

# Horizons

*Research*

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*Winter/Spring 2009*



## UNDERSTANDING THE ORIGINS OF CANCER



- *Improved Antibiotic*
- *Micro Robots*
- *Clean-Tech Companies*
- *SandBot Struggles*
- *Cooling Radars*



“Ovarian cancer is called the silent killer because by the time symptoms arise and it’s detected, it has typically spread throughout the body. Our laboratory takes an integrated approach to studying ovarian cancer by investigating its causes, establishing accurate and reliable diagnostic tests, and developing novel and effective therapies.”

– John McDonald, chief scientist of the Ovarian Cancer Institute and associate dean for biology development in the School of Biology

“We are interested in making derivatives of this peptide drug that retain their potency and are efficiently processed by biochemical machinery. We want to put in substitutions to the genetic machinery that may create a more water-soluble analog and could potentially be used for development of a new class of antibacterial agent.”

– Wendy L. Kelly, assistant professor in the School of Chemistry and Biochemistry and the Parker Petit Institute for Bioengineering and Bioscience



“What the Army wants is very small robots smart enough to go off on their own and then alert you when they find something. These wouldn’t be dumb sensor carriers; they would interpret what their sensors are telling them.”

– Mike Heiges, GTRI senior research engineer

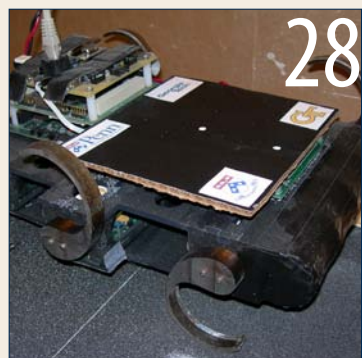
“Reducing the time it takes to recall a product will have a positive effect on consumers’ willingness to purchase other products from the same company, and if the recall is handled well, the stock price may recover to the same level as before the incident.”

– Manpreet Hora, assistant professor in the College of Management



“Clean technologies have very significant environmental and economic promise. Several companies based on Georgia Tech research are producing clean-tech products today here in Georgia or are knocking at that door, and numerous others show real promise.”

– Stephen Fleming, Georgia Tech’s chief commercialization officer



“This is new territory because researchers have not examined the interaction between an animal’s foot and sand like they have a whale’s or duck’s flipper and water. Sand is a uniquely challenging terrain because it can shift quite easily from solid to fluid to solid and requires different locomotion strategies.”

– Daniel Goldman, assistant professor in the School of Physics

“As radar systems and other sensor systems get more complicated, the computational requirements are becoming a bottleneck. We are capitalizing on the ability of GPUs to process radar, infrared sensor and video data faster than a typical computer and at a much lower cost and power than a computing cluster.”

– Daniel Campbell, GTRI senior research engineer



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**Cover:** School of Biology associate professor Kirill Lobachev and postdoctoral fellow Vidhya Narayanan look through a plate displaying mutant yeast cells that are defective in making fragile chromosomes. Such chromosomes are hot spots for rearrangements that can lead to cancer. (Photo: Gary Meek)

## Georgia Tech Research Horizons Magazine

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The number of pages in this issue and the number of copies printed have been reduced because of state budget reductions.

Researchers have identified the genetic machinery responsible for synthesizing thiostrepton, a powerful antibiotic that could provide a new weapon in the battle against bacteria – if it could be made water soluble. Knowing the gene cluster used to synthesize the drug could permit scientists to make modifications that would make thiostrepton more useful.

A culture of the *Streptomyces laurentii* bacterium that produces thiostrepton.

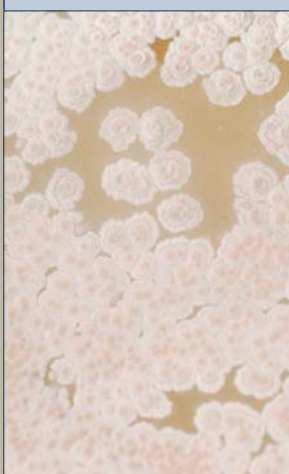


Photo: Gary Meek

# Improving an Old Antibiotic:

## Researchers Identify Genes for Thiostrepton, a Powerful Drug Whose Use Is Now Limited

By John Toon

**R**esearchers at the Georgia Institute of Technology have identified the genetic machinery responsible for synthesizing thiostrepton, a powerful antibiotic produced by certain bacteria. Though effective against the dangerous MRSA (methicillin-resistant *Staphylococcus aureus*) and vancomycin-resistant *enterococci*, thiostrepton currently is limited in applications for human use because it is not water soluble.

Identification of the gene cluster responsible for producing thiostrepton sets the stage for genetic manipulations that could make the drug more useful by improving its water solubility, potentially providing a new tool in the high-stakes battle against bacteria. Beyond the possible medical applications, the research produced a scientific surprise: thiostrepton is derived from a genetically encoded peptide that undergoes no fewer than 19 different modifications, one of the most complex such processes known – a surprising capability for a bacterium.

“We are interested in making derivatives of this peptide drug that retain their potency and are efficiently processed by biochemical machinery,” says Wendy L. Kelly, an assistant professor in Georgia Tech’s School of Chemistry and Biochemistry and the Parker Petit Institute for Bioengineering and Bioscience. “We want to put in substitutions to the genetic machinery that may create a more water-soluble analog and could potentially be used for development of a new class of antibacterial agent.”

Details of the work were published in the *Journal of the American Chemical Society* on March 5, 2009.

The research was sponsored by the Camille and Henry Dreyfus Foundation, the American Society of Pharmacognosy and Georgia Tech.

Kelly, graduate student Lisa Pan and postdoctoral fellow Chaoxuan Li began their study of thiostrepton by having the genome of one bacterium that produces it – *Streptomyces laurentii* – sequenced by a commercial laboratory. They then studied different parts of the genome, searching for the genes responsible for producing the drug.

“It was a combination of DNA sequencing, bioinformatic analysis of the encoded proteins and biochemical characterization,” explains Kelly. “We didn’t really know where on the chromosome this would be localized. Instead of taking a single shot and looking only at one location, we used a shotgun strategy that gave us insight into many different regions on the chromosome at the same time.”

Fortunately, in simple organisms like bacteria, genes responsible for a particular task tend to be located close together, so when the researchers found one relevant gene, they knew the rest would be nearby. The researchers produced a knockout mutant to confirm that the genes they had identified were the correct ones.

The mechanism by which the bacterium produces thiostrepton turned out to be of considerable interest. Because peptides produced directly by ribosomal synthesis tend to be comparably simple, researchers had expected the complex thiostrepton molecule to be produced by a non-ribosomal route.

However, the Georgia Tech team showed that the

drug results from a process controlled by the ribosome – which makes it a good target for genetic manipulation.

“The fact that we have a gene that produces a peptide that undergoes post-translational modification makes this a simpler target for biosynthetic engineering,” Kelly notes. “Before this finding, we didn’t know that such extensive modifications could be made to a peptide. Finding this mechanism completely changes how we look at this and similar systems, and changes the potential for biosynthetically engineering effective new systems.”

Kelly’s research team will next seek to understand the complex pathway used to synthesize the drug, then attempt to modify the right component of that machinery to create a variant of thiostrepton that is water soluble.

“You can think about this in terms of an assembly line for manufacturing cars, with the changes occurring in stages during construction,” she said. “The same would be true of a mi-

croorganism building up a complex molecule. Some modifications that occur later in the process may require certain key elements to be present first. We need to understand what modifications are necessary and what features of the structure are important for recognition and processing down the line.”

Produced by certain terrestrial and marine bacteria, thiostrepton was identified in the 1950s, and first synthesized in the laboratory in 2004. Thiostrepton and related thiopeptide antibiotics fight bacteria by disabling their protein biosynthesis, and also have promising anti-malarial and anti-cancer activity.

“With the development of resistance and pathogens such as MRSA, there’s a crisis developing in anti-microbial treatments,” Kelly notes. “If they were to become resistant to the few drugs that are currently available to fight them, they would become untreatable. There is a big push to identify new drugs for clinical use in humans that are effective against these strains.” **rh**

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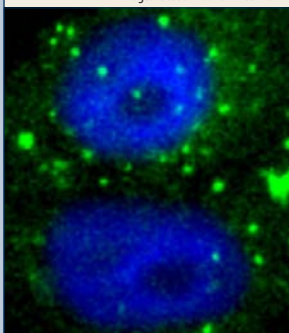
Photo: Gary Meek



Assistant professor Wendy Kelly (left), postdoctoral fellow Chaoxuan Li (center) and graduate student Lisa Pan discuss the genetic machinery for thiostrepton.

Georgia Tech researchers are exploring the molecular changes that lead to the development of cancer. Understanding these complex events could ultimately lead to new strategies for preventing the disease, new diagnostic techniques and new treatments.

Image: Kacee Sims and Alfred Merrill



Sphingolipids are involved in creating autophagic vesicles that can promote or limit tumor growth. The autophagosomes of these breast cancer cells are stained green; for reference, the nuclei are stained blue.

# Understanding the Origins of Cancer:

## Scientists Investigate the Molecular Changes that Lead to Disease

By Abby Vogel

Cancer is the most-feared of human diseases, often striking without warning and seemingly without identifiable cause. Decades into the nation's war on cancer, we have learned that the disease is far more complex than we originally believed.

At the Georgia Institute of Technology, researchers are pursuing many different directions in their quest to understand how cancer arises. They are adding their findings to a deepening understanding of the complex molecular pathways that turn a normal cell into a malignant one. Ultimately, that knowledge may lead to new strategies for preventing cancer, new diagnostic techniques for finding it early – and to drugs and other agents that may provide cures.

This article describes Georgia Tech research into the origins of cancer including:

- How hormones fuel certain cancers;
- The potential role of non-mutational changes, called epigenetics;
- An integrated approach to studying ovarian cancer;
- Mechanisms for repairing double-strand DNA breaks;
- Predicting where DNA will break, and how often it will break; and
- Understanding the role of cell-signaling molecules such as sphingolipids.

This is the first in a series of three reports that will focus on cancer research at Georgia Tech. The other

two will highlight efforts to develop new diagnostics and new treatments.

## Revealing Hormone Links to Cancer

Hormones fuel some types of cancer, including breast cancer, in which malignant cells feed on estrogen – the principal female sex hormone. That suggests strategies to stop the cancer's spread might include blocking the site where estrogen binds to its receptor or inhibiting the gene that controls production of estrogen.

Marion Sewer, an associate professor in the Georgia Tech School of Biology, focuses her research on a protein called liver receptor homolog 1 (LRH1). Inhibiting LRH1 could potentially slow the progression of hormone-sensitive breast cancer by stopping estrogen production.

"We are investigating LRH1 because it binds to sequences of DNA and activates the gene that produces estrogen," says Sewer. "Although LRH1 is not typically present in normal breast tissue, it is present at high levels in breast cancer cells. We're trying to figure out what activates it and causes it to be overproduced in cancerous tissue."

Biologists know that activation of LRH1 cannot occur until a particular small molecule binds to it, but they are unclear about the identity of that molecule. Sewer and Eric Ortlund, an assistant professor in the

Department of Biochemistry at Emory University, are trying to identify the molecule – called a ligand – that binds to LRH1 and activates it.

In collaboration with Alfred Merrill, a professor in the Georgia Tech School of Biology and the Smithgall Chair in Molecular Cell Biology, Sewer is also isolating LRH1 from breast cancer cells and using mass spectrometry techniques to identify any ligands that are bound to the receptor.

“If we can figure out what the ligand is and design some analog of the ligand that would inhibit its ability to bind to DNA and produce estrogen, we may discover a better anti-cancer therapy method,” explains Sewer.

In a related project, Sewer is investigating the genes that control production of vitamin D. These are members of the same family of genes – called cytochromes P450 – that control production of estrogen.

“Since vitamin D levels have been shown to be much lower in breast cancer patients and studies have linked insufficient vitamin D to an increased risk for breast cancer, we are investigating sphingolipid

molecules that increase the presence of the genes that produce the active form of vitamin D,” notes Sewer.

The molecules – called 1-deoxysphingamines – were originally isolated from mollusks and have been shown to have anti-cancer properties. Graduate student Tenzing Phanthok and undergraduate student Viniya Patidar are investigating the role of 1-deoxysphinganine in increasing vitamin D production and in turn preventing cancer cells from multiplying.

Since these 1-deoxysphingamines are naturally produced in the body, it is possible that cancer progression is a result of altered production of 1-deoxysphinganine. Perhaps the level of these molecules could be used as a cancer biomarker or indicator, Sewer says.

Sewer’s work is funded by the National Institutes of Health, National Science Foundation and a Georgia Cancer Coalition Distinguished Scientist Award.

*This project was supported by Award No. R01GM073241 from the National Institute of General Medicine Sciences (NIGMS) and Award No. MCB-0347682 from the National Science Foundation (NSF). Any opinions, findings, conclusions or recommendations expressed are those of the researcher and do not necessarily reflect the views of the NIGMS, the National Institutes of Health or the NSF.*

Photo: Gary Meek

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School of Biology professor Marion Sewer (left) and graduate student Tenzing Phanthok conduct an experiment to investigate proteins that, when inhibited, could potentially slow the progression of hormone-sensitive breast cancer by stopping estrogen production.

# Investigating the Role of Epigenetics in Cancer

While many biologists investigate cancer genetics – mutations in DNA sequences that cause the disease – a growing group of biologists is examining the role of cancer epigenetics, which are changes that contribute to malignancy without causing changes in DNA sequences.

Yuhong Fan, an assistant professor in Georgia Tech's School of Biology, believes that the scientific field of epigenetics may help shape the future of cancer diagnosis and treatment.

"Cancer cells have drastically different epigenetic patterns compared to normal cells," explains Fan, who is also a Georgia Cancer Coalition Distinguished Cancer Scholar. "Many epigenetic changes may appear prior to the development of invasive cancer, so I think that doctors might one day be able to detect epigenetic

markers for cancer before a tumor appears."

Epigenetic studies concentrate on the way the genome is marked and packaged inside a cell's nucleus. Much of Fan's research focuses on the role of H1 linker histones, a family of 10 proteins that helps to package the DNA within chromosomes.

Fan and Arthur Skoutchi, chair of the Department of Cell Biology at the Albert Einstein College of Medicine at New York's Yeshiva University, previously observed the effects of partially reducing H1 levels in mice. The work showed that H1 histones are important to an organism's normal development. Expanding on these findings, Fan recently teamed with John McDonald, chief scientist of the Ovarian Cancer Institute and associate dean for biology development in the School of Biology, to determine if the multiple H1 subtypes are regulated differently in benign and malignant ovarian cancer tissues.

"We found that some of the H1 subtypes were expressed at significantly

higher levels in the cancerous tissue compared to the benign tissue and some were expressed at significantly lower levels," notes Fan. "The most remarkable finding was that these differences, whether increases or decreases, were consistent among multiple samples."

With this knowledge, Fan's next step is to find out what genes and functions are affected by changes in expression of each subtype. To do this, her group plans to change the level of each H1 subtype in cancer cell culture and monitor what happens to cell growth and cell fate.

