COVER STORY

Taking the Pain Out of Needles
Microneedles being developed by Georgia Tech offer a painless technique for delivering drugs. Thinner than a human hair, they could improve administration of existing medications and open the door for microprocessor-based, need-responsive delivery systems.
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Arrays of micron-scale "microneedles" offer new technique for drug delivery.

By John Toon

Most medical patients immediately associate needles with pain. But someday soon that may no longer be the case for patients who require small quantities of high-potency medications that must be taken through the skin.

These patients can thank Georgia Institute of Technology researchers who are developing "microneedles" much thinner than the diameter of a human hair. They could become the basis for a new pain-free drug delivery technique.

Arrays of the microneedles could improve administration of existing medications, allow development of new therapeutic compounds and open the door for microprocessor-based systems for delivering drugs continuously or in response to body needs. Produced with fabrication techniques originally developed for the microelectronics industry, the tiny needles can avoid causing pain because they penetrate only the outermost layer of skin, which contains no nerve endings.

Georgia Tech researchers believe their microneedles would be especially useful with large protein-based molecules, such as those produced through new biotechnology processes. Such drugs often cannot be taken orally, but must be administered frequently enough to make
traditional needle injection impractical or unpleasant.

"We envision microneedles being 'user-friendly' for patients, similar to the current transdermal patches that are in common use," says Dr. Mark R. Prausnitz, assistant professor in Georgia Tech's School of Chemical Engineering. "We expect in its final design that a microneedle array would be quite easy to use. Patients would just peel a liner off and stick it onto the skin. They would not see any needles, and there should be no pain associated with it."

Researchers presented details on the work earlier this year at the 25th International Symposium on Controlled Release of Bioactive Materials. The Journal of Pharmaceutical Sciences has accepted the researchers' paper for publication. In addition to Prausnitz, the research team includes Dr. Mark G. Allen, associate professor in Georgia Tech's School of Electrical and Computer Engineering, and graduate students Sebastien Henry and Devin McAllister.

The first use for the microneedle arrays would be for one-time injections. But Prausnitz believes the arrays could also be left attached to the skin to provide continuous administration of medication under the control of microprocessor-based equipment.

"This system could provide constant communication between the drug reservoir and the inside of the body," he explains. "Using a microprocessor to control a pump would allow the device to be programmed to deliver a drug at variable rates. The pump could also be controlled by the patient or a clinician."

If microneedle arrays were also used to withdraw bodily fluid for analysis, the microprocessor-based equipment could automatically administer drugs based on the body's need. Such a feedback system would be useful in regulating the blood sugar levels of diabetics, Prausnitz notes.

Using reactive ion etching microfabrication techniques originally developed for integrated circuits, the researchers have so far built solid silicon microneedle arrays 10 millimeters square. The existing needles are 150 microns long and leave holes about one micron in diameter when removed from the skin.

Prausnitz and Allen expect further development will reduce the length and diameter of the microneedles, make them hollow to increase the rate of drug delivery and permit mass fabrication of arrays at least a
centimeter square. If the diameter of the microneedles can be reduced, the holes they produce could be small enough to exclude bacteria, eliminating a potential source of infection.

Prausnitz expects that with high-volume production, the microneedle arrays would be competitive in cost with existing disposable drug delivery techniques.

"I do believe that microneedle technology offers great potential for delivering drugs through the skin, avoiding the barrier presented by the outer stratum corneum," says Dr. John C. Ansel, professor in the Department of Dermatology at Emory University School of Medicine and chief of Dermatology Services at the Atlanta Veterans Administration Medical Center. "The fact that it is virtually painless and does not pose a significant risk for infection is a major advance in this area of drug delivery."

The major challenge ahead, he cautions, will be to demonstrate in a clinical setting that this approach can effectively deliver therapeutic quantities of various drugs safely and economically.

Most drugs now are delivered orally, or through injections. To be orally administered, drugs must resist decomposition in the body's gastrointestinal tract, be readily absorbed through the intestinal wall and survive attacks by enzymes in the liver. Conventional hypodermic needles get drugs directly into the bloodstream, but cause pain, create the potential for infection and require medical training to use.

The skin can readily absorb a limited number of compounds, such as nicotine. Researchers are developing techniques for improving transdermal drug administration using chemicals, electricity and ultrasound to make the skin more permeable. But the microneedles could be both simpler and more effective for delivering drugs through the skin, providing the benefits of needle injection without the disadvantages of conventional needles, Prausnitz says.

By eliminating the constraints imposed by other delivery techniques, the microneedle arrays could give drug developers more freedom to select compounds without concern for how they might be administered.
Through limited laboratory testing, the researchers have demonstrated that their microneedles can significantly increase absorption of a drug compound through the skin by as much as 25,000-fold. Once the microneedles penetrate the outer layer of skin known as the stratum corneum, they can carry medications into deeper areas of the skin where the compounds diffuse, are absorbed by capillaries and carried into the bloodstream.

"We'd like to have needles that just penetrate that outer barrier, but not much farther, to avoid hitting nerves and causing pain," Prausnitz says. "Preliminary testing on humans has shown that insertion of microneedles into the skin does not cause pain."

Before the microneedles can be used to administer drugs to humans, the researchers must demonstrate their safety and effectiveness through extensive animal and human testing. Potential problems could arise, Prausnitz warns, if high levels of drugs under the skin cause local inflammation, or if the body reacts to the needle material itself.

Using existing silicon material, the tips of a very small number of the needles can break off in the skin. Researchers must also study whether the minute amount of silicon left behind may cause problems, or whether needle breakage could be eliminated with the use of other materials or improved needle design.

This work has been sponsored by Georgia Tech internal research funds.
The Life on Mars Debate

Citing growth patterns associated with non-biological origin, researchers dispute claims of "nanofossils" in Martian meteorite.

By Jane M. Sanders

It was about 13,000 years ago, according to carbon-14 dating, when a chunk of very old Martian meteorite landed in the Far Western Icefield of the Allan Hills Region of Antarctica. It inhabited that cold ground until 1984 when geologist Roberta Score found it and immediately realized it was unusual.

But the probably did not realize at the time that the rock would become the source of a long-running scientific debate — whether the meteorite contains evidence of life on the Red Planet.

In the latest volley of argument in the debate, a team of researchers, including a Georgia Institute of Technology adjunct professor, cited mineral growth patterns associated with non-biological origin in the meteorite.

In a paper published in the July issue of the journal Planetary and Space Science, the researchers report evidence that these crystals were formed by epitaxial processes at temperatures that were likely too high for biological organisms to exist. The findings cast new doubt on claims by the JSC researchers (led by Dr. David S. McKay) that the so-called "Mars rock" contains nanofossils.

Using transmission electron microscopy, the Georgia Tech researchers discovered that magnetite crystals in the meteorite, known as ALH84001, were actually intertwined with carbonates as opposed to being clumps of crystals as the JSC researchers thought. "This process is an order of magnitude more complex than the JSC researchers thought," Bradley says.

Epitaxial formation rules out intracrystalline precipitation of the magnetics by Martian organisms, a theory hypothesized by NASA scientists who believe the meteorite contains nanofossils, says Dr. John Bradley, an adjunct professor in Georgia Tech's School of Materials Science and Engineering.

"Early skepticism has evolved into international consensus among meteoriticians and planetary scientists, with the exception of the JSC team, that this rock does not contain Martian nanofossils," Bradley says.

Bradley conducted the current and previous research with Drs. Hay McSween of the University of Tennessee in Knoxville and Ralph Harvey of Case Western Reserve University in Cleveland, Ohio. In their first paper, the researchers used transmission electron microscopy (TEM) to discover that elongated forms in the meteorite contained crystalllographic defects that look like a spiral staircase, Bradley says. These defects, called screw dislocations, twist in a way that results when different high-temperature growth mechanisms are in play.

The JSC team, using field emission scanning electron microscopy, had claimed that these worm-like, elongated forms were nanofossils. If true, they should contain internal "daisy chains" of aligned magnetite crystals called magnetosome. Bradley's team found elongated, rod-shaped magnetites called "whiskers" instead. But JSC researchers countered that the differences resulted from scientists using different microscopy techniques and thus seeing different objects.

