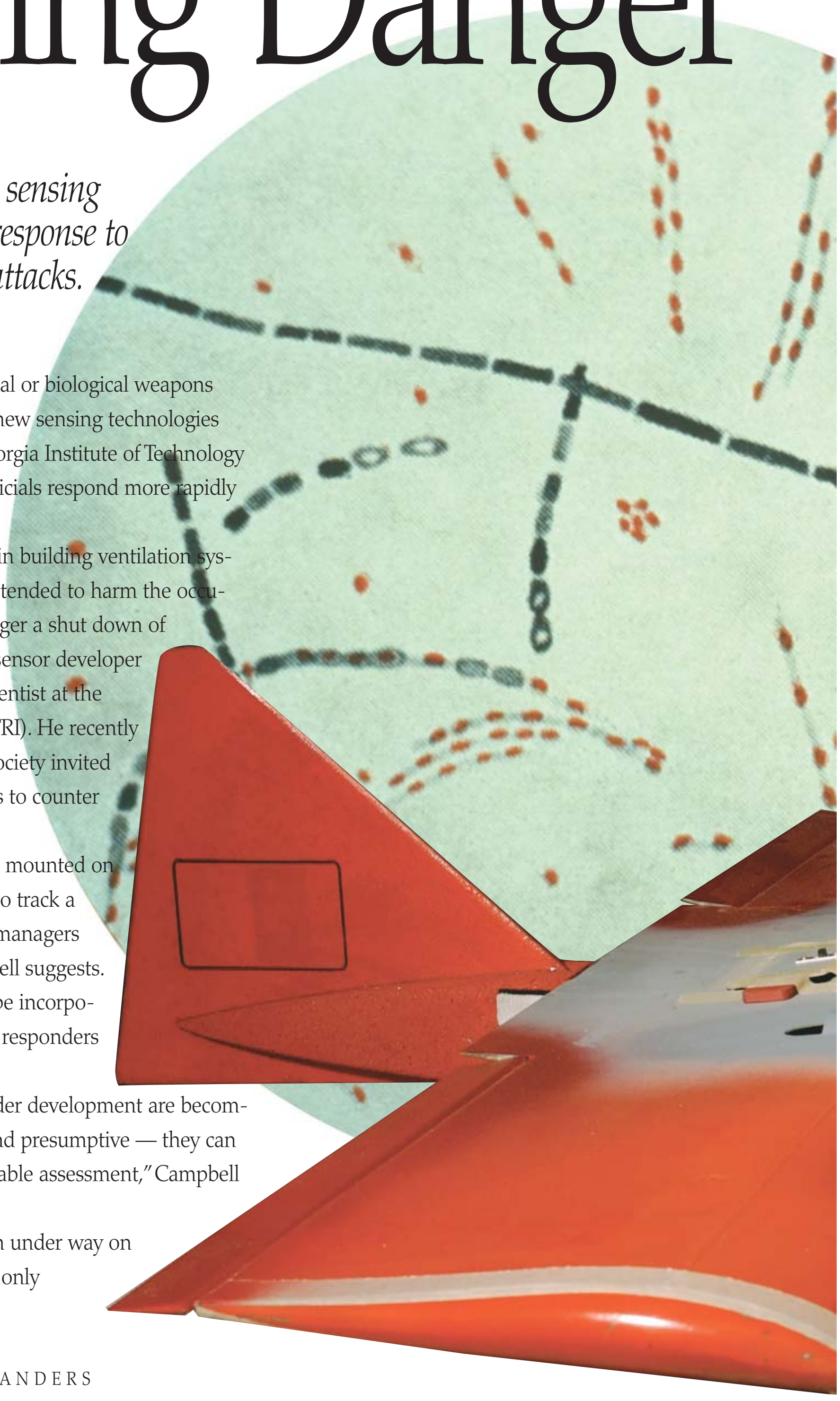
Sensing Danger

Researchers develop new sensing technologies to improve response to chemical and biological attacks.



@ **Georgia Tech researchers are developing technologies to counter terrorism and improve homeland security. In our cover story, we report on novel sensors for chemical and biological substances that might be used as terrorist weapons. We also describe a mapping tool to help officials coordinate incident response and software to facilitate sharing of criminal information. Finally, we report on efforts to improve seaport security.**

Should terrorists use chemical or biological weapons against the United States, new sensing technologies being developed at the Georgia Institute of Technology could help public safety officials respond more rapidly and effectively to the threats.