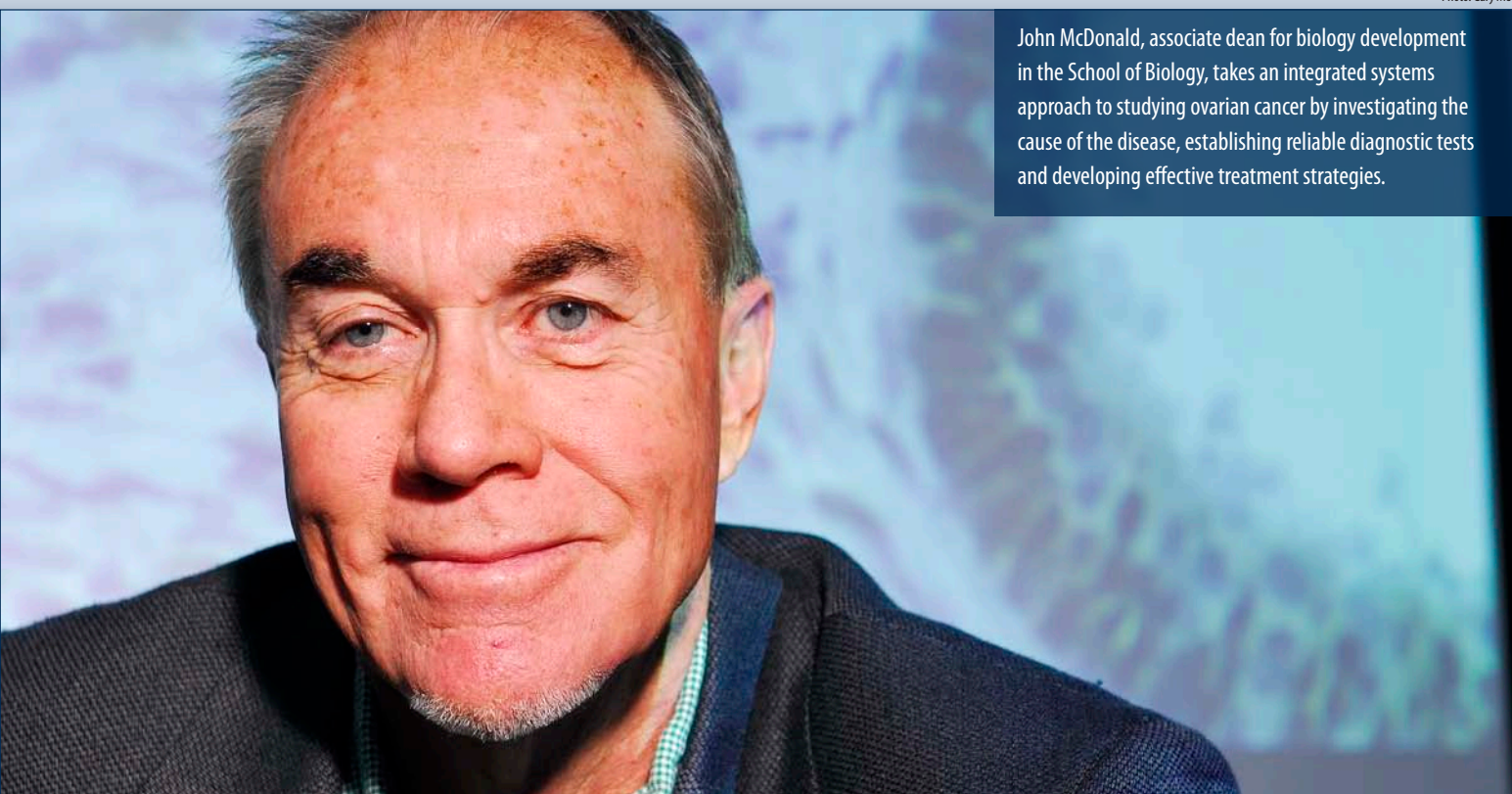
"We hope that measuring the expression level of one or more of these H1 subtypes can be used as an epigenetic biomarker for the cancer diagnosis of the future," adds Fan. "Since the expression patterns are consistent, you could easily measure a few epigenetic characteristics, rather than looking at thousands of genes."

Funding for Fan's research is provided by the National Institutes of Health and the Georgia Cancer Coalition.



Yuhong Fan, an assistant professor in the School of Biology, investigates how mouse embryos develop with varying amounts of H1 linker histone proteins, which help package DNA within chromosomes.





John McDonald, associate dean for biology development in the School of Biology, takes an integrated systems approach to studying ovarian cancer by investigating the cause of the disease, establishing reliable diagnostic tests and developing effective treatment strategies.

## Examining How Ovarian Cancer Develops

Unlike many cancer biology researchers who investigate general processes underlying many cancers, John McDonald focuses his investigations broadly on one type of cancer – ovarian.

Ovarian cancer is the most lethal gynecological cancer, with the American Cancer Society predicting that in the United States alone each year, more than 20,000 women will be diagnosed with ovarian cancer and 16,000 will die from it.

“Ovarian cancer is called the silent killer because by the time symptoms arise and it’s detected, it has typically spread throughout the body,” says McDonald, chief scientist of the Ovarian Cancer Institute and associate dean for biology development in the School of Biology. “Our laboratory takes an integrated approach to studying ovarian cancer by investigating its causes, establishing accurate and reliable diagnostic tests, and developing novel and effective therapies.”

One focus of McDonald’s research is to determine how cancer cells develop in the ovaries. While it is estimated that up to 90 percent of ovarian carcinomas are derived from ovarian surface epithelial cells – cells that create the thin layer of tissue that covers the ovaries – the behavior of these cells differs from other epithelial-derived carcinomas because they become more specialized as malignancy progresses.

To investigate this behavior in more detail, McDonald and Nathan Bowen, a research scientist and Georgia Cancer Coalition Distinguished Cancer Scholar, compared the gene expression profiles of ovarian surface epithelial cells isolated from the surface of healthy ovaries with those of malignant ovarian tumors collected by the Ovarian Cancer Institute.

The results showed that more than 2,000 genes were expressed at significantly different levels in the two sample types. Genes associated with adult stem cell maintenance were expressed at a much higher level in the cells isolated from healthy ovaries.

“We found that changes in the expression of genes involved in maintaining the

inertness and stem cell nature of epithelial surface ovarian cells may be instrumental in the initiation and development of ovarian cancer,” explains McDonald.

The results also showed that the surface of the ovary exhibits the characteristics of an adult stem cell niche, which is a protected environment where stem cells remain inactive until a signal triggers their cell cycle and they differentiate.

Expanding on these results, McDonald, Bowen and postdoctoral fellows Roman Mezencev and Lijuan Wang are currently examining the sensitivity of ovarian cancer stem cells and differentiated cancer cells to existing chemotherapy agents.

“The preliminary results indicate that existing chemotherapy agents may effectively kill cancer cells but not touch these cancer stem cells, which could be why ovarian tumors and other cancers frequently recur,” adds McDonald.

This work was supported by the Ovarian Cancer Institute, Georgia Cancer Coalition, Golfers Against Cancer Foundation, Ovarian Cycle Foundation, Robinson Family Foundation and Deborah Nash Harris Foundation.

# Investigating DNA Repair Mechanisms

Exposure to environmental carcinogens such as tobacco smoke and ultraviolet radiation can result in various types of DNA damage and subsequently lead to the development of cancer if the damage is not repaired.

Double-strand breaks, in which both strands in the DNA double helix are severed, are particularly hazardous to cells because they can lead to genome rearrangements. And their repair is intrinsically more difficult.

Biologists typically believed that double-strand breaks could only be repaired by homologous intact DNA – until recently, when Francesca Storici, an assistant professor in Georgia Tech’s School of Biology, showed that RNA could be used as a template to directly repair DNA in yeast cells. This contradicted the dogma that genetic information had to flow from DNA to RNA.

“Using RNA that naturally resides inside a cell to repair damaged DNA could represent an additional line of defense against DNA damage,” says Storici, who is also a Georgia Cancer Coalition Scholar. “The capacity of RNA to record itself into DNA could be the basis of a wholly unexplored process of RNA-driven DNA evolution.”

These unique RNA functions may have important implications in gene targeting and gene therapy because RNA molecules mimicking RNA oligonucleotides could be generated directly in the nucleus of targeted cells via transcription from vectors.

Since her initial discovery in yeast, Storici has used RNA to repair broken chromosomal DNA in human cells in culture and to correct a base defect in the genome of bacterial cells, suggesting that RNA-templated DNA repair is a more general mechanism. She is currently examining exactly how this direct transfer of RNA information to DNA occurs.

“While we can gain a lot of insight from understanding how a cell can repair its DNA, we can also use that information to create a better method for correcting genetic defects,” notes Storici.

Her goal is to develop a tool to correct a particular mutation on a specific chromosome while causing minimal damage to the DNA. One way to do that, Storici says, might be to search for factors that facilitate delivery of the targeting molecule to the nucleus and promote the exchange of DNA strands.

To test the tool she develops, Storici is working with and constructing different human cell lines, and monitoring the repair of specific genetic defects with a simple flow cytometry assay.

Given the ability of RNA to transfer genetic information to chromosomal DNA and the possibility of amplifying RNA within cells at will, Storici plans to continue investigating new directions in gene targeting and treatment of cancer and other genetic diseases.

Francesca Storici, an assistant professor in the School of Biology, counts yeast colonies that grew after transformation using RNA-containing oligonucleotides.



Photo: Gary Meek

# Understanding the Role of Sphingolipids in Cancer Development

For almost 30 years, Georgia Tech professor Alfred Merrill has been studying lipids – the fats, oils, cholesterol and certain vitamins that our bodies need to grow and survive. Today, his expertise lies in a subgroup of lipids called sphingolipids, which influence cell structure, signaling and interaction.

“The lipid backbones of sphingolipids are important cell-signaling molecules that turn on and turn off intracellular proteins that are involved in cell growth, death, and an interesting process called autophagy that has recently gained much attention in the cancer research field,” says Merrill, who is also the School of Biology’s Smithgall Chair in Molecular Cell Biology.

Autophagy – meaning “self-eating” –

involves the degradation of cellular compartments, called organelles, and cellular proteins. During this process, a cell forms a vesicle that encapsulates its cytoplasm and some of the organelles and then fuses with digestive enzymes that degrade the contents of the vesicle and make them available for cell nutrition.

Interestingly, autophagy has been implicated in both cancer cell death and survival. Since Merrill’s research has shown that sphingolipid signaling is essential for creating autophagy vesicles, these metabolites may be involved in both promoting and limiting tumor growth.

Autophagy promotes cancer cell survival by allowing cells to respond to changing environmental conditions, such as nutrient deprivation. During starvation, autophagy allows cells to degrade proteins and organelles and thus obtain a source of nutrients that would not be available otherwise.

“Cancer cells use autophagy because as they are developing they have a period in which they go into a nutrient crisis because they haven’t established their own blood and nutrient flow, so they use autophagy as

a way to survive in the meantime,” explains Merrill.

However, this same process of gaining nutrients can lead to tumor cell death as well. Merrill’s laboratory found that a number of anti-cancer agents promote the formation of these vesicles through sphingolipid signaling.

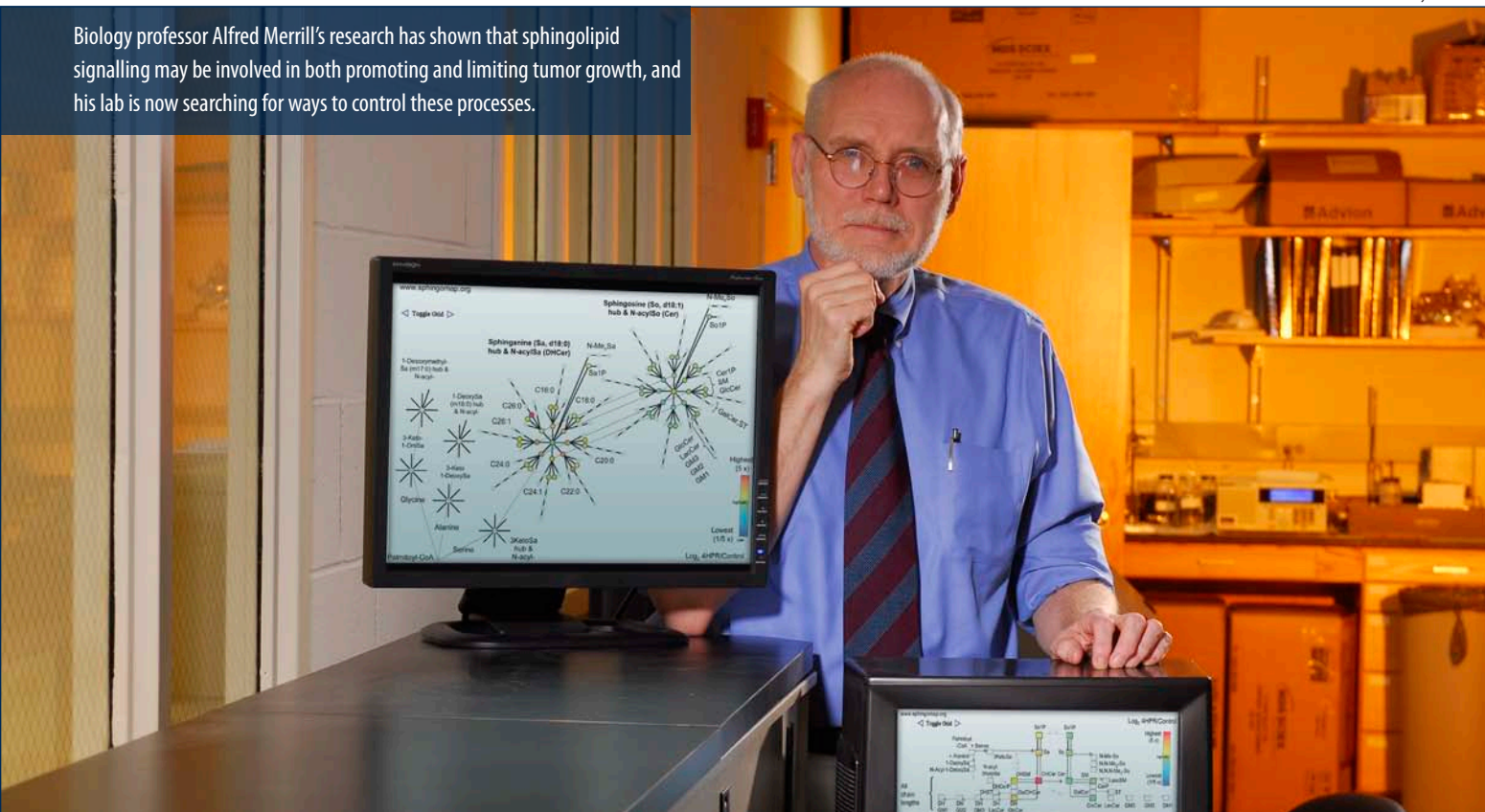
“Preliminary data supports the theory that the autophagic vesicles in cancer cells are unstable, so if one of their components—the sphingolipids—is out of balance, this can cause them to break apart and spill out their toxic contents, killing the cancer cell,” adds Merrill.

While the mechanism through which autophagy inhibits tumor development is still unclear, graduate student Kacee Sims is examining the role of sphingolipid pathways in the conversion of autophagy from a cancer cell survival pathway to a cell death pathway.

*The project described was supported by Award No. U54GM069338 from the National Institute of General Medicine Sciences (NIGMS). Any opinions, findings, conclusions or recommendations expressed are those of the researcher and do not necessarily reflect the views of the NIGMS or the National Institutes of Health. Significant funding to support this research was also provided by the Smithgall Endowment to Georgia Tech.*

Photo: Gary Meek

Biology professor Alfred Merrill’s research has shown that sphingolipid signalling may be involved in both promoting and limiting tumor growth, and his lab is now searching for ways to control these processes.



# Investigating the Complexity of Chromosome Breaks

Everyone has fragile sites on their chromosomes that are particularly prone to breaking, making them hot spots for rearrangements that can lead to hereditary diseases and cancer. Georgia Tech School of Biology associate professor Kirill Lobachev is trying to understand what's special about these regions, the consequences of the breaks, and the pathways that are involved in promoting and repairing these breaks.

"It is becoming clear that the fragile sites often contain unstable repetitive sequences that can adopt unusual DNA structures," says Lobachev. "We think that everyone is probably a carrier of these unstable motifs that can cause chromosomes to break anytime, so we ultimately want to be able to predict where a chromosome is going to break and how frequently this break will occur, and determine if we can prevent it."

Determining whether a particular chromosomal region is predisposed to breakage requires knowledge about the structural parameters of the unstable sequences that make chromosomes fragile, such as their size or composition of the genetic sequences they contain. Using the yeast *Saccharomyces cerevisiae* as a model organism, Lobachev's laboratory has been able to mimic some of the structural instability that cancer cell chromosomes exhibit.

In a recent study, Lobachev and colleagues demonstrated that DNA replication machinery sometimes stalls when it reaches a long sequence of palindromes – sequences that read the same way backward and forward. Further analysis has shown that chromosomes break when DNA replication is slowed or altered.

"Long palindromes were known to change the shape of DNA from a double helix into a

School of Biology associate professor Kirill Lobachev and postdoctoral fellow Vidhya Narayanan look at a plate displaying mutant yeast cells that are defective in making fragile chromosomes, which are hot spots for rearrangements that can lead to cancer.