So Bradley's team duplicated the JSC researchers' scanning electron microscopy (SEM) procedures at Georgia Tech using the same metal coatings, gold and palladium, to make the specimen surfaces conductive. With SEM, Bradley's team found the same worm-like objects. Then, however, they rotated and tilted the meteorite specimen to get a different microscopic angle. From that perspective, the worm-like objects appeared to be inorganic mineral layers or protruding ledges. Their worm-like segmental structures were actually artifacts of the gold and palladium coatings on the specimens. "They looked like the edge of a stack of copy paper in which a few pages are sticking up on edge," Bradley says.

In a rebuttal paper accompanying the Bradley team's 1997 article in Nature, the researchers countered that these non-biological worm-like structures are present in the meteorite, but that their nanofossils are "deficient."

"It's like looking for worms in a plate of spaghetti," Bradley says. "If the worms look like spaghetti noodles and they're not wriggling around, how can you be sure they're worms and not noodles?"

In the current paper, researchers focused on epitaxially grown magnetic single crystals. They are key indicators of the geological and thermal history of the surface fracture zones of the Martian rock, they say. Magnetic crystals, apparently formed by several different high-temperature growth mechanisms, are found in several distinct mineral settings in this meteorite.

With regard to whiskers, the researchers cite various evidence of epitaxial crystal growth and high-temperature origin of magnetites in the meteorite. TEM techniques allowed researchers to view the well-defined spatial orientation relationship between magnetic and carbonate crystals. Epitaxy can occur if two similarly patterned lattice planes of crystal structures are parallel. Previous studies have shown that the ideal lattice "misfit" between two crystal structures should not be more than 15 percent. In this case, the lattice "misfit" was only 11 to 13 percent, which is ideal for epitaxial growth, Bradley says.

Furthermore, many of the epitaxially formed magnetite whiskers in the meteorite appear to be free of internal defects, the researchers say. Such is the typical case of crystals formed at elevated temperatures, while those grown at lower temperatures tend to have high densities of internal defects.

Also, researchers found epitaxially formed magnetic crystals in mineral specimens from volcanoes in Indonesia and Alaska. These crystals formed at temperatures in excess of 600 degrees Celsius, researchers say. They compared these to the magnetites in the meteorite because volcanoes also exist on Mars. The comparison provided further evidence of a high-temperature origin, Bradley says.

But perhaps the most startling evidence of all were worm-shaped objects within the fracture zones of the meteorite. They looked like biomineral halos and, like bacterial colonies, the authors explained, "We propose that these structures were produced by a bacterial "cloud" from a volcanic eruption on Mars." These objects were deposited from fluids saturated with carbon dioxide at temperatures higher than 100 degrees Celsius, a temperature around which microorganisms flourish here on Earth.

"It's like looking for worms in a plate of spaghetti," Bradley says. "If the worms look like spaghetti noodles and they're not wriggling around, how can you be sure they're worms and not noodles?"

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imaging in the electron microscope. (Similar worm-like structures have recently been observed in lunar rocks and, because the Moon is sterile, nobody is arguing that they might be the remains of lunar organisms.)

It's been almost two years since the press conference. The claims in the paper that started it all have been thoroughly examined by the scientific community at large. A quiet consensus has emerged that the ALH84001 meteorite contains no evidence of past Martian life. Apparently the scientific process of checks and balances is alive and well. Now the focus has shifted to Mars itself. For better or worse, the ALH84001 debate has raised the ultimate cosmological question, "are we alone?"

It may require several missions (and perhaps even a drilling rig on its surface) to unambiguously answer the question of whether life exists or ever did exist on the Red Planet. An armada of Mars probes and landers are in the works; NASA has created the new Astrobiology Institute at its Ames, Calif., facility, which was rumored to be up for closure; the public appears interested; and Congress has not yet blinked.

Many in the meteoritics community (most of us are chemists, geologists or physicists) are "going biological" over the prospect of a stream of new research dollars for updating laboratory equipment and support for a new generation of planetary biologists.

Mr. Goldin was right, it is an exciting time to be alive.
Technology Transfer

Program moves faculty research into commercial realm.

By Rick Robinson

Once academia regarded it with misgivings. Now, because of it, researchers and universities are receiving substantial financial support, and new jobs and businesses are being created.

"It" is technology transfer — bringing university research to the commercial realm. Each year U.S. colleges and universities emphasize it more.

A major player in Georgia's technology-transfer effort is the Advanced Technology Development Center (ATDC). Each year, under the Faculty Research Commercialization Program, ATDC gives grants that help faculty from Georgia's six top research schools — Clark-Atlanta University, Emory University, Georgia State University, Georgia Institute of Technology, Medical College of Georgia and University of Georgia — move their research into the marketplace.

The one-year grants of the Faculty Research Commercialization Program (FRCP) are relatively modest, ranging from $30,000 to $100,000. But such targeted funding can have a dramatic effect on a researcher's prospects of producing a marketable invention.
Dr. William Ribarsky, a senior research scientist with Georgia Tech's College of Computing, says his 1998 FRCP grant let him convert existing terrain-visualization software to PCs — in time to take advantage of rapid growth in the 3-D video capability of PCs.

"When you get money like this at opportune times, you really can develop some capabilities that you couldn't otherwise," Ribarsky says.

**Licensing Versus Startups**

Over the past seven years, some 45 FRCP-funded projects have resulted in brisk business between Georgia universities and private enterprise — a welcome change from earlier times, says Wayne Hodges, director of ATDC.

Hodges recalls that until FRCP started in 1992, there was little interaction between faculty members and ATDC. What was needed, he says, was "a mechanism to encourage faculty members to look at commercialization opportunities. . . . And once they had something, the FRCP provided money to use for proof of concept."

Technology transfer generally takes one of two roads: technology licensing or start-up companies. From the university standpoint, each approach has its strong points. Technology licensing usually involves an agreement with an existing corporation; for both university and researcher, such a deal is easier, and some return is assured. With a start-up company, there is more risk, but high potential rewards.

In the FRCP's early days, the issue of technology licensing versus creating start-up companies was not critical, Hodges says. "We weren't as concerned about whether it was licensed or whether a new company was started — we were interested in encouraging the concept of commercialization."

But that is changing.

**A Trend Toward Startups**

To date, the majority of FRCP-funded, tech-transfer successes have involved technology licensing. Such licensing agreements are, of course, very welcome to schools in Georgia and elsewhere. In fact, U.S. colleges and universities received $365 million in licensing revenue in 1996, according to the Association of University Technology Managers.

But seven FRCP projects have thus far resulted in actual start-up companies, with two more projects showing immediate promise. Officials in Georgia academia and government like those numbers and are eager to see them climb.
A major motivating factor is the potential economic impact of startups. In the past, Hodges explains, universities tended simply to license technology and then measure their success by revenue dollars received. Increasingly, many schools — and the states that help fund them — are looking at success more in economic development terms.

"The states have discovered that they've got this huge economic driver in the form of universities, and they want to take advantage of that," Hodges says. At the same time, many university research budgets are expanding as corporations downsize their applied research staffs and outsource such work to the schools, he adds.

For universities, the start-up company route is admittedly riskier and more difficult to make successful, but the potential rewards are much greater, says Dr. Charles Liotta, Georgia Tech's Vice Provost for Research and Dean of Graduate Studies. "When you license something, you get a certain number of dollars as reward. But when Georgia Tech takes equity in a start-up company, and then that company becomes large and profitable down the road, Georgia Tech will profit from it, and so will the economy."

Liotta believes a state university has a responsibility to foster the state economy. "Universities in general, and Georgia Tech in particular, have come to feel very strongly that they are part of the local community — that they have taken from the local community and they want to give back," he says.

**Business Plan Required**

Last year, for the first time, the FRCP program encouraged its grant recipients to be entrepreneurial, and several were offered a degree of business advice or assistance.

This year, fiscal 1999, those funded are expected to try to launch start-up companies. In fact, researchers had to submit business development plans along with research proposals just to be considered for FRCP funding.

"We want to serve as a 'venture catalyst,' " says Hodges. "In addition to licensing opportunities, we now look much more seriously at potential company startups. This approach will further support ATDC's mission of formation and growth of advanced technology startups."
For 1999, the FRCP program has teamed each grant recipient with a business advisor — possibly an industry partner, but in most cases a group from a university business school. The partner will develop a business plan and do market research for the fledgling company. "Now, we are more fully leveraging not only the technical expertise in the University System, but also the talent inherent in the business schools," Hodges says.

