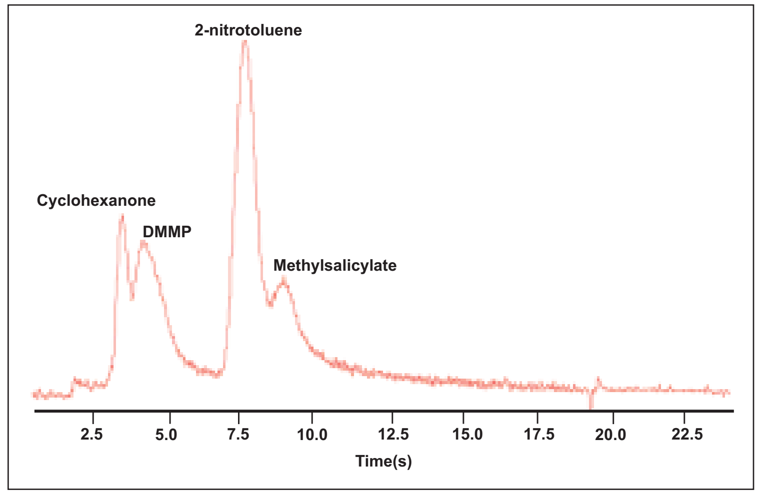
The ASIC will reside with other system components on a 7 x 10mm silicon platform containing recessed chip cavities, through-wafer interconnects, and solder-based "smart-pad" microconnectors. The microsystem operates from a 3V coin cell and is 2mm thick with a 5mm radius, yielding an entire system volume of less than 0.5cc—an unprecedented size for a microsystem of its versatility and performance.



A micromachined silicon platform that allows the complete data-gathering microsystem to be smaller than 0.5cc.

High-Speed Gas Chromatography

At the heart of the environmental testbed is the micro gas chromatograph (μGC). As the μGC continues to develop, its performance continues to exceed expectations. During the past quarter, separating four different chemical warfare agents (with boiling points between 155°C and 223°C) in less than 10 seconds was achieved for the first time. Cyclohexanone is a solvent used in C4 explosives, dimethyl methanephosphonate (DMMP) is a simulant for sarin, 2-nitrotoluene is a byproduct in trinitrotoluene (TNT), and methylsalicylate is a simulant for sulfur mustard gas. The miniature columns of the μGC are not only very fast at separating chemicals, but they operate at fractions of the power consumed by macro columns.



Researchers Integrate Components of Wireless System Onto One Chip

WIMS researchers have demonstrated the technology for integrating all components of a wireless system onto one chip. They created an accurate and efficient miniature antenna and replaced the quartz frequency resonator with a wine-glass resonator. This accomplishment has many applications, including making earpiece-sized cell-phones.

The miniature antenna ($1cm^2$) is a slot antenna, rather than a traditional antenna. Instead of using a metal wire, they have covered an entire plane with metal and etched a spiral slot, or groove, into the metal. Because wire surrounds the slot, the efficiency of radiating the electromagnetic waves is increased.

The wine-glass MEMS resonator replaces the functionality of a quartz crystal, but unlike quartz crystal, it is compatible with silicon processing. Therefore, it is easily integrated into the chip. With the wine-glass resonator and the miniaturized antenna, researchers demonstrated a Zigbee (ISO-802.15.4) radio link.

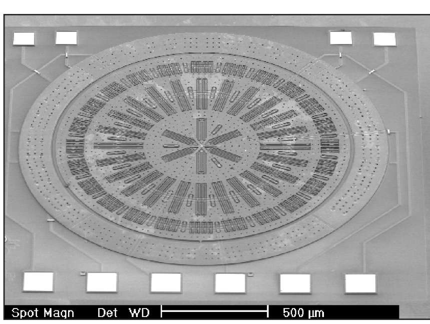

EETIMES

New fuse type may herald IC self-repair

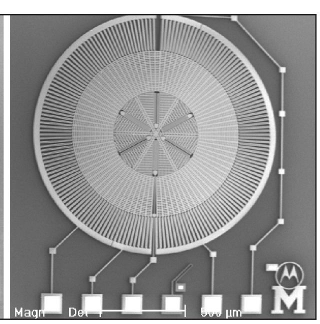
Article appeared in the August 9, 2004 issue of EE Times magazine.