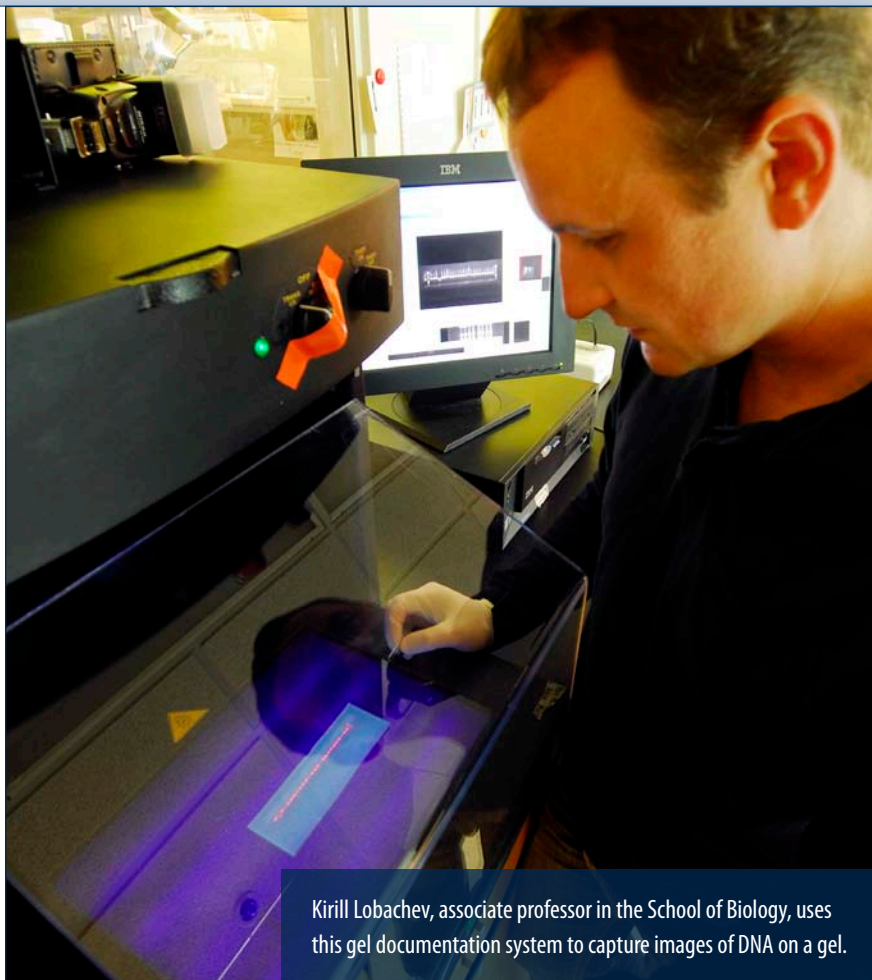
Photo: Gary Meek

hairpin or cruciform structure, but this was one of the first studies to show that these changes could affect DNA integrity,” explains Lobachev.

In addition, Lobachev and postdoctoral fellow Vidhya Narayanan determined that palindromic sequences induce a particular type of DNA break that is a precursor to a process involved in cancer called gene amplification. Amplification of genes involved in metabolism or inactivation of drugs can lead to chemotherapy resistance, and amplification of genes that turn normal cells into cancer cells are known to occur in several late-stage cancers.

They showed that gene amplification depends on the location of an oncogene relative to the break – called a hairpin-capped double strand break – and the end of the chromosome. The study indicated that restricting breakage of the unstable sequences may be a promising strategy for pharmaceutical cancer prevention and treatment.

In the future, knowing what genetic sequences are more likely to lead to chromosomal fragility and being able to explore genetic pathways involved in this process may help researchers identify persons who might be prone to developing cancer, adds Lobachev. 

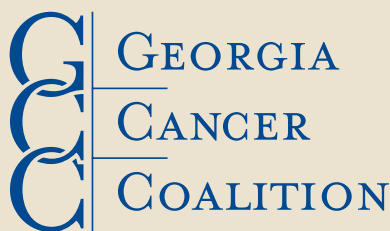


Kirill Lobachev, associate professor in the School of Biology, uses this gel documentation system to capture images of DNA on a gel.

Photo: Gary Meek

## Collaboration with the Georgia Cancer Coalition

The Georgia Cancer Coalition's (GCC) mission is to reduce the number of cancer deaths in Georgia. One key initiative toward accomplishing that goal is naming Georgia Cancer



Coalition Distinguished Cancer Clinicians and Scientists. In concert with Georgia's academic universities, the GCC supports the recruitment of national leaders in cancer research to Georgia. At Georgia Tech, 11 researchers have been named Distinguished Cancer Scholars, including:

- Ravi Bellamkonda, professor, biomedical engineering
- Nathan Bowen, senior research scientist, biology
- Erin Dickerson, research scientist, biology
- Yuhong Fan, assistant professor, biology
- Melissa Kemp, assistant professor, biomedical engineering

- Valeria Tohver Milam, assistant professor, materials science and engineering
- Shuming Nie, professor, biomedical engineering
- Marion Sewer, associate professor, biology
- Francesca Storici, assistant professor, biology
- Dongmei “May” Wang, assistant professor, biomedical engineering
- Ming Yuan, assistant professor, industrial and systems engineering

The Georgia Cancer Coalition has also awarded seven Cancer Research Awards to Georgia Tech faculty members investigating how to prevent, treat and cure breast, ovarian and prostate cancers. Michelle Dawson, an assistant professor in Georgia Tech's School of Chemical and Biomolecular Engineering, recently received one of these grants for her research into the development of specialized cells designed as gene delivery vehicles to target and treat breast cancer.

When the U.S. Air Force identified a need for enhanced missile protection for its fleet of A-10 aircraft, GTRI responded quickly with a multidisciplinary team that included specialists in electrical engineering, software development, systems engineering and mechanical engineering. The upgrade is now active on the U.S. A-10 fleet worldwide.

Photo: Gary Meek



Principal research engineers Mike Willis and Charlie Carstensen, and research engineer Melanie Hill (l-r) were members of a multidisciplinary GTRI team that completed a recent upgrade of the missile-defense capability of the A-10 aircraft.

# On the Fly:

## Multidisciplinary Team Tackles Urgent Aircraft Defense Upgrade

By Rick Robinson

When the U.S. Air Force found that one of its key combat aircraft needed more protection from an enemy missile threat, a multidisciplinary team from the Georgia Tech Research Institute (GTRI) went into action.

The problem was a pressing one. The A-10 attack aircraft, an Air Force workhorse, needed important additions to its electronic warfare (EW) countermeasures systems.

"This was a rush program – they needed it right away," says research engineer Melanie Hill, who was GTRI's lead engineer on the program. "We made it a priority across many different GTRI groups because of the broad requirements, which included electrical engineering, software development, systems engineering and mechanical engineering."

At issue was the ability of the A-10 to detect infrared signals from certain classes of enemy weapons. The A-10, an attack aircraft that often flies at lower alti-

tudes to use its heavy guns and missiles against ground targets, could be vulnerable to those weapons.

The A-10 already carried extensive electronic warfare equipment, including the ALQ-213, a central controller that is the core of the airplane's electronic warfare systems. Essentially, it is the pilot's control center for threat protection.

The ALQ-213 takes information from the aircraft's individual EW systems – which include a radar warning receiver and signal-jamming pods – and processes that data in a coordinated manner. The controller also handles the dispensing of chaff and flares, which are countermeasures used to decoy hostile missiles.

The GTRI team's first task was to take an existing infrared-detection tool, the AAR-47 missile warning system, and determine whether it could do the job on the A-10. Then the team had to decide exactly how to add the AAR-47 to the A-10, and how to

integrate the new missile-warning functions into the ALQ-213 controller.

The effort, called the A-10 Infrared Countermeasures (IRCM) Program, was on a tight schedule from the start, with 200 days to move from concept to flight test. The project was sponsored by the Warner Robins Air Logistics Center at Robins Air Force Base.

Engineers from across GTRI pulled together to meet the deadline. GTRI principal research scientist Charlie Carstensen used a pedestal-mounted A-10 located at an Air Force facility in Rome, N.Y., to establish that the AAR-47 was a viable option for the A-10.

With principal research engineer Mike Willis as program manager, principal research engineer Jeff Hallman led the AAR-47 research effort, and principal research engineer Byron Coker led the team developing the software that allowed the AAR-47 to communicate with the ALQ-213.

A successful flight test kept the program on schedule.

GTRI's next task was to take the prototype equipment that had passed the flight test and use it to develop a standardized installation kit that included a complete package of technical drawings. The kit would then be used to perform hundreds of upgrades on U.S. A-10s worldwide.

Research associate Kim Wood was a leader in electrical/mechanical design and aircraft installation, and principal research engineer Rod Beard and electrical engineer Wallace Gustad were among the GTRI personnel who worked on the original prototype used for flight testing, as well as on development of the upgrade installation kits. Numerous other engineers, technologists and scientists worked on the program's mechanical engineering and drafting needs.

To help get the actual A-10 upgrade process under way, GTRI supported the manufacture of

the initial production kits, and then turned the engineering over to the Air Force for continued production.

The upgrade is now active on the U.S. A-10 fleet worldwide.

In a separate but related project, a GTRI team that included Byron Coker, Mike Willis and Lee Montaña was successful in automating the functions of the ALQ-213 on the A-10 and the F-16 combat aircraft. Now pilots of those aircraft can put their entire EW suite on fully automatic operation, giving them greater freedom to concentrate on missions.

"I think the success of the IRCM program says something about GTRI's ability and readiness to focus a broad spectrum of expertise on a given need, even in a short timeframe," Hill says. "A lot of different disciplines in GTRI worked on this program, and they worked together in ways that were both timely and highly effective." 

Photo: Melanie Hill

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**“We made it a priority across many different GTRI groups because of the broad requirements, which included electrical engineering, software development, systems engineering and mechanical engineering.”**

**— Melanie Hill,  
GTRI research engineer**



The A-10 attack aircraft, shown here undergoing maintenance, is an important element of U.S. air-to-ground offensive capability.

Georgia Tech researchers are contributing to the Micro Autonomous Systems and Technology (MAST) Collaborative Technology Alliance Program, a five-year initiative sponsored by the U.S. Army Research Laboratory (ARL). The goal is to create tiny intelligent mobile robots that could someday assist U.S. armed forces.

Photo: Gary Meek



The USARsim software environment is being used by Georgia Tech researchers to help investigate the basic capabilities for miniature robots.

# Micro Brigade:

## Miniature Robot Ensembles Could Aid Future Armed Forces Missions

By Rick Robinson

As Army soldiers take up secure positions behind a wall, they deploy a small reconnaissance team – a very small one. Some hopping, some flying, the stealthy recon squad vanishes into a suspicious building for long minutes, then relays the all-clear back to its relieved partners outside.

It's an intriguing scenario; it just hasn't happened yet. But the chances that tiny intelligent mobile robots could someday assist U.S. armed forces and other personnel are improving, thanks to a major research program led by BAE Systems and including the Georgia Institute of Technology among 10 principal and general members.

Called the Micro Autonomous Systems and Technology (MAST) Collaborative Technology Alliance Program, the new five-year initiative is sponsored by the U.S. Army Research Laboratory (ARL).

The Georgia Tech Research Institute (GTRI), Georgia Tech's College of Computing and the School of Aerospace Engineering and School of Physics are involved in the program, with Georgia Tech researchers contributing to three of four primary MAST research teams.

"At this point, it's difficult to say which practical systems will come out of this, because we're doing basic research at the moment," says Mike Heiges, a GTRI senior research engineer. "By bringing together world-class expertise from several different fields, it's hoped that within five years real-world applications can be developed."

The program includes four principal research teams:

- **Integration**, led by BAE Systems, Inc., oversees all research efforts and addresses the application of results to practical systems. The team includes the California Institute of Technology/Jet Propulsion Laboratory, Georgia Tech and the

University of California Berkeley.

- **Microelectronics**, led by the University of Michigan, addresses the hardware aspects of control, communications and sensing for autonomous robot operation. The team includes the University of California Berkeley and the University of New Mexico.
- **Microsystems Mechanics**, led by the University of Maryland, addresses locomotion technology for tiny mobile robots. The team includes the California Institute of Technology/Jet Propulsion Laboratory, Georgia Tech, North Carolina A&T State University and the University of California Berkeley.
- **Processing for Autonomous Operation**, led by the University of Pennsylvania, addresses autonomous navigation, distributed perception and group behaviors for an ensemble of intelligent and mobile micro autonomous systems. The team includes Georgia Tech, the University of California Berkeley and the University of New Mexico.

Other institutions participating include Boston University, Harvard University, the Massachusetts Institute of Technology, Vanderbilt University, the University of Milan (Italy), the University of Sydney (Australia); and two companies: Centeye and Daedalus.

Heiges, working with GTRI principal research engineers Jim McMichael and Lora Weiss, is supporting the integration effort. The GTRI integration team is collaborating with Dimitri Mavris of Georgia Tech's Aerospace Systems Design Laboratory.

The integration team's immediate focus involves determining the most desirable capabilities for the



palm-sized robots. Currently, the Army uses unmanned systems that are sizeable and send back a raw data stream that must be constantly monitored by human operators.

“What the Army wants is very small robots smart enough to go off on their own and then alert you when they find something,” Heiges says. “These wouldn’t be dumb sensor carriers; they would interpret what their sensors are telling them.”

Also participating in the program is assistant professor Daniel Goldman of the Georgia Tech School of Physics. Collaborating with the University of Maryland-led microsystems mechanics team, Goldman is developing models of different ground surfaces to better understand locomotion on complex terrain like sand and leaf litter. (See story on page 28 of this issue).


In another Georgia Tech effort, GTRI principal research engineer Tom Collins is leading a team focused on the processing for autonomous operations. Collins is collaborating with several investigators from the College of Computing, including Regents’ professor Ronald Arkin; Henrik Christensen, director of the Robotics and Intelligent Machines Center, and associate professor Frank Dellaert. Working with the University of Pennsylvania and others, the Georgia Tech researchers are contributing to the intelligence technology necessary for small-robot operation.

It’s a distinct challenge, Collins says. Potential operating environments are still unknown, and that’s problematic since a small robot can’t necessarily handle the same physical challenges as a larger robot.

“We’re looking at very complex locomotion mechanisms that we have to plan paths for – things that may jump, crawl or fly,” Collins says. “We have to look at everything in a rather abstract and general sense, while also dealing with all the problems of scale.”

Also at issue is how the robots will interact. Intelligence could be distributed to each individual machine, or the robot ensemble could send data to one highly developed processing node. Currently, research favors a decentralized approach in which individual robots would share information among their companions to form a more complete picture.

It’s likely that robot ensembles will be programmed quickly by people with limited training. Moreover, operators won’t be able to carry elaborate gear in the field.

“We’ll need to keep it simple,” Collins says. “The operator could specify the mission type, then choose a few parameters like direction and the number of robot participants. Then, relatively quickly, you’ve got a bunch of robots programmed and ready to go.” 