Barry Rosenberg, director of technology licensing for Georgia Tech, cautions that universities have to think carefully about where and how they place their support.

"It needs to be recognized that not every technology is suitable for a startup," he says. "It has to be an appropriate technology." Wayne Hodges agrees, explaining that a thorough assessment process, examining a technology's market potential and risks versus returns, is a critical element in the decision to nurture a startup.

Georgia universities continue to offer extensive funding sources to aid technology licensing efforts, such as the Georgia Tech Research Corp. and the technology licensing offices of the other five Georgia Research Alliance universities, Hodges says.

A New Way of Thinking

Part of the task of increasing research commercialization lies in addressing how academic culture regards it. While academia has accepted the concept of universities getting income from technology transfer, the idea of researchers holding equity in their own companies is among the unresolved issues involving entrepreneurial research grants. Groups at Georgia Tech are now re-examining the school's conflict-of-interest policy, which currently bars researchers who own equity in a company from doing research for that company as an employee of the university.

One concern is that research could be skewed by those who stand to make money from it. For entrepreneurial research to work, many believe that universities must put mechanisms in place to make sure that research is held sacred on every level, Hodges says.

Unquestionably, pressure will continue to mount for states and universities to encourage research commercialization. Among the recipients of the $365 million that universities received from patent licensing in 1996, there were some big winners, according to the Association of University Technology Managers. Some 40 percent of the money went to the three leaders: the University of California system with $63.2 million; Stanford with $43.8 million, and Columbia with $40.6 million. While such sums do not defray the billions universities spend on research, they're substantial enough that no school wants to walk away from them.
"The ivory tower concept in the U.S. has diminished rapidly since 1982," says technology-licensing director Rosenberg. He explains that many, if not most, university-developed inventions derive from federally funded research. In 1982 Congress changed the rules for such research, giving universities rights to their inventions (while the federal government retained royalty-free use of the technology).

"That freed up the relationship between government and industry," he says. "Before 1982, I understand that very little government-funded technology moved into industry."

In 1996, Georgia Tech ranked 33rd in tech-transfer income out of 131 institutions surveyed that year by the Association of University Technology Managers. Rosenberg observes that many universities ranked above Tech have medical schools and derived most of their income from life sciences technologies. Agricultural inventions also perform well for some research universities, he adds.

**A Quickening Pace**

The pace of Georgia startup success stories is increasing. In the past two years, four FRCP-aided start-up companies have come out of Georgia Tech, and at Emory the FRCP has fostered a startup and helped an existing company expand.

One company that helped shape the FRCP's current direction is Virtually Better, formed by Dr. Larry F. Hodges, a professor in the College of Computing at Georgia Tech, and by Dr. Barbara Rothbaum, a professor of psychiatry at the Emory University School of Medicine. Recipients of a 1997 FRCP grant, Hodges and Rothbaum received business assistance from three executive MBA Emory students who committed to Virtually Better via a field study coursework requirement. (The virtual reality research that led to the company is a joint project between Tech and Emory, and both schools hold an equity position in the new firm.)

Enzymatic Deinking Technologies (EDT), in Norcross, Ga., is an FRCP-aided company founded in 1994. Based on technology developed by Dr. Karl-Erik Eriksson of the University of Georgia, EDT now employs 20 people who work in research and development, manufacturing, marketing, sales and technical service, says CEO Jim Tausche, who co-founded the company along with Eriksson and Jan Yang. The company's business is now much broader than the enzymatic deinking application that started it, Tausche says.

Dr. David N. Ku received a $49,000 FRCP grant in fiscal 1998 that helped him kick off his new company, Restore Therapeutics, which markets a patented new biomaterial. Ku, who holds a medical degree from Emory University and a doctorate in aerospace engineering from Georgia Tech, sees a significant role for his carbon-based biomaterial invention in orthopedic and other medical restoration work. As director of the vascular
laboratory at Emory as well as a professor of mechanical engineering at Tech, Ku also foresees a role for his invention in heart surgery.

"The grant came at an opportune time," Ku says. "It helped us deal with staffing changes ... and helped us produce the biomaterial in a much more efficient way, with new molds and equipment. We have been able to show excellent bio-compatibility using these funds."

For Dr. John D. Muzzy, a chemical engineering professor at Tech, his 1998 $40,000 FRCP grant was important in starting a new company called Georgia Composites. The business markets a mat-like recycled material made of glass-reinforced polypropylene carpet waste. It can replace expensive "virgin" polypropylene in various fields, including automotive parts.

Simply having the grant in hand "gave us a lot more credibility," Muzzy says, when his group approached industry with his invention. "People who we met thought, 'Well, they've gone through this approval process — they must really have something.'"

Moreover, the grant money "really helped us adapt the technology as we started working with commercial equipment," he says.

Georgia Composites now has a marketing office at the ATDC building on the Georgia Tech campus, and the company has partnered with the Astechnologies Co. of Roswell, Ga., to produce the new product.

Recently, seven researchers — three from Emory, two from Georgia Tech and two from the University of Georgia — were awarded 1999 FRCP grants totaling $325,000. Each researcher has a business advisor, and hopes are high.

"If we can find additional funding, we want to increase substantially the number of projects we're funding," says Hodges, director of ATDC. "I believe there is real opportunity for growth in this program - because it will help realize the state's economic development goals."

For more information, you may contact Wayne Hodges, Advanced Technology Development Center, Georgia Institute of Technology, Atlanta, GA 30332-0390. (Telephone: 404/894-5217) (E-mail: wayne.hodges@edi.gatech.edu)
A black liquid occasionally bubbles out of the ground on a large Taylor Street plot of land in Augusta, Ga. Black gold? Texas tea?

No such luck for the residents of this inner city urban community. Instead, this black liquid is coal tar, the contaminated remnant of a former manufactured gas plant that closed more than four decades ago. Since then, coal tar has seeped into the soil and groundwater on this site and into the surrounding area, greatly concerning community residents.

Meanwhile, residents of Boulevard Heights in southeast Atlanta are dealing with raw sewage spills into a creek, a host of old vacant buildings and abandoned lots that have become illegal dumping grounds.

And to the south, residents in the town of Tifton, Ga., are concerned about a former fertilizer plant that has been dubbed the state's largest, most contaminated Superfund site.

"The need is clearly there in Georgia, and throughout the country. Communities dealing with these complex environmental issues need independent, free or low-cost technical expertise to
help them make informed decisions," says Eliesh O'Neil Lane, a research scientist at the Georgia Tech Research Institute (GTRI). "And research universities, such as Georgia Tech, are strategically positioned to offer that help. We are a civic institution established to develop substantive knowledge, practical skills and social attitudes responsive to society."

In short, it is part of the Georgia Institute of Technology's mission to serve the community by promoting the general welfare of Georgia through science, engineering, and industrial research. It is now stepping up that commitment with the Initiative for Community Outreach, Research and Education (ICORE), funded by GTRI and additional funds to address specific projects.

**Service Mission**

ICORE, formed in 1996, grew out of an earlier Tech initiative to address public health issues and to redevelop brownfields, which are abandoned properties with either a real or perceived environmental and/or health threat to the surrounding community. Now, Lane and GTRI senior scientist Bob Schmitter co-direct ICORE. It seeks to build a community-integrated research and development program that addresses the problems, including brownfields, of Georgia communities. Basically, ICORE coordinates the transfer of Georgia Tech's technology and wide variety of expertise to neighborhoods in need. It does this through outreach, research and education activities that emphasize community participation.

"We are developing a multidisciplinary program to come up with solutions to problems in communities today. We are working side by side with community residents to do this," Lane says.

Both Georgia Tech President Dr. Wayne Clough and GTRI director Dr. Edward Reedy endorse ICORE. "We support ICORE because it is a perfect example of how pairing Georgia Tech's expertise with a community project can solve infrastructure problems that can advance the capabilities of a community," says Andrea Ashmore, special assistant to the president.

Because of Georgia Tech's breadth of expertise on campus, it is a perfect place to encourage such programs as ICORE, Reedy says. ICORE draws upon the resources and expertise of numerous Georgia Tech units, including GTRI's Safety, Health and Environmental Technology Division, the School of Public Policy, the College of Architecture's City Planning Program, the School of Civil and Environmental Engineering, the Economic Development Institute and the Center for Sustainable Technology.