For example, chemical sensors in building ventilation systems could detect a release of gas intended to harm the occupants. The detection might then trigger a shut down of the ventilation system, says optical sensor developer Dan Campbell, a senior research scientist at the Georgia Tech Research Institute (GTRI). He recently presented an American Chemical Society invited lecture on using sensor technologies to counter terrorism.

Chemical sensors could also be mounted on an unmanned aerial vehicle (UAV) to track a chemical plume, giving emergency managers insight on evacuation plans, Campbell suggests. And rapid biological sensors could be incorporated into handheld devices for first responders investigating a suspicious package.

"Many sensor technologies under development are becoming reliable, versatile, inexpensive and presumptive — they can help first responders make a reasonable assessment," Campbell notes.

At Georgia Tech, work has been under way on sensing technologies that could not only

BY JANE M. SANDERS

RESEARCHER PHOTOGRAPH BY GARY MEEK

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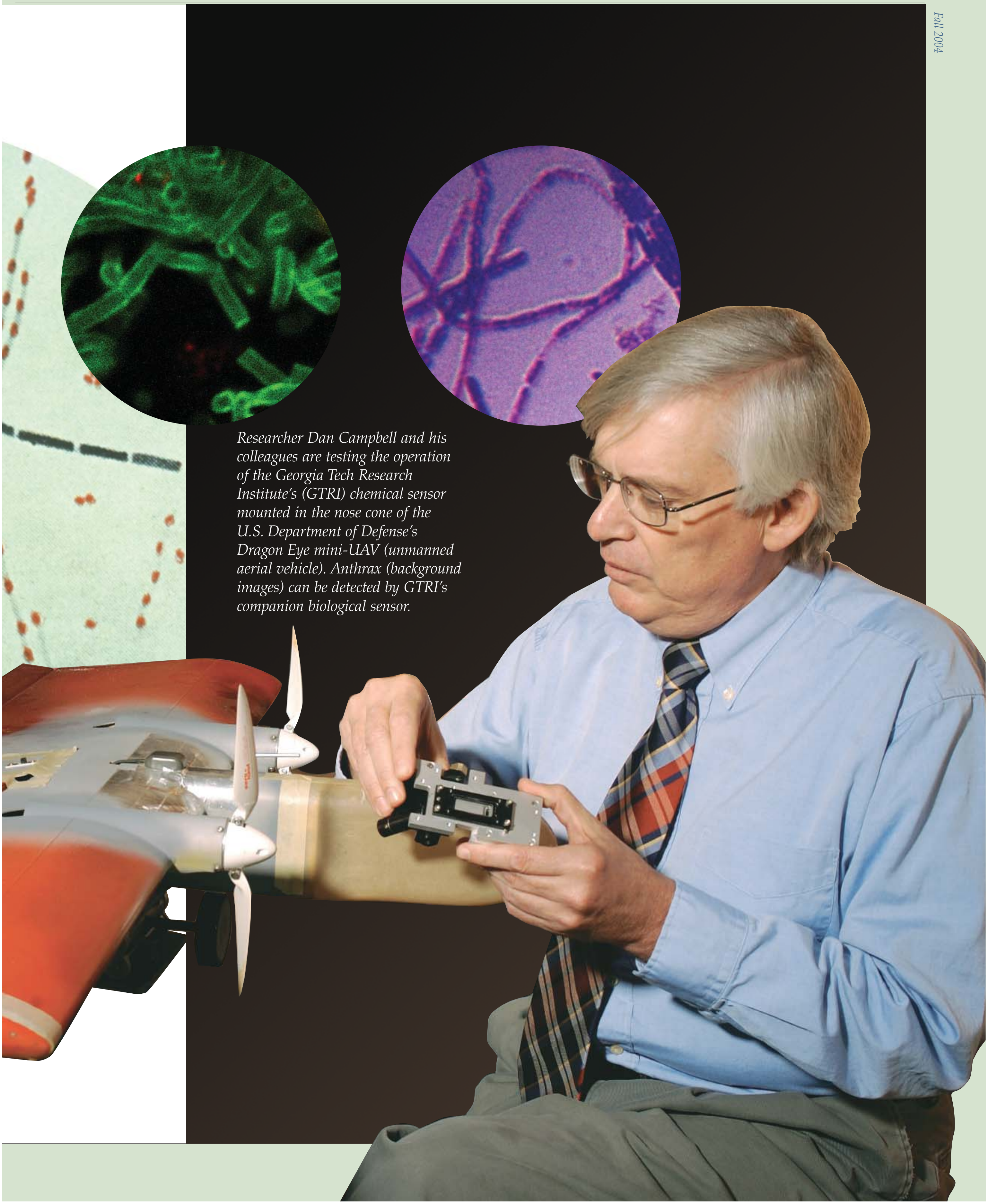