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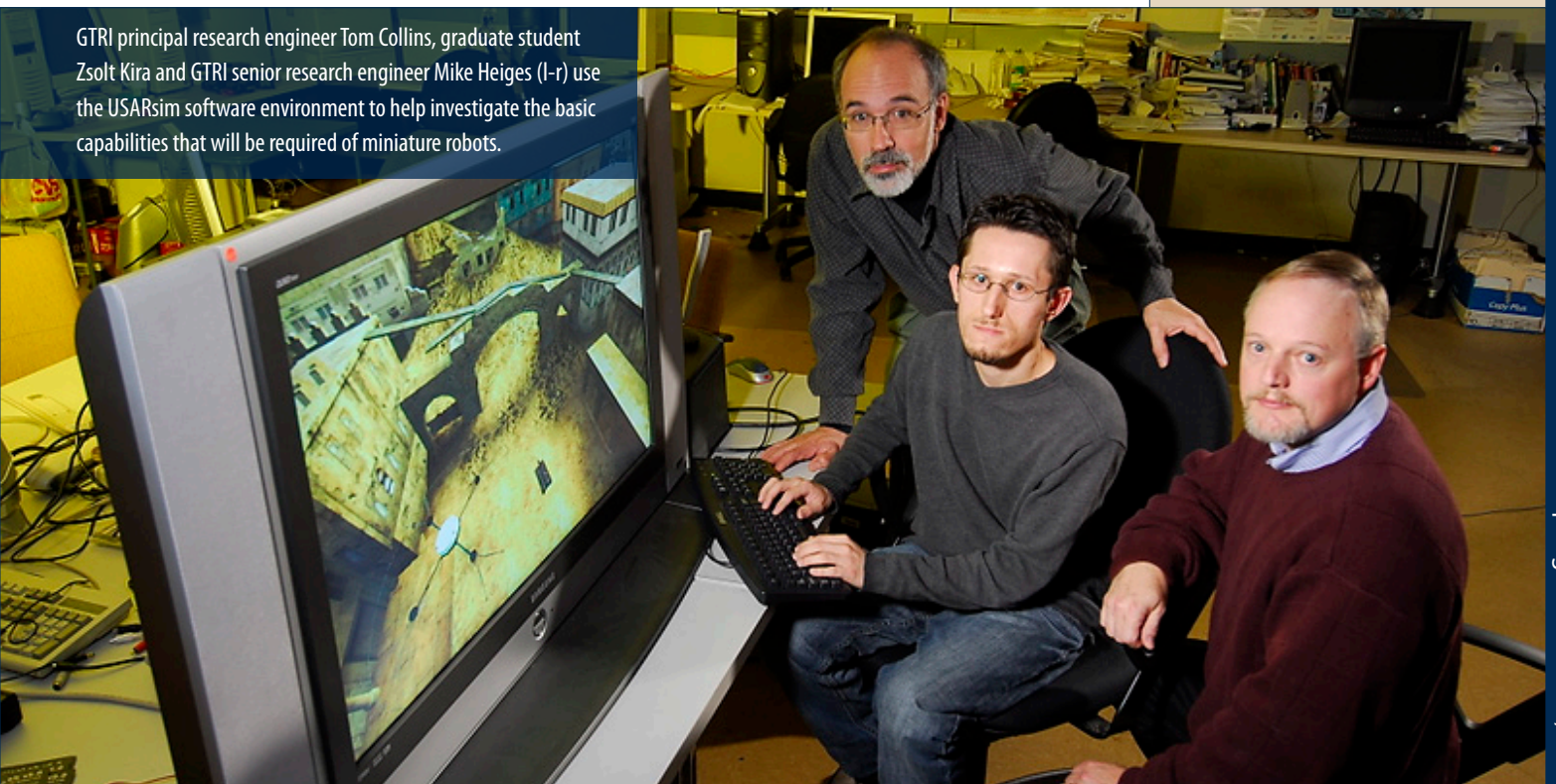
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**“What the Army wants is very small robots smart enough to go off on their own and then alert you when they find something. These wouldn’t be dumb sensor carriers; they would interpret what their sensors are telling them.”**

**— Mike Heiges, GTRI senior research engineer**

GTRI principal research engineer Tom Collins, graduate student Zsolt Kira and GTRI senior research engineer Mike Heiges (l-r) use the USARsim software environment to help investigate the basic capabilities that will be required of miniature robots.



A study of more than 500 toy recalls between 1988 and 2007 suggests ways that firms can minimize the business impact of a recall. Among the findings: companies must engage the public early, act quickly and make it easy for consumers to exchange defective products or receive a refund.

Research done by College of Management assistant professor Manpreet Hora examines the risk of operational failures, such as product recalls, and how firms recover and learn from these failures.



# Toy Recall:

## Study Describes How Companies Can Recover from a Product Recall

By Abby Vogel

A product recall can significantly affect a company's bottom line and its reputation, but a swift recall and restitution to purchasers can minimize harm to the company – and even improve customer satisfaction. A study examining more than 500 toy recalls between 1988 and 2007 suggests ways that firms can minimize the business impact of a recall.

The results of the study, conducted by researchers at the Georgia Institute of Technology and the University of Manitoba, were described May 2, 2009 at the Annual Conference of the Production and Operations Management Society. The research was funded by the Social Sciences and Humanities Research Council of Canada.

"Recalls undermine trust in a specific brand, and it can take the company a long time to recover from the damage to its reputation, but it doesn't have to take a long time if the company uses good crisis management tactics," says Manpreet Hora, an assistant professor in Georgia Tech's College of Management. "Reducing

the time it takes to recall a product will have a positive effect on consumers' willingness to purchase other products from the same company, and if the recall is handled well, the stock price may recover to the same level as before the incident."

According to Hora and Hari Bapuji, an assistant professor at the University of Manitoba, effective recovery from a product recall begins with the way in which the company announces the recall. The firm should engage the public and disclose all relevant recall and replacement information as soon as possible. Even if the recall was the result of an out-sourcing or off-shoring decision, the company should take shared responsibility for the error, the researchers say.

"Consumers are forgiving, so if a firm apologizes, acknowledges the problem, and doesn't make the mistake again and again, consumers will continue to be loyal to that brand," says Hora.

After apologizing, the firm needs to get the product off store shelves and out of consumers' hands as quickly as possible.

To do this, the firm must choose the best way to compensate the product purchasers and determine who will interface with the customers. There are many choices – the manufacturer, distributor or retailer can collect the recalled product and restitution can be provided by repairing or replacing the product or refunding the purchase price.

"Firms must keep in mind that the best choices are those that decrease the time it takes to recall the product, and our analysis shows that it takes much longer to recall the product if the company that announces the recall is farther away from the consumer," explains Hora.

Firms need to collaborate and communicate well with their downstream distributors and retailers so that the distributors and retailers are willing to handle the recall for the manufacturer, leading to much faster recalls. However, if there are millions of units being recalled, it can be a logistical nightmare for the retailers to handle the issue.

When it comes to the type of restitution, shorter recall time

is associated with exchanging rather than refunding the recalled product. The firm will fare better if the consumer doesn't have to jump through a lot of hoops for restitution, which may mean allowing consumers to visit a local retailer to return the item for a refund.

The researchers also studied how different types of recalls and defects affected the time it took to recall a product. Their results showed that manufacturing defects, such as lead content in toys, took much less time to recall than design defects such as detachable magnets.

Hora and Bapuji are currently expanding their study to investigate how other industries

recover from product recalls and whether firms learn from product recalls outside of their own industries.

"Having effective recovery strategies for dealing with product recalls efficiently and in a timely manner is imperative," notes Hora. "If a firm handles a product recall crisis well, it can be turned into an advantage for that company by actually increasing consumer satisfaction beyond where it was before the recall." **rh**

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**“Reducing the time it takes to recall a product will have a positive effect on consumers' willingness to purchase other products from the same company.”**

**— Manpreet Hora, assistant professor in the College of Management**

Georgia Tech assistant professor Manpreet Hora's examination of more than 500 toy recalls showed steps companies should take to avoid long-term harm.



## Georgia Tech Researchers' Work is Covered in the News Media

Photos: Gary Meek

Readers of more than 150 news outlets in the U.S. and Europe learned that closing schools wasn't necessarily the only option available to authorities for controlling the spread of the new H1N1 flu. The Associated Press mentioned the findings of a pandemic flu model developed by Pinar Keskinocak and Julie Swann from the Stewart School of Industrial and Systems Engineering. The model found that a four-week voluntary quarantine of households affected by the virus would be at least as effective as a six-week school closure at reducing the percentage of the population affected by the virus. Top media outlets carrying the story included the *Atlanta Journal-Constitution*, CBS News, the *Dallas Morning News*, *Forbes*, the *San Diego Union Tribune*, *San Francisco Chronicle* and *San Jose Mercury News*. (See the article in the Fall 2008 issue of *Research Horizons* magazine).

Versatile robots being used for a broad range of exploration on Earth and other planets face a very significant challenge: traversing sand and other granular media. Researchers investigating the problem of robot locomotion on such surfaces are learning that slower walking may be better than rapid movement to avoid being bogged down in sand. These findings, published in the journal *Proceedings of the National Academy of Sciences (PNAS)* by School of Physics

professor Daniel Goldman, were covered by a broad range of media. Outlets reporting on how robots should walk on sand included *Discover Magazine*, Discovery Channel News, MSNBC, *IEEE Spectrum*, *InTech*, National Public Radio, *New Scientist*, and *Scientific American*. (See the article on page 28 of this issue of *Research Horizons* magazine).

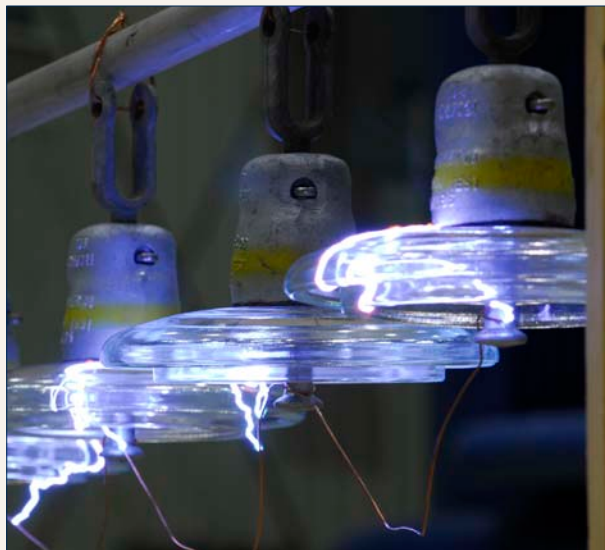
Acoustics research aimed at quieting unmanned aerial vehicles was reported in a number of technical and trade publications. The research, by Rick Gaeta, Gary Gray and others in the Georgia Tech Research Institute (GTRI), was covered in *Aviation Week & Space Technology*, *National Defense* and the Web site The Future of Things. Working with special acoustic test facilities, the GTRI researchers were able to separate UAV engine sounds from other sources of noise. (See the article in the Fall 2008 issue of *Research Horizons* magazine).

A study published in the journal *Proceedings of the National Academy of Sciences (PNAS)* showed for the first time that microneedle patches could be as effective as traditional hypodermic needles at delivering a vaccine against seasonal flu. The work, by a team of researchers from Georgia Tech and Emory University, tested the patches on mice. Media outlets reporting on the work



(Top) GTRI senior research engineers Rick Gaeta, left, and Gary Gray display a propeller-dynamometer device developed to test UAV aeroacoustics.

(Bottom) Researchers test insulators using high-voltage current at the NEETRAC facility south of Atlanta.



included Biology News, CNN, *MICRO Manufacturing*, MSNBC, *Scientific American*, Scientist Live, WGCL-TV and WSB-TV. At Georgia Tech, the work is being led by Mark Prausnitz in the School of Chemical and Biomolecular Engineering.

Georgia Tech's National Electric Energy Testing Research and Applications Center (NEETRAC) conducts research designed to improve the reliability of the nation's electric utilities,

including studies on how to protect electric utility equipment from lightning. The work, led by NEETRAC director Rick Hartlein, was reported in several technical and trade media outlets, including *Electric Net*, *R&D Magazine* and *Utility Automation*. NEETRAC is part of the School of Electrical and Computer Engineering. (See the article in the Fall 2008 issue of *Research Horizons* magazine).

# Georgia Tech Faculty and Staff Receive Recognition

Chemistry and biochemistry professor **Bridgette Barry**, chemical and biomolecular engineering professor **Charles Eckert**, and School of Electrical and Computer Engineering chair **Gary May** became fellows of the American Association for the Advancement of Science (AAAS).

**Kim Cobb**, assistant professor in the School of Earth and Atmospheric Sciences, and **Nick Feamster**, assistant professor in the School of Computer Science, each received a Presidential Early Career Award for Scientists and Engineers (PECASE).

Biomedical engineering professor **Xiaoping Hu**, associate professor **Michelle LaPlaca** and visiting professor **Zvi Schwartz** were recently named fellows of the American Institute for Medical and Biological Engineering.

The IEEE elected aerospace engineering professor **Wassim Haddad** and biomedical engineering professors **Xiaoping Hu** and **Allen Tannenbaum** to its College of Fellows.

**Mostafa El-Sayed**, Julius Brown Chair and Regents' professor in the School of Chemistry and Biochemistry, received the second Ahmed Zewail Prize in Molecular Sciences from *Chemical Physics Letters* and its publisher Elsevier.

School of Chemical and Biomolecular Engineering assistant professor **Michelle Dawson** received a 2009 Georgia Cancer Coalition Cancer Research Award.

School of Earth and Atmospheric Sciences professor **Philippe Van Cappellen** was named a Georgia Research Alliance Eminent Scholar.

**Laurie Garrow**, assistant professor in the School of Civil and Environmental Engineering, received a National Science Foundation CAREER award and the New Faculty Member Award from the Council of University Transportation Centers-American Road & Transportation Builders Association.

Electrical and computer engineering professor **Ian Ferguson** was named an SPIE Fellow.

Interactive computing professor **Gregory Abowd** was named a fellow of the Association for Computing Machinery (ACM).

Regents' operations management professor **Cheryl Gaimon** was named a fellow of the Production and Operations Management Society.

The **GTRI Communications Office** won the Grand Award at the Council for the Advancement and Support of Education Region III conference in the category of graphic identity programs.

School of Interactive Computing professor **Beth Mynatt**, director of the Graphics, Visualization and Usability (GVU) Center, was named to the Computer Human Interaction Academy.

**Thomas Barker**, biomedical engineering assistant professor, received the 2008 Walter A. Rosenblith Young Investigator Award from the Health Effects Institute.

Biomedical engineering assistant professor **Niren Murthy** was awarded the Society for Biomaterials 2009 Young Investigator Award.

Physics professor **Uzi Landman** received a Humboldt Research Award.

School of Chemical and Biomolecular Engineering professor **Chris Jones** received a 2009 Camille and Henry Dreyfus Foundation fellowship.

School of Chemical and Biomolecular Engineering assistant professor **Hang Lu** received a 2009 Sloan Research Fellowship.

**Athanasios Nenes**, an associate professor in the School of Earth and Atmospheric Sciences, received the 2009 Henry G. Houghton Award from the American Meteorological Society.

College of Architecture professor of practice **David Green** was awarded a 2008 Bronze Medal from American Institute of Architecture Georgia chapter.

**Dominic Assimaki**, assistant professor in the School of Civil and Environmental Engineering, received the 2008 Arthur Casagrande Professional Development Award from the American Society of Civil Engineers Geo-Institute.

GTRI employee **Sandra Kirchofer** was awarded the Jim Hardy Property Person of the Year Award from the Shamrock Chapter of the National Property Management Association.

Civil and environmental engineering professor **Michael Meyer** received the Georgia Society of Professional Engineers' award for Engineer of the Year in Education.

Civil and environmental engineering professor **Jim Spain** received the 2009 Procter & Gamble Award in Applied and Environmental Microbiology.

Electrical and computer engineering associate professor **John Papapolymerou** received the

2009 Outstanding Young Engineer Award from the IEEE Microwave Theory and Techniques Society.

**Karim Sabra**, assistant professor in the Woodruff School of Mechanical Engineering, received the 2009 A. B. Wood Medal from the Institute of Acoustics in Great Britain.

**Scott Bair**, principal research engineer in the Woodruff School of Mechanical Engineering, received the 2009 International Award from the Society of Tribologists and Lubrication Engineers.

**Yogendra Joshi**, the McKenney-Shiver Chair in Building Mechanical Systems in the School of Mechanical Engineering, received a 2008 IBM Faculty Award.

Mechanical engineering professor **Itzhak Green** received the 2009 Captain Alfred E. Hunt Memorial Award from the Society of Tribologists and Lubrication Engineers.

**Jianmin Qu**, professor in the Woodruff School of Mechanical Engineering, won the 2008 Outstanding Sustained Technical Contribution Award from the IEEE Components, Packaging & Manufacturing Technology Society.

Industrial and systems engineering professor **Jianjun Shi** received the 2008 Institute for Operations Research and the Management Sciences Fellow Award.

**Sundaresan Jayaraman**, a professor in the School of Polymer, Textile and Fiber Engineering, was appointed to the Board on Manufacturing and Engineering Design of the National Academies.