"Many issues that currently affect our communities cannot be solved by one perspective
alone," Reedy says. "For example, issues such as brownfields are not merely environmental in nature. These potentially contaminated tracts of land are also plagued with issues such as crime, lack of economic development and opportunity, and environmental injustice. Through programs such as ICORE, researchers from all areas of campus can come together to identify holistic multidisciplinary solutions to such problems."

**Outreach and Education**

But the task is not easy. ICORE representatives sometimes face a skeptical public when they get involved in community issues.

So, Lane says: "We've been very blunt up front in telling them we are here to offer our expertise to help the community solve their issues of concern. We're not in it for the money or the glory. Public service is part of our campus mission, and we enjoy it. Gradually, a partnership is built on trust and openness."

A good example of such a relationship is ICORE's work on the revitalization of the Reynoldstown, Peoplestown and Martin Luther King (MLK) Jr. Historic Districts in Atlanta. This two-year project, which began in January, is funded by a grant from the Environmental Protection Agency's Office of Environmental Justice. Through a memorandum of agreement with local community development organizations, Georgia Tech personnel are identifying brownfields in these areas, conducting site assessments, identifying contamination, training community residents in pollution prevention and suggesting potential future uses of revitalized brownfields.

"We are experiencing a wonderful partnership with the Georgia Tech Research Institute," says Ute Banse, an architect/planner for the Historic District Development Corporation (HDDC), a non-profit organization active in the MLK Jr. Historic District. "Georgia Tech's lead and asbestos program approached us about using some of our older homes, which still have lead paint, as class and testing sites. For HDDC it is a big help to get some lead testing and related professional assistance at no cost."

Meanwhile in southeast Atlanta, the neighborhood of Boulevard Heights has welcomed
Georgia Tech's involvement in solving its pollution problems. Raw sewage spills from water treatment facilities have contaminated nearby Intrenchment Creek, fouling the air and water. The community, Georgia Tech and local businesses are establishing a partnership to evaluate pollution issues and develop a pollution prevention program with the underlying goal of revitalization.

Other projects under the umbrella of ICORE are two EPA-funded technical assistance projects in Augusta, Ga., and Tifton, Ga. Both cities have heavily contaminated former industrial sites that have caused considerable community concern, Lane says. Through the Technical Outreach Services for Communities, a program of the EPA's Hazardous Substance Research Centers, Georgia Tech personnel are providing independent technical information to guide residents through the environmental cleanup and site reuse processes. Specific assistance includes interpretation of technical documents, speaking at community workshops and training community leaders in conflict resolution.

In Augusta, a former manufactured gas plant site, which closed in 1955, is contaminated with benzene, xylene, naphthalene — all coal tar components. Some of these contaminants have also spread into the soil and groundwater of the neighboring community. Cleanup work began in early 1998, and soon thereafter Georgia Tech representatives met with community activist Charles Smith. Now they are providing technical assistance to the community.

In Tifton, a former fertilizer production site is contaminated with KO61, a steel manufacturing byproduct that contains heavy metals such as cadmium, chromium and lead. In 1991, state officials discovered the fertilizer plant was not in operation and that hazardous waste flue dust was dumped on the ground and abandoned at the plant site and a nearby farm. Cleanup began in 1993 and took two years. The plant site and surrounding areas, including a local cemetery, continue to be monitored, and residents remain concerned, says Shirley Jordan, executive director of the non-profit People Working for People. Lane and Schmitter have explained the cleanup and testing to residents and were recently available to answer their questions at a community meeting.

Research

The third component of ICORE is research, which is gradually developing as Georgia Tech establishes partnerships with communities. "This is socio-technical research, a constantly emerging field," Lane says. "It is the human side of technology development and scientific research."

One promising area of research is the redevelopment of former Department of Defense and Department of Energy sites that have been contaminated through many years of operation, Schmitter says. DOD and DOE are long-time clients of GTRI, and assisting them in this new arena will provide a new dimension to the capabilities GTRI can offer to
the federal departments, he adds.

Three faculty members serving as ICORE steering committee members are also interested in ICORE-related research, as well as service possibilities.

"I firmly believe that for us in an academic institution like Georgia Tech, so close to an urban environment full of challenges and opportunities, this type of initiative is a gold mine with tremendous intellectual, scholarly and, more importantly, social value," says Dr. Jorge Vanegas, an associate professor in the School of Civil and Environmental Engineering.

Dr. Larry Keating, an associate professor in the College of Architecture, has long been involved in community-based policy research in Atlanta. Now, he is looking forward to having a broader spectrum of expertise available to areas where he has already established a presence. "There are so many issues to address — poverty, racism, environmental problems, brownfields, lead-based paint in housing, and toxic waste dumps," Keating says.

In the School of Public Policy, associate professor Dr. Richard Barke is bringing to ICORE his expertise on stakeholder participation in scientific and technological policy disputes. "ICORE offers an opportunity to put into practice some new ideas about closing the gap between the technology haves and have-nots," Barke says. "... It also could uncover new research opportunities as we identify gaps in our understanding of technical and policy problems."

**Making a Difference**

Despite the considerable environmental, economic and social hurdles to cross, ICORE representatives believe they can make a difference in many communities, Lane says. Though she cautions that Georgia Tech's efforts must stay focused on long-term solutions.

"True revitalization is an economic, environmental, physical and sustainable revitalization of these areas that not only changes the look of the community, but its perception of itself and its long-term viability," Lane says.

Vanegas echoes her emphasis on the long term. He adds, "From economic development to enhancement of the built environment, all is possible."

**For more information**, you may contact Eliesh O'Neil Lane, Georgia Tech Research Institute, Georgia Institute of Technology, Atlanta, GA, 30332-0837. (Telephone: 404/894-8044) (E-mail: eliesh.lane@gtri.gatech.edu); or Bob Schmitter, Georgia Tech Research Institute, Georgia Institute of Technology, Atlanta, GA, 30332-0837. (Telephone: 404/894-8064) (E-mail: bob.
A Sustainable Biosphere

Scientists study salt marsh to understand global warming.

In a place where sea meets land, a seemingly endless stretch of grass fluctuates constantly as it contends with the relentless flow of the ocean. In this zone is located the salt marsh, one of the most fertile, dynamic natural ecosystems in the world, teeming with plant and animal life.

This environment is the object of an important interdisciplinary study at Sapelo Island, Ga. Here, scientists associated with the Georgia Institute of Technology have been trying to understand the biogeochemical processes at work in the marsh — that is, the exchange of biogeochemical elements such as carbon, phosphorus, nutrients and metals between living and non-living components of the environment. They want to know how these processes relate to the productivity, faunal activity and hydrology of the marsh system. An understanding of these relationships is crucial to predicting the effects of global warming on the coastal environment.

The scientists presented their work earlier this year at a joint meeting of the Ecological Society of America and the American Society of Limnology and Oceanography. The conference was titled "Land-Water Interface: Science for a Sustainable Biosphere."

"We had among some of the highest rates of organic matter decomposition ever measured in marine
systems," says senior author Dr. Joel Kostka, a Georgia Tech adjunct professor and researcher at the Skidaway Institute of Oceanography, a research unit of the University System of Georgia. One reason for the higher than expected results may have been the length of time the study was conducted; very few studies have looked at decomposition rates by microorganisms over a two-year study period, as it was in this study, Kostka explains.

Researchers believe microorganisms in salt marsh sediments play a significant role in the cycling of materials in and out of the ecosystem. By examining microorganisms, such as bacteria, which occur in all of the sediments in the salt marsh, the scientists hope to determine what drives the microbial activity. By looking at the total marsh environment across several seasons, they are learning how nutrients flow through the system.

Numerous variables affect microbial activity in the soils, says Dr. Philippe Van Cappellen, an associate professor in Georgia Tech's School of Earth and Atmospheric Sciences. He and Tech graduate student Alakendra Roychoudhury are working with Kostka on this continuing study. Those variables include temperature, inundation by the tides, plant composition in the area, the hydrology of the area, the input of organic material, runoff from the adjoining land area and mixing of the sediment.