Researcher Dan Campbell and his colleagues are testing the operation of the Georgia Tech Research Institute's (GTRI) chemical sensor mounted in the nose cone of the U.S. Department of Defense's Dragon Eye mini-UAV (unmanned aerial vehicle). Anthrax (background images) can be detected by GTRI's companion biological sensor.

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>
> — **Dan Campbell**, senior research scientist at the Georgia Tech Research Institute

improve homeland security, but also enhance response to industrial accidents, environmental pollution and food-borne pathogens.

Here, we feature three of the numerous Georgia Tech projects aimed at creating better methods and practical applications of these sensing technologies.

Multi-Purpose Optical Sensor

Campbell and his GTRI colleagues have been developing an integrated-optics sensor that can detect the presence of biological agents in minutes and chemical agents in seconds. They are tuning the sensor for detection of industrial pollutants, food-borne pathogens and, most recently, agents associated with terrorist attacks. The U.S. Marine Corps Warfighting Laboratory and Marine Corps Systems Command supported the latter research.

The sensor, which may cost much less than current devices, consists of a laser light source, a planar waveguide (a small piece of glass through which the light travels) and a detector for monitoring light output.

Reactions on the waveguide surface alter the speed of light through the waveguide. This change is monitored with an interferometer by comparing a reference beam with another beam traveling under the sensing chemistry. Signal processing software interprets the sensor's results and delivers information on the agents' identity and quantity. The waveguide chip is small enough that it can accommodate several sensing channels designed to detect a wide variety of chemical and biological agents.

"We've built one platform for all possible uses, both in the air and in the water," Campbell explains. "You don't change out the laser or detector. You just plug in the chip you need and you're ready to go."

Researchers have successfully and rapidly detected numerous agents — including Salmonella and Campylobacter bacteria, anthrax, ricin, chlorine and ammonia in lab tests, as well as groundwater contaminants such as chlorinated hydrocarbons in field tests.

Recently, they have improved the sensor's reliability and sought new applications for the technology. To sense biological agents, the device takes rapid, direct measurements of the binding of an antigen to a chemical receptor on the waveguide surface. Researchers previously used antibodies as receptors. But they are more expensive and less reliable than aptamers, the synthetic, nucleic-acid-based receptors used in the sensor now, Campbell says. GTRI research scientist Jie Xu has been assisting Campbell with the aptamer work.

GTRI is exploring several opportunities for its sensor. The U.S. Naval Research Laboratory and the Marine Corps Warfighting Laboratory are seeking applications for their Dragon Eye mini-UAV (unmanned aerial vehicle). So GTRI researchers are testing the operation of the chemical sensor mounted in the UAV's nose cone.

Meanwhile, Campbell has just begun work for AIMSI, an Oak Ridge, Tenn., company that wants to use GTRI's sensing technology in a handheld device for first responders and a groundwater monitoring device for environmental professionals.

Fully Integrated Sensing Systems

Researchers from several universities, including Georgia Tech, are collaborating on the development of integrated micro-optical sensors for chemical and biological agents of national security concern. The goal is to merge optical sensing technology — like GTRI's — with highly integrated electrical circuits into a fully integrated sensing system on a silicon chip.