- compiled by Abby Vogel



Bowman



LaPlaca



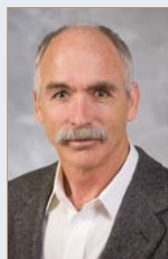
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Garrow



Mynatt



Spain



Van Cappellen

FACTULTY & STAFF AWARDS & HONORS

Georgia Tech's \$500 million-per-year research program is spinning off a broad range of startup companies working in the areas of clean technology. These companies are producing high efficiency solar cells, long-term weather forecasts, ride-sharing programs based on mobile phone and GPS technology, and electrochemical sensors to get the most use out of motor oils.

In Suniva's manufacturing plant north of Atlanta, company founder Ajeet Rohatgi holds a 6-by-6 inch "pseudo-square" solar cell made there.



Photo: Gary Meek

# Clean-Tech to Market:

## Young Companies Utilize Georgia Tech Research to Help Ease Global Environmental Impact

By Rick Robinson

As pump prices gyrate and global temperatures rise, the world's dependence on hydrocarbon fossil fuels looks increasingly precarious. Elevated greenhouse gas levels and a string of particularly destructive storms have created new interest in ways to reduce impacts on the world's environment and slow climate change.

At the Georgia Institute of Technology, young companies arising from the Institute's \$500 million-per-year research program are developing cleaner, more-sustainable technologies. Focusing mainly on cleaner production or more efficient use of energy, these ventures are converting research discoveries into applications with broad benefits.

"Clean technologies have very significant environmental and economic promise," says Stephen Fleming, Georgia Tech's chief commercialization officer and director of the Commercialization Services Division in Georgia Tech's Enterprise Innovation Institute. "Several companies based on Georgia Tech research are producing clean-tech products today here in Georgia or are knocking at that door, and nu-

merous others show real promise."

Commercialization Services identifies, evaluates and promotes Georgia Tech research discoveries that show commercial potential. Most such discoveries fall into two categories: those that may be licensed to established corporations, and those few – about one in 10 – that can provide foundations for new companies.

The VentureLab program of the Georgia Research Alliance supports development of those companies through grants and other assistance that helps them get started. Here are some highlights of Georgia Tech's "green" companies:

**Suniva Inc.** began manufacturing high-efficiency crystalline-silicon photovoltaic cells in October 2008 at a 73,000-square-foot facility in Norcross, Ga. Suniva is the Southeast's first maker of solar cells, and it has plans to expand quickly.

Using technology based on the research of Georgia Tech Regents' professor Ajeet Rohatgi, the company is presently manufacturing its ARTisun™ solar cells at a rate of 32 megawatts (MW) annually – which would produce enough electricity to supply about 6,300

homes, Rohatgi says.

Suniva plans to triple its annual output to nearly 100 MW. The company currently employs about 70 people and expects to add more staff as it grows.

Suniva uses a patented technology it calls Star™ to extract maximum performance from wafers of mono-crystalline silicon, a material often used for solar power generation.

A solar cell contains several layers, and every layer plays a role in the cell's overall efficiency. Rohatgi has studied solar cells in depth for some 30 years, learning how to optimize each layer to get maximum output – at the least cost.

"We want to be right at the sweet spot," explains Rohatgi, who is both Suniva's founder and chief technology officer. "We want cells that are highly efficient but low in cost, and that can generate power at a cost comparable to the power you buy from the electric company."

Rohatgi's solar-cell research has received significant funding over many years from the U.S. Department of Energy.

"Suniva is a shining example of how government support for research can lead to very real job

creation," notes Robert Knotts, director of federal relations for Georgia Tech. "It's a strong reminder of why we should invest in research."

Suniva's current solar-cell output falls in the 17- to 18-percent efficiency range, which Rohatgi classifies as high, especially among lower-cost cells. But the company is continuing to improve its technology, and recently the National Renewable Energy Laboratory certified a new Suniva cell and cell structure at 20 percent efficiency.

Suniva is a graduate of Georgia Tech's Commercialization Services, which evaluates the commercial potential of technology developed at Georgia Tech and helps faculty members and other research staff form companies based on their research. In early 2008, Suniva joined the Advanced Technology Development Center (ATDC), Georgia Tech's science and technology incubator. It graduated from that program in April 2009.

To date, Suniva has received total funding of \$55.5 million from several venture capital organizations, including Menlo Park, Calif.-based

New Enterprise Associates (NEA). Even more significant, Suniva now has contracts worth more than \$1 billion through 2013.

Rohatgi, who runs the University Center for Excellence for Photovoltaic Research and Education in Georgia Tech's School of Electrical and Computer Engineering, gained one important advantage early on: first-class management.

"With the help of NEA and Commercialization Services, Suniva has assembled a great management team with enormous experience in running technology manufacturing companies," he says. "Being able to put together such a well-established team played a big role in my decision to start the company."

Suniva's chairman and CEO, John W. Baumstark, is a technology-industry veteran with wide experience that includes serving as CEO of DWL before its acquisition by IBM and as chief operating officer of TRADEX Technologies before and during its acquisition by Ariba Inc. for \$5.6 billion in 2000.

The company's vice president of manufacturing, Stephen P. Shea, ran BP Solar's manufac-

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Suniva's new 73,000-square-foot manufacturing plant north of Atlanta employs some 70 people, and more staff will be added in coming months.

turing line for many years. Daniel L. Meier, vice president of research and development, has worked for the National Renewable Energy Laboratory and has managed R&D for two other companies.

"In the next two to three years, we expect the quality-price balance of our product will put us at grid parity at a dollar per watt," Baumstark says. That means power from Suniva cells would cost about the same as buying power from an electric company.

**Climate Forecast Applications Network (CFAN)** is using cutting-edge computer models to develop weather and climate forecasts on time scales from days to decades. The three-year-old company caters to clients needing forecast products

beyond the traditional five-day forecasts provided by the National Weather Service, such as energy and insurance companies.

CFAN's capabilities include proprietary extended-range hurricane forecasting. They've been providing this service for an energy-sector company for two years. CFAN's forecasts help that company manage both its energy-production and energy-trading activities in advance of a storm.

Last summer, CFAN correctly informed this energy-sector client that Hurricane Ike would strike Houston directly. What's more, CFAN did so a week before the storm hit land, several days ahead of other forecasters.

"Our clients took a direct hit on this one," says Judith Curry, professor and chair

of the Georgia Tech School of Earth and Atmospheric Sciences and a CFAN principal. "They used our forecasts for all their storm-related logistics, including evacuation."

Companies in the retail sector also have a strong stake in accurate hurricane forecasts, she explains. For example, building supply companies want to move plywood and other materials to the correct hurricane target area. Sending it to the wrong spot can mean a financial loss.

Other CFAN clients include the insurance sector, which wants weather models that anticipate storm and flooding risks over the next 10 to 30 years. Insurance companies seek such data, Curry says, because they believe that ongoing climate change will alter future weather patterns.

CFAN's secret?

"Let's just say we have a proprietary multi-model statistical dynamical method that includes European weather models," says Peter J. Webster, a School of Earth and Atmospheric Science professor who is also a CFAN principal. "We give a customized forecast product to each client. They come to us with a particular problem requiring particular forecasting, and we come up with a product just for them."

Like most Georgia Tech companies, CFAN has its roots in a research project. Webster was developing flood forecasts for the Asian Disaster Preparedness Center, an organization that works to prevent loss of life from storm-related flooding in such vulnerable countries as Bangladesh.

That work brought the team to the attention of Ben Hill, a technology advisor for Georgia Tech Commercialization Services. He told them their research might have the right stuff to be the basis of a new company.

Today CFAN has a scientific staff of eight, income approaching seven figures and good prospects.

The company has also worked with the World Bank, helping the Caribbean adapt to climate change. At issue: finding ways for those regions to deal with rising sea levels, more hurricanes and less rainfall.

Professor Judith Curry, a principal of Climate Forecast Applications Network, is chair of the Georgia Tech School of Earth and Atmospheric Sciences.

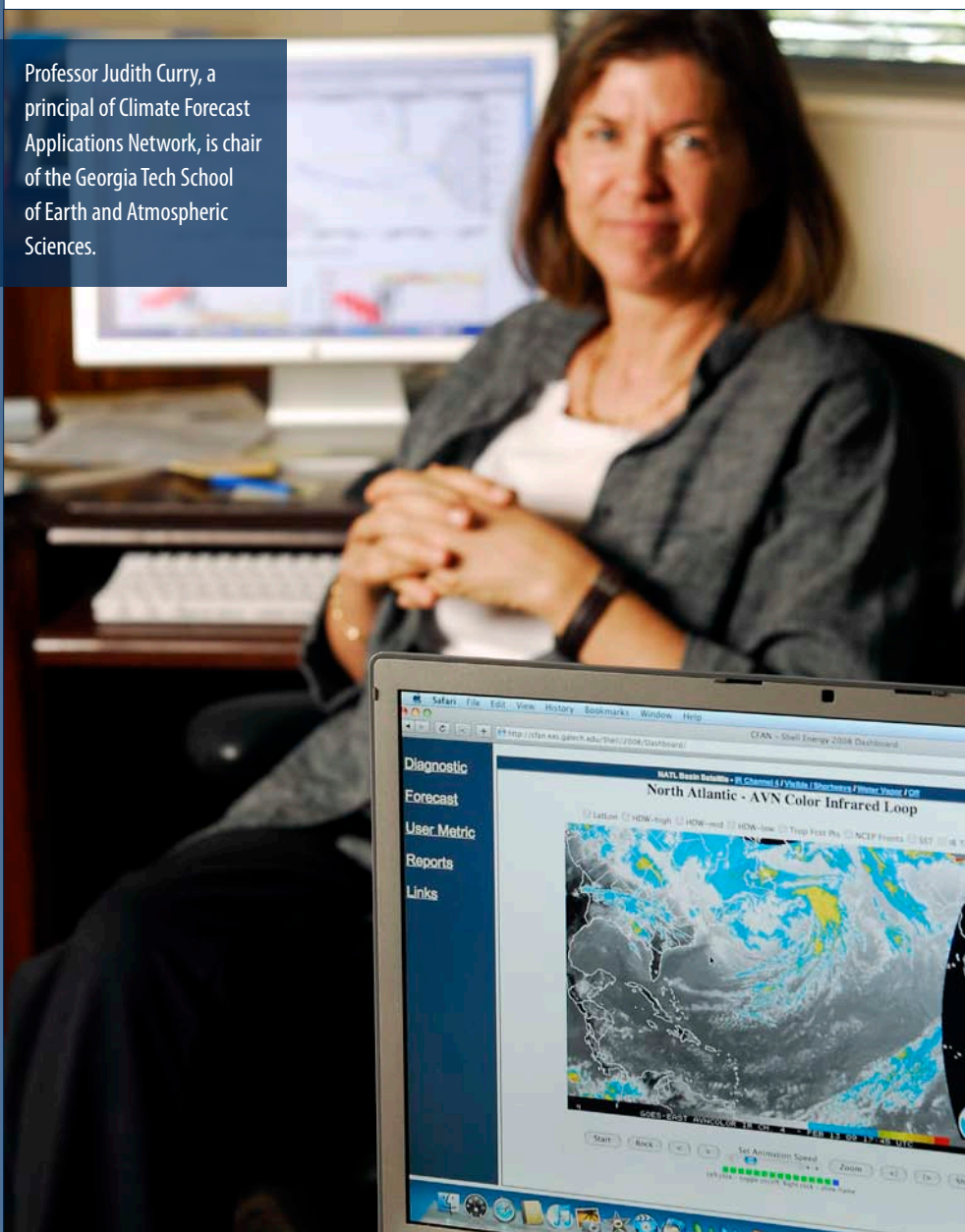


Photo: Gary Meek



Says Curry: "The whole issue of climate services is becoming potentially a growth area as companies, resources managers and agencies grapple with climate variability and change."

**RideCell** aims to make existing urban transportation more efficient by making it more accessible.

This young company covers both the private and public sides of the street. It uses technology that's already in the hands of millions – mobile phones and global positioning system (GPS) chips – to offer on-demand car pooling that's safe as well as flexible. It can also supply mobile-phone users with the kind of information – including schedules and actual in-route arrival times – that increases the usability of public transit systems like MARTA and localized systems such as Georgia Tech's Stinger buses.

"Think of it as accessing all modes of transit via your mobile phone, in real time," says RideCell CEO Dave Kaufman. "We want to make car pooling, van pooling and MARTA much more attractive and reliable options than they are now."

In today's Atlanta, he explains, 71 percent of people ride in single-occupancy vehicles, while only 10 percent of 2.5 million commuters car pool. The top reason that people continue using their private vehicles is flexibility. If they need to work late, or leave early to pick up a sick child, they don't want to be tied to a car pooling schedule.

RideCell's service, based on technology developed by Stephen L. Dickerson, an emeritus professor in the School of Mechanical Engineering, can make car pooling almost as convenient as that personal car, says company chief technology officer Aarjav Trivedi. A user can input travel time, destination and other preferences into a RideCell-enabled mobile phone, then watch as the system shoots back a range of ride options that offers smoking and even gender-preference choices.

RideCell founder professor Stephen L. Dickerson, CTO Aarjav Trivedi and CEO Dave Kaufman (l-r) show off mobile phones with RideCell's transit-locating software installed.



Photo: Gary Meek

The first concern people raise for a system like this involves security, Trivedi acknowledges.

"It's not as simple as just matching people up – developing trust is key," he says. "Everyone wants to be sure the ride they're getting is a safe one."

RideCell's solution, he says, is "limited networks of trust" based on existing social networks. A corporate or university directory would represent one such existing network. Georgia Tech faculty and staff, for

example, could agree to ride with other Georgia Tech employees.

A multi-layered registration process would ensure that only bona fide staff would find their way into the RideCell system. Various kinds of vehicle and/or driver identification, from license-plate numbers and online photos to on-vehicle decals, might heighten security.

RideCell even uses the mobile phone's Bluetooth capability to automate authentication between driver and rider. And GPS-

tracking technology could detect when a vehicle went off course, which might signal trouble.

Once established, individual networks of trust could combine forces. For example, Georgia Tech employees could agree to share ride information with employees from nearby Coca-Cola.

RideCell is still working on its software, and not every mobile phone can host the company's system – although text messaging enables coverage of most of the mobile market. In addition, RideCell has made its product available to in-car GPS platforms including Dash Express.

RideCell's software even includes an integrated-billing function. The system adjusts subscriber accounts for transportation in either private vehicles or van pools – riders get billed, drivers get a credit.

"And that's just the beginning," says company founder Dickerson. "This technology can be extended to high-occupancy toll lanes and even traffic metering, which could save billions in infrastructure build-out."