WIMS PhD Student Published Best Results for an Angular Accelerometer

Gary O'Brien recently completed his Ph.D. dissertation in Electrical Engineering at the University of Michigan titled "MEMS Angular Rate and Acceleration Sensors with CMOS Switched Capacitor Signal Conditioning." Microelectromechanical sensors were designed to measure angular rate and acceleration signals. Sensors were fabricated in micromachined polysilicon and silicon on insulator (SOI) structural films (shown below). The sensors output a differential capacitance signal based on the displacement of a seismic mass in reference to an externally applied rotation. The angular rate sensor utilizes normal mode energy coupling transfer caused by Coriolis acceleration applied to the resonant seismic mass while exposed to an external rotating frame of reference. The angular acceleration sensor is comprised of a non-resonant spring suspended seismic mass. Displacement of the seismic mass as a function of angular acceleration is sensed by dual differentially referenced arrays of interdigitated variable capacitors. The angular rate sensor provides a resolution of 3.8degrees/sec (in a 20Hz BW) for a hybrid system, which can be improved to 0.48degrees/sec when an integrated version is used. The angular accelerometer provides a resolution of 0.8 r/s^^{2} (in a 100Hz BW) over a range of ±228 r/s^^{2}. This is the best result published for an angular accelerometer.



Surface Micromachined Angular Rate Sensor

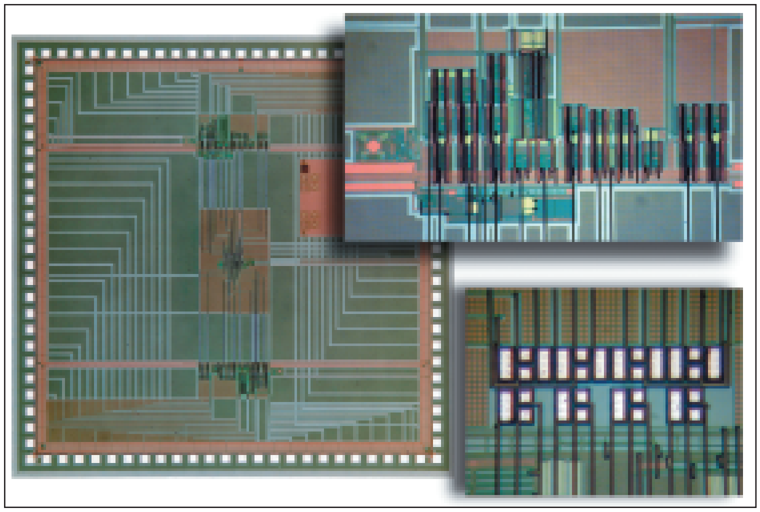


SOI Angular Acceleration Sensor

Sensors for Recording Neurochemical and Neuroelectrical Events

Communication between neurons is a complex interaction of electrical and chemical signals; therefore, detecting both forms of communication enhances our understanding of neuron behavior. Devices capable of recording neuroelectrical and neurochemical events in cell culture have recently been developed at the University.

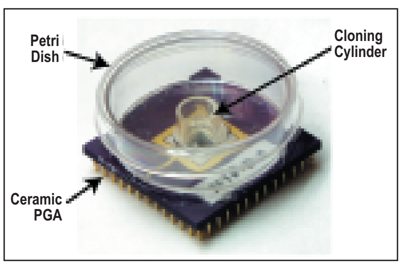
These devices—electrochemical transducers consisting of platinum and silver/silver chloride electrodes—use voltammetric analysis for detecting chemicals and a separate platinum electrode to monitor electrical action potentials. A ceramic PGA package with attached Petri dish and cloning cylinder creates a sterile, thermally stable environment to support cell growth on the surface of the chip. It also provides a high I/O count, supporting an array of sensors that identify cause-and-effect relationships in the signals detected.



Die Photograph of the Active Neural Sensor Array with enlargements of the circuit and sensing interface elements.

This method supported human neuron cell cultures for over seventy days while recording both neurochemical and neuroelectrical activity. The detection limits for dopamine were better than 100nM.

A more advanced version with on-chip signal amplification was developed by post-processing a design implemented in a commercial CMOS process to add electrochemical sensors. The University of Michigan is currently working on combining their micromachined neuroprobe process with this technology to create advanced probes that monitor chemical and electrical communication.



Completed Passive Neural Sensor Array. The petri dish and cloning cylinder provide a sterile environment for cell cultures.

The work was suppored by: Advanced Sensor Technologies of Farmington Hills, Michigan, the NIH through NINDS SBIR Grant #1 R43 NS37989-01, and the NSF WIMS Engineering Research Center.

Personnel Focus

Michel Maharbiz Elected Vice President of Latino Faculty and Staff Association

WIMS professor, Michel Maharbiz, was recently elected vice president of the Latino Faculty and Staff Association (LFSA) of the University of Michigan. He will serve for the 2004-2005 academic year. His goal is to engage the LFSA in the issues of the Latino engineering community, with particular interest in helping bright, energetic students move into engineering research careers and obtain advanced technical degrees.

The LFSA began two years ago in an effort to create a work and community environment that would support the needs and aspirations of Latino faculty and staff. It seeks to establish a network for exchanging information and ideas through mentoring, workshops, seminars, and other related activities. Among the many roles it plays, the LFSA took the lead in organizing this year's Hispanic Heritage Month (September 15-October 15, 2004).

Recent Events

Polly Anderson Supports Research in Biomedical Sensors

The Engineering Research Center draws only about one third of its overall microsystems support from the National Science Foundation. The remaining funding comes primarily from other Federal agencies, but in a few cases support also comes from direct gifts. The most important of these gifts has come from Pauline (Polly) V. Anderson of Cupertino, CA. She and her husband, Reid, endowed the J. Reid and Polly Anderson Professorship in Manufacturing Technology at Michigan in 1985. That chair is now held by ERC Director Ken Wise. In addition, for the past several years she has been a strong supporter of Michigan's work developing biomedical sensors—cochlear implants for the deaf, as well as wireless pressure and flow sensors for use in the cardiovascular system. This additional support, which now exceeds one million dollars, has made possible the realization of initial prototypes of both cochlear implants and wireless flow sensors (active stents), some of which have been mentioned in previous editions of *WIMS World*. Her support has also funded the degree programs of a number of graduate students at Michigan, including Danielle Merriam (master's degree in electrical engineering 2002), Andrew DeHennis (Ph.D. degree in electrical engineering 2004) and current students Pamela Bhatti and Beth Isaksen. Michigan is fortunate indeed to have Ms. Anderson as a member of the WIMS ERC team.

WIMS Director Ken Wise and WIMS ERC team member and supporter Polly Anderson.

WIMS senior technical staff member, Robert Gordenker and the TIME MACHINE Racing Team, has participated in regattas on Lakes Erie, St. Clair, Huron, and Ontario for the past 6 summers. A team of 10 sailors is required to handle this 35-foot-long, 10,500-pound racing sailboat. The J/35 one-design fleet is widely regarded as one of the most competitive. WIMS technology is aboard with the instrumentation's heel sensor being a MEMS device and control of the system done wirelessly from on deck. More information is available at http://www.eecs.umich.edu/~rgordenk.

Seminar Series

July 13, 2004
Professor Jamie Phillips
Solid State Electronics Laboratory, EECS Dept., University of Michigan
"Novel Oxide Materials for Semiconductor Optoelectronic Devices and Sensors"

July 20, 2004
Professor Michel Maharbiz
EECS Dept., University of Michigan
"Microgradients, Microgradients, and More Microgradients"

September 14, 2004
Chris Braidwood
Marshall, Gerstein & Borum LLP
"Maintaining Patentability Despite Pre-Filing Publication"

Tuesday, September 21, 2004
Jeffrey T. Borenstein, Ph.D.
Draper Laboratory, Cambridge, MA
"Microfabricated Systems for Regenerative Medicine"

Friday, September, 24, 2004
Professor Reza Ghoddsi
University of Maryland
"Integrative MEMS Materials and Processes for Microsystems"

Education Highlights

Sally Ride Science Festival

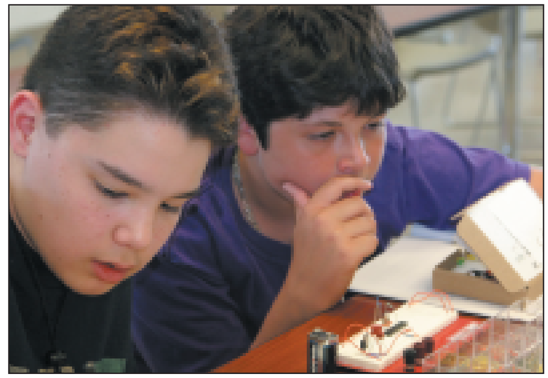
The WIMS ERC and Michigan State University's (MSU) Diversity Programs Office (DPO) hosted an exhibit in the third annual Sally Ride Science Festival held at the University of Michigan. This exhibit contained LEGO robotic demonstrations built this summer by teens who participated in the WIMS for TEENS program. WIMS also featured an interactive computer game that the Student Leadership Council designed for the Ann Arbor Hands-On Museum. Participants listened to songs and tried to match the songs to their titles; however, they could only do so with limited-range hearing. Each song was played with just a few channels of sound, duplicating what a person who is profoundly deaf hears. Participants found it extremely difficult.