"The advantages of this system will be better performance, a smaller size that uses less power, full integra-

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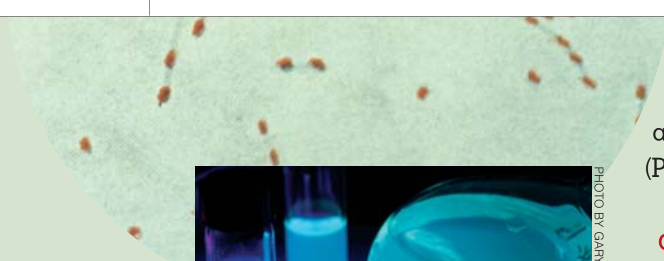
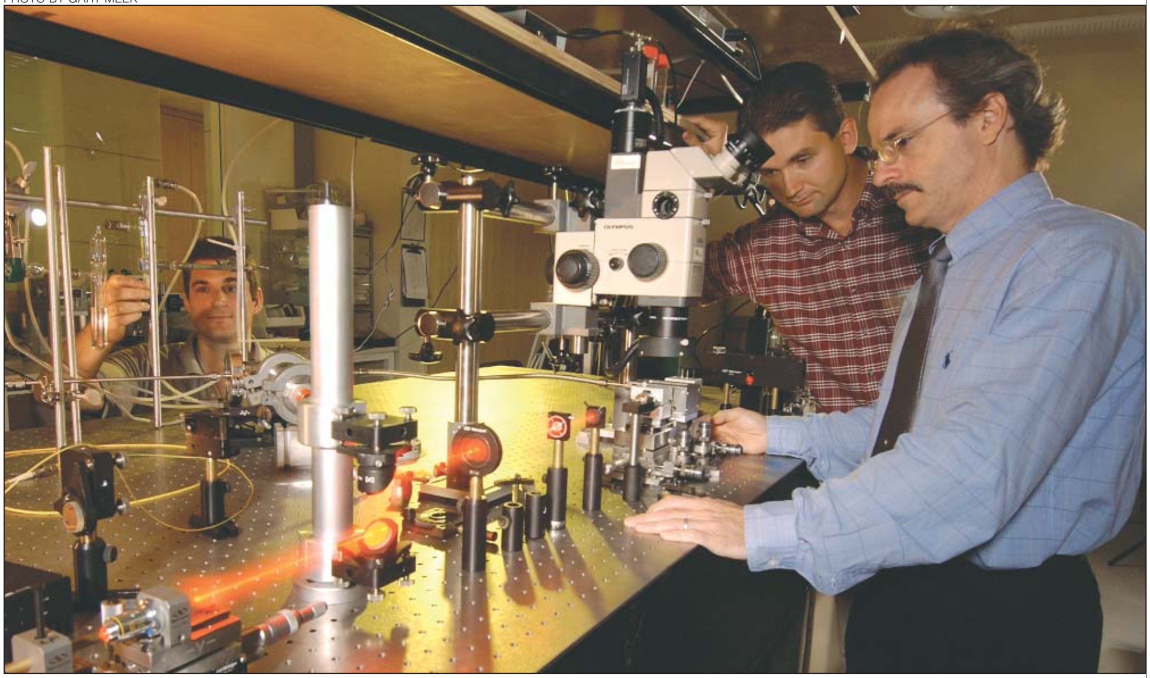


PHOTO BY GARY MEEK

> "We don't want to work with something like anthrax right now, so we're testing these polymers (PPEs) with free lectins to see if we can detect lectin binding with the polymer. We're looking for a change in the amount of fluorescence or a change in the color of fluorescence."
>
> — **Uwe Bunz**, a Georgia Tech professor of chemistry and biochemistry who is conducting research with support from a proof-of-concept grant from the National Institutes of Health

PHOTO BY GARY MEEK



Researchers test an optical sensor with this experimental setup in the lab of Stephen Ralph, right. Researchers Cliff Henderson, center, and Jeffrey Lillie, are part of the research team.

tion and a low cost of only a few dollars per chip," explains Stephen Ralph, the Georgia Tech School of Electrical and Computer Engineering associate professor who is leading a $1.5 million part of the project. "This is our vision. We still have a lot of science and engineering to do to merge these technologies into a fully integrated system."

Now in its fourth year, this proof-of-concept stage of the research — which is funded by the Defense Advanced Research Projects Agency (DARPA) through the University of Illinois — will conclude in December 2004, but researchers are seeking support for continued study.

"The remarkable advantage of a fully integrated system is the ability to apply dynamic signal enhancement strategies to improve sensitivity and selectivity while reducing the likelihood of false positives," Ralph says. "We have fabricated a fully integrated system, although challenges remain in the integration of the optical sources in an efficient manner with the rest of the chip."