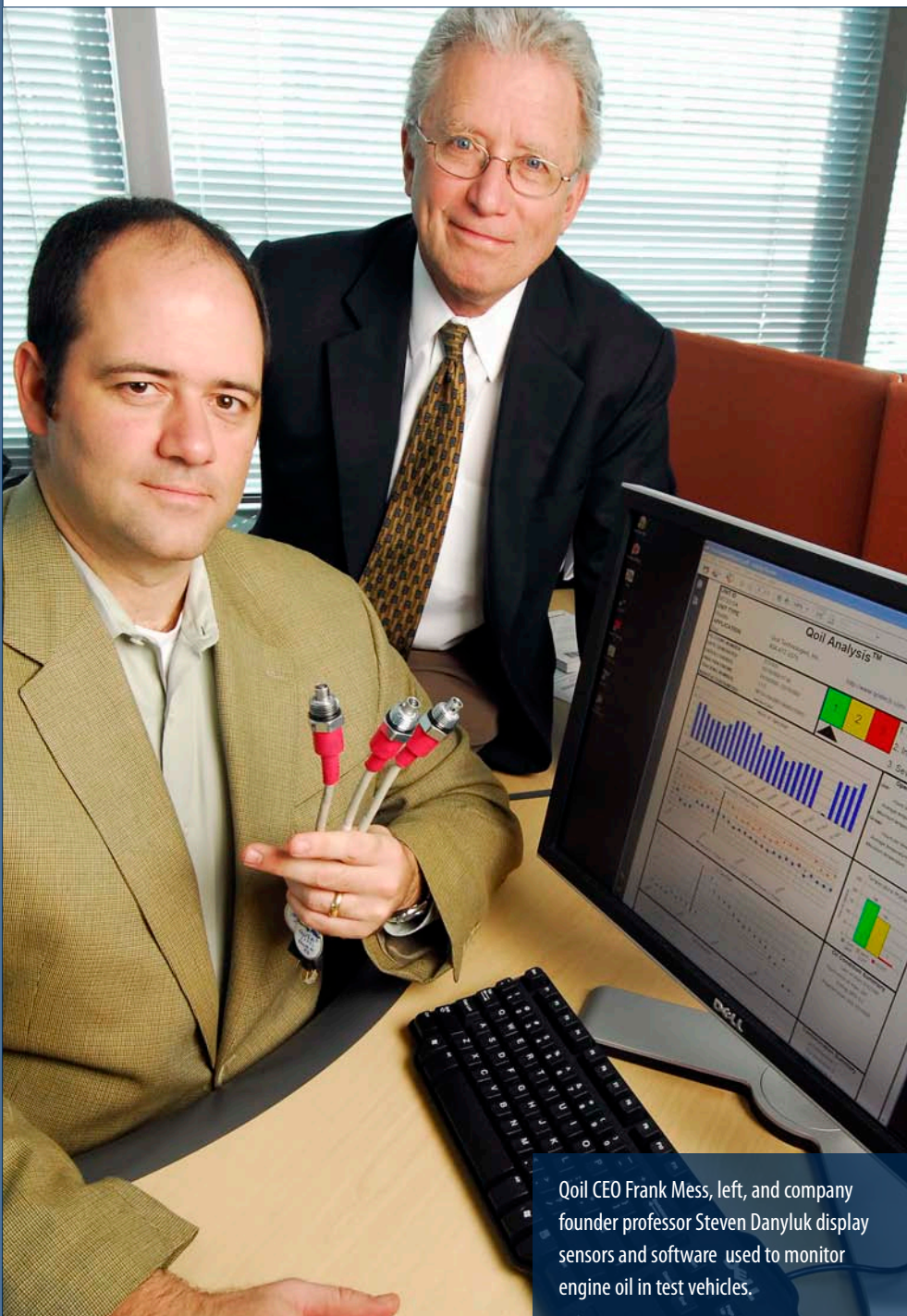
RideCell is already moving into the real world of convenient car pooling. The company is setting up a system trial involving some 150 Georgia Tech faculty, students and staff. It's hoped that the trial, performed in cooperation with Georgia Tech Parking and Transportation, will help iron out software glitches and provide a major step toward wider deployment.

Why would people give up their beloved private vehicles to car pool or take MARTA?

Trivedi says there are several motivations. One is that gasoline prices can be expected to go back up – maybe not tomorrow but soon. A second is that "many people really do want to be green." A third is that some want to limit wear and tear on their cars – or avoid having to own a car at all.

"And some people simply like riding with other people," he adds.

**Coil Technologies** – Many ventures aim to conserve oil, but few specifically target engine oil.



Coil CEO Frank Mess, left, and company founder professor Steven Danyluk display sensors and software used to monitor engine oil in test vehicles.

Photo: Gary Meek

Coil uses a patent-pending electrochemical sensor to continually evaluate the condition of lubricating oil. Its technology can provide data on not only the motor oil but also on the engine it's protecting.

"Historically, it's been cheaper just to change your oil every 3,000 miles than to take a chance on damaging your engine," says Frank Mess, CEO of Coil (pronounced "coil"). "The net result is that hundreds of millions of barrels of oil or more are wasted every year as perfectly good motor oil is thrown out."

Currently, he explains, vehicle-fleet owners who want to evaluate engine oil must have samples extracted and sent to a lab. It's a bit like what diabetics had to go through before portable blood testing equipment, he says. It's laborious, and periodic lab results are generally a poor substitute for on-the-spot information.

Coil's technology provides real-time electrochemical analysis of engine oil by placing sensors in the oil flow. The result is that owners can extract maximum life from their increasingly expensive motor oil. And, by monitoring for early signs of engine damage, the Coil approach can help head off expensive repairs.

Based on the research of Steven Danyluk, the Morris M. Bryan Jr. Chair in Mechanical Engineering for Advanced Manufacturing Systems at Georgia Tech, Coil's sensors initially make the most sense for fleet vehicles, Mess says. But private vehicles could also benefit as the technology becomes more widespread and affordable. The company is also working with potential customers in other industrial segments who need to protect high-value engines and gearboxes.

Coil now has 24 prototype oil-monitoring systems operational on commercial vehicles in the field. These installations use a bypass flow loop, in which oil flows past the sensor and back into the engine. Ultimately, Mess says, the sensor will likely be threaded straight into an engine port.

Signals from the sensor are processed and transmitted to Coil's analysis system in

Atlanta, where the company uses internally developed algorithms to analyze the data and produce detailed reports on oil and engine health.

"We've had significant success in monitoring the chemical degradation of the oil as a function of time, as well as successes in detecting early failure symptoms that prevented expensive equipment failures," Mess says.

In addition to VentureLab seed funding, Coil has received a first round of venture capital. Coil sensors are currently being manufactured in-house, but the company has engaged external partners as it prepares to ramp up production.

The company is a member of the Advanced Technology Development Center (ATDC).

**Vehicle Monitoring Technology (VMT)** monitors vehicle activity and vehicle emissions in conjunction with driver behavior to promote safety, better air quality and energy efficiency. Its technologies are based on the research of Randall Guensler, a professor in the Georgia Tech School of Civil and Environmental Engineering, and Jennifer Ogle, now at Clemson University. Guensler and Ogle are also principals in the company.

VMT is currently providing monitoring services for vehicle activity and emissions in various U.S. localities. The company specializes in several areas including technology development for instrumented vehicle-data collection and analyzing the impact of pricing schemes, such as HOV toll lanes, on traffic and emissions.

**C2 Biofuels** is an outgrowth of a Georgia Tech Strategic Energy Institute (SEI) project that seeks to develop fuel-ethanol production from biomass material available in large quantities in the Southeast, including Southern yellow pine.

C2 Biofuels is supported by Sam Shelton of SEI and the Georgia Tech School of Mechanical Engineering and Bill Bulpitt of SEI. In addition, a team at the Georgia Tech School of Chemical and Biomolecular Engineering and the University of Georgia is

helping to evaluate and develop processes and technologies.

The startup is led by Roger Reisert, a Georgia Tech alumnus who has designed, built and operated refineries. Reisert says the company plans to build and begin operation of a pilot plant in 2009. The schedule also calls for a larger demonstration plant, to be built in 2010, and a commercial plant by 2012.


The goal: to deliver fuel-grade cellulosic ethanol to service stations at \$1.70 a gallon.

**Applied Nanomaterials** is working on nanoscale generators that could power very small devices and bio-sensors. The company is based on the work of Zhong Lin Wang, a professor in the School of Materials Science and Engineering.

**Innovolt** uses patented technology to enhance energy management and energy efficiency, especially in the area of power protection and the prevention of equipment damage from energy surges. The technology is based on the work of Deepak Divan, a professor in the School of Electrical and Computer Engineering. The company graduated from ATDC in May 2009.

**Lumoflex** is developing organic photovoltaic materials that could result in substantial power savings and flexible form factors in a number of products. The company derives from research by Seth Marder and Joe Perry of the School of Chemistry and Biochemistry and Bernard Kippelen and Greg Durgin of the School of Electrical and Computer Engineering.

**Virtual Aerosurface Technologies** develops tiny devices that, installed in aircraft wings or wind turbines, emit "microjets" of air that adjust lift and drag to improve control and save fuel. These microjet devices are based on the work of Ari Glezer of the School of Mechanical Engineering.

**Bach Energy** seeks to extract biofuels from municipal solid waste via a gasification process. The technology is based on the research of Art Ragauskas, a professor in the School of Chemistry and Biochemistry. 

Versatile robots being used for a broad range of exploration on Earth and other planets face a very significant challenge: traversing sand and other granular media. Researchers investigating the problem of robot locomotion on such surfaces are learning that slower may be better to avoid being bogged down in sand.

In this poppy seed-filled trackway, Georgia Tech researchers conducted controlled experiments to study why robots have difficulty traversing sand and other granular media like dirt, rubble or slippery piles of leaves.



Photo: Daniel Goldman

# SandBot Struggles:

## Researchers Learn Why Robots Get Stuck in the Sand – and How to Keep Them Going

By Abby Vogel

Today's mobile robots explore complex terrains across the globe and even on Mars, but have difficulty traversing sand and other granular media like dirt, rubble or slippery piles of leaves.

A study published Feb. 10, 2009, in the journal *Proceedings of the National Academy of Sciences* takes what may be the first detailed look at the problem of robot locomotion on granular surfaces. Among the study's recommendations: robots attempting to move across sandy terrain should move their legs more slowly, especially if the sand is loosely packed.

"We have discovered that when a robot rotates its legs too fast or the sand is packed loosely enough, the robot transitions from a rapid walking motion to a much slower swimming motion," says Daniel Goldman, an assistant professor in the School of Physics at Georgia Tech. The project was funded by the Burroughs Wellcome Fund and the U.S. Army Research Laboratory.

The physics of movement on granular media has been largely unexplored systematically, so Goldman and his team set out to inves-

tigate the performance of a small, six-legged device called SandBot. The robot was designed by Haldun Komsuoglu and Daniel Koditschek at the University of Pennsylvania.

"This is new territory because researchers have not examined the interaction between an animal's foot and sand like they have a whale's or duck's flipper and water," says Goldman. "Sand is a uniquely challenging terrain because it can shift quite easily from solid to fluid to solid and requires different locomotion strategies."

To conduct controlled experiments, Georgia Tech physics graduate student Chen Li built a trackway for SandBot to run along. The trackway consists of an eight-foot-long poppy seed-filled container with tiny holes in the bottom through which air can be blown. The air pulses elevate the granules and cause them to settle into a loosely packed solid state, allowing the researchers to closely control the density of the material.

"We used poppy seeds as the granular material because they were large enough not to get into the SandBot motors but light enough to be manipulated with

our air blowers," explains Goldman. "We have done experiments with small glass beads, which more closely approximate desert sand, and found no qualitative change in the results."

In the desert, typical volume fractions for granular media range from 55 to 64 percent. For the study's initial experiments, the researchers packed the poppy seeds to a volume fraction of 63 percent, placed SandBot onto the surface and set its C-shaped legs to rotate five times per second. The little robot, which could bounce quickly across hard ground, became completely stuck in the granular material after just a few steps.

The researchers discovered that the problem was the rotational motion of the robot's limbs. The SandBot moves its limbs in an alternating tripod gait, and during a rotation each limb moves fast while it is in the air and more slowly while it is on the ground. The researchers found that the robot could walk across the sand quickly – at a speed of one body length per second – if the rotation frequency was fixed and three parameters were adjusted: the durations of the slow

and fast phases and the angle at which the limb changed from slow to fast.

“A systematic study of the motion then revealed that changes in volume fraction of less than 1 percent resulted in either rapid motion or slower swimming,” adds Goldman. “We saw similar sensitivity when we changed the limb rotation frequency.”

To study this phenomenon further, Goldman and Paul Umbanhowar of Northwestern University developed a simple kinematic model of penetration and slip of a curved limb on granular media. The model results showed that the relationship of the speed to the volume fraction and frequency of leg rotation was largely controlled by the degree to which the robot limbs penetrated into the sand with each step.

The higher the limb frequency and the looser the granular material, the deeper the robot sank into the granular material. Thus the length of the

step the robot could take was shortened, and when the step size became too short the robot took its next step into ground disturbed by the previous step. This triggered a catastrophic loss of speed and a shift from walking to continuous paddling through the poppy seeds.

Goldman believes that this study’s experiments and model describing the basic behavior of motion on granular media will help biologists understand how animals appear to move effortlessly across a diversity of complex substrates.


*This material is based on research sponsored by the Army Research Laboratory and was accomplished under Cooperative Agreement Number W911NF-08-2-0004. The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the official policies, either expressed or implied, of the Army Research Laboratory or U.S. Government.* 

Photo: Daniel Goldman

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**“ This is new territory because researchers have not examined the interaction between an animal’s foot and sand like they have a whale’s or duck’s flipper and water. Sand is a uniquely challenging terrain because it can shift quite easily from solid to fluid to solid and requires different locomotion strategies.”**

**— Daniel Goldman, assistant professor in the School of Physics**



By studying the physics of movement on granular media, Georgia Tech researchers learned that robots attempting to move across sandy terrain should move their legs more slowly, especially if the sand is loosely packed.

With support from DARPA and in collaboration with Raytheon, GTRI researchers are investigating new materials that may be needed to remove heat from future generations of high-power radar systems. The new material is combined with liquid to exploit evaporative cooling.

GTRI research engineer Jason Nadler shows a sample of a prototype material that may be used to remove heat from future radar systems.

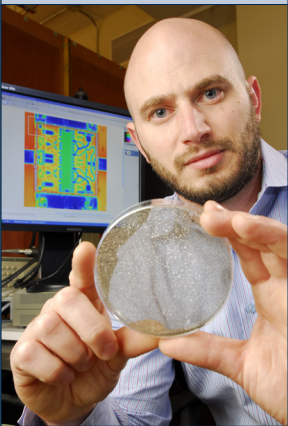


Photo: Gary Meek

# Cool Aid:

## Novel Heat-Transfer Material Could Allow More Powerful Radar Electronics

By Rick Robinson

Open any computer and you're sure to see at least one massive cooling device, complete with metal fins and a noisy fan. Today's high-power processing chips generate lots of heat – and those chips can fry quickly without some serious cooling.

Researchers at the Georgia Tech Research Institute (GTRI) are developing a novel material for transferring heat away from ultra-high-power defense electronics. The exotic material, a composite of diamond and copper, is one of the materials under development as part of a new concept called a "Thermal Ground Plane" that aims to remove heat up to 100 times more effectively than present thermal-conducting schemes.

Such a performance leap could be vital to cooling next-generation radars, says Jason Nadler, a GTRI research engineer. Nadler is investigating ways to bring new materials and techniques to bear on the problem.

"Many areas of electronics are running up against the same issue: you just can't move the

heat away fast enough to let the devices be reliable," Nadler says. "As we rely increasingly on very high-power devices, the methods of getting heat away from them have to become more efficient."

Georgia Tech is working with the Raytheon Co. on a project that seeks to raise thermal conductivity capabilities to 20,000 watts per meter Kelvin (a measure of thermal-conductivity efficiency). That's a tall order, considering that the current conductivity champion, for radar applications, is a copper material with performance of approximately 200 to 300 watts per meter Kelvin.

The three-phase, four-year project is sponsored by the Microsystems Technology Office of the Defense Advanced Research Projects Agency (DARPA).

This improved cooling capability could benefit future high-power transmit-receive (T/R) module packages. Because of their higher power, those transmit-receive modules will also have higher cooling needs that may require a Thermal Ground Plane – a sort of heat-dissipating

sandwich about one millimeter thick that would be part of the T/R module's packaging.

"A Thermal Ground Plane is basically a materials system," Nadler explains. "The most thermally conductive natural material, pure diamond, has a conductivity of about 2,000 watts per meter Kelvin. We're aiming for 20,000, and to do that we have to look at the problem from a materials systems standpoint."

Nadler's material is one of those under development to serve as the heart of the Thermal Ground Plane. The conductivity of that material would be improved with the addition of a liquid coolant able to carry heat away from the T/R module devices in the same way that sweat cools a body. A metal heat sink would help the liquid coolant dissipate the heat by condensing the vapor back to a fluid.

Using a liquid coolant takes advantage of phase changes – the conversion of matter between liquid and vapor states. The diamond-copper material would conduct heat to the liquid cool-

ant and optimize cooling through wicking and evaporation. Then, the heat would be rejected as the vapor is re-condensed to a liquid on the side attached to the metal heat sink.

“The trick is to use evaporation, condensation and intrinsic thermal conductivity together, in series, in a continuous system,” Nadler says. “The whole device is a closed loop.”

Challenges remain, however, including some specific materials issues. To form the desired materials, diamond and copper must be integrated into a porous structure that can best transfer heat and facilitate efficient evaporation.


But diamond and copper don’t bond well, due in part to their different coefficients of thermal expansion and chemical incompatibility. Diamond doesn’t expand much when heated, while copper expands moderately. That difference leads to a thermal-expansion mismatch, which can fracture the interface between the two materials when they’re heated.

In addition, the porous internal structure of the diamond-copper material must have exactly the right size and shape to maximize its

own intrinsic heat conductivity. Yet its internal structure must also be designed in ways that can help draw the liquid coolant toward the heat source to facilitate evaporation.

Nadler explains that liquid coolant flow can be maximized by fine tuning such mechanisms as the capillarity of the diamond-copper material. Capillarity refers to a given structure’s ability to draw in a substance, especially a liquid, the way a sponge absorbs water or a medical technician pulls a drop of blood up into a narrow glass tube.

To be effective, the size of a capillary structure must be precisely controlled; if it’s too large or too small, the wicking phenomenon won’t occur. The GTRI team must size the diamond-copper material’s internal structure to maximize capillarity.

“We’re finding ways to change the cellular structure of the diamond-copper material at the nanoscale and the microscale,” Nadler says. “We’re doing this by making complex open-celled structures – basically tiny foams with exactly the right properties.” 

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**“ Many areas of electronics are running up against the same issue: you just can’t move the heat away fast enough to let the devices be reliable. As we rely increasingly on very high-power devices, the methods of getting heat away from them have to become more efficient. ”**

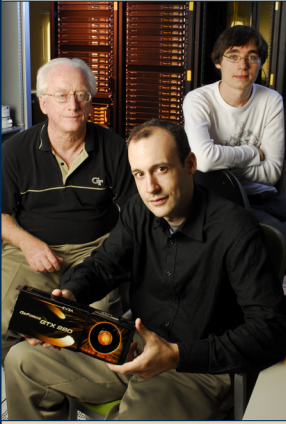
**— Jason Nadler, GTRI research engineer**

A novel material made of surface-enhanced high-purity diamond microparticles, shown here, could help cool high-power defense electronics up to a hundred times more efficiently than current technologies.



To support the video game industry, chip manufacturers have developed a new generation of powerful graphics processors whose parallel structure makes them valuable to defense applications. Researchers have developed programming tools that make it easier to use these processors.

Photo: Gary Meek



Mark Richards (left), Daniel Campbell (center) and Andrew Kerr are using graphics processing units (GPUs) to quickly perform linear algebra and signal processing operations for defense applications.

# Inexpensive Parallel Processing:

## Programming Tools Facilitate Use of Video Game Processors for Defense Needs

By Abby Vogel

Video gaming computers and video game consoles available today typically contain a graphics processing unit (GPU), which is very efficient at manipulating and displaying computer graphics. However, the unit's highly parallel structure also makes it more efficient than a general-purpose central processing unit for a range of complex calculations important to defense applications.

Researchers in the Georgia Tech Research Institute (GTRI) and the Georgia Tech School of Electrical and Computer Engineering are developing programming tools to enable engineers in the defense industry to utilize the processing power of GPUs without having to learn the complicated programming language required to use them directly.

"As radar systems and other sensor systems get more complicated, the computational requirements are becoming a bottleneck," says GTRI senior research engineer Daniel Campbell. "We are capitalizing on the ability of GPUs to process radar,

infrared sensor and video data faster than a typical computer and at a much lower cost and power than a computing cluster."

Mark Richards, a principal research engineer and adjunct professor in the School of Electrical and Computer Engineering, is collaborating with Campbell and graduate student Andrew Kerr to rewrite common signal processing commands to run on a GPU. This work is supported by the U.S. Defense Advanced Research Projects Agency and the U.S. Air Force Research Laboratory.

The researchers are writing functions defined in the Vector, Signal and Image Processing Library (VSIPL) to run on GPUs. VSIPL is an open standard developed by embedded signal and image processing hardware and software vendors, academia, application developers and government labs. GPU VSIPL is available for download at <http://gpu-vsimpl.gtri.gatech.edu/>.

The researchers are currently writing the functions in Nvidia's CUDA™ language, but the underlying principles can

be applied to GPUs developed by other companies, according to Campbell. With GPU VSIPL, engineers can use high-level functions in their C programs to perform linear algebra and signal processing operations, and recompile with GPU VSIPL to take advantage of the speed of the GPU. Studies have shown that VSIPL functions operate between 20 and 350 times faster on a GPU than a central processing unit, depending on the function and size of the data set.

"The results are not surprising because GPUs excel at performing repetitive arithmetic tasks like those in VSIPL, such as signal processing functions like Fourier transforms, spectral analysis, image formation and noise filtering," notes Richards. "We've just alleviated the need for engineers to understand the entire GPU architecture by simply providing them with a library of routines that they frequently use."


The research team is also assessing the advantages of GPUs by running a library of benchmarks for quantitatively comparing high-



performance, embedded computing systems. The benchmarks address important operations across a broad range of U.S. Department of Defense signal and image processing applications.

Preliminary studies have shown several of the benchmarks have straightforward parallelization schemes that result in faster operation without requiring significant optimization. For other benchmarks, additional research needs to be conducted

into optimizing the use of multiple GPUs.

For the future, the researchers plan to continue expanding the GPU VSIPL, develop additional defense-related GPU function libraries and design programming tools to utilize other efficient processors, such as the cell broadband engine processor at the heart of the PlayStation 3 video game console. 

Georgia Tech researchers have reprogrammed the Vector, Signal and Image Processing Library (VSIPL) to run on graphics processing units (GPUs), such as the one shown here.



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“As radar systems and other sensor systems get more complicated, the computational requirements are becoming a bottleneck. We are capitalizing on the ability of GPUs to process radar, infrared sensor and video data faster than a typical computer and at a much lower cost and power than a computing cluster.”

— Daniel Campbell, GTRI senior research engineer

## Companies Team with Georgia Tech in 100G Optical Networking Consortium

Photo: Diana Fouts

Ten companies have joined with the Georgia Institute of Technology to establish the Georgia Tech 100G Optical Networking Consortium, believed to be the first academic-industrial consortium of its kind in the world.

To date, more than \$2.2 million in support has been designated for this facility by the consortium's founding research members: ADVA Optical Networking, Ciena, OFS and Verizon – and by supporting members Avonex, IBM, Narda Microwave East, Nistica, Picometrix and RSoft Design Group.

The consortium and facility allow academic and industry personnel to perform multidisciplinary research in all aspects of 100-gigabit-per-second transmission, supported by the diverse and complementary strengths of the industrial partners and faculty members. Research topics range from fundamental studies of 100G optical transmission to assessment of optical and electronic technologies that will be used in such high-speed optical networks.

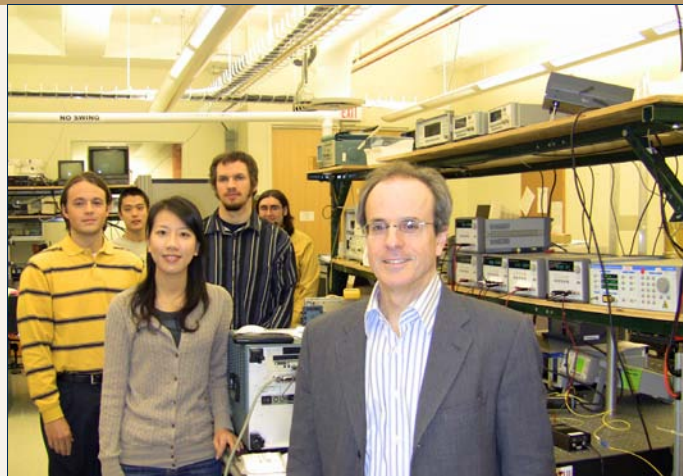
A variety of network architectures will be studied, including realistic impairments found in regional and ultra-long-haul links. These efforts also actively support the upcoming IEEE 100G standard for short-reach, client-side transport in the local area network and future IEEE standards for short-reach transmission over laser-optimized, multi-mode fiber in data centers.

Historically, networking infrastructure has migrated to systems with increased transmission ca-

capacity, thereby allowing increased efficiency and the delivery of content-rich services, notes Stephen E. Ralph, the consortium's director and a professor in Georgia Tech's School of Electrical and Computer Engineering (ECE). Critical to the success of these new technologies is the ability to deploy them over existing fiber infrastructure, which is equivalent to increasing the capacity of a highway ten-fold without changing the roadway, he said.

"Our industry-led effort creates a unique opportunity for students and industry to define and validate the enabling technologies necessary for 100G networks," Ralph says. "The creation of this consortium at Georgia Tech enhances the competitiveness of our member companies, creating job growth in this critical area of communications and networking. The faculty of Georgia Tech is uniquely able to advance understanding in signal processing, high-speed circuits, and optical components and systems. This unique combination, together with the expertise of our industry researchers, will enable member companies to develop and demonstrate technical advantages and accelerate deployment of next-generation systems and services while simultaneously influencing the next-generation standards."

Located in Georgia Tech's Technology Square Research Building, the new 100G test bed and extensive supporting simulation capabilities enable rigorous and independent evaluation of optical and electronic signal processing strategies, new modulation formats and



Professor Stephen E. Ralph (foreground) is the co-director of the 100G Optical Networking Consortium. His research group includes Andrew Stark, Cheng Lin, Yu-Ting Hsueh, Ben Clarke and Patrick Decker.

receiver technologies, high-speed silicon CMOS-based electronics, and classical/modern forward error correction, all in realistic optical fiber transport and electronic transceiver environments.

Co-director of the effort is Gee-Kung Chang, Byers Eminent Scholar Chair in optical networking. Joining Ralph and Chang in the quest for 100Gbps transport is Byers Professor John D. Cressler, whose research addresses high-speed electronics challenges, and Professor John Barry, whose work focuses on critical signal processing issues. Chang, Cressler and Barry are also based in the School of Electrical and Computer Engineering.

Construction on the Consortium's 100G test bed started in July 2008 and was made possible with additional support from the Georgia Tech Office of the Senior Vice Provost for Research and Innovation and the Georgia Research Alliance. The first test bed link, which will allow testing of new modulation concepts within a point-to-point link engineered for 10Gbps

systems, became fully functional in November 2008. Two additional milestones, which will include the creation of a long-haul dense wavelength division multiplexed (DWDM) mesh network environment exceeding 1,000 kilometers, will be met by July 2009, when the facility will be fully functional.

"The 100G effort makes Georgia Tech the place to be for those interested in pursuing 100G technologies," says Mark Allen, senior vice provost for research and innovation and a Regents' professor in the School of Electrical and Computer Engineering. "From an economic development perspective, the implications could be huge, as our faculty, students and industry partners create technologies that support 100G transport and that could be commercialized in a number of ways."

– Jackie Nemeth

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# Helping Astronomers Collect More Accurate Images of the Sky

Photo: David Roberts

The brightness of stars and galaxies seen through a telescope can vary from day to day because of atmospheric variability. The sky's inconsistency is due to the presence of atmospheric aerosols – seen as haze – that scatter and absorb some of the light from the stars and distort what is seen through the telescope.

To address this problem, researchers at the Georgia Tech Research Institute (GTRI) developed a device to accurately assess the impact of this variability on light traveling through the Earth's atmosphere. The tool was developed in collaboration with the University of New Mexico and supported by the National Science Foundation.

"Until now, astronomers never had an independent way to measure the transparency of the atmosphere," says Gary Gimmestad, a GTRI principal research scientist. "They always had to compare

their measurements to the standard star catalog, which was itself created without having this atmospheric information."

The device developed by Gimmestad, senior research scientist David Roberts and senior research engineer John Stewart is called the Astronomical Lidar for Extinction (ALE). It scans the entire sky to probe for cirrus clouds and accurately measures the transmission of the atmosphere by taking measurements at multiple angles above the horizon.

"ALE provides real-time continuous and unattended monitoring, and measurements of the amount of atmospheric extinction – the absorption or scattering of light – as well as its cause, whether low-lying aerosols, dust or smoke," says Roberts.

When activated, the device transmits rapid pulses of eye-safe green laser light into the atmosphere, which are scat-

tered back to two detectors. Measuring the scatter provides a distance-resolved profile of gas, particles and clouds that allows astronomers to calculate precisely the amount of light lost in traversing the atmosphere at a specific moment.

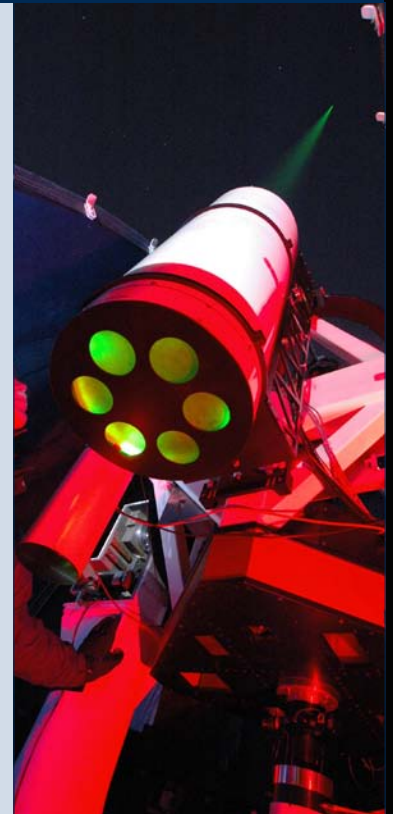
Using that information, the researchers calculate extinction coefficients, which are applied to the telescope's photometric data to correct the photometric images for the light loss in the atmosphere. The result is more accurate stellar photometry along with a precision profile of the structure of Earth's atmosphere.

The Astronomical Lidar for Extinction system is currently in use at the University of New Mexico campus observatory.

– Abby Vogel

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The Astronomical Lidar for Extinction.

# Human-Factors Issues Enhance "Purpose-Built" Law Enforcement Vehicle

Photo: Carbon Motors

The Georgia Tech Research Institute's (GTRI) expertise in human-factors issues helped an Atlanta-based startup company create the world's first vehicle designed specifically to meet the patrol needs of law enforcement agencies.

The Carbon Motors E7, slated for production in 2012, features an ergonomic "cockpit" designed to help drivers safely and efficiently interact with the vehicle under high-stress conditions. It features a large touch screen with voice-activated controls and a backup manual system.

"Like the pilots of jet fighters, law enforcement officers must interact extensively with their vehicles, receive and evaluate large amounts of information and make split-second decisions in high-pressure en-

vironments," notes Dennis Folds, GTRI's chief scientist and head of its Human Systems Integration Division. "The assistance we provided Carbon Motors helped the company develop a new-generation vehicle cockpit designed to help these officers do their jobs safely and efficiently."

The human-machine interface was one of the most critical aspects of the new vehicle, which was designed to meet more than 100 requirements recommended by law enforcement agencies across the nation, said William Santana Li, chairman and CEO of Carbon Motors Corp.

"We wanted to reach out beyond the usual automotive design groups," he says. "Getting insight from GTRI's military and aerospace background was helpful. There



The Carbon Motors E7 is the world's first vehicle designed specifically to meet the needs of law enforcement agencies. GTRI helped the company with human-factors issues.

are a lot of similarities between what a fighter pilot has to do and what a police officer has to do while chasing a suspect at 100 miles per hour at 3 a.m."

Powered by a 300-horsepower clean-diesel engine that can accelerate it to 60 miles per hour in 6.5 seconds, the E7 will be offered with more than 70 options – in-

cluding an automatic license plate reader, radiation detector and night-vision capabilities. The vehicle is designed to meet a 250,000-mile durability specification, and it will use up to 40 percent less fuel than current law enforcement vehicles, which are modified passenger cars.

"Today, the 425,000 law enforcement

vehicles that patrol our country in most cases do not meet federal safety standards because they have been modified in a haphazard way for police work," Li adds. "We will give these agencies a safer product with world-

class performance and a reduction in total lifecycle cost."

The company recently showed a running prototype vehicle to law enforcement agencies around the country. According to Li, the response

has been "overwhelming," and he expects the company's first year of production to be sold out before manufacturing begins.

— John Toon

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## Hair Structures of Blind Cavefish Inspire Flow Sensors

Image: Vladimir Tsukruk

A blind fish that has evolved a unique technique for sensing motion may inspire a new generation of sensors that perform better than current active sonar.

Although members of the fish species *Astyanax fasciatus* cannot see, they sense their environment and the movement of water around them with gel-covered hairs that extend from their bodies. Their ability to detect underwater objects and navigate through their lightless environment inspired a group of researchers to mimic the hairs of these blind cavefish in the laboratory.

While the fish use these hairs to detect obstacles, avoid predators and localize prey, researchers believe the engineered sensors they are developing could have a variety of underwater applications, such as port security, surveillance, early tsunami detection, autonomous oil rig inspection, autonomous underwater vehicle navigation and marine research.

"These hair cells are like well-engineered mechanical sensors, similar to those that we use for balance and hearing in the human ear, in which the deflection of the jelly-encapsulated hair cell measures important flow information," says Vladimir Tsukruk, a professor in the Georgia Tech School of Materials Science and Engineering.

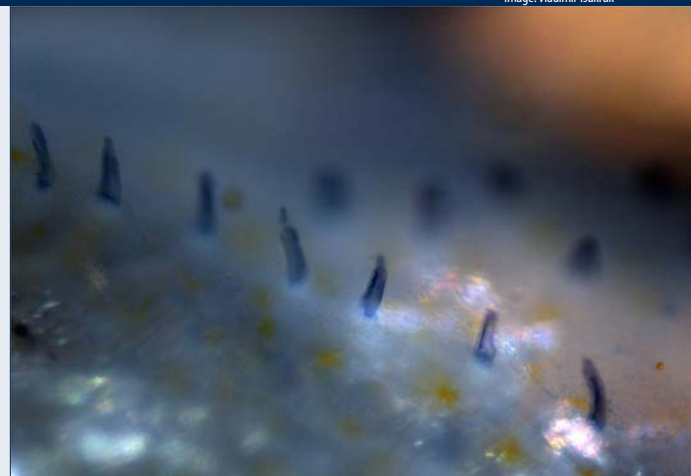
In a presentation at the

American Physical Society meeting in March 2009, researchers from Georgia Tech described their engineered motion detector. This research was sponsored by the Defense Advanced Research Projects Agency (DARPA).

Tsukruk and graduate students Michael McConney and Kyle Anderson conducted preliminary experiments with a simple artificial hair cell microsensor made of SU-8, a common epoxy-based polymer. They found that the cell by itself could not achieve the high sensitivity or long-range detection of hydrodynamic disturbances created by moving or stationary bodies in a flow field. The hair cell needed a gel-like capsule – called a cupula – to overcome these challenges.

"After covering the hair cell with synthetic cupula, our bio-inspired microsensor had the ability to detect flow better than the blind fish," says Tsukruk, who also holds an appointment in Georgia Tech's School of Polymer, Textile and Fiber Engineering. "Adding the cupula allowed us to detect a much smaller amount of flow and expand the dynamic range because it suppressed the background noise."

Before the research team began synthesizing the gel-like material in the laboratory, they used optical microscopy and confocal fluorescence microscopy to



*This optical micrograph of a blind cave fish's body shows a row of stained cupula. The fish use these gel-covered hairs to detect obstacles, avoid predators and localize prey.*

determine the size, shape and properties of real cavefish cupula. One type of cupula they found was cylindrical-shaped, with a height approximately five times greater than its diameter. The tallest part of the cupula was far enough away from the surface that it was exposed to free-flowing water and could bend with the hair to detect changes in flow.

To create the synthetic cupula in the laboratory, McConney dropped a solution of poly(ethylene glycol) tetraacrylate dissolved in methanol directly on the hair flow sensor. Once the droplet dried, he lowered another droplet until it made contact with the last drop and continued adding droplets until he constructed a tall hydrogel structure.

To date, the researchers have fabricated an array of eight micro-

sensors and shown that the array is able to detect an oscillating object underwater. They are currently looking for industrial partners to scale up the research by fabricating arrays of thousands of these sensors and testing them in real marine environments.

Cheryl Coombs from Bowling Green State University and Chang Liu from the University of Illinois also contributed to this research.

— Abby Vogel

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# New Center to Support Medical Device Development

Photo: Rob Felt

Four of Georgia's leading research and health care organizations have joined together to create a new innovation center that will accelerate the development and commercialization of next-generation medical devices and medical technology. The first of its kind in the Southeast, the Global Center for Medical Innovation (GCM) will include a comprehensive medical device prototyping center.

Supported by Georgia Tech, Saint Joseph's Translational Research Institute (SJTRI), Piedmont Healthcare and the Georgia Research Alliance (GRA), the new center will bring together the complete medical device marketplace – which includes universities, research centers and clinicians; established drug and device companies; investors, and early-stage companies. The new center will be located adjacent to the Georgia Tech campus in Technology Enterprise Park (TEP).

"The convergence of the life sciences with engineering provides a unique opportunity to expand our technology in areas that will support the health care industry of the future," said G. P. "Bud" Peterson, president of Georgia Tech. "The

Global Center for Medical Innovation will bring together in one location the key infrastructure needed to rapidly move new medical devices and new medical technologies to market."

The new center will include a complete medical device prototyping center, a capability to produce evaluation devices using "good manufacturing practices" mandated by the U.S. Food & Drug Administration (FDA), and the ability to manage, coordinate and aggregate intellectual property from the partner organizations and interested private companies.

The Saint Joseph's Translational Research Institute (SJTRI), the research division of Saint Joseph's Health System, will add the capability for preclinical studies of new devices and technologies. SJTRI has recently opened a new, state-of-the-art, 32,000-square-foot preclinical research facility at Technology Enterprise Park. With the GCM resources, that will provide a comprehensive set of services for developing, testing and prototyping medical innovations.

The leading-edge medical research conducted at the founding institutions



Mark Allen, Georgia Tech's senior vice provost for research and innovation, confers with Jay Yadav, M.D. (left), chairman of the Piedmont Healthcare Center for Medical Innovation.

will be the engine behind the new center. By bringing together physicians with direct experience at treating patients with scientists and engineers, GCM will facilitate the development of technology that meets real-world medical needs.

"Physicians on the front lines of patient treatment have a very real appreciation of the need for new technology, but they often lack the resources to translate their ideas and solutions into new medical devices," said Jay S. Yadav, M.D., chairman of the Piedmont Health-

care Center for Medical Innovation, a cardiologist with Piedmont Heart Institute Physicians and CEO of Atlanta medical device company CardioMEMS. "By collaborating with institutions like Georgia Tech, we can meet patient needs and create new business opportunities."

— John Toon

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# New Technique Sees Single RNA Molecules Inside Living Cells

Image: Philip Santangelo

Biomedical engineers have developed a new type of probe that allows them to visualize single ribonucleic acid (RNA) molecules within live cells more easily than with existing methods. The tool will help scientists learn more about how RNA operates within living cells.

Techniques scientists currently use to image these transporters of genetic information within cells have several drawbacks, including the need for syn-

thetic RNA or a large number of fluorescent molecules. The fluorescent probes developed at the Georgia Institute of Technology circumvent these issues.

"The probes we designed shine bright, are small and easy to assemble, bind rapidly to their targets and can be imaged for hours. These characteristics make them a great choice for studying the movement and location of RNA inside a single cell and the interaction be-

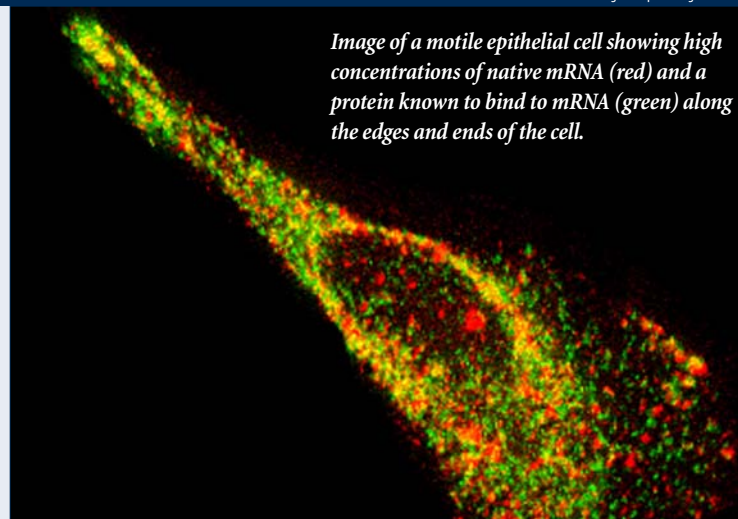


Image of a motile epithelial cell showing high concentrations of native mRNA (red) and a protein known to bind to mRNA (green) along the edges and ends of the cell.

tween RNA and binding proteins,” says Philip Santangelo, an assistant professor in the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University.

Details of the probe production process and RNA imaging strategy were published in the journal *Nature Methods* on April 6, 2009. In addition to Santangelo, Georgia Tech graduate student Aaron Lifland, Emory University associate professor Gary Bassell and Vanderbilt University professor James Crowe Jr. also contributed to this research.

In the study, the probes – produced by attaching a few small fluorescent molecules called fluorophores to a modified nucleic acid sequence and combining the se-

quences with a protein – exhibited single-molecule sensitivity. That allowed the researchers to target and follow native RNA and non-engineered viral RNA in living cells.

“The great thing about these probes is that they recognize RNA sequences and bind to them using the same base pairing most people are familiar with in regards to DNA,” explains Santangelo. “By adding only a few probes that would bind to a region of RNA, we gained the ability to distinguish a targeted RNA molecule from a single unbound probe because the former lit up two or three times brighter.”

For their experiments, the team used a bacterial toxin to transport the probes into living cells – a delivery technique, that

when combined with the high affinity of the probes for their targets, required significantly fewer probes than existing techniques. The toxin created several tiny holes in the cell membrane that allowed the probes to enter the cell’s cytoplasm.

The researchers tested the sensitivity of conventional fluorescence microscopy to image individual probes inside a cell. Previous studies showed that these techniques were able to image an accumulation of probes inside a cell, but the current study demonstrated that individual probes without cellular targets could be observed homogeneously distributed in the cytoplasm with no localization or aggregation.

With single-molecule sensi-

tivity accomplished, the researchers investigated whether they could visualize individual RNA molecules using the probes. To do this, they simultaneously delivered probes designed to target a human messenger RNA (mRNA) sequence region and a probe designed with no target in the human genome. They were able to image unbound probes of both types as well as individual RNA molecules that had attached to the former probes.

— Abby Vogel

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## Turning Poultry Waste into Fuel

Researchers at the Georgia Tech Research Institute (GTRI) are developing cost-effective techniques for separating and converting poultry processing residuals into higher-value products such as high-grade fuels. The techniques would provide a beneficial use for these byproducts, which are typically blended back into lower-value products.

“Our ultimate goal is to extract usable, quality feedstocks from poultry processing byproducts such as brown grease extracted from wastewater pretreatment processes. If successful, we will help reduce costs by providing a cheap and simple way for the industry to better utilize their low-quality waste

oil and grease byproducts,” says John Pierson, a GTRI principal research engineer.

To achieve this goal, Pierson and GTRI research coordinator Robert Wallace teamed with the Cumming, Ga.-based company American Proteins to obtain samples of poultry-processing waste materials. They first focused their efforts on developing better ways to separate usable portions of the waste – such as free fatty acids, neutral oil and waxes – from unusable portions, such as solids and other insoluble materials.

Using improved refining and degumming techniques, the researchers were able to effectively reduce the volume of waste material by 75 percent.

“We are currently working

on increasing the efficiency of these separation techniques, and on scaling up our separation techniques for use in a plant rather than the laboratory,” notes Wallace.

In addition to developing improved separation processes, the researchers are working to convert the various fractions into biofuels at a higher yield than currently possible with typical processes. For this project, Pierson and Wallace teamed with Christopher Jones, a professor in Georgia Tech’s School of Chemical & Biomolecular Engineering; Tom Fuller, a GTRI principal research engineer and a professor in the School of Chemical & Biomolecular Engineering; and graduate student Eric Ping.

Photo: Gary Meek



*GTRI principal research engineer John Pierson works to improve refining and degumming techniques to convert poultry processing residuals into fuel.*

The team is currently conducting solid-catalyst research to convert recovered usable fractions into alkane hydrocarbons or kerosene fuel, a primary ingredient for jet fuel. Initial efforts have identified promising solid-catalyst materials capable of converting selected fractions of polished brown grease more efficiently than traditional processes.

"Recovering these value-added products from waste oils is very important because it gives the industry

greater flexibility in revenue generation as the recovered, value-added products can be used for traditional products or biofuels, whatever the market will bear," added Pierson.

This project is supported by GTRI's Agricultural Technology Research Program, GTRI's independent research and development program, and Georgia's Traditional Industries Program for Food Processing.

— Abby Vogel

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*GTRI research coordinator Robert Wallace places a poultry processing byproduct into a pressure reactor used to conduct unique chemical reactions.*



## Initiative Helps Rural Hospitals Adopt Performance Improvement Techniques

Photo: Leah Yetter

Seven rural Georgia hospitals are participating in a new initiative designed to help increase their capacity to serve patients, improve the quality of their services and reduce costs. The benefits will come from adopting performance improvement techniques that are already widely used in manufacturing.

The two-year demonstration project, led by the Georgia Institute of Technology through a grant from Healthcare Georgia Foundation, will help train hospital staff in lean, quality and other techniques that identify waste in processes and find ways to eliminate it.

Georgia Tech has successfully used the approach with hospitals in Atlanta, Columbus, Newnan and Vidalia. Its "lean health care" training programs have been licensed for use nationwide by the American Hospital Association.

"We want to take the techniques that have proven to be so successful in large hospitals and use them in small, rural hospitals," says Frank Mewborn, director of the Healthcare Performance Group in Georgia Tech's Enterprise Innovation Institute. "Rural hospitals typically don't have the resources to hire outside consultants to help with performance improvement issues, so we very much appreciate the support from Health-

care Georgia Foundation to make this initiative possible."

Georgia Tech project leaders are working with health care professionals at the participating hospitals to conduct lean assessments, teach basic lean concepts, develop value stream maps to analyze the flow of materials and information, and implement rapid process improvement techniques.

Beyond direct process improvements, the initiative will also provide long-term benefits through senior leadership and hospital staff who have been trained in the lean techniques and who will share them with other departments and facilities. Success will be measured by improvements made during the process, and by the ability of each hospital to continue the process improvement efforts after the initiative's conclusion.

Rural hospitals face a financial crisis because their patients are less likely than those of metropolitan hospitals to have health insurance. At the same time, hospitals in underserved areas face other competitive disadvantages as they confront rising costs.

"A lot of rural hospitals are struggling to make payroll every month," Mewborn notes. "They don't have revenue opportuni-

ties from more profitable kinds of surgeries because they may not have a large enough market. They are meeting an essential need for health care in their areas, but their reimbursement rates tend to be low."

Such facilities need to find sustainable ways to become more efficient, which is why Healthcare Georgia Foundation provided the grant to Georgia Tech.

"This grant award represents a tremendous opportunity to achieve greater efficiencies in health care quality and costs," says Gary D. Nelson, president of the Foundation. "By taking this issue on from both clinical and operational perspectives, we can achieve sustainable efficiencies where they are most needed in our state."

One of Georgia Tech's first lean health care projects was with the emergency department at Meadows Regional Medical Center in Vidalia, Ga. As a result of the process improvement activities done there, the average time patients remained in the emergency department was reduced 44 percent and physicians were able to see more patients per hour – all while maintaining a 92 percent patient satisfaction rating.

— John Toon



*At St. Francis Hospital in Columbus, Georgia Tech helped improve the process for managing infusion pumps.*

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### **An Urgent Aircraft Upgrade**

When the U.S. Air Force found that one of its key combat aircraft needed more protection from an enemy missile threat, a multidisciplinary team from the Georgia Tech Research Institute (GTRI) went into action.

The problem was a pressing one. The A-10 attack aircraft, an Air Force workhorse, needed important additions to its electronic warfare (EW) countermeasures systems.

“This was a rush program – they needed it right away,” says research engineer Melanie Hill, who was GTRI’s lead engineer on the program. “We made it a priority across many different GTRI groups because of the broad requirements, which included electrical engineering, software development, systems engineering and mechanical engineering.”

At issue was the ability of the A-10 to detect infrared signals from certain classes of enemy weapons.

**See story on page 14.**

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