The Engineering Research Center for Wireless Integrated MicroSystems (WIMS)

Annual Report 2009

University of Michigan (Lead University)
Michigan State University
Michigan Technological University

Kensall D. Wise, Director
Yogesh B. Gianchandani, Deputy Director

MichiganEngineering

University of Michigan
College of Engineering

UNIVERSITY OF MICHIGAN

NSF Engineering Research Center for Wireless Integrated MicroSystems (WIMS)
2114 EECS Bldg.
1301 Beal Ave.
Ann Arbor, Michigan 48109-2122
734 764-3346 tel.
734 647-2342 fax
http://www.wimserc.org

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The WIMS ERC is grateful to the following member companies for their support during 2009.

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An Overview of the WIMS ERC

Microelectronics has revolutionized data processing, communications, and control; however, its impact elsewhere has been muted by the lack of devices for interfacing with the non-electronic world. Integrated sensors and actuators are needed for use in transportation, environmental monitoring, health care, biology, defense, infrastructure monitoring, automated manufacturing, and a variety of consumer products. They will form the front-ends of distributed information technology networks and bridges between electronics and the cellular and molecular worlds.

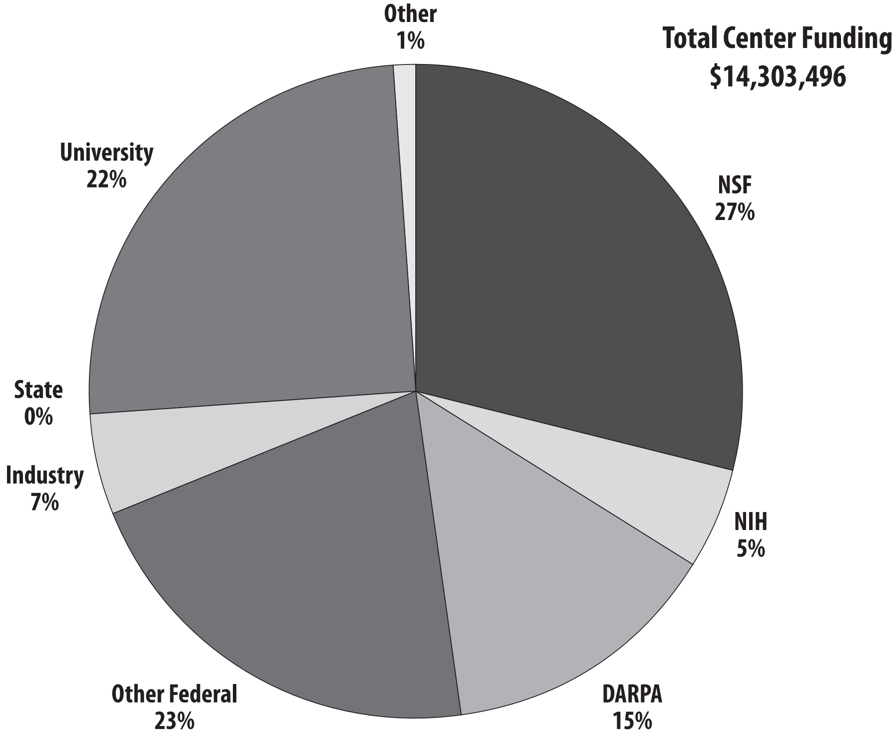
Since 1974, the University of Michigan has been a world leader in the development of integrated sensors, microelectromechanical devices (MEMS), and microsystems. Its research produced the first pressure sensors with on-chip readout circuitry (1976), the first silicon uncooled infrared detectors (1980), the first practical probes for exploring the central nervous system at the cellular level (1982), the dissolved-wafer silicon-on-glass process (1984), the first conductivity-based "microhotplate" gas detectors (1988), and the first programs in integrated sensing systems (1988) and wafer-level packaging (1989). In 1992, the dissolved-wafer process produced the first integrated gyroscope, and in 1994, Michigan reported the first integrated ring gyro. By the late-90s, multi-channel "Michigan probes" were changing research directions in the neurosciences and were being provided to investigators worldwide. Work in microfluidics had produced the first monolithic DNA analysis chip with electronic readout, and Michigan had emerged as a world leader in MEMS-based filters, antennas, and switches for telecommunications. The first tactical-grade ring gyros had been demonstrated along with accelerometers capable of $5\mu g$ resolution. Integrated sensors were becoming integrated microsystems, employing features such as digital compensation and built-in self-test to achieve high accuracy and high reliability at relatively low cost.

In 2000, the University of Michigan joined with Michigan State University and Michigan Technological University to form the Engineering Research Center for Wireless Integrated MicroSystems (WIMS ERC). This partnership has combined Michigan's programs in sensors and microsystems with Michigan State's expertise in diamond technology and Michigan Tech's capabilities in packaging, micromilling, and hot embossing. Funded by the National Science Foundation, with additional support from the three partnering core universities, other federal agencies, and a consortium of some twenty companies, the WIMS ERC has merged micropower circuits, wireless interfaces, MEMS, and advanced packaging to create microsystems that will have a pervasive impact on society during the next two decades.

The goal of the WIMS ERC is a *generic* platform for sensor-driven microsystems capable of sensing non-electronic variables with high accuracy, interpreting the signals, and then communicating the results over distances from a few centimeters to a few kilometers. The microsystems range in size from 10–20cm^3 (a small calculator or cell phone) to less than 1mm^3 (smaller than a single grain of rice). WIMS ERC projects are organized around testbed microsystems chosen to illustrate the range of requirements faced by microsystems generally. The first testbed is a family of neural prostheses aimed at treating disorders such as deafness, paralysis, epilepsy, and Parkinson's disease. Michigan pioneered neural interface technology, which is now the focus for efforts worldwide. In 2007, the first implantable multi-channel microsystem was realized for cortical recording. It consisted of thin-film electrode arrays along with integrated electronics for *in vivo* spike detection and wireless power/data transfer. During 2008, we began developing a new version of this system that adds the capability for multi-point stimulation while drastically reducing system size, and in 2009, we developed the world's most highly integrated electrode arrays and began applying them to mapping the auditory system at the cellular level, working in collaboration with the Kresge Hearing Research Laboratory. Such detailed studies of auditory physiology have never before been possible. A similar system architecture is also being used for a cochlear implant based on parylene thin-film electrode arrays. The arrays employ 32 sites on 250μm centers (consistent with 128-site human arrays) and monolithic backing structures that provide the compliance needed for deep insertions (a wide range of perceived pitch) and the curl needed to hug the modiolar wall (minimizing thresholds). In collaboration with the Kellogg Eye Center at the University of Michigan, an intraocular pressure sensor is also being developed for treating glaucoma. This system uses a new glass-in-silicon process technology to merge an embedded sub-microwatt processor, a power source based on energy-scavenging, a hermetically-sealed pressure sensor, and an ultra-wide-band wireless link in a volume of only 1mm^3. The second ERC testbed is a wristwatch-size environmental microsystem for monitoring pressure, temperature, humidity, and air quality. The heart of this system is an integrated gas chromatograph (μGC) targeted at rapid gas analysis with sub-part-per-billion sensitivity. We continue to make dramatic progress in this area, demonstrating the highest resolution ever reported for micromachined columns as well as prototype versions of the required preconcentrators, valves, detectors, and pumps. Applications in pollution monitoring, homeland security, and the detection of biomarkers in breath are being explored. We expect that when fully realized these gas analyzing microsystems will outperform their tabletop ancestors.

An important part of the WIMS ERC is its work to develop interdisciplinary educational programs in microsystems. This includes pioneering programs in K–12 education, led by Michigan State, that use MEMS to illustrate scientific principles and highlight the exciting careers that can be had in engineering. Some 72 pre-college short courses have enrolled over 2,700

2009 WIMS Center Funding Sources



students to date (51% underrepresented minorities and 43% women). Over 60% of these students have gone on to college majoring in science and engineering, helping address an increasingly critical national priority. At the college level, the multi-year Integrated Microsystems Enterprise program at Michigan Tech has now enrolled nearly 200 students, producing data-gathering modules that have been delivered to high-school students throughout the Upper Peninsula to facilitate a variety of exciting science experiments. Twelve new college courses in microsystems have been created by the ERC, including five at the University of Michigan that are the core of a Master of Engineering degree in Integrated Microsystems and a new Certificate program. The "*Introduction to MEMS*" course is now offered internationally. These innovative educational programs are helping train the engineering leaders that will be needed in the twenty-first century.

The Center is now home to 100 projects involving 33 faculty, 120 graduate students, 101 undergraduates, and over 30 staff distributed across eight universities. Funding for these efforts comes from a mixture of federal, industrial, and other sources, including the National Science Foundation (NSF), the National Institute of Standards and Technology (NIST), the National Institutes of Health (NIH), the Army Research Laboratory, and the Defense Advanced Research Projects Agency (DARPA). In addition to efforts at the three core Universities, important programs are underway at the University of Utah, North Carolina A&T University, Prairie View A&M University, Spelman College, and the University of Puerto Rico at Mayaguez. As the end of NSF support for the ERC approaches in 2010, we are moving actively toward a WIMS Institute centered in the University of Michigan College of Engineering but also extending across the University, forming additional collaborations with industry and academia on a global basis.

This Annual Report summarizes the activities of the WIMS ERC during 2009, including faculty activities, project descriptions, and publications. We hope you find it interesting.

Ken Wise

Director, WIMS ERC