

# Horizons *Research*

*A Publication of the Georgia Institute of Technology*

*Winter 2010*



**75 YEARS OF SOLVING  
TOUGH RESEARCH PROBLEMS**



- *Jeweled Beetles*
- *Stifling Drug Innovation*
- *Improving Cancer Therapy*
- *Bioremediation Bacteria*
- *Improving Fuel Cells*



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“Part of why GTRI is strong in systems engineering is because we’re non-profit and independent – we can choose the best solution from a variety of options. And part of it is that we have long-time subject-matter experts who are able to grow a very broad view of problems within their technical areas over time.”

– Tom McDermott, GTRI director of research

## COVER STORY

“We are just now starting to catch up with what these beetles have been doing for many, many years. There are hundreds of thousands of species, and the way they generate color is just stunning – especially since it is all done with water-based systems...”

– Mohan Srinivasarao, professor in the School of Polymer, Textile and Fiber Engineering

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“With the current health care debate, consumers and policymakers need to understand that while we are getting cheap drugs now, it may be at the cost of novel future innovations and long-term access to new treatments because in our current system, industry revenues support continued research and development, and patents support revenues.”

– Matthew Higgins, the Imlay Assistant Professor of Strategic Management in the College of Management

“Instead of just measuring the size of a tumor, clinicians can quantify the leakiness of tumor blood vessels to determine the extent of angiogenesis in each tumor and decide which patients should undergo anti-angiogenic therapy or other aggressive treatment regimens.”

– Ravi Bellamkonda, professor in the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University

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“Using this technology, we can make photovoltaic generators that are foldable, concealed and mobile. Optical fiber could conduct sunlight into a building’s walls where the nanostructures would convert it to electricity.”

– Zhong Lin Wang, Regents professor in the School of Materials Science and Engineering



“These findings suggest that...it might be time to start replacing the traditional microbiology approaches for identifying and classifying new species with genomics- or proteomics-based methods.”

– Kostas Konstantinidis, assistant professor in the School of Civil and Environmental Engineering

“We are working to reduce the cost of solid oxide fuel cells to make them viable in many new applications, and this new material brings us much closer to doing that.”

– Meilin Liu, Regents professor in the School of Materials Science and Engineering



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**Cover:** Mitchell Walker, an assistant professor in the School of Aerospace Engineering, and Jud Ready, a senior research engineer in the Georgia Tech Research Institute (GTRI), are collaborating on technology that will improve satellite propulsion systems. See page 43 for more on that project, and see page 6 for our cover story on GTRI, Georgia Tech's applied research unit.

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Using microscopy techniques, researchers have attempted to understand how the jeweled beetle *Chrysina gloriosa* creates its striking green color. They learned that the insect uses a unique helical structure that reflects light of two specific colors – and of only one polarization.

Photo: Gary Meek



Unique reflecting structures create the jeweled beetle's strong green color.

(Bottom) Researcher Jung Ok Park holds a sample of the jeweled beetle.



Photo: Gary Meek

# Jeweled Beetles:

## Scientists Unlock Optical and Liquid Crystal Secrets of Iridescent Metallic Green Insects

By John Toon

A small green beetle may have some lessons to teach scientists about optics and liquid crystals – complex mechanisms the insect uses to create a shell so strikingly beautiful that for centuries it was used in jewelry.

In an article published in the July 24, 2009, issue of the journal *Science*, Georgia Tech researchers provide a detailed analysis of how the jeweled beetle *Chrysina gloriosa* creates its striking colors using a unique helical structure that reflects light of two specific colors – and of only one polarization. The reflecting structures used by the beetle consist predominately of three different polygonal shapes whose percentages vary with the curvature of the insect's shell.

"Iridescent beetles, butterflies, certain sea organisms and many birds derive their unique colors from the interaction of light with physical structures on their external surfaces," said Mohan Srinivasarao, a professor in the Georgia Tech School of Polymer, Textile and Fiber Engineering. "Understanding how these structures give rise to the stunning colors we see in nature could benefit the quest for miniature optical devices and photonics."

With support from the National Science Foundation, Srinivasarao and colleagues Vivek Sharma, Matija Crne and Jung Ok Park used two different microscopy techniques to study the surface structures on the shell of the beetle. What they found confirmed earlier suggestions that the colors are produced from liquid crystalline materials, which self-assemble into a complex arrangement of polygonal shapes each less than 10 microns in size.

"When we looked at the beetle's surface, we found tiles in the shapes mostly of hexagons, pentagons and heptagons," Srinivasarao said. "These patterns arise, we think, because of the nature of the cholesteric liquid crystal and how the liquid crystal phase structures itself at the interface between air and fluid. We think these patterns result because the liquid crystal must have defects on the surface when exposed to air, and those defects create the patterns in the beetle's shell or exoskeleton."

Because of simple geometric restrictions, the percentage of each shape depends on the curvature of that particular section of the shell. "This is really a pattern formation issue," said Srinivasarao. "It is difficult to pack only hexagons onto a curved surface. On flat surfaces, there are fewer defects in the form of five- and seven-sided cells."

In addition, the five- and seven-sided cells normally appear in pairs, an issue also dictated by the geometric difficulties of packing the shapes onto curved surfaces. The researchers found very similar structures in the 10 different beetles purchased from an insect supply house.

Liquid crystalline materials are valuable industrially and used in displays for laptop computers, portable music players and other devices. They are also used in children's thermometers, where temperature affects the color of light reflected from the material, indicating whether a child has a fever.

While the structures are determined genetically, their final form depends on the living conditions the beetle experiences during its growth and development, Srinivasarao noted.

The fact that these jeweled beetles reflect circular polarization was identified in the early 1900s by a Nobel Prize-winning physicist, A.A. Michelson, who hypothesized that the circular polarization might result from a “screw structure” within the insect’s cuticle. The solidified structures produced from a cholesteric liquid crystal and its defects on the beetle’s shell reflect bright green light with a wavelength of 530 nanometers mixed with yellow light in a wavelength of 580 nanometers.

“The most dramatic way to get saturated color is through what this beetle does with the circularly polarized light,” Srinivasarao said. “The reflection is very metallic and angle-dependent, and this is due to the helical pitch of the cholesteric liquid crystal!”

Sunlight normally contains light in equal quantities with a left circular polarization and a right circular polarization. The jeweled beetle’s

exoskeleton, however, reflects only light with a left circular polarization.

How the beetles benefit from the specific color and polarization isn’t known for sure, but scientists speculate that the optical properties may confuse predators, causing them to misjudge the location of the insects – or suggest that they may not be good to eat. The colors may also help the insects find mates.

“We are just now starting to catch up with what these beetles have been doing for many, many years,” Srinivasarao said. “There are hundreds of thousands of species, and the way they generate color is just stunning – especially since it is all done with water-based systems, mostly based on the biopolymer chitin. This is self-assembly at several levels, and we need to learn a lot more to duplicate what these insects do.” **rh**

Photo: Gary Meek

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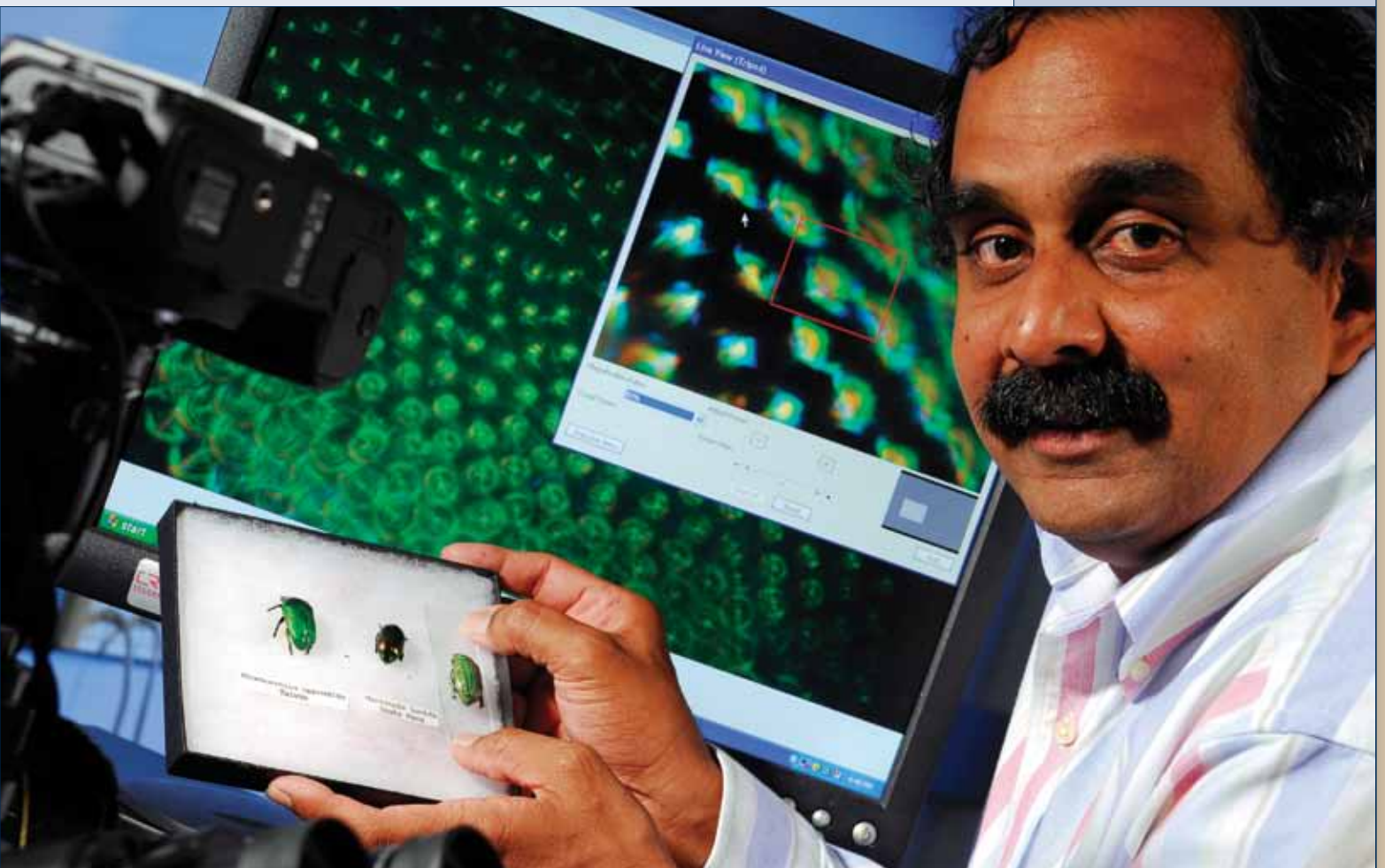
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“We are just now starting to catch up with what these beetles have been doing for many, many years. There are hundreds of thousands of species, and the way they generate color is just stunning – especially since it is all done with water-based systems...”

