inventing the future

Getting Small

Cleveland Clinic researchers are using technology developed for aircraft and autos to miniaturize machines that go inside your body

BY ANTON ZUIKER

They are cutting-edge machines smaller than your fingernail. They have become crucial to the safe operation of bigger, complex machines like automobiles and airplanes. They're known as MEMS, short for microelectromechanical systems. And researchers at The Cleveland Clinic are actively working on ways to use MEMS technology for the most complex machine of all – the human body. Soon, a patient will not only arrive at the Clinic in a vehicle whose efficient operation is made possible by MEMS; when she goes home, she may well have such a device implanted to monitor her recovery.

The pursuit of the small could be the source of big innovations at the Clinic. And Shuvo Roy and Aaron Fleischman are the hospital's dream team, for their job is just that: dreaming up ways to apply MEMS technology to biomedical needs. "MEMS doesn't refer to one technology," says Roy. "It's a way of making things small and smart." Some of their creations will be as small as a grain of rice.

In their labs at the Clinic's Lerner Research Institute, Roy and Fleischman are working with a vascular surgeon to develop sensors for monitoring the minute pressure changes within an aneurysm. An implantable device, now in the works, will monitor the healing process after a spine fusion. Another effort is seeking ways to fit smart sensors onto surgical instruments, which could then tell whether a surgeon is cutting into soft tissue or a blood vessel. Indeed, MEMS for surgical tools and implantable devices are expected to have the most impact on hospital patients – not just at the Clinic, but worldwide.

Roy and Fleischman studied MEMS at Case Western Reserve University, where both earned doctorates in electrical engineering and computer science. As they were finishing their research at CWRU, each received multiple job offers and were set to part – Roy to the West Coast, Fleischman to the East. But then, Fleischman heard back from the Biomedical Engineering department at the Cleveland Clinic and, honoring his pact with Roy, asked the Clinic to hire his research partner as well. Since late 1998, the two have collaborated at the

BioMEMS Laboratory, a part of the Clinic's Lerner Research Institute. (The Institute annually spends $52.6 million on medical research.

The goal of the BioMEMS team is to bring cutting-edge technology developed for the aeronautical and automotive fields to medicine. Roy predicts their research and development of MEMS devices will have a global impact within 10 years.

Today's automobiles are equipped with MEMS accelerometer sensors that react swiftly to abrupt deceleration, triggering the inflation of airbags. Sensors near the engine measure pressure and temperature and monitor fuel consumption. Airplanes also rely on MEMS for many functions, from keeping the cabin pressurized to measuring air speed to detecting ice build-up on the wings.

Traditional electronics, even MEMS made of silicon, wouldn't last long inside a plane's gas turbine engines, which can heat to 1,500 degrees Celsius. The research that Roy and Fleischman did at CWRU looked for ways to develop new MEMS from materials, such as silicon carbide, that could be deployed inside such engines to monitor their performance, help ensure correct fuel-to-air ratios by gauging the chemical mix of the exhaust – and sound an alarm if a part begins vibrating more than it should.

Roy's research suggested MEMS technology for "smart" ice-detection systems, to warn pilots when an airplane's wings are beginning to freeze; his work was also used by NASA to keep the space shuttle from icing up in orbit. Roy helped the agency develop new sensors for its Mars probes, as they hurtle through the harsh environment of space.

The body is an even tougher setting to deal with, he says, because it has an active defense mechanism, in its immune system, that attempts to kill and destroy interlopers, whether they've been sent to hurt or heal (think of the 1966 film *Fantastic Voyage*). Because of this, BioMEMS devices must be coated with chemicals, biological material or polymers acceptable to the body. "These are not trivial problems," says Roy.

MEMS developers are also striving for safe methods of telemetry that can allow a device to send signals to a receiver outside the body. "We need to address [these methods], not only because the technology is cool, but because it must be safe for the patient."

The proximity of the Clinic, CWRU and NASA-Glenn Research Center creates a unique opportunity for collaboration here, says Roy, and thus gives Cleveland a leg up on research and development. CWRU's "clean room," a dust-free, temperature-controlled lab space, is where Roy, Fleischman and other members of the Ohio MEMS-net consortium assemble their devices. A spin-off division of NASA became the Glennan Microsystems Initiative, which aims, among other goals, to develop tools for minimally invasive surgery.

While most MEMS technology companies are based on the West Coast, Ohio might be considered the center of the BioMEMS field: Each September, Ohio State University hosts the pioneering BioMEMS and Biomedical Nanotechnology World Conference.

In a paper published last October in the journal *Neurosurgery*, Roy and Fleischman predicted the transformation of neurosurgery through MEMS technology. Possible applications include intracranial pressure-monitoring systems, spine monitoring systems and neural prostheses that could control epileptic brain activity. Similarly, says Roy, the deep brain stimulation surgery performed at the Clinic (*Live*, January 2001) might well evolve to include an implanted MEMS device to better control the involuntary movements of Parkinson's disease.

Even healthy persons might use MEMS someday. Already, such devices are being used in sleep movement studies, where subjects wear "tilt monitors" to record nighttime tosses and turns. Athletes might use these sensors to control their posture, says Roy. "Not all BioMEMS systems have to be implanted," he adds. MEMS sensors have been built into a sleep vest that can warn parents when a baby susceptible to Sudden Infant Death Syndrome has stopped breathing. A healthy John Glenn, when he returned to space a few years ago, swallowed a BioMEMS pill that, as it worked its way through his gut like the tiny sub in *Fantastic Voyage*, monitored the effects of weightlessness on his inner organs.

Other researchers are applying mathematical models of ants and other animals to BioMEMS. Swarm theories look at how creatures incapable of certain behavior on their own, but able, as a community, to operate in ways that clearly show intelligence, might lead to smart devices that mobilize a microscopic army to surround a tumor and destroy it. Drug-delivery devices could pinpoint areas of the body for drug therapy; one device can already dispense minuscule and precise doses of painkillers to treat lower back pain.

But the Cleveland Clinic, says Roy, will never be in the business of selling its MEMS products. "We figure out how to solve problems." A technology transfer office passes on prototypes to start-up companies.

A recent Clinic first – though it didn't come out of the BioMEMS lab – won national attention earlier this year, when Dr. Jay Yadav, an interventional cardiologist, announced the development of a thumbnail-size heart monitor that can be implanted in the heart wall. Using wireless telemetry, the device will relay information about pressure changes in the heart's chambers to a computer or monitor outside the body. Thus, technology that helps a plane engine run smoothly will help diseased hearts maintain optimal performance.

This R&D work isn't cheap, notes Roy. But, once a device has been designed and tested, millions can be turned out relatively inexpensively, much like the mass-produced microchips that run our personal computers. The Pittsburgh-based MEMS Industry Group estimates that, by 2004, there will be five MEMS devices for every person in the U.S., in our cars and our bodies. ■

Former editor Anton Zuiker covers the frontiers of technology and change for Live.