Researchers have not yet tested the sensor with any agents of concern, but have experimented with compounds having similar properties and demonstrated sensitivities in the hundreds of parts-per-billion range using their signal enhancement strategies. Additional funding will enable tests of "mock" agents that have similar chemical composition to the substances terrorists might use. Then, they hope to make the device more sensitive and address fabrication issues, Ralph adds.

The Georgia Tech-based research team involves Ralph and Associate Professor of Chemical Engineering Cliff Henderson and their students. Also involved are for-

"We have fabricated a fully integrated system, although challenges remain. . ."

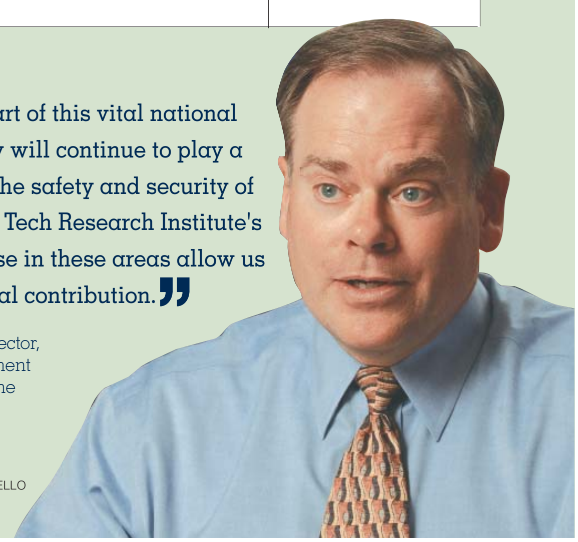
— **Stephen Ralph,** associate professor of electrical and computer engineering

Georgia Tech Research Institute senior research scientist David Gottfried is collaborating with the University of Georgia's Center for Food Safety to develop the sensing chemistry to detect infectious disease agents, including potential bioweapons, in water, fruit juice, milk, food and the environment.

"We are pleased to be part of this vital national effort. Information technology will continue to play a vital role in helping improve the safety and security of the United States. The Georgia Tech Research Institute's (GTRI) experience and expertise in these areas allow us an opportunity to make a vital contribution."

— **Stephen Cross**, GTRI director, on the organization's development of the software foundations for the Global Justice XML Data Model

PHOTO BY NICOLE CAPPELLO



mer Georgia Tech Professor Nan Jokerst and Associate Professor Martin Brooke, now at Duke University.

Meanwhile, their collaborators at Colorado State University and the University of Michigan are working on microfluidic sensors with a fully integrated design.

Detecting Fluorescence Changes in Polymers

A type of highly fluorescent polymers called PPEs, or poly(paraphenyleneethynylene), could be the basis for a chemical sensing system that would detect pathogens and toxins that might be used in a bioterrorism attack. The

Seaport Security

Innovation center working with academia and industry to develop new logistics and security technologies.

BY T.J. BECKER

When it comes to the operation of seaports, security and efficiency challenges are closely linked.

"We could generate 100 percent security simply by locking the 'front doors' of ports, but obviously that would have drastic consequences to U.S. commerce," says Page Siplon, director of the Maritime Logistics Innovation Center (MLIC) in Savannah.

He points to the Georgia Ports Authority (GPA), which contributes more than $35 billion annually to the state's economy and has a hand in providing jobs for one out of 14 Georgians. "Anything we can do to enhance the shipping process will generate more revenue," he adds.

MLIC is the first of Georgia's innovation centers, an initiative launched by Gov. Sonny Perdue in 2003 to spark economic development in mid-sized cities throughout the state. Located at Georgia Tech's Savannah campus, MLIC is a unique partnership between GPA, the Georgia Department of Economic Development and the University System of Georgia. MLIC is working with private industry to develop new technologies and adapt existing ones for the safe, efficient movement of freight.

Take external tracking and tracing. Seaports typically operate on a queue system where trucks arrive at port gates and enter a first-in/first-out processing system, relaying information about whether they are delivering or picking up goods along with the contents of the cargo. If all goes well, this only takes a few minutes. But whenever there is a problem — be it a security issue or a simple error in paperwork — long delays result and slow the movement of freight.