Along with the microorganisms at work in the marsh, larger forms of animal life also affect nutrient cycling in the marsh. Large populations of fiddler crabs that inhabit the mud flats in the salt marsh can greatly enhance productivity in the area, Koskta says. Their burrows, which can extend 20 centimeters into the soil, allow salt water to infiltrate the mud, which in turn introduces oxygen into the sediments.

"The injection of oxygen changes microbial activity," Kostka says, "and that changes chemical and nutrient releases."

The research was funded by Georgia Tech's Earth and Atmospheric Sciences program, the Georgia Sea Grant College program, the Office of Naval Research, the Skidaway Institute and the National Science Foundation through an initiative aimed at encouraging interdisciplinary studies.

— Patricia J. West

For the full-text news release, see www.gtri.gatech.edu/res-news/WARMING.html. For more information, you may contact Dr. Joel Kostka, Skidaway Institute of Oceanography, 10 Ocean Science Circle, Savannah, GA 31411. (Telephone: 912/598-2395) (E-mail: joel@skio.peachnet.edu); or Dr. Philippe Van Cappellen, School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta, GA 30332-0340. (Telephone: 404/894-3883) (E-mail:...
**Tiny Computers Of Carbon?**

Nanotubes that conduct without heating could be the basis for new electronics.

Researchers are now one step closer to a practical application for electron wave effects in extremely small-scale circuits.

In a paper published in the June 12 issue of the journal *Science*, a team of scientists from the Georgia Institute of Technology reported observing ballistic conductance — a phenomenon in which electrons pass through a conductor without heating it — at room temperature in multi-walled carbon nanotubes up to five microns long. (A micron is a millionth of a meter.)

Structures of that size operating under those conditions could one day be useful for fabricating ever-smaller electronic devices. Their ability to conduct relatively large currents without harmful resistance heating would allow use of the very small conductors.

"This is the first time that ballistic conductance has been seen at any temperature in a three-dimensional system of this scale," says Dr. Walt de Heer, a professor in Georgia Tech's School of Physics. "There would be interest in this for ultra-small..."
electronics because it shows that you can constrain current flows to narrow areas without heating up the electronics. It also introduces a new stage of electronics in which the wave nature of electrons becomes important."

In a simple experimental design using the positioning equipment of an atomic force microscope, the researchers found the electrical resistance of the multi-walled carbon nanotubes remained constant — regardless of their length or width. This quantum conductance is not seen in larger structures.

"In classical physics, the resistance of a metal bar is proportional to its length," says Dr. Z.L. Wang, a professor in Georgia Tech's School of Materials Science and Engineering. "If you make it twice as long, you will have twice as much resistance. But for these nanotubes, it makes no difference whether they are long or short because the resistance is independent of the length or the diameter."

The researchers hope to follow up their work with measurements of other predicted device properties of the nanotubes. The research is sponsored by the U.S. Army Research Office and the Georgia Tech Foundation.

— John Toon

For the full-text news release, see www.gtri.gatech.edu/res-news/QUANTUM.html. For more information, you may contact Dr. Walter de Heer, School of Physics, Georgia Institute of Technology, Atlanta, GA 30332-0430. (Telephone: 404/894-7880) (E-mail: deheer@electra.physics.gatech.edu); or Dr. Z. L. Wang, School of Materials Science & Engineering, Georgia Institute of Technology, Atlanta, GA 30332-0245. (Telephone: 404/894-8008) (E-mail: zhong.wang@mse.gatech.edu)

Prescription: Realism

Researchers develop realistic flight simulator to test pilot impairment.
"Your workload inside the cockpit can be very intense."

These words from U. S. Army Capt. Scott Rauer, pilot and former graduate student at the Georgia Institute of Technology, are a model of understatement. Modern military jet aircraft are the ultimate challenge in human/machine interaction. Piloting, navigation, communications and weapons management can present pilots with "information overload." Thus, pilots must avoid anything that diminishes their mental edge.

Yet military doctors face an unusual dilemma in treating pilots: the extensive array of the modern pharmacopeia. Which drugs, both prescription and over-the-counter, can affect pilot performance? How much of a given drug can a pilot take before becoming impaired?

Obviously, a flight simulator would be the safest way to measure the effects of medication use among pilots. But conventional flight simulators are not designed for drug impairment studies, and they are not easy to reconfigure. Also, the availability of flight simulators is limited, and time on simulators is expensive. So how do you test for the effects of medication? The answer — recently developed by NTI Inc. of Dayton, Ohio, with assistance from GTRI researcher Dr. Brian Stevens — is a very realistic flight simulator that will record the needed data and run on a relatively inexpensive, off-the-shelf personal computer.

"The part that makes it more realistic is very high fidelity aircraft mathematical models and aerodynamic data, many tables of aerodynamic data," says Dr. Brian L. Stevens, a GTRI senior research engineer and principal investigator for the NTI contract. Rauer, with his pilot training and relevant aerospace engineering coursework, was the ideal graduate research assistant. He assisted in the model development.

The mathematical models use the data — some of it from NASA and the U.S. Air Force — to provide realistic aircraft dynamics in various flight conditions. These conditions range from combat maneuvering to flying a precise course in severe weather or turbulence. The mathematical models coupled with computer graphics and a set of flight controls — stick, throttle and rudder pedals — provide a realistic flight simulator.
The heart of the simulation is a computer model of the F-16 fighter jet. Stevens developed the model for a book on aircraft controls and simulation. Subsequently NTI contracted with Stevens to develop the aircraft flight models for the simulator program for use in tests of how pilots react to unusual circumstances.

The program, known as the Situation Awareness Flight Test Evaluator (SAFTE), uses Stevens' computer model as its core. The graphics in the program provide an area of about 60 by 150 nautical miles in which aircraft can fly. This area includes mountains, four towns, a river and other topographical features suggested by a former F-16 pilot consulting for NTI. The program combines all the data and graphics and can operate in as little as two-millisecond steps, making the simulation extremely realistic — especially in comparison with most personal or game simulations, which operate in 50-millisecond steps.

NTI used the simulation at the University of North Dakota on 100 subjects who were trained to fly the simulator, and then tested. Yet, there were limitations to the simulation. Time and cost constraints prevented the graphics from being very realistic. Data on a tricycle landing gear, used by the F-16 and most fighter and trainer aircraft, were not readily available, so researchers substituted a bicycle landing gear.

Perhaps the most significant limitation was the power of the computers on which the program runs. Researchers ran the program on two personal computers — one dedicated to graphics and one to run the flight calculations that made the program realistic. To do this required the team to write a special real-time "executive program" to control operations.

Subsequently, NTI developed its Flight Performance Assessment Simulation System (FPASS) to evaluate the effects of medications on U.S. Air Force pilot performance. That development gave Stevens the chance to upgrade and expand the flight simulation. In addition to the F-16, it now includes the T-1 and T-38 training aircraft, and each has a tricycle landing gear. Perhaps more importantly, it allows simulation modifications that take advantage of advances in personal computer technology.

"This effort brings everything in line with current commercial standards," Stevens says. NTI modified the program to run on the Windows '95 operating system on a single 300-megahertz computer. Now, the simulation can use Microsoft scenery files, providing more realistic graphics and allowing the simulation to use thousands of already available files. In addition, researchers can use more complete aerodynamic data sets on the newer system.

Of course, researchers had to make some compromises because of changes to the simulation system. The original simulation ran in real-time because it was a DOS
program, which allows the simulation to have exclusive control of the computer and its resources. The Windows operating system does not allow this control, but provides near real-time operations. Windows '98, the next generation of the Windows operating system will provide a better interface with the flight controls, Stevens says.

In addition to more realistic scenery, the improved simulation features a realistic working cockpit. The new image shows gauges that are accurately reacting to simulation conditions. A new audio capability allows instructions or other data to be "radioed" to the pilot, and may even allow them to acknowledge that the transmission was received.

The result of this work is an extremely realistic flight simulator, which according to Stevens is "equivalent to the official simulators and other professional training simulators in terms of the accuracy of its aircraft models." The difference is, this simulator collects data on the pilot's actions, allowing scientists to gather data if and when common medications affect pilot performance.

— C. Blake Powers

For more information on this simulator, contact Dr. Brian Stevens, Sensors and Electromagnetic Applications Laboratory, Georgia Tech Research Institute, Atlanta, GA 30332-0856. (Telephone: 770/528-7765) (E-mail: brian.stevens@gtri.gatech.edu)

Traffic Fatalities and Seat Belts
New study to investigate higher fatality rate in Southeast.

The southeastern United States consistently has the nation's highest rate of fatal traffic crashes. These southeastern states — Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina and Tennessee — also have a significantly higher proportion of fatal crashes in which drivers were not wearing, or not properly wearing, their seat belts, according to a preliminary study done by the Georgia Institute of Technology, the Federal Highway Administration (FHWA) and the National Highway Safety Administration (NHTSA).

"The Southeast systematically ranks poorly with respect to fatal crashes compared to the remainder of the U.S. — we need to identify the causal factors and implement effective countermeasures," said lead researcher Dr. Simon Washington, an assistant professor in the
Now, with preliminary results in hand, that is exactly what Washington, assistant civil engineering professor Dr. Karen Dixon and transportation officials from each southeastern state are doing. They have just begun a two-year study to determine the causes for this disturbing trend. State safety officials will use this information to formulate solutions. Washington is coordinating the research effort, which will include university researchers from each of the southeastern states.

The entire research team will investigate the top five potential contributing factors to fatal crash occurrence. They expected to choose the top five by the end of the summer based on each state's informal top 10 list.

"Among some of the factors likely to be studied are: alcohol and drug related crashes; occupant restraint use; speeding and police enforcement; fixed objects crashes; intersection-related crashes; and rural versus urban crashes," Washington said. "Studies of these and other factors are likely to reveal new and detailed insight into the relative importance of these factors on fatal crash occurrence.

"This large regional study is unusual because each state will have researchers studying and analyzing crash factors in their states, while Georgia Tech provides analysis coordination and regional analysis support," Washington said. "Also, the Federal Highway Administration and the National Highway Traffic Safety Administration are working together to provide oversight of the research effort. As a result of the inter-state cooperation of researchers and safety officials, we are hopeful that the results are likely to be used to implement safety policies and programs."

— Jane M. Sanders

For the full-text news release, see [www.gtri.gatech.edu/res-news/TRAFFIC2.html](http://www.gtri.gatech.edu/res-news/TRAFFIC2.html). For more information, you may contact Dr. Simon Washington, School of Civil and Environmental Engineering, Georgia Institute of Technology, Atlanta, GA 30332-0355. (Telephone: 404/894-6476) (E-mail: simon.washington@ce.gatech.edu)
And That Which Is Old Shall Be New Again
GTRI researchers are assisting with helicopter cockpit redesign.

How do you transform a complex older aircraft, which requires three people to fly, into a state-of-the-art system that can be successfully flown by two?

That is the challenge faced by Kaman Aerospace and its partner, Litton Guidance and Control of Northridge, Calif., in refitting almost a dozen Kaman SH-2 Seasprite helicopters for the Royal Australian Navy (RAN). The straightforward part of the job is in stripping the surplus Seasprites purchased by the Australians down to the airframe and refurbishing them to be almost new, or "zero hour" airframes. The challenge for the companies is in developing a completely new flight system for what will be, essentially, a new type of Seasprite helicopter.

That is where human factors researchers from the Georgia Tech Research Institute's (GTRI) Electronic Systems Laboratory come into the picture as a subcontractor for Litton. Led by senior research scientist Dr. Dennis Folds, they are making sure the strengths and limitations of humans will be considered central to the redesign.
"It (the redesign) is an extremely interesting process," says RAN Lt. Commander Stuart Harwood of the Naval Aviation Systems Resident Project Team. "You don't realize what goes on behind (the scenes), getting to where you can fly."

Numerous steps and processes are involved, Harwood notes, and designers have to make the machine as smart as possible so the crew can concentrate on its proper job. "Georgia Tech is playing an extremely important role," Harwood says. "Georgia Tech is helping us to get it right."

The key to "rightly" developing this new Seasprite variant is not in helping develop or select the technology, Folds says. "It is getting the tech(nology) where people can make the best use of it."

The researchers are focusing on details — from the placement of controls to the development of computer software screens that will be the heart of the new flight systems. They work with pilots, tactical coordinators, and Kaman and Litton representatives to develop and refine every design aspect so the meshing of machine and people is as smooth and seamless as possible, Folds says.

He and his colleagues are also drawing upon previous experience. Folds has been involved with aviation-related projects since being a master's degree student. And when not working in aviation, he helped design and develop intelligent transportation systems. Work he and GTRI did with Litton on a U.S. Marine Corps cockpit upgrade helped lead to this challenging assignment, Folds says.

Modifying the cockpit of an existing aircraft is a lot different than designing a new cockpit, Folds says. With modifications, you can't always do what you would like to do; things always have to be built around or worked around, he notes. In this project, the basic cockpit dimensions cannot be changed, and state-of-the-art displays and controls must be placed in the existing cockpit shell.

The new system is indeed state-of-the-art, similar to the advanced systems on the new Boeing 777. Replacing the
mechanical gauges and other devices used for decades are four computer display screens and advanced electronics. Using these screens, and the powerful systems behind them, a two-person crew can fly the helicopter, conduct search-and-rescue operations or fight in combat.

Because of the increased workload — not to mention the intense environment of flight — the screens must be intuitive, Folds says. Operations or emergencies are not the time to be concentrating on how to use the system, but on using it.

Ensuring that it is usable, that machines do what machines do best and people do what people do best, is what the GTRI human factors team does best. Combine this expertise with that of Kaman, Litton and the Royal Australian Navy, and this Seasprite will indeed, "Get it right."

— C. Blake Powers

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Environment of the Future
New book examines environmental impact assessment for the new millennium.

A new book co-edited by a Georgia Institute of Technology researcher explores the state of the art and the future of environmental impact assessment methods.

*Environmental Methods Review: Retooling Impact Assessment for the New Century* was published this past spring. It was edited by Dr. Alan Porter, a Georgia Institute of Technology professor of industrial and systems engineering, and John
Fittipaldi, a 1978 master's graduate of Tech's city planning degree program, who is a senior fellow at the Army Environmental Policy Institute (AEPI). AEPI relocated to Georgia Tech in 1994 to collaborate with Tech faculty on environmental policy projects such as this book. The book features articles by an international group of experts on various environmental assessment (EA) and impact assessment (IA) tools and techniques.

The book's intention is to point readers to the state of the art of good practice in EA and IA, the editors say. It also emphasizes the need for improved methods, particularly with increased demand for sustainable development.

Environmental assessment practitioners in the Army and other military branches, military contractors and others outside of the armed services can use the book for guidance, the editors say. The editors also expect the book will alert graduate students and faculty to methodological issues needing further research.

Seven sections in the book deal with the themes represented in the authors' papers. They are: Perspectives on the Field, Overviews, Strategic Assessments, Processes, Risk Assessment, Domain-Oriented IA and Models in Environmental IA.

Among the writers offering perspectives are Lynton Caldwell, the person most recognized with crafting the National Environmental Policy Act of 1969 (NEPA). The other paper reflects upon the Army's interest in introducing relevance and efficiency often lacking in many environmental assessments.

The overview section features five papers. Two reflect upon the performance of EA in developed economies. The third paper presents a contrasting view of recent changes in Chinese EA practice. The fourth provides an overview of EA and IA methods. And the fifth article poses critical environmental sustainability concepts that can guide various EA approaches.
The strategic environmental assessment section focuses on what one of the authors calls the single most important direction in the field. All six of the papers in this section focus on the application of EA above the project level.

Papers in the processes section share a theme of "doing," the editors say. They range from selecting methods to training. The section also includes papers on "cheaper, better, faster" ways to conduct EA and the integration of NEPA into IA and ecological management.

The risk assessment (RA) section seeks to open communication between the RA and EA/IA communities. One paper contrasts RA guidelines, and the other considers risk communication issues in EA.

The focus is on methods applied to particular IA disciplines in the domain-oriented IA section of the book. Eight papers address social, economic, climate, health, ecological systems and environmental justice.

The EIA models section contains three papers: one on the selection of models and parameters for analysis of environmental impacts; another points to the value of health risk assessments in EA; the third makes the case for consideration of transportation activities in EA.

— Jane M. Sanders

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Dynamic Disorder
"Frustrated" lubricant molecules offer new strategy for reducing friction in mechanical devices.

For decades, researchers have struggled to reduce friction in mechanical systems by improving the chemical composition of the lubricants used to separate moving parts. Now, an atomic-scale study of thin-film lubricants suggests a promising new strategy.

Researchers at the Georgia Institute of Technology reported in the June 25 Journal of Physical Chemistry that by rapidly oscillating the width of the lubricant-filled gap separating two sliding surfaces, they can significantly reduce friction between them.
The technique keeps the lubricant in a state of dynamic disorder, preventing the formation of molecular layering that can increase friction. Based on molecular dynamics simulations, the findings would be of particular interest to designers of micro-scale machines.

"This is a novel way of controlling friction," said Dr. Uzi Landman, director of Georgia Tech's Center for Computational Materials Science (GTCMS). "Through the use of small amplitude oscillations of the gap between two solid surfaces, the ordering process of the lubricant is frustrated, which maintains the lubricant in a liquid state. This allows steady motion of the surfaces with a small coefficient of friction."

Studies by Landman and colleagues Jianping Gao and W.D. Luedtke suggest that varying the gap by as little as 5 percent can maintain the necessary level of disorder.

The research builds on earlier studies showing that thin-film lubricant molecules confined between two solid surfaces organize themselves into well-ordered layers. In a confined film of approximately 20 Angstroms, a lubricant such as hexadecane forms four to five layers in which the long-chain molecules all lie parallel to the sliding plane.

The molecular organization creates what Landman calls a "semisolid." Such a structure resists the shearing forces necessary to slide the two surfaces it separates, increasing the force necessary to make them move.

Creating small variations in the distance between the sliding surfaces upsets the ability of the lubricant molecules to fit "comfortably" between the surfaces, he said. Decreasing the gap forces some molecules out, while increasing it allows more molecules in. This constant rearranging of molecules prevents formation of the ordered layers in the lubricant film.

The research was sponsored by the U.S. Air Force Office of Scientific Research and the U.S. Department of Energy. The molecular dynamics simulations were performed at the Pittsburgh Supercomputing Center, the National Energy Research Scientific
Honors

**Dr. Ronald H. Bayor**, a professor in the School of History, Technology and Society, received an Outstanding Book Award from the Gustavus Myers Center for the Study of Human Rights in North America for his book *Race and the Shaping of Twentieth-Century Atlanta*.

**Dr. William L. Chameides**, Regents Professor in the School of Earth and Atmospheric Sciences, was elected a member of the National Academy of Sciences, one of the highest honors bestowed upon a scientist. Chameides’ research has focused on the processes that cause ground-level ozone, one of the most common secondary air pollutants in the lower atmosphere.

**Dr. Miriam Drake**, dean and director of libraries, was awarded an honorary Doctor of Library Science degree from Simmons College in Boston, Mass. She is responsible for having made an electronic library system accessible to every student, staff and faculty member at Georgia Tech. Drake is a recent past president of the Special Libraries Association and a member of numerous editorial boards and college advisory boards.

**Dr. Robert Nerem**, professor of mechanical engineering and Parker H. Petit Distinguished Chair for Engineering in Medicine, was inducted in London as an Honorary Member of the Institution of Mechanical Engineers. There are relatively few Americans who can claim this distinction.

**Dr. Rao R. Tummala**, Pettit Chair Professor in Electronics Packaging, received Georgia Tech's 1998 Distinguished Professor Award. Tummala is also a Georgia Research Alliance...
Eminent Scholar and director of the Packaging Research Center, the largest electronics packaging center in the world. The award, which comes with a $15,000 prize donated by the Class of 1934, is the most prestigious honor for Georgia Tech faculty members. Recipients are chosen for their scholarly achievements, teaching ability and professional development of Tech students.

**Dr. C.P. Wong**, a professor in the School of Materials Science and Engineering, received the 1997 ECTC Best Paper Award from the Institute of Electrical and Electronics Engineers. He won the award for his paper titled "High Performance No Flow Underfills for Low-Cost Flip-Chip Applications." He co-authored the paper with students S.H. Shi and G. Jefferson.
Industrial effluent in Georgia's waterways is nothing new, nor are increasingly stringent regulations designed to keep pollutants in line. But new approaches to mitigate the problem at the source have shown promise, and a university-industry partnership in Georgia is leading the way.

In 1994, the state Environmental Protection Division told Springs Industries in Griffin, Ga., that it must meet strict metals and toxicity limits to continue discharging effluent — up to 2 million gallons daily — from a towel-making operation and a yarn-dyeing plant into the headwaters of Cabin Creek.

Researchers from the Consortium on Competitiveness for the Apparel, Carpet and Textile Industries (CCACTI) worked with the Griffin plant. They suggested a closed-loop treatment system that completely reuses process water, with the goal of reducing wastewater volume to as near zero as possible.

For Dr. Fred Cook, head of Georgia Tech's School of Textile and Fiber Engineering, the project exemplifies what CCACTI is all about — applying university-based knowledge to assist one of Georgia's largest industries.

Funded by state government and textile-based firms, CCACTI is a logical collaboration given Georgia's 100 years of involvement with the textile industry. Not only are textiles omnipresent — from the cotton in your shirt to the nylon in the carpet to composites in your car to carbon fabric in the space shuttle — but the $13 billion industry itself is woven into the state's economy. As many as 140 of the state's 159 counties house some sort of textile-related business, Cook says. In parts of rural Georgia those companies are the major employer, indeed have been since the late 19th century when northern textile manufacturers moved south to be closer to their cotton supply and to cheaper labor.

CCACTI is a necessary mechanism, Cook says, one that provides direct technical assistance and technology transfer. Considerable research takes place under the auspices of the National Textile Center (NTC) and other organizations. But CCACTI "closes the loop" by making academia's expertise available to companies, an aspect especially useful to firms lacking technical staff, he says. Projects are cooperative, and participating plants agree to be beta test sites.

"The idea is to find niches where the University System can make the biggest impact," says Georgia Tech's Susan Shows, manager of CCACTI. Also, the entire industry can learn from the results of each individual project, she adds. In fact, one of the funding selection criteria is how pervasive the issue is.

Beyond that, CCACTI is a model of intercollegiate cooperation, with most projects involving researchers from Georgia Tech and the University of Georgia as well as other colleges and universities.

But it's by no means an academic exercise or ivory tower experiment. CCACTI has an active industry advisory board, and industry partners...
Traditional Industries Program

Launched in 1994 by Gov. Zell Miller and the General Assembly, the Traditional Industries Program (TIP) brings industry leaders and university-based researchers together to improve the competitiveness of Georgia's three mainstay industries — pulp and paper, food processing, and textiles/carpet/apparel.

Combined, these industries employ 260,000 Georgians, almost half of the state's manufacturing workforce. But despite their size, they face serious problems, including foreign competition and domestic regulatory issues.

Each of the three has formed a public-private partnership where industry identifies critical competitiveness problems, then works closely with faculty from Georgia's colleges and universities to define needs, select research projects and monitor their progress. To date, CCACTI has supported more than 30 such efforts. Among them are:

- development of a non-formaldehyde, wrinkle-free finish for garments. Researchers successfully formulated a new polycarboxylic acid-based finish with better wrinkle resistance and strength retention than the currently used, and environmentally unfavorable, formaldehyde-based system. (Earlier this year, Georgia-based Callaway Chemicals licensed the technology and began marketing it internationally.)

- compilation of an Internet-based source of information for recycling textile/carpet/apparel waste. This database lists more than 200 waste dealers and material recyclers, businesses that conceivably can reroute some of the industry’s solid waste from landfills to useful products.

- investigation of the feasibility of fibers for reinforcing concrete and roadbeds. To alleviate landflling of the industry's annual 150 million pounds of solid waste, researchers are exploring the addition of textile wastes to structural concrete and to soils of new roads and highways to gain more strength and stability.

Many of CCACTI's projects claim an environmental component, appropriately enough, Cook says, in this emerging era of sustainable textile manufacturing and industrial ecology.

At Springs Industries, CCACTI's initial efforts focused on reducing effluent at the towel-making facility. By modifying the plant's water-based manufacturing processes and installing more efficient washing equipment, researchers and company engineers cut the plant's total daily effluent from some 1.8 million gallons to 900,000 gallons.

In the yarn-dyeing plant, researchers found that overflow rinses could be replaced with more efficient types and that some rinses could be completely eliminated without damaging the quality of the yarn. These changes reduced the second plant's effluent by 25 percent.

"It is apparent that environmental compliance issues are best approached initially through source reduction efforts," says plant manager Dave Lamb. "Source reduction serves to reduce both chemical and utility consumption. CCACTI provided us opportunities to explore innovative ways to improve our process efficiency while maintaining cost and quality standards."

Project leader Cook says in practice the company's volume of effluent was cut by half, and the technology exists to achieve additional benefits. Also, the results can be readily applied to other textile-related operations, he adds.

Another CCACTI project with significant environmental ramifications entails air emissions from carpet mills. Amendments to the federal Clean Air Act will require carpet manufacturers to have air permits by 2000. These permits will address volatile organic compounds (VOCs) and hazardous air pollutants (HAPS), about which there is limited information in carpet making. Accurate estimates of hourly emission rates will help determine a company's permitted operating capacity or application of control technologies or both.

Project leader Dr. Jim Mulholland, an associate professor in the Georgia Tech School of Civil and Environmental Engineering, says the U.S.
Environmental Protection Agency (EPA) asked industry to provide emissions data, and that's where CCACTI came in. Instead of using calculations based on chemical inventory records and material safety data sheets, CCACTI investigators decided on a more accurate method — collecting and analyzing emissions directly from the factory stacks. The approach was a snapshot, says Mulholland. In the lab researchers were subsequently able to reproduce the types of emissions observed in the field and study in a cost-effective manner how these emissions are formed and controlled.

Dalton-area industry participants included Mohawk Industries, Carriage Industries, and World Carpets, and CCACTI researchers worked closely with environmental teams from the plants. "They were very cooperative, and it has been a fruitful collaboration," Mulholland says.

The initial phase entailed collecting more than 400 air emission samples from 22 stacks at two continuous dye plants and two latex coating plants. Later, researchers gathered a similar number of samples from two batch dye plants and two yarn heat-setting facilities.

The major results are in identifying and quantifying emissions and in gaining a better understanding of how emissions depend on various chemicals and processes, Mulholland says. Companies relying on calculated emissions have overestimated their total emissions while failing to characterize the distribution of chemical compounds found in the stacks. "We're finding that the emissions for single plants would not put them in a 'major source category' under existing regulations," says Mulholland, adding that the CCACTI information may go to EPA this fall.

The analysis may allow EPA to identify carpet manufacturing processes of greatest concern, Mulholland suggests, and possibly enable suppliers to target chemicals for reformulation to achieve maximum emission reduction. Another benefit is that state environmental officials can add valuable data to existing air emission inventories. "A lot is known about air emission sources such as cars and power plants, but not much about many industrial sources such as carpet manufacturers," he says.

Some CCACTI projects have been completed, but others are ongoing — for example, an examination of bioconversion to further reduce the quantity of landfilled solid wastes. Another is looking into the optimum level of chemicals in denim manufacture, with the idea of reducing chemical costs by at least 30 percent. One new project will respond to consumer concerns related to mold and mildew growth associated with carpets, Shows says.

One measure of success is the response from industry. Roy Bowen, president of the Georgia Textile Manufacturers Association, says, "The key to CCACTI's success is that industry wants to be involved in these projects. Our companies and researchers are working together to solve problems that directly impact industry's bottom-line performance. That's how CCACTI is making Georgia's textile industry more competitive today."

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Over the past five years, the state has invested more than $25 million in the program to provide research, new technology and technical assistance, and the three industries have matched that investment.

For more information on each of the three industries, you may contact:

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**Traditional Industries Program for the Pulp and Paper Industry**: Karl
A common piece of workplace advice — "work smart" — can be aptly applied to a revolutionary environmental monitoring and analysis system that promises to reduce the time and costs involved in analyzing contaminants.

A team of researchers that includes Georgia Institute of Technology engineers has developed the system — called E-SMART (Environmental Systems Management, Analysis and Reporting nEwork). Researchers predict it will dramatically improve the efficiency and effectiveness of environmental monitoring. The system — consisting of data management hardware and software and integrated optic chemical sensors — operates in real time and measures very small amounts of contaminants. In addition, researchers say it will reduce health and safety risks and help ensure environmental compliance.

"Right now the only way technicians have for field analysis is to go out and take samples, bring them back to the laboratory and perform wet chemistry tests," says Nile Hartman, a principal research engineer at the Georgia Tech Research Institute (GTRI). "It's expensive — about $200 a sample plus the technician's time. So instead we have developed a sensor..."
that operates in situ (at the site of contamination) and continuously monitors the site. So you have huge savings in time and cost."

At the heart of the project are smart sensors that detect a variety of chemical contaminants, including heavy metals, solvents, and petroleum oil and lubricants. The integrated optic interferometric sensors were developed over the past decade and patented in 1997 by Hartman and the Georgia Tech Research Corporation.

The sensor was licensed commercially by the Atlanta-based Photonic Sensor Systems Inc., a recent graduate of Georgia Tech's Advanced Technology Development Center, a business incubator for high-tech companies. Photonic Sensor Systems is also a member of the Department of Defense (DOD) funded E-SMART research team, and GTRI is its subcontractor for the project. Other members of the E-SMART team are General Atomics, U.S. Air Force Armstrong Laboratory, Isco Inc. and Science & Engineering Analysis Corporation.

Laser-based technology originally developed for optical communications allows the multichannel microsensor fitted with the proper chemical coatings to detect multiple contaminants in soil, groundwater and air. The speed of light increases or decreases when passing through materials of differing optical properties, Hartman explains. Detection of contaminants becomes possible by measuring a contaminant's influence on the optical properties of the sensor. Then researchers observe the effects on these properties through changes in the transmitted laser light.

The sensors are integrated into the E-SMART team's standardized smart sensor networks that collect, manage and analyze the sensor data. The resulting analysis will allow environmental site managers to predict fate and transport of contaminants, perform remedial design, and gain regulatory and public approval of remedial approaches.

"This system will allow real-time assessments of what we're doing to the environment," Hartman says. "We can see if we're doing bad things to it or if we're making improvements through pollution abatement techniques and processes."

An E-SMART field test, expected to begin later this year, will probably be conducted at a U.S. Air Force base where cleaning agents used to degrease metal aircraft parts have seeped into soil and groundwater, Hartman says. Researchers will install sensors in monitoring wells, streams and in cone penetrometers, rods driven 200 to 300 feet into the ground. The sensors will be designed to detect benzene, toluene, ethyl benzene and xylene (BTEX compounds). With the contaminant type and concentration data collected by the sensors, E-SMART will map the contaminant plume at the site. Then site managers can take this easily interpreted analysis and take appropriate corrective action, if needed, Hartman says.
Field tests at other Department of Defense sites, and even perhaps at a Department of Energy site, will follow this one, Hartman says. With this step yet to complete, the sensor technology is still a year or two from availability on the national and international commercial markets, he added.

When it does become available, the E-SMART system and even the sensor as a stand-alone environmental monitor will have numerous applications in the private sector, Hartman says. Manufacturing facilities might use the sensor to simply monitor their output. Site monitoring personnel could determine their exposure to dangerous chemicals. And water plant managers could better monitor their process control to ensure properly cleaned drinking water.

"The big advantage of this sensor is that it operates in real time in situ. You get an output that is concentration dependent," says Hartman, a part owner of Photonic Sensor Systems.

"Speed is another advantage of these sensors. Compared to most sensors, these operate fairly fast: You get a response in seconds," Hartman says. "Also, the fact that these sensors work in water is a big advantage. There are not many sensors out there that can make that claim. One more advantage is the sensors' sensitivity. They can measure down in the parts per billion range."

In addition to environmental monitoring, the sensors are expected to have applications in food safety and medical testing, Hartman says. This fall, Hartman, GTRI research engineer Dr. Dan Campbell and Georgia Tech biology professor Dr. Paul Edmonds will supervise a field test of a biosensor intended to rapidly detect salmonella bacteria in meat in poultry processing plants.

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1996 Traffic Fatality Rates* in the Southeastern U.S.

* per 100 million vehicle miles of travel
** state's national rank in parentheses