Astronaut Sally Ride speaks to eight hundred girls and their parents at the festival.

As part of the festival, girls attended hands-on classes, while parents went to adult presentations. WIMS Professor Leo McAfee began the adult session by introducing the WIMS ERC and its opportunities for youth and higher education. Dr. Aurles Wiggins from MSU's DPO followed with remarks on how to keep girls interested in math and science and what resources are available for help.

The Sally Ride Science Festival is designed to excite girls from the fifth to the eighth grade about math and science at a time when most lose interest. Sally Ride, the first American female astronaut to fly into space, spoke to eight hundred girls and their parents at this festival in order to encourage continued learning in these fields.

Summer Program at MSU Challenges Teenage Students

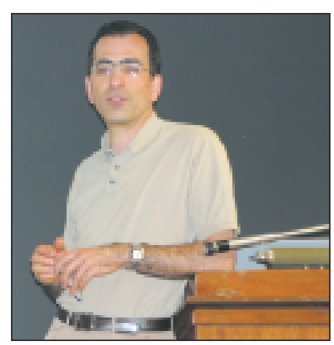


Joshua Kim and Alexander Guzman working together on a WIMS Lab experiment.

This summer, twenty teenage students learned how important math and physics are when designing and working with engineering laboratory experiments. For one week, students came to Michigan State University's College of Engineering department for a full day of courses. They were taught to solve problems, program computers, work in teams, and be creative. Students participated in a Wireless Integrated Microsystems introductory short course where they learned to apply math concepts to other subject areas. For several, this was a first-time experience. In the short time frame of a week, students barely had enough time to cover the basics of microcontroller programming, but were excited to learn the possibilities of what microcontrollers could do. They also reported that they were challenged academically in this program, but enjoyed learning subjects that normally weren't covered in their classes at school, and felt this program would help them to be more successful academically.

Third Annual Women In Engineering (WIE) Program Held at MSU

Michigan State University's Diversity Programs Office held the third annual Women In Engineering program for high school women in their junior and senior years. During their two-week stay at MSU, students learned MathaPhysics (an integration of math and physics), C++ programming, Unigraphics, and WIMS.



Professor Najafi giving the Women in Engineering participants an overview of the WIMS ERC.

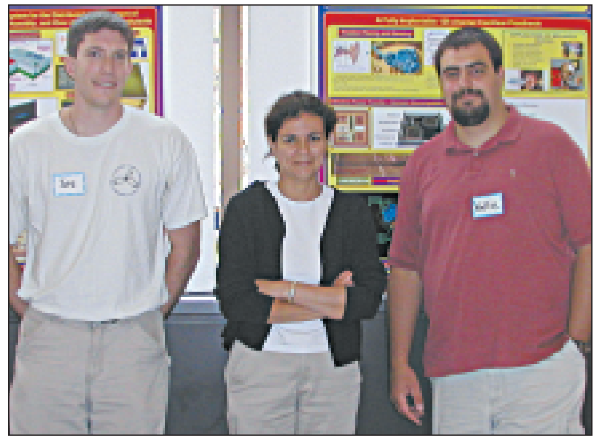
For the first week of the WIMS class, the women worked on five digital circuit and programming labs before tackling a final project. The projects included programming classic video games (Nibbles, Race Car, and Memory Match), music boxes, and a traffic light. The video game projects were the most challenging due to the large number of variables needed. This made the programs more challenging to write, particularly for students who had no prior programming experience.

A few of the women had already participated in the four-week DAPCEP program this summer, or last year's Women In Engineering program. These women were free to choose a more difficult final project and work on it for both weeks.

Teamwork was also critical for each group of students, since they had such a short time to work on the projects. Each group needed to work together well to maximize their efficiency in order to complete the project on time. Even with the tight time constraints, all of the women were able to complete their projects and demonstrate what they learned during the course.

Student Leadership

Student Leadership Council News



Joe Potkay, Luciana da Silva, and Willie Steinecker at Welcome Day for new students.

Throughout the quarter, the WIMS Student Leadership Council (SLC) continued to work towards an interactive Internet Web page for the Ann Arbor Hands-On Museum (AAHOM). Through games and audio-visual interaction, children can learn about hearing and cochlear implants. The Web page was presented and delivered to the AAHOM for testing and feedback. WIMS and the SLC are currently searching for a student to finish the work on this project.

In August, WIMS students helped organize and attend a Center picnic at Huron Mills Metro Park. Faculty, staff, and students from the University of Michigan and Michigan State University enjoyed grilling, talking, and playing sports.

In September, the SLC welcomed new engineering students to the University of Michigan. The SLC set up several posters summarizing the WIMS Center and encouraging new students to seek undergraduate and graduate research experience in WIMS. Flyers, WIMS candy bars, and WIMS highlighters were distributed to prospective students to briefly inform them about the Center and encourage them to participate.

Currently, the SLC is compiling a resume book to distribute to WIMS ERC member companies. Last year, the book resulted in several students earning internships.

In the coming quarter, SLC students will prepare for and attend the October IAB meeting, attend the NSF ERC annual meeting in Washington, DC, and continue work on ongoing projects.

Joe Potkay
President, WIMS SLC

Industrial Liaison's Report

At the October 19, 2004 Industrial Advisory Board meeting, the Center announced a new program to assist in commercializing technology. The Center is working with the Samuel Zell and Robert H. Lurie Institute for Entrepreneurial Studies (ZLI) to develop a program that will allow MBA students and WIMS students to delve deeply into the business issues that surround the process of commercializing technology. This *Program for Research Commercialization Potential* will scrutinize technologies, potential markets, customers, and value statements, which must be addressed before a meaningful business plan can be created.

The program will run from November 2004 to April 2005. It will focus on various team project reports where students will articulate recommendations on whether to commercially advance a given technology (with specific benefits cited) to the business plan stage, to "kill" the advancement, or to advance the idea at a later time when updated information becomes available.

The reports will be reviewed with our IAB members at our May 2005 IAB meeting. We believe that this team building will assist in moving technology into the right marketplace as fast as possible.

If any members are in Ann Arbor during the year and would like to discuss the program in detail, just contact me. As we enter into the winter wonderland phase it is an ideal time to analyze not only how we can develop technology, but how we can commercialize it in a cost-effective manner.

Joseph M. Giachino
Associate Director, Industry

Presentations/ Publications

K. King, S.W. Yoon, N.C. Perkins, and K. Najafi, "The Dynamics of the Golf Swing as Measured by Strapdown Inertial Sensors" **5th International Engineering of Sport**, Davis, CA, 2004.

P. Mohseni and K. Najafi, "A 1.48-mW Low-Phase-Noise Analog Frequency Modulator for Wireless Biotelemetry," **IEEE Trans. Biomed. Eng.**, in press.

P. Mohseni and K. Najafi, "Wireless Multichannel Biopotential Recording Using an Integrated FM Telemetry Circuit," in Proc. **26th Annual International IEEE-EMBS Conference**, pp. 4083-4086, San Francisco, CA, September 1-5, 2004.

Y. Yao, M.N. Gulari, J.F. Hetke, and K.D. Wise, "A Low-Profile Three-Dimensional Neural Stimulating Array with On-Chip Current Generation," **Digest IEEE Conf. on Engr. in Med. and Biol.**, San Francisco, CA, pp. 1994-1997, September 2004.

G.E. Perlin and K.D. Wise, "The Effect of the Substrate on the Extracellular Neural Activity Recorded with Micromachined Silicon Microprobes," **Digest IEEE Conf. on Engr. in Med. and Biol.**, San Francisco, CA, pp. 2002-2005, September 2004.

Doctoral Dissertations

Maysam Ghovanloo
"Wireless Microsystem for Neural Stimulating Microprobes" University of Michigan, 2003
Current Position: Assistant Professor at North Carolina State University
Advisor: Professor Khalil Najafi

Timothy D. Strong
"Microfabricated Voltammetric Neuro-Arrays for Use in Vitro"
University of Michigan, 2004
Current Position: Engineer at Sensicore, Inc.
Advisor: Professor Richard Brown

Schedules of upcoming seminars as well as a listing of publications are available at www.wimserc.org.

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WIMS World is published quarterly by the Engineering Research Center for Wireless Integrated MicroSystems.

WIMS World
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