"By the time a truck arrives at the gate, it's almost too late to do much about a security concern," Siplon says. Because of long lines of traffic, seaport authorities have few options but to move vehicles forward and deal with any problems on site, he explains: "If we could start the information exchange before trucks reach the port, we would have time to do deeper security validation and could re-route vehicles if anything is questionable."

With that in mind, MLIC is creating a "mobile test-bed" to see how various technologies such as global-positioning systems (GPS), general-packet radio service (GPRS) and radio-frequency identification (RFID), can be combined to improve external tracking and tracing. Aiding in this project are American Port Services, CarrierWeb and Cingular, three of MLIC's first member companies.

Other MLIC projects include:

- **Internal tracking and tracing**. RFID tags can help locate cargo, but when several levels of containers are stacked in the port yard, reception problems proliferate. So MLIC wants to find ways to improve asset visibility. MLIC's research is expected to result in the formation of new companies.
- **Scanning and detection**. U.S. Customs and Border Protection agents use various technologies

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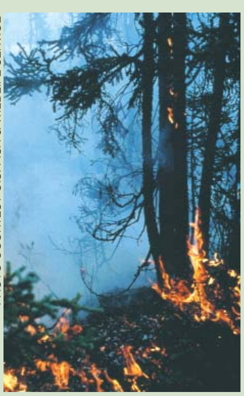

PHOTO COURTESY U.S. FISH & WILDLIFE SERVICE

Georgia Tech Research Institute engineers are working with the Georgia Forestry Commission to adapt the Geographic Tool for Visualization and Collaboration (GTVC) to track smoke during planned burns of forested land. Other potential applications for GTVC include tracking of chemical plumes and planning evacuation routes, as well as tracking of human and animal diseases. Georgia Emergency Management Agency officials also use GTVC for hurricane and flooding evacuation planning and for public event activity planning.

agents of concern include cholera, anthrax and ricin.

"Fluorescence is very sensitive to the chemical environment," says Uwe Bunz, a Georgia Tech professor of chemistry. "So it's a very good tool to report changes."

PHOTO COURTESY GA. DEPT. OF ECONOMIC DEVELOPMENT

to search incoming shipments for explosives, radioactive materials and illegal immigrants, but existing tools have limitations. For example, bananas and television sets can cause false positives in some radiation-detection devices.

- **Distribution-center tracking and tracing**. Faculty researchers are analyzing how technologies affect the supply chain. Participants include Georgia Tech Professor Chip White, MLIC's executive director, and trade and logistics expert Karl Manrodt, an assistant professor at Georgia Southern University.

Looking at the entire supply chain is critical because a solution that might work well for one partner could cause problems for another, Siplon notes.

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With a one-year, proof-of-concept grant from the National Institutes of Health, Bunz is exploring the feasibility of detecting changes in the fluorescence or color of PPEs when they interact with a pathogen or toxin. But the goal has presented some technical challenges.

PPEs are typically not soluble in water, but for use as sensors, they must be, Bunz says. So researchers added very polar, water-like extensions to the lipophilic, or butter-like, substituent chemical side chains that extend from the long chemical backbones that form PPEs.

Researchers must also make PPEs mimic the sensing functions of human cells in a primitive way, Bunz explains. On the surface of pathogens and some toxins are proteins called lectins that bind with sugar molecules on the surface of human cells to attack them. Similarly, Bunz wants to add sugar molecules to the chemical side chains that extend from PPEs. Then he will see if these sugars bind with lectins.

Researchers have been synthesizing a library of PPEs and other polymers with sugars attached, and they have begun early-stage testing of these materials.

"We've done a little of this lectin sensing, but to do this better, we need to use longer extendable linkers for the sugars attached to our polymers," Bunz says. "It's a major challenge to do this."

If the concept proves feasible, Bunz will seek additional funding and collaborate with a biosafety laboratory that can work with the pathogen anthrax and/or the toxin ricin.

@ **Read more at: gtresearchnews.gatech.edu/reshor/rh-f04/danger.html**

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GTRI scientists and engineers successfully demonstrated the operation of their chemical sensor mounted in the nose cone of the U.S. Defense Department's miniature unmanned aerial vehicle (UAV) called Dragon Eye. Next, they want to shrink the sensor from its current one-half-pound size to about one ounce. Then they plan to mount sensors on each of the UAV's wings to get a more precise reading on the source of a chemical plume.

PHOTO BY GARY MEEK