# The Engineering Research Center for Wireless Integrated MicroSystems (WIMS)

*Annual Report 2008*

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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, 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.

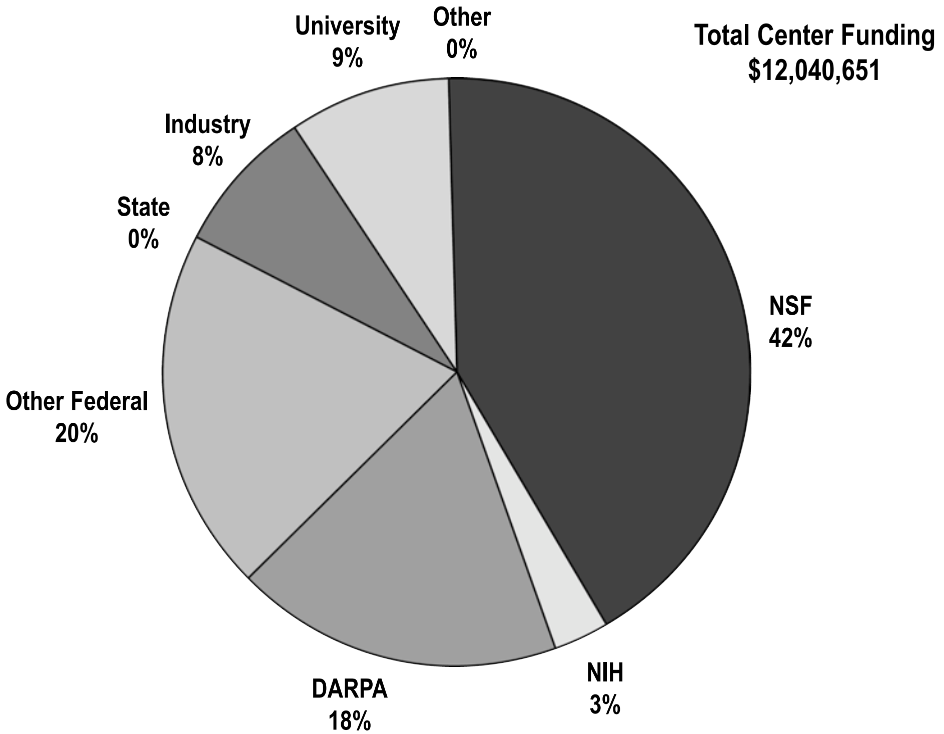
Since 1974, the University of Michigan has been a world leader in the development of integrated sensors, microelectromechanical systems (MEMS), and microsystems. Its research produced the first pressure sensors with on-chip readout circuitry (1976), the first silicon uncooled infrared detectors (1980), 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 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 over 7,500 of these devices have now been 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 combines 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 contributions 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 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) to less than 1mm$^3$ (much smaller than a single grain of rice). WIMS ERC projects are organized around two 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 intense efforts worldwide. In 2007, the first implantable multi-channel microsystem was realized for cortical recording, consisting 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 reducing system size and power dissipation. We hope to demonstrate this new system in animals during the coming year and have already begun using its highly integrated electrode arrays for mapping the auditory system in ways never before possible. A similar architecture is also being used for a cochlear implant based on parylene thin-film electrode arrays, some of which employ integrated backing structures to achieve the compliance needed for deep insertions and a wide range of pitch perception. Also in the biomedical microsystems area, an intraocular pressure sensor is being developed with sub-microwatt power dissipation. 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 micro gas chromatograph ($\mu$GC) targeted at rapid gas analysis with 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, detection of biomarkers in breath, and homeland security are being explored. Like the neural testbed, this area has become a hot topic worldwide, and we expect that when fully realized these microsystems will outperform their macro counterparts in many areas.

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 using MEMS to illustrate scientific principles and highlight the exciting careers that can be had in engineering. Nearly 60 pre-college short courses have now enrolled almost 2000 students to date, including many women and minorities. Most of these students have gone on to college at WIMS ERC universities, majoring in science and engineer-

*WIMS Center Funding 2008*



ing. At the college level, twelve new courses in microsystems have been created, 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. Our "Introduction to MEMS" course is now offered nationally and 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 95 projects involving 32 faculty, 102 graduate students, 61 undergraduates, and over 30 staff 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 Institutes of Health (NIH), 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 direct 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, extending across the University, and forming additional collaborations with industry and academia on a global basis.

This Annual Report summarizes the activities of the WIMS ERC during 2008, including faculty activities, project descriptions, and publications. We hope you find it interesting.

Ken Wise

Director, WIMS ERC