— Mohan Srinivasarao, professor in the School of Polymer, Textile and Fiber Engineering



Professor Mohan Srinivasarao holds a collection of jeweled beetles. The background microscope image shows shapes on the shell that create the unusual colors.

The Georgia Tech Research Institute (GTRI) is Georgia Tech's applied research organization. Founded 75 years ago, GTRI has grown into a \$200-million-per-year enterprise with nearly 1,500 faculty and staff. GTRI conducts research in a broad range of areas, including sensor technologies, systems engineering, information and communications technologies, and test and evaluation.

Photo: GTRI



GTRI researchers developed the ULTRA II to evaluate new concepts for absorbing energy from roadside explosions. The goal is to better protect vehicle crew members.

# GTRI at 75:

## The Georgia Tech Research Institute Celebrates 75 Years of Problem-Solving – and Looks Ahead to the Next 75 Years

By Rick Robinson

In 2009, the Georgia Tech Research Institute (GTRI), Georgia Tech's applied research organization, celebrated 75 years of solving difficult research problems for government and industry. From humble beginnings as Georgia's engineering experiment station, GTRI has grown into a \$200-million enterprise with nearly 1,500 faculty and staff.

GTRI's research relies on four underlying competencies developed over the course of those 75 years:

- Sensor technologies
- Systems engineering
- Information and communications technologies
- Test and evaluation

This cover section of *Research Horizons* focuses on GTRI's present and future, and includes an interview with its director, Stephen E. Cross. A longer section on GTRI's history is available on the *Research Horizons* Web site: ([gtresearchnews.gatech.edu/gtri-history/](http://gtresearchnews.gatech.edu/gtri-history/)).

In the 75 years since it opened its doors, GTRI has become the largest research unit at Georgia Tech, and one of the largest university-based research organizations in the nation.

"We're extremely proud to be Georgia Tech's applied-research arm," said Stephen E. Cross, vice president of Georgia Tech and director of GTRI. "I'd like to think that if the great innovator Thomas Edison were alive today, he would have created GTRI."

Yet the Georgia Tech Research Institute, Cross acknowledges, differs from the Edison approach in some critical ways. Unlike Edison's isolated invention factory, GTRI makes a point of working closely with others – especially Georgia Tech's academic colleges. It's a collaboration that fosters a research depth capable of dealing with the most challenging problems.

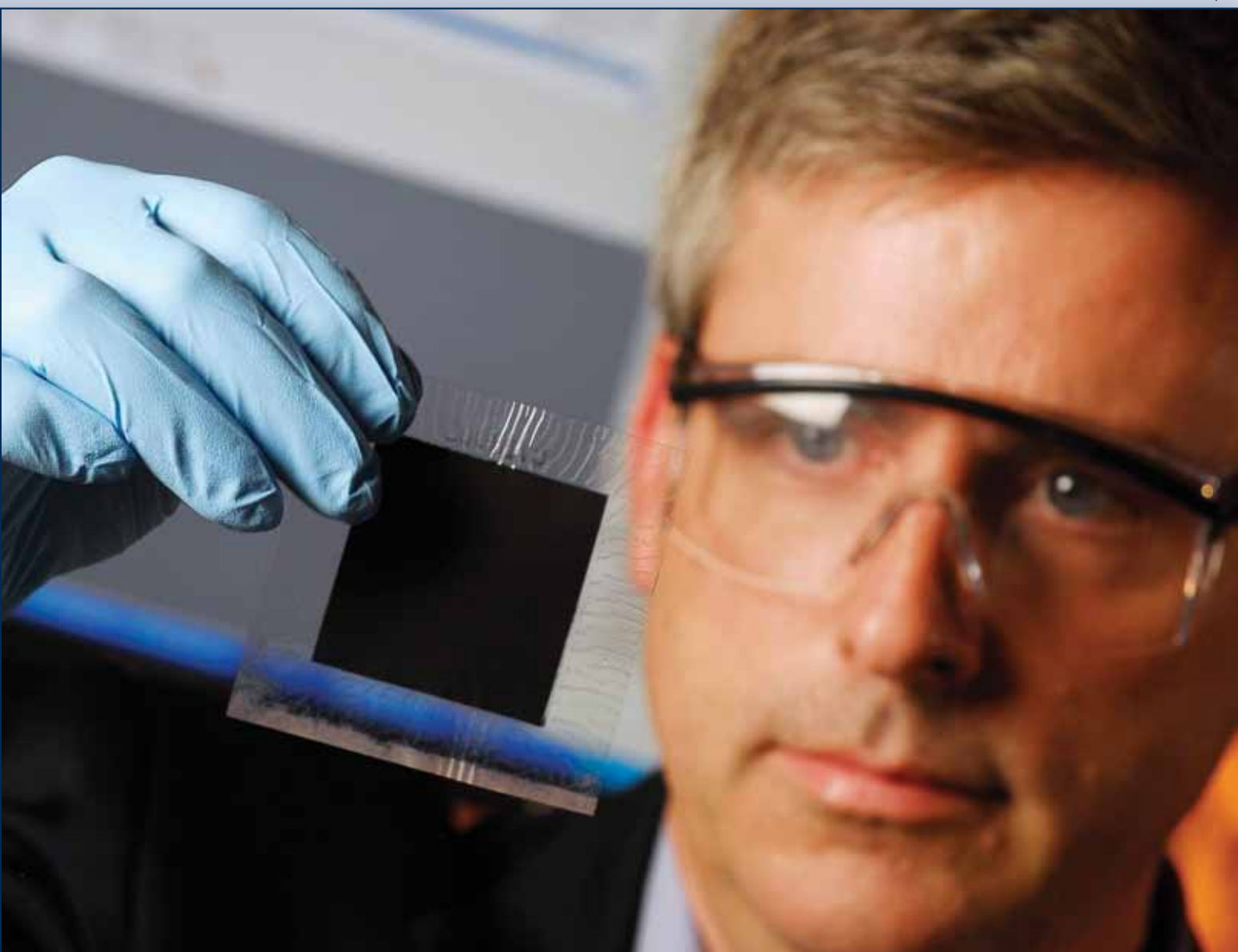
While numerous U.S. research universities have spun off their applied-research functions into separate organizations, Cross said, GTRI has become ever more tightly integrated with Georgia Tech's academic units. Collaboration between the academic and the applied sides has been a conscious direction for Georgia Tech since it was founded; its 1885 charter mandated an approach to technological education that would directly support the state's economic growth.

Speaking at the GTRI 75th Anniversary Technology Symposium, Georgia Tech President G.P. "Bud" Peterson remarked that as Georgia Tech looks ahead, "clearly it's important that we continue to expand the collaboration between GTRI and the academic units. As universities are increasingly called upon to become drivers of innovation and high-end economic development, the

## GTRI Present: A Capable and Agile Organization Focuses on Real-World Problems

Applied research. The Georgia Tech Research Institute (GTRI) doesn't mince words in describing its job – it's the applied research unit of the Georgia Institute of Technology. Its purpose is to use science and engineering to solve real-world problems.





Tom Fuller, director of the Center for Innovative Fuel Cell and Battery Technologies, holds a sample of a new material that could improve fuel cell durability. In addition to his GTRI position, Fuller is also a professor in Georgia Tech's School of Chemical and Biomolecular Engineering.

importance of the role of GTRI and organizations like it will continue to grow."

### Consistent Growth

The Research Institute that began in 1934 as the State Engineering Experiment Station (EES) employs nearly 1,500 people today, including some 700 researchers. Of those, more than 40 GTRI faculty members also have appointments in the academic colleges and perform teaching roles along with their research.

Today's GTRI has seven laboratories and 13 field offices located throughout the United States and in Ireland. It also has numerous

facilities on the Georgia Tech campus and a secure 55-acre research facility in Cobb County north of Atlanta.

After several years of particularly strong growth, GTRI's research awards for fiscal 2009 topped \$200 million, a total that is up 63 percent in the past three years. GTRI is the largest single contributor to Georgia Tech's total research budget of about \$500 million.

The Research Institute has hired 120 new research staff in the past year, and plans to hire an additional 100 research staff in the near term. The number of Georgia Tech graduate and undergraduate students currently working as co-op students at GTRI

now stands at more than 350; it's a workforce that's an important plus for research flexibility and creativity. (See sidebar story on student researchers on page 13 of this issue.)

GTRI's customers include a who's who of U.S. federal agencies, U.S. and overseas corporations, U.S. allies, and state and local governments. Among GTRI's major sponsors are the Department of Defense agencies, the Defense Advanced Research Projects Agency (DARPA), the state of Georgia, major U.S. defense contractors, and many other governmental and commercial entities.

"We've shown pretty good progress for an organization that was authorized by the



Designed by GTRI for the U.S. Air Force's 46th Test Group, BICOMS was the world's largest mobile system for measuring radar cross section when it was completed in 1999. It is shown here at Holloman Air Force Base in New Mexico.

state legislature in 1919 but couldn't get funded until 1934 – and which started out in the basement of Georgia Tech's Old Shop Building," Cross said.

### Capabilities and Collaboration

GTRI performs research and development in dozens of areas, from radar to robotics, from electronic defense to energy, from product testing to food processing. It also provides a wide range of services, from analyzing indoor environments to teaching workplace safety.

The vast majority of the Institute's work relies on four underlying competencies developed over many decades, said Tom McDermott, GTRI's director of research. They are sensor technologies, systems engineering, information and communications technologies, and test and evaluation.

"You could argue that sensor technology is our core strength," he said. "GTRI probably has the broadest capability in terms of different sensing technologies of any research body in the world."

GTRI, he explained, provides research and development in a vast array of sensor technologies. It has broad sensing capabilities

that began with World War II radar research. That work led to pioneering, internationally recognized work in millimeter-wave radar technology.

Today GTRI's sensor capabilities cover every bandwidth of the electromagnetic spectrum used for defense and communication, as well as chemical sensors vital to numerous defense and industry applications.

But, McDermott added, even the most advanced sensors have little utility without the other collaborating capabilities – systems engineering, information and communications technology, and test and evaluation.

For example, GTRI today tackles challenging multi-sensor problems. Yet the task of fusing data from a variety of sensor sources would be next to impossible without sophisticated computing and networking. Just as important, successful design of a complex sensor-based system would be hard to achieve without systems engineering expertise. Equally useful are the advanced modeling capabilities of the test and evaluation disciplines that help guide the system-design process.

"Part of why GTRI is strong in systems engineering is because we're non-profit and

independent – we can choose the best solution from a variety of options," McDermott said. "And part of it is that we have long-time subject-matter experts who are able to grow a very broad view of problems within their technical areas over time."

Another key is the collaboration that takes place at GTRI across the disciplines, said Terry Tibbitts, director of the Electronic Systems Laboratory (ELSYS), GTRI's largest lab with roots going back to the Engineering Experiment Station's work in radar and signal processing. Tibbitts pointed to a recent high-priority project that added vitally needed missile protection to the A-10 attack aircraft, an Air Force workhorse. To deal with the vulnerability, GTRI mounted an urgent effort, the A-10 Infrared Countermeasures Program. The work mobilized researchers and technicians from across the Research Institute, including ELSYS and several other GTRI labs.

In 200 days – a brief period by most defense-project standards – the team went from program-concept meetings to a successful flight test. Today, the entire U.S. A-10 fleet is protected by the countermeasure technology GTRI developed.

"Programs like this one show GTRI's greatest strengths – we're small enough to move very quickly, but big enough to have the deep capabilities needed to handle an entire program for a sponsor," Tibbitts said. "We're also good at collaborating across disciplines – we know each other's strengths, and we work well together."

Gisele Bennett is director of the Electro-Optical Systems Laboratory (EOSL), a major contributor to GTRI's sensor capability. She noted that GTRI's identity as a multi-disciplinary organization has been the product of many decades of effort.

"GTRI has evolved slowly and deliberately from a research institute with a narrow range of technical expertise to one that has a very broad and deep range of technical expertise," she said. "I'm personally confident we can maintain our technical pre-eminence in our





GTRI researcher Jeff Hallman troubleshoots systems on an A-10 aircraft as part of a priority program that upgraded missile protection.

core areas, while also branching out by applying core expertise gained over the decades to other disciplines.”

### **The Economic Imperative**

Like Georgia Tech, GTRI was founded with a mandate to contribute to the economy of the state of Georgia and the surrounding region. The Research Institute pursues that critical assignment on several levels.

One effort involves direct support of the economy through research on tough challenges facing Georgia industry. To that end, GTRI has performed important research and problem-solving for many important industries, including food processing, carpet manufacturing, paper and others.

The Georgia Tech Research Institute maintains an extensive on-campus facility, the Food Processing Technology Building, to support Georgia’s vast poultry processing industry, among others. GTRI’s support for the food industry has included many innovations, including one of the first computer-vision systems for improving quality in poultry processing.

“Food processing is a very good example of where GTRI is able to take the sensor, robotics, computer-vision and manufacturing technologies that we’ve developed – largely with defense funding – and apply them to an industry that’s important to the economy,” said GTRI director Cross.

The Research Institute also provides

services that directly support the state’s employers and their workforce. The Occupational Safety and Health Program, located in GTRI’s Human Systems Integration Division, helps businesses keep workplaces safe by complying with the requirements of the federal Occupational Safety and Health Administration (OSHA).

The program offers free on-site safety consultations to smaller Georgia companies. It also teaches a large number of OSHA safety and health courses, mainly through Georgia Tech Distance Learning and Professional Education.

GTRI plays an important role in advancing the technical knowledge of U.S. defense professionals, both in the military and in industry. Through Georgia Tech’s Defense

Technology Professional Education Program, engineers, scientists and faculty from GTRI and Georgia Tech's College of Engineering teach nine certificate programs and some 80 courses at eight U.S. sites, as well as via video-conferencing and online video.

### The New Company Connection

An important GTRI role involves assisting the development of new high-technology companies in Georgia. Its first startup was Scientific Atlanta, founded in 1952 by several EES personnel. The venture prospered, becoming internationally known for satellite Earth stations and cable TV equipment, and was acquired by Cisco Systems, Inc. in 2006.

GTRI works with Georgia Tech's business assistance and economic development unit, the Enterprise Innovation Institute (EI<sup>2</sup>), to offer technical support for new technology companies.

EI<sup>2</sup> is widely known as home to Georgia Tech's successful startup-company accelerator, the Advanced Technology Development Center (ATDC), which has graduated more than 120 startups since 1980. GTRI works directly with the Strategic Partners Office within EI<sup>2</sup> to connect companies to Georgia Tech resources and promote broadly based development initiatives in Georgia.

One result of that collaboration is the FutureMedia<sup>sm</sup> initiative, directed by Renu Kulkarni, which is aimed at helping to make Georgia a global leader in the burgeoning fields of digital, social and multi media. (See related story on GTRI's future on page 12 of this issue).

"There's a great deal of interaction between GTRI and EI<sup>2</sup> now," said research director McDermott. "We've been able to work with some of the startup companies that are incubating there, and we believe there will be plenty of collaboration in the future."

The Georgia Tech Research Institute also works with EI<sup>2</sup>'s Industry Services division, an outreach program that provides support to Georgia manufacturers, including direct



GTRI researchers Gary Gray (left) and David Price program a "Mini ModPOD" portable imaging system they developed to estimate the number of refugees after a natural disaster and assess the need for health and humanitarian services.

technical, engineering and other assistance. Industry Services personnel can connect companies that have specific manufacturing challenges to GTRI engineers, scientists and technicians.

Not the least of GTRI's contributions is the economic impact of the salaries of its nearly 1,500 employees, a number that includes some 700 degreed research engineers and scientists, said Tom Horton, GTRI's chief of staff and director of government relations.

By the most conservative of economic multipliers, GTRI's contribution to Georgia's economy last year was about \$450 million, Horton said. That number includes the

impact of salaries, as well as direct and indirect GTRI expenditures among Georgia businesses for everything from pencils and paper to computers and sophisticated research equipment.

"Of course, we are a non-profit organization," Horton said. "But if it were a business, GTRI's revenues and number of employees would place us within the top 15 corporations in Georgia."

Horton noted that GTRI and Georgia Tech contribute to Georgia's attractiveness as a home for national and international corporations. He cited the NCR Corporation's recent decision to move its worldwide headquarters to Duluth, Ga., and CEO






GTRI researchers Lora Weiss and Rusty Roberts pose with examples of unmanned systems: a Dragon Eye unmanned aerial vehicle and an iRobot ATRV unmanned ground vehicle. Both have been modified by Georgia Tech.



Bill Nuti's comment that "working in partnership with the world-class academic institutions in Georgia" was part of the attraction.

Cross argues that GTRI's unique blend of capability, commitment and organizational agility developed naturally over the decades. The Institute has dealt successfully with many challenges, and a positive mentality developed as a result.

"Interdisciplinary collaboration and the willingness to accept a tough challenge are among our greatest assets," he said. "I'm proud of the people of GTRI. They can take great Georgia Tech research – some of it done here, much of it done in the colleges – bring it together and apply it to solve real-world problems." 

## GTRI Future: Calculated Risks, Key Technologies Characterize the GTRI of the Future

The GTRI of the future will likely look much like the GTRI of today, but with broadly expanded capabilities in cutting-edge technologies and more collaboration with Georgia Tech's academic colleges.

During its 75-year journey, Georgia Tech's applied-research institute has chosen its growth areas carefully. GTRI has never tried to be all things to all sponsors; it extends its research into areas that appear to offer promise – as well as the expected tough challenges.

"There are phrases we should outlaw as researchers, such as 'it can't be done' or 'it's never been done that way before,'" said Stephen E. Cross, GTRI's director. "We should never be overly concerned about risk. We want to take calculated risks, but we should never use risk as a reason for not tackling something."

GTRI has used its four core competencies

– sensor technologies, systems engineering, information and communications technologies, and test and evaluation – to develop internationally known specialties in radar, electronic warfare, antennas and communications technologies, among numerous others.

Today the Research Institute is bringing those core skills to bear on new areas of expertise. An active recruitment effort has brought to GTRI a cadre of new researchers who are accomplished in several critical focus areas.

The concepts of open and disruptive innovation have been useful in directing development paths, GTRI leaders explain. In open innovation, an organization uses both internal and external ideas to advance technology. Disruptive innovations are those that create unexpected change; they're often problematic because they compete with time-honored approaches, yet they present unique opportunities to a research organization.

"At GTRI, we've found that open- and disruptive-innovation concepts are very helpful in guiding our understanding of how to recognize future opportunities – and how to pursue them," said Tom McDermott, GTRI's director of research.

The object, of course, is to expand GTRI's problem-solving capacity in a number of crucial 21st century technology arenas – which will in turn support and facilitate research throughout the Research Institute.

### Digital Media

GTRI leadership believes that Georgia, already quite active in several media areas, can become a global leader in the exploding fields of digital, social and multi media. The FutureMedia<sup>sm</sup> Initiative, directed by former Motorola executive Renu Kulkarni, is a broad-based Georgia Tech program aimed at leveraging the efforts of Georgia universities, corporations, venture capitalists, entrepreneurs and government to make the state a digital-media powerhouse.

Georgia Tech initiated an October 2009 FutureMedia<sup>sm</sup> conference in Atlanta that brought together 260 academics, officials and

executives from as far away as Singapore and South Korea to discuss Georgia's media future. GTRI, the Georgia Tech Research Network Operations Center, Georgia Tech's GVU Center and the Georgia Electronic Design Center were among many Georgia Tech groups that presented scores of technology demonstrations to conference participants.

"We want to create an open-innovation ecosystem that will make Georgia a global pioneer in this field," Kulkarni said, "and provide a model not only for what we do in future digital media, but also in how we do it."

### Autonomous Systems and Robotics

GTRI is pursuing a number of high-stakes programs in an arena that will clearly play an extensive role in humanity's future. This work includes the Micro Autonomous Systems and Technology (MAST) program, a multi-year initiative sponsored by the U.S. Army Research Laboratory. GTRI is working with Georgia Tech's College of Computing and the College of Engineering, as well more than a dozen universities and companies, to develop small, intelligent mobile robots capable of collaboration as well as advanced locomotion.

In related work, a GTRI team is developing unmanned underwater vehicles that can function both autonomously and collaboratively to carry out a range of under-sea missions. In another program, GTRI researchers are supporting development of a road map to improve the testing and evaluation of unmanned and autonomous systems, and are also investigating common-control technology for unmanned systems.

### Energy and Environment

GTRI investigators, collaborating with Georgia Tech's College of Engineering and the College of Sciences, are extensively involved in the fields of fuel cells, solar energy, batteries, wind turbines, supercapacitors and biofuels. The Research Institute is an active participant in Georgia Tech's Center for Innovative Fuel Cell and

# Students at GTRI:

## Adding an Important Dimension

Students add an important dimension to GTRI. As an integral part of Georgia Tech, GTRI has always pursued a wide-ranging teaching mission, in addition to its primary research and development role. The Research Institute has strong and expanding connections with Georgia Tech's academic colleges, and more than 40 GTRI researchers have dual appointments as Georgia Tech adjunct faculty.

Nearly 350 Georgia Tech graduate and undergraduate students have positions at GTRI through the Division of Professional Practice, which operates the Cooperative Education Program (Co-op Program).

"GTRI has a very customer-focused mission, and the colleges have more of a student education focus," said Tom McDermott, GTRI's director of research. "But those roles often have real synergy – students bring new ideas from the classroom, they learn a lot applying that knowledge to real-world problems, and we often learn new things from them."

In some cases, student familiarity with cutting-edge technologies, their differing perspectives and their youthful zeal can be game-changers.

Recently, GTRI has been examining the advantages of research projects that are entirely student-led. Though the primary aim of such projects is educational, the Research Institute is also interested in what can happen when youthful eyes are focused on long-standing research challenges.

In one program, sponsored by the Office of Naval Research, student teams were asked to design and build unmanned underwater vehicles. The vehicles, customized from available commercial products, had to be able to perform complex missions underwater.

"The program was a tremendous success," said GTRI Director Stephen E. Cross, himself a professor in Georgia Tech's Stewart School of Industrial and Systems Engineering and an adjunct professor in the College of Computing. "It was a great example of collaboration between GTRI and several Georgia Tech engineering schools. The Navy was very pleased, and it is sponsoring other student-led projects this year."

GTRI has initiated an Applied Studies Program, within the Student Co-op program, to help utilize student talent

Georgia Tech students make important contributions to GTRI research projects. Here, John Turgeson and Chris McClanahan work with senior research engineer Simeon Harbert (center) on a food processing project.



for research. Under this approach, student teams work on sponsored GTRI research within the structure of a semester-length academic project.

Students can also be an important research resource in cyber-intelligence and cyber-warfare research, said Jeff Moulton, a GTRI principal research associate. Students' familiarity with the latest online technologies, tricks and trends can make them invaluable to more senior researchers.

"Our adversaries are often smart, motivated, creative young people," Moulton said. "We need to be able to think like they think, and our students can do that. We can leverage their ability to think outside the box, while also offering them a great learning experience."

— Rick Robinson

# Georgia Tech and GTRI:

## Fostering a Close and Collaborative Relationship

**G**eorgia Tech and GTRI have a special – even unique – relationship. GTRI is indeed “a business embedded in a university,” as some have called it. But though it’s in many ways a different kind of entity, it strives to collaborate closely with Georgia Tech’s academic colleges.

Georgia Tech’s drive to foster collaboration between basic and applied research goes way back. The Georgia Institute of Technology was founded in 1885 with a charter that emphasized both engineering education and applied technology.

“I’d like to see GTRI become known everywhere as the organization that pulls technology straight out of academics and applies it to the problems of our customers – and the world,” said Tom McDermott, GTRI’s director of research. “An increasing part of our mission should be to actively search across campus for basic technologies and then apply them.”

GTRI’s financial structure is significantly different from that of the academic colleges. The Research Institute depends on the sponsored research its researchers bring in. For GTRI personnel, none of whom are tenured, no contract means no work – and potentially no position.

That approach has its advantages, noted GTRI Director Stephen E. Cross. GTRI’s research awards – which topped \$200 million in fiscal 2009 – are the largest segment of the university’s overall research budget of about \$500 million.

“Because of our growth, there are many active ways that we can help campus get through budget shortfalls,” he said. “In recent years, we’ve tripled the amount of sponsored work that comes through GTRI to campus entities.”

A number of professors worked for GTRI when their summer salaries were affected by recent state budget cuts, he added. A growing amount of GTRI’s independent research and development (IRAD) money is also being used to fund collaborative research with academic faculty. And GTRI also increased its co-op student total from 200 to nearly 350 after numerous graduate students across campus lost their funding.

There can be tension between GTRI and the academic colleges, McDermott admitted.

“Sometimes our missions – student-focused or customer-focused – are in conflict, but often they synergize,” McDermott said. “We’re actively working to take advantage of the synergy.”

— Rick Robinson

Photo: Gary Meek

Collaboration between GTRI and researchers in the School of Aerospace Engineering led to development of this secure Collaborative Visualization Environment (CoVE).





Battery Technologies and its mission to help turn the fuel-cell promise into reality. At the fuel-cell center – directed by GTRI's Tom Fuller, who also has an appointment in the Georgia Tech School of Chemical and Biomolecular Engineering – GTRI researchers are addressing the systems engineering issues surrounding compact fuel cells for soldiers, as well as the larger systems needed for transportation and distributed power generation.

GTRI is also conducting a broad range of research in energy modeling, utilizing its established expertise in information technology, communications and networking. Research includes development of modeling and simulation tools that enable the evaluation of different energy strategies. Other GTRI projects are developing technologies to reduce the environmental impact of energy and water usage, and investigating the health and environmental benefits of green technologies.

## Cyber Warfare

At GTRI, information operations (IO) is an area of particular focus. Researchers are pursuing a broad range of projects related to the role of intelligence technologies in national defense. This work involves close collaboration with the Georgia Tech Internet Security Center (GTISC).

The cyber battlefield is of special importance. This high-priority area, involving defensive and offensive use of computers and the Internet, is a rapidly growing research area. GTRI's Center of Excellence for Emerging Information Technologies is investigating security issues involving both current and emerging digital technologies. The aim is to better protect U.S. military, government and other information systems, ensuring that the element of technology surprise remains a U.S. asset.

GTRI is active in more than a dozen IO/cyber-related projects sponsored by a variety of government agencies. Researchers are conducting several new initiatives to build

cyber-intelligence capabilities in emerging technologies, including techniques that simulate hostile intrusion attempts into networks and other critical areas. They are also pursuing the development of enhanced security for novel architectures, and construction of a \$200,000-plus IO laboratory that will support research ranging from cloud computing to converged infrastructures.

## Systems Engineering Expertise

Supporting U.S. systems engineering capabilities, in both government agencies and in industry, is a growing focus at GTRI. In fall 2009, the Research Institute helped launch a new Professional Master's Degree in Applied Systems Engineering (PMASE). This College of Engineering degree is aimed at mid-career engineers in government and corporations who manage complex systems and want to expand their systems-engineering knowledge.

The program combines traditional teaching with group learning, distance

# GTRI 75 Year Time Line



1934 – The State Engineering Experiment Station (EES) opens in Georgia Tech's Old Shop Building, with a little more than \$5,000 in state funding and 13 part-time faculty researchers.

1939 – EES – a.k.a. "the Research Station" – moves into the Research Building, its first purpose-built home base.

1943 – An EES researcher discovers that certain radio frequencies heat food, but is too busy with wartime projects to develop the phenomenon further.

1919

1919 – The Georgia General Assembly authorizes a state engineering experiment station, but leaves it unfunded.



1934-1940 – Georgia Tech's expertise in rotorcraft research begins with EES's work on the autogyro, a short-winged aircraft that presaged the helicopter.

1940

1940 – Federal funding linked to World War II begins bringing in more projects, including work in wind-tunnel testing and communications technology.

education and face-to-face interactions, and is aimed at filling a significant gap in higher education offerings for working engineers. Graduates are expected to be proficient in methods and practices of systems engineering, and to develop awareness of cutting-edge research shaping the future of the discipline. A unique aspect of the degree is an experiential component based on pioneering work in systems analysis tools and methods developed by the Aerospace Systems Design Laboratory in the Georgia Tech School of Aerospace Engineering.

### International Cooperation

GTRI is also emphasizing expanded international research partnerships and collaboration. GTRI continues to ramp up its GT-Ireland initiative, which is focused on collaboration in radio-frequency identification technology. Georgia Tech, supported by GTRI, is also involved in educational and research collaborations in France, Singapore and China.

"The international strategy for Georgia Tech and GTRI involves a rapidly growing number of nations around the globe," said

director Cross, who is also a Georgia Tech vice president. "We have to consider the uniqueness of each country and its goals, and we also want to consider the benefit of these affiliations to the Atlanta campus and to Georgia."

### Security Research

The GTRI of the future will focus its research and development efforts wherever the U.S. needs advanced investigation and innovation.


In one homeland-security field, GTRI is helping protect shipping containers, which have been long identified as an area of vulnerability that terrorists could exploit. GTRI has developed a container security device that monitors whether container doors have been opened in route by an unauthorized user, explained Gisele Bennett, director of GTRI's Electro-Optical Systems Laboratory (EOSL).

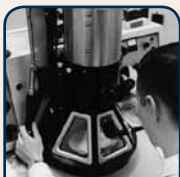
"We've used GTRI's sensor expertise, built up over many decades, to develop a device that works well and has been successfully tested. This technology will move into a pilot phase very soon," she said.

GTRI sensor experts are also designing a wall intrusion detection system for composite containers. This research, performed in collaboration with Georgia Tech's School of Electrical and Computer Engineering, could detect any breaching of a shipping container's walls.

Cross noted that in one especially high-priority area, GTRI is tackling the deadly problem of improvised explosive devices (IEDs) in war zones around the world. For example, the ULTRA II design concept is aimed at producing military vehicles with a new type of protected personnel compartment. The concept uses a sacrificial "blast wedge" to absorb energy from IEDs and improve occupant safety in future light armored patrol vehicles.

In years to come as in the past, Cross added, GTRI's core research and applications will help support innovations that can aid U.S. business and economic growth.

"A large part of our future strategy," Cross said, "is to take the defense technology that we create – and the problem-solving expertise we develop – and move it into other market areas to benefit commercial industry and result in more jobs here in Georgia." 



1947 – The Research Station installs one of the first U.S. electron microscopes; the \$13,000 device goes to work on basic kaolin research.



1952 – EES personnel help found Scientific Atlanta, later renowned for its satellite Earth stations and cable TV equipment.



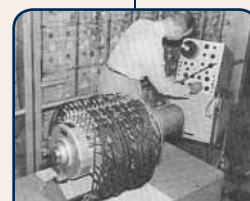
1959 – As interest in nuclear technology soars, EES opens the Radioisotopes and Bioengineering Laboratory.

1950

1949 – EES research income passes the \$1 million mark.

1946 – The name "Georgia Tech Research Institute" is given to a non-profit corporation created to handle EES contract and patent issues.

1950 – The Korean conflict increases federal funding, leading to pioneering work at EES in millimeter-waves – an area of GTRI expertise today.



1955 – Georgia Tech opens the Rich Electronic Computer Center, housing a 38-foot-by-20-foot UNIVAC 1101 with 48 kilobytes of memory.

# Q&A on GTRI:

Recently, GTRI director and Georgia Tech vice president Stephen E. Cross was interviewed about GTRI's growth and future plans. The following is a shortened version of that interview, which was conducted by Rick Robinson.

*The Georgia Tech Research Institute has changed considerably in 75 years, going from a few people in the basement of the Old Shop Building to about 700 research faculty and close to 1,500 total employees today. How would you describe GTRI's current progress?*

We're definitely in a growth period. Our research awards have risen about 63 percent in the past three years to more than \$200 million in fiscal 2009. We've scaled up our research staff so that we're able to do all this work. And that also means growth in the ways in which we contribute to the overall economic vitality of the state.

Of the 120 people we've hired in the past year or so, 120 of them are Georgia Tech quality. They're just phenomenal

people. We may be one of the few organizations in the world to really benefit from the global financial crisis, because in the past year especially there have been a lot of really talented, skilled people who have been looking for work. We might not have had that opportunity if the economy had been stronger.

Ultimately, what I see is growth in the ways in which we contribute to the overall economic vitality of the state while enhancing our national stature.

*Is that growth rate sustainable?*

Probably yes, but we don't want to sacrifice technical quality for the sake of growth. We're grappling with that issue right now, trying to figure out how large we should be ideally. We do know that we don't want to grow too large. We've seen some of our competitors become rather sluggish and not as innovative because of what you might call excessive growth.

We're probably going to grow by another 100 to 150 people this year, bringing us up to about 800 research faculty posi-



Stephen E. Cross, director, Georgia Tech Research Institute, and vice president, Georgia Institute of Technology.

tions. But if we grow beyond that we're going to be seriously space-constrained.

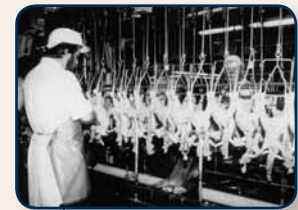
Right now we're looking at leasing another entire building if we grow much larger. We moved many research staff into the former GCATT building at 250 14th Street three years ago. That quite large building is now becoming fully utilized. In fact, we're in the process of moving our administrative offices from



1966 – Richard C. Johnson develops the compact range, an antenna-measurement technology that remains important today.



1970 – EES's high-temperature ceramic expertise leads to a fused-silica technique for forming complex shapes such as missile radomes.



1973 – The Agricultural Technology Research Program is established to support Georgia's economically important poultry industry.

1960

1968 – Veteran radar researcher Maurice Long becomes director; his tenure will emphasize EES's continuing independence within Georgia Tech.

1970

1971 – New contracts and grants at EES total a record \$5.2 million.

1969 – EES begins work on protecting pacemakers from microwaves – a research field that continues today at GTRI's Medical Device Test Center.



1976 – Donald J. Grace, a colleague of Georgia Tech President Joseph M. Pettit when both were at Stanford University, becomes EES director.

**GTRI** 75 YEARS



the Centennial Research Building (CRB) to 14th Street – so that we can provide more room for two laboratories in CRB that are growing very quickly.

*What are the most important things that GTRI needs to do going forward?*

The two things that I think are most critical are a good attitude toward risk and interdisciplinary collaboration.

It might sound kind of trite, but going forward you never want to say no. One of the things we should never be that concerned about is risk. We need to stick with calculated risk, prudent risk – but we should not use the simple fact of risk as a reason for not trying something new.

And part of a “can-do” approach requires striving to get better and better at interdisciplinary work. For example, our sensors people have gotten pretty good at working across the frequency spectrum: our electro-optics people work with our infrared people, who work with our radio-frequency people, who work with our terahertz people. And that hasn’t always happened.

The best news is that great new ideas always seem to come at the intersection of fields. So the more interdisciplinary collaboration we can get, the better.

Some of the things we’re looking at now – in cyber operations and social/cultural modeling and sensor fusion – are all things that couldn’t be done without taking an interdisciplinary perspective.

*What kind of GTRI do you envision 25 years down the road?*

We were the first research site at Georgia Tech, and today we’re the largest research center here. But I hope that, by continued collaboration with our colleagues in the Georgia Tech colleges, new kinds of research centers will evolve that will benefit all of Georgia Tech.

I believe we can create a new development model that will rival Silicon Valley, based on market-centric industries that emerge in thematic areas at Georgia Tech – whether it be in energy or biotechnology or future media or systems engineering.

For example, our current emphasis on future media could work out very successfully during the next 25 years. I can see whole new industries developing out of that, creating corporations that would hopefully locate near the Georgia Tech campus in Atlanta, or in Savannah, or in other parts of the state.

Research in autonomous vehicles is taking place all across campus, including in GTRI. Georgia could become one of the leading places for autonomous vehicles; we could test them here, build them here and teach people how to maintain them here.

So I can see such industries forming around thematic areas that come out of Georgia Tech. That kind of industrial growth could benefit the economic development of Georgia and of the whole Southeast.

*In your six years as director of GTRI, what do you consider your most significant accomplishment?*

My real accomplishment has been what I call the upside-down organization chart. I tried to make it clear when I came up here that my job is to support the laboratory directors and



1977 – Solar energy research heats up at EES with construction of a 325-kW, 500-mirror Solar Thermal Test Facility, the second largest in the U.S.



1980s – GTRI/EES work on millimeter-wave radar culminates in development of what was at the time the world’s highest-frequency microwave radar, operating at 225 GHz.



1985 – Coinciding with Georgia Tech’s 100th birthday, GTRI moves into a new home, the \$12.5 million, six-story Centennial Research Building.



1978 – EES acquires its Cobb County research complex – and soon adds a state-of-the-art electromagnetic-radiation measurement range.

1979 – The Huntsville Research Laboratory begins operations, giving EES a presence at Redstone Arsenal that continues to this day.

1980

1984 – EES celebrates its 50th Anniversary by, among other things, changing its name to the Georgia Tech Research Institute (GTRI).



1987 – GTRI unveils its first Light Detection And Ranging (LIDAR) system.

the heads of our support units, and that their job is to support the researchers.

My thought was that you wouldn't have much of a research institute if it wasn't for the researchers. So when I drew the organization chart, I drew it upside down, with management at the bottom and researchers at the top. That's what I've been most proud of, and I've been trying hard to convince people I'm really serious about it.

#### *What is GTRI's greatest single strength?*

The people here – they are truly special. They're all focused on solving problems, and they do.

And we have put in place a plan to preserve what is the real charm of GTRI, and that is the freedom that the research faculty have to try out new ideas and to pursue their aspirations – as long as they're guided by the overall strategy of where we're trying to go in sensors, information technology, systems engineering, materials and our other areas of expertise. Within those parameters, researchers can carve out their own careers and become as accomplished as they want in research, or go on to pursue a research-management career.

And we in GTRI management will strategically align things so we're able to support them in that. We're really trying to make it easier for the research faculty do their work – to help them write proposals and as much as possible clear away all the grunt work associated with research.

We haven't made all the improvement we would like. But the evidence suggests that it's kind of all going in one direction, and judging from our research awards, it's a successful direction.

#### *What's a good day for you at GTRI?*

The best days I have are when I walk around the labs and support units and talk to people. I especially like calling on the younger researchers – the people who are under 40 years old – and just seeing how excited they are about their work. It's just really rewarding to see that.

And what's neat is, I see that enthusiasm in my support staff, too. I talk to the people in business services or our facilities group or our research security group or our financial group – and they're all excited about what they're doing. They're excited because they can see the impact that it's having.

*What about GTRI's international research efforts, especially in Ireland? How is that working out?*

Our intention with Georgia Tech Ireland right from the very beginning was to work with their research universities. The Irish government wanted their research universities to have the applied research model that we have here at Georgia Tech.

We signed the contract three years ago. Actually, we've been there physically just a little over two years. It's been a steep learning curve, and the global financial crisis hasn't helped. It's a high-risk proposition to take a business model and put it into another country that's not familiar with it.

And what we learned was, to be there in another country we really need to be in partnership with another excellent university. And right now we're in discussions with one of the major research universities there – I can't say more than that right now – but we're very likely before long to form a joint venture collaboration with that university and have a much better business model with a better support approach.

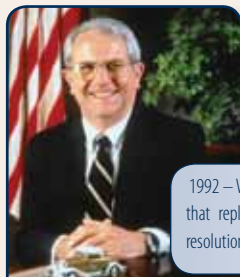
There's plenty of other good news in Ireland. We already have four fairly good-sized

**1990**

1990 – GTRI supports development of a computer-generated virtual tour of proposed Olympic venues, often called a key to Atlanta's successful Olympic bid.

**GTRI 15 YEARS**

1992 – Admiral Richard H. Truly succeeds Don Grace, who retires after a record 16 years as director.



1992 – Work begins on FalconView™ software for pilots that replaces hand-drawn mission maps with high-resolution graphics on a laptop screen.



1993 – Director Richard Truly begins a diversification aimed at increasing GTRI's non-defense research in the wake of the Soviet Union's collapse and a decline in defense funding.



1997 – Veteran GTRI researcher Edward K. Reedy succeeds Richard Truly as director, emphasizing increased collaboration with state government and industry.



1998 – GTRI's Severe Storms Research Center opens to research methods for increasing the length and accuracy of tornado warnings in Georgia.





In a GTRI wind tunnel, senior research engineers Rick Gaeta, left, and Gary Gray check a propeller that has been attached to a dynamometer for testing.

projects under way that include funding support. We have a test bed for wireless sensor technology operating, and we've been doing work in Internet protocol television across Ireland, on top of their high bandwidth networks. We've won our first European Union project, we've had Georgia Tech electrical-en-

gineering faculty who have spent a summer with us in Ireland, and we've had students who have been over there working with us.

One of the important things in Georgia Tech strategic planning is to figure out what our international strategy should really be overall. If you look at the places where Geor-

gia Tech is now, in France and Singapore and China, and our possibilities elsewhere – they're all different. It's important to find the best strategic way to think about how we approach these relationships. **rh**



2000 – Research awards at GTRI pass the \$100 million mark during this millennial year.



2004 – GTRI establishes the Military Sensing Information Analysis Center – SENSAC – to support military sensing technology areas.



2006 – The first overseas GTRI office opens in Athlone, Ireland, emphasizing Internet protocol TV, radio frequency identification, biotechnology and sustainable energy.

**GTRI 15 YEARS**

**2000**



2003 – Stephen E. Cross becomes director, promising growth in both established and new research areas, and improved collaboration with Georgia Tech's academic colleges.

2005 – The Food Processing Technology Building opens, providing a state-of-the-art headquarters for GTRI's Food Processing Technology Division.



2009 – Research awards top \$200 million, up 63 percent over a three-year period; GTRI now has nearly 1,500 employees, including some 700 research faculty.

2009 – The FutureMedia™ initiative launches to help develop Georgia leadership in digital media.

2009 – The Georgia Tech Research Institute celebrates its 75th anniversary.



# A Computer-Generated Victory

**"O**ne of the International Olympic Committee (IOC) members was asked if he'd ever been to the southern United States – and he said, 'Oh, yes, I've been to Los Angeles,'" recalled Fred Dyer recently.

"So we kind of knew what our problem was – we had to take Atlanta to them."

That's exactly what a GTRI-led group did, adds Dyer, a 40-year Research Institute veteran who helped manage the effort. A group of scientists, engineers and designers brought Atlanta to the IOC by means of a computer-based interactive video demonstration.

All available sources say the idea started with the late Georgia Tech President John Patrick Crecine. It happened during a visit from Billy Payne, who spearheaded Atlanta's bid for the Olympic Games and later served as CEO of the Atlanta Committee for the Olympic Games.

"Back around 1988, Billy Payne went to Dr. Crecine because he wanted Georgia Tech to build a model, a big table showing the proposed Atlanta Olympic venues," recalls A. Ray Moore, retired director of the Georgia Tech Research Communications Office. "And Dr. Crecine, who was very sharp and technically superior, said, 'Billy, that's old-fashioned. What you need is a virtual tour to show to the IOC.'"

Virtual reality technology was cutting-edge in 1990 – and very different from the physical models used by other Olympic-city hopefuls. Nevertheless, Payne went along with Crecine's suggestion.

Mike Sinclair, then a GTRI senior researcher and director of Georgia Tech's Interactive Multimedia Technology Center, led a team assembled from GTRI, other Georgia Tech units, the Atlanta Art Institute and Georgia State University.

The centerpiece of Atlanta's Olympic bid package was a seven-foot-high, three-screen interactive videodisc system equipped with touch-screen and trackball controls. It used virtual reality techniques, computer graphics, animation and aerial photography to allow viewers to take a virtual tour – narrated by Moore – of planned Olympic venues (which included Georgia Tech as the Olympic Village). The Atlanta team also created portable systems that were taken to meetings – even displayed in Washington, D.C. at a Congressional meeting room.

Dyer says the roots of the Olympic interactive video system could be traced to Engineering Experiment Station

projects, including missile defense modeling and simulation research. He personally remembers helping to build a flat-panel, touch-screen visual display for use in U.S. submarines – in 1964.

At one point, the Atlanta team was working on 15 or 20 workstations at once as they developed the interactive video system. Three presentation versions were produced, running on different hardware – including a full-color computer-simulated "fly-through" of the Olympic whitewater events venue for network television use.

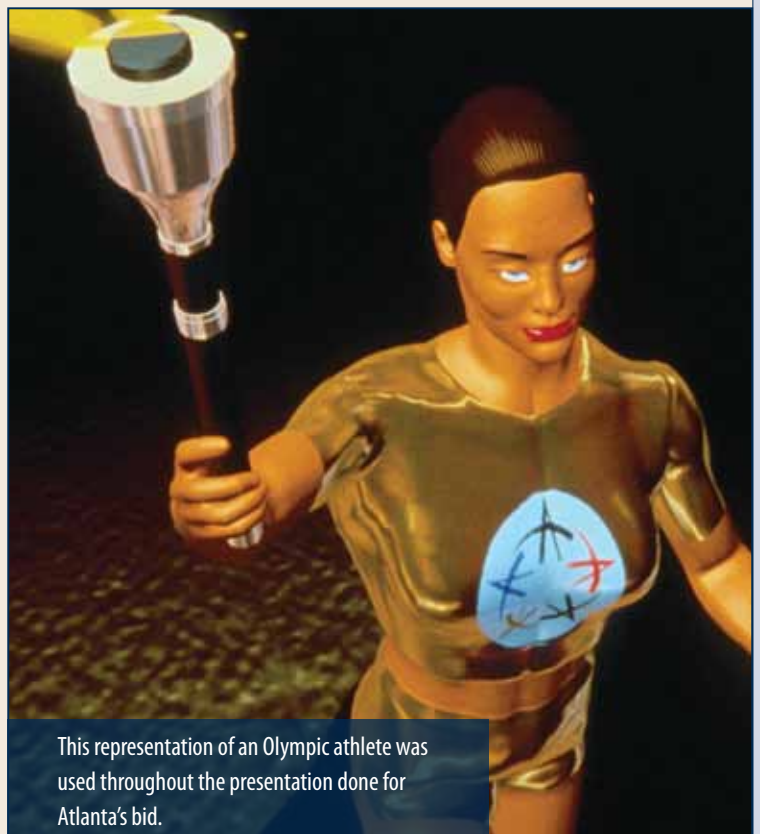
It worked. IOC members, including members of European royalty, were riveted by the interactive system.

"They'd never seen anything like it," Dyer recalls.

In September 1990, IOC President Juan Antonio Samaranch announced that the 1996 Centennial Games would be held in Atlanta.

**For more of GTRI's history, please visit [gtresearchnews.gatech.edu/gtri-history](http://gtresearchnews.gatech.edu/gtri-history).**

— Rick Robinson



This representation of an Olympic athlete was used throughout the presentation done for Atlanta's bid.

The development of new and innovative pharmaceuticals is being stifled by a U.S. law and successful patent challenges that embolden generic competition, according to an article published in the Oct. 16, 2009, issue of the journal *Science*. This decline in innovation could have a long-term harmful impact on the development of new drugs and new treatments.

Photo: iStockphoto



Patent challenges are stifling the development of new drugs, two Georgia Tech faculty members argue in an article published in the journal *Science*.

# Drug Trouble:

## Patent Challenges Reduce Pharmaceutical Innovation and Productivity, Researchers Suggest

By Abby Vogel

**T**he development of new and innovative pharmaceuticals is being stifled by a U.S. law and successful patent challenges that embolden generic competition, according to an article published in the Oct. 16, 2009, issue of the journal *Science*.

Matthew Higgins and Stuart Graham, assistant professors in the Georgia Tech College of Management, argue in their article that the recent surge in Paragraph IV patent challenges – a provision of the Hatch-Waxman Act of 1984 – is reducing the incentives for pharmaceutical innovation and contributing to productivity and revenue declines in the pharmaceutical industry.

“With the current health care debate, consumers and policy-makers need to understand that while we are getting cheap drugs now, it may be at the cost of novel future innovations and long-term access to new treatments because in our current system, industry revenues support continued research and development, and patents support revenues,” explained Higgins, the Imlay As-

sistant Professor of Strategic Management at Georgia Tech.

Although Congress passed the Hatch-Waxman Act to ensure timely, affordable access to innovative drugs, 25 years later the law’s balance between pharmaceutical innovation and access is tipping away from the incentives needed to support innovation, the researchers say.

A contributor to this shift is the recent surge in Paragraph IV challenges, which allow manufacturers of generic drugs to challenge a brand company’s patents by claiming that either the patent is invalid or the generic drug does not infringe the patent. If the generic company wins the challenge, the brand company loses its remaining market exclusivity for that product.

Federal Trade Commission statistics show that generic firms won 42 percent of the Paragraph IV challenges filed from 1992 to 2000. Since 2001, pharmaceutical companies have filed 749 lawsuits responding to Paragraph IV challenges on 243 unique brand-name products. These suits nearly tripled from

2002 to 2003 and doubled from 2006 to 2007.

“A Paragraph IV lawsuit will likely cost a generic manufacturer \$5 million to \$10 million, compared to at least \$800 million required for a brand company to develop a drug and bring it to market,” said Graham, who is also a licensed attorney. “And the reward for being the first successful Paragraph IV challenger is substantial – 180 days during which no other generic-producing company may enter the market and an average potential payoff during those 180 days alone of \$60 million. The law is creating incentives to bring challenges on more and different types of drugs.”

As the number of patent challenges has increased, the number of new compounds approved annually by the U.S. Food and Drug Administration (FDA) has fallen from an average of 35 from 1996 to 2001 to just 20 in the time period 2002 to 2007. Without policy intervention, the effective life of key patents will continue to decline, which will further compress the payback


period during which brand-name firms can recoup research and development investments, according to the researchers.

"Lawmakers should consider increasing the length of time brand-name drugs are on the market before generic drugs can enter, because the current five-year period is typically insufficient to recoup research and development costs," added Higgins.

Graham and Higgins suggest that exclusivity be extended for first-in-class and high-risk, high-necessity drugs, such as a preventive medicine for Alzheimer's disease or osteoarthritis. In addition, they propose that policymakers use incentives to encourage private investments in research to complement public research or offer increased exclusivity to curative and preventive drugs. Auctions could allow companies to bid on specific research projects in return for extended data or market exclusivity.

A 2007 report from The National Academies recommended that the United States should

at least double the duration of data exclusivity to bring it closer to allowances awarded in the European Union, Japan and Canada. Congress is currently debating a rule allowing 12-year data exclusivity for biologic drugs. These drugs include a wide range of products such as vaccines, blood and blood components, allergenics, somatic cells, gene therapy, tissues and recombinant therapeutic proteins.

The researchers are continuing their investigations into the causes of pharmaceutical productivity decline through a recently formalized relationship that allows them access to IMS Health's databases. The relationship came through Georgia Tech's connection with former IMS board member and Georgia Tech alumnus John Imlay. The company's databases – widely considered the gold standard in pharmaceutical and health care market intelligence – cover the entire life cycle of drugs from how doctors and patients used them to how they fared in the marketplace. 

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**“With the current health care debate, consumers and policy-makers need to understand that while we are getting cheap drugs now, it may be at the cost of novel future innovations and long-term access to new treatments because in our current system, industry revenues support continued research and development, and patents support revenues. ”**

**– Matthew Higgins, the Imlay Assistant Professor of Strategic Management in the College of Management**



Stuart Graham (left) and Matthew Higgins, assistant professors in Georgia Tech's College of Management, recommend that lawmakers consider increasing the length of time brand-name drugs are on the market before generic drugs can enter.



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

A device that allows veterinarians to check the blood pressure of gorillas without anesthesia could help improve the health of captive gorillas worldwide. Known as the Gorilla Tough Cuff, the device was developed by Zoo Atlanta staff in collaboration with students and faculty of the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University. The device allowed Zoo Atlanta to become the first zoological institution in the world to obtain voluntary blood pressure readings from a gorilla. More than 300 media outlets reported on the project, including the *Associated Press*, the *Atlanta Journal-Constitution*, the *Denver Post*, LiveScience.com, the *Huffington Post*, the *Los Angeles Times*, MSNBC.com, the *New York Daily News*, *The New York Times*, the *San Francisco Chronicle*, WABE-FM and WXIA-TV. Created as a senior design project by biomedical engineering undergraduates David Sotto, Nisha Bhatia, Stephanie Drewicz and Scott Seaman, the prototype has now been successfully tested on one of Zoo Atlanta's 22 western lowland gorillas. The students also had guidance from Hanjoong Jo and Franklin Bost from the Coulter Department. (See the article on page 47 of this issue of *Research Horizons* magazine.)

The development of a new type of three-dimensional photovoltaic system based on optical fiber was reported in more than 75 media outlets, including the Australian Broadcasting Corp. (ABC), the British Broadcasting Corp. (BBC), Discovery News, *Electronic Design News* (EDN), *Electronic Engineering Times*, *Electronics Weekly*, MSNBC.com, *National Geographic*, *Photonics Spectra*, *Photovoltaics World*, *Scientific American* and *Technology Review*. Using zinc oxide nanostructures grown on optical fibers and coated with dye-sensitized solar cell materials, the new structures could allow photovoltaic systems to be hidden from view and placed away from traditional locations such as rooftops. The system was developed in the laboratory of Regents professor Zhong Lin Wang and published in the journal *Angewandte Chemie*. (See the article on page 36 of this issue of *Research Horizons* magazine.)

A \$6.5 million DARPA grant will support the development of improved components for boosting the efficiency of electric propulsion systems used to control the positions of satellites and planetary probes. Focusing on improved cathodes for devices known as Hall Effect thrusters, the research would reduce propellant consumption in commercial, government and military satellites, allowing them to remain in orbit longer, be launched on smaller or cheaper rockets, or carry larger payloads. The work was reported by two dozen media outlets, including Fox News, MSNBC.com, Nanotechnology News, *R&D Magazine*, Space.com, and *Technology Review*. The project is a collaboration of researchers Jud Ready and Mitchell Walker in the Georgia Tech Research Institute (GTRI) and the School of Aerospace Engineering. (See the article on page 43 of this issue of *Research Horizons* magazine.)



Photo: Gary Meek

(Top) Georgia Tech's Jonathon Giffin (left) and Patrick Traynor recently received a grant to develop tools that improve the security of mobile devices and the telecommunications networks on which they operate.

(Bottom) Georgia Tech researchers have developed a new type of three-dimensional photovoltaic system based on optical fiber.



Photo: Gary Meek

A grant that will fund research aimed at improving the security of smart phones and the networks on which they operate generated significant interest from trade and technical media outlets. Funded by the National Science Foundation, the research could lead to techniques for repairing malware-infected phones remotely. Outlets reporting on the project included *The Atlanta Business Chronicle*, *Chronicle of Higher Education*, *ComputerWorld*, *Network World*, *PC World*, *SC Magazine* and *Telephony Online*. The work is being led by Patrick Traynor and Jonathon Giffin, both assistant professors in the School of Computer Science. (See the article on page 42 of this issue of *Research Horizons* magazine.)

A new crew survivability concept that would build military vehicles around a protected personnel compartment and use a sacrificial "blast wedge" to absorb energy from improvised explosive devices was reported by several key media outlets. If used on future generations of light armored patrol vehicles, the concept could significantly improve safety for the occupants. The work was reported by *The Engineer*, Gizmag.com, Homeland Security Newswire, *Laboratory News* and *R&D Magazine*. The principal researchers are Vince Camp and Kevin Massey in the Georgia Tech Research Institute.

# Georgia Tech Faculty and Staff Receive Recognition

School of Electrical and Computer Engineering professors **Dave Keezer** and **Manos Tentzeris**, principal research engineer **Rick Hartlein**, adjunct professor **Ian Ferguson**; and Computational Science and Engineering professor **David Bader** were named IEEE Fellows. GTRI's **Jim Scheer** became an IEEE Life Fellow.

Chemical & biomolecular engineering professor **Elsa Reichmanis** was named a Fellow of the American Chemical Society.

**C.F. Jeff Wu**, a School of Industrial and Systems Engineering professor, was named a Fellow of the Institute for Operations Research and the Management Sciences.

Biomedical engineering professor **Brani Vidakovic** was selected as a Fellow of the American Statistical Association.

**Clifford Henderson**, associate professor in the School of Chemical & Biomolecular Engineering, was named a Fellow of SPIE.

Mechanical engineering professors **Al Ferri** and **Peter Hesketh** were elected Fellows of the American Society of Mechanical Engineers. Hesketh was also named a Fellow of the Electrochemical Society.

**Nancy Nersessian**, Regents professor in the School of Interactive Computing, was elected Fellow of the Cognitive Science Society.

Physics professor **Pablo Laguna** and materials science and engineering professor **Vladimir Tsukruk** were elected as Fellows in the American Physical Society.

Aerospace engineering professors **Lakshmi Sankar** and **Dimitri Mavris** were

elected Fellows of the American Institute of Aeronautics and Astronautics (AIAA). GTRI senior research engineer **Michael Heiges** was named an AIAA Associate Fellow.

Regents professor in the School of Chemistry & Biochemistry **Mostafa El-Sayed** was named an Honorary Fellow of the Chinese Chemical Society.

**Keith Edwards** and **Beki Grinter**, associate professors in the School of Interactive Computing, were named Distinguished Scientists by the Association for Computing Machinery.

GTRI senior research engineer **Brett Walkenhorst** was selected as a Senior Member of IEEE.

**Fumin Zhang** and **Patricio Vela**, assistant professors in the School of Electrical and Computer Engineering; **Fox Harrell**, assistant professor in the School of Literature, Communication, and Culture and GVU; **Ming Yuan**, assistant professor in the School of Industrial and Systems Engineering; **Hang Lu**, assistant professor in the School of Chemical & Biomolecular Engineering; and **Young-Hui Chang**, assistant professor in Applied Physiology, received National Science Foundation CAREER Awards.

Mechanical engineering assistant professor **Baratunde Cola**, and School of Chemistry & Biochemistry assistant professors **Wendy Kelly** and **Jake Soper** received 2009 Young Faculty Awards from the Defense Advanced Research Projects Agency.

Biomedical engineering assistant professor **Melissa Kemp** and School of Chemistry & Biochemistry assistant professor **Christine Payne** received

2009 National Institutes of Health Director's Young Innovator awards.

Civil and environmental engineering associate professor **Jaehong Kim** won the 2009 Paul L. Busch Award from the Water Environment Research Foundation. Kim also received the 2009 Excellence in Review award from the *Environmental Science and Technology* journal.

Industrial design instructor **Richard Braunstein** received a Silver IDEA award and won a spot in *Buildings Magazine's* Top 100 Products.

**Ioannis Brilakis**, assistant professor in the School of Civil and Environmental Engineering, received the 2009 American Society of Civil Engineers Associate Editor Award.

**Justin K. Romberg**, an assistant professor in the School of Electrical and Computer Engineering, received a 2009 Packard Fellowship for Science and Engineering.

The GTRI Communications office, led by **Kirk Englehardt**, received two Phoenix Awards and a certificate of excellence from the Georgia Chapter of the Public Relations Society of America and nine awards from the Atlanta Chapter of the International Association of Business Communicators. The office was also selected as one of five organizations nationally in the "Best Place to Work in PR" in the non-profit category by PRNews.

**Don White**, professor in the School of Civil and Environmental Engineering, received the 2009 T.R. Higgins Lecture Award from the American Institute of Steel Construction.

Regents professor in materials science and engineering **C. P. Wong** received

the 2009 David Feldman Outstanding Contributions Award from the IEEE Components, Packaging & Manufacturing Technology Society.

**Kirk Bowman**, an associate professor in international affairs, was named the 2008 CASE Professor of the Year in Georgia.

Electrical and computer engineering assistant professor **Saibal Mukhopadhyay** received a 2009 IBM Faculty Partnership Award.

**Jennifer Clark**, assistant professor in the School of Public Policy, won the 2009 Regional Studies Association Best Book Award.

**Walt de Heer**, Regents professor in the School of Physics, received the 2009 Nanoscience Prize at the 10th International Conference on Atomically Controlled Surfaces, Interfaces and Nanostructures.

Biomedical engineering department chair **Larry McIntire** received the Biomedical Engineering Society's 2009 Distinguished Service Award.

**Cheryl Gaimon**, Regents professor of operations management, received the 2009 Distinguished Service Award from the INFORMS Technology Management Section.

**Robin Thomas**, professor in the School of Mathematics and School of Industrial and Systems Engineering, was awarded a 2009 Fulkerson Prize from the American Mathematical Society and the Mathematical Programming Society.

Aerospace engineering professor **J.V.R. Prasad** and collaborators received the American Society of Mechanical Engineers Melville Medal.

- compiled by Abby Vogel



David Bader



Nancy Nersessian



Fumin Zhang



Fox Harrell



Wendy Kelly



Melissa Kemp



Larry McIntire

# FACULTY & STAFF AWARDS & HONORS

Georgia Tech researchers are pursuing many different directions toward improving existing cancer treatment methods and developing new therapeutic techniques, including attacking cancer stem cells, improving radiation therapy and treatment planning, assessing tumor aggressiveness and improving other weapons in a battle against the disease. Much of this work is being done in collaboration with researchers at medical institutions.

This computed tomography image of a prostate shows an imaging-guided dose-escalated radiation treatment plan. Red shading indicates tumor pocket areas that will receive the maximum radiation dose.



Image: Eva Lee

# Treating Cancer:

## Researchers Develop and Improve Techniques for Attacking Cancer on Multiple Fronts

By Abby Vogel

Cancer treatment typically involves surgery, radiation therapy, chemotherapy, hormone therapy or biological therapy. An oncologist may use one therapy or a combination of methods, depending on the type and location of the cancer, whether the disease has spread, the patient's age and general health, and other factors.

At Georgia Tech, researchers are pursuing many different directions toward improving existing cancer treatment methods and developing new therapeutic techniques, including:

- Attacking cancer stem cells;
- Improving radiation therapy;
- Including motion and biological information in planning treatment;
- Assessing a tumor's ability to create new blood vessels;
- Developing a new approach to targeted cancer therapy;
- Increasing responses to chemotherapy;
- Enabling personalized drug delivery; and
- Analyzing gene expression data to predict response to drugs.

This is the third in a series of three reports focusing on cancer research at Georgia Tech. The first highlighted efforts to understand how cancer arises, and the second featured cancer detection and diagnostic techniques.

## Attacking Cancer Stem Cells

Recent evidence suggests that certain cancers may persist or recur after treatment because a few cells – called cancer stem cells – survive existing therapy and then seed new tumors. These stem cells can be particularly resistant to chemotherapy and radiation.

"In the future, effective cancer therapy may require the detection and elimination of cancer stem cells in tumors," said Gang Bao, the Robert A. Milton Chair in Biomedical Engineering in the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University. "Developing a method to detect cancer stem cells is challenging because evidence suggests there is only one cancer stem cell for every 100,000 to 1 million cancer cells in tumor tissue, so the method must be very sensitive."

Bao and postdoctoral fellow Won Jong Rhee recently developed a new method that effectively discriminates cancer stem cells from other cancer cells by locating protein markers on the surface of stem cells and stem cell-specific genes inside cancer stem cells. The work was published on April 2, 2009, in the journal *BMC Biotechnology*.

The researchers located live stem cells by simultaneously detecting the presence of the stem cell



surface protein marker SSEA-1 with dye-labeled antibodies and stem cell-specific mRNA – called Oct-4 – inside the stem cells using molecular beacons.

“By fluorescently imaging the level of Oct-4 mRNA in the cytoplasm of live stem cells with molecular beacons, we were able to increase the detection sensitivity and specificity,” explained Bao, who is also a Georgia Tech College of Engineering Distinguished Professor.

Since initially developing this method for detecting and isolating stem cells, the research team has been improving the method’s efficiency and specificity by targeting multiple mRNAs and cell surface markers using molecular beacons and antibodies. According to Bao, the next stage for this research is to isolate cancer stem cells from human tumor tissue samples.

“After we isolate the cancer stem cells, we still need to learn more about them, including the pathways or genes responsible for their development and whether they behave the same when isolated from different patients. Then we need to identify drug molecules that can kill them,” he added.

Funding for this research is provided by the Emory-Georgia Tech National Cancer Institute Center for Cancer Nanotechnology Excellence (CCNE).

*This work was funded by grant number U54CA119338 from the National Institutes of Health (NIH). The content is solely the responsibility of the principal investigator and does not necessarily represent the official view of the NIH.*

## Improving Radiation Therapy

One critical challenge in radiation therapy has always been how best to minimize damage to normal tissue while delivering therapeutic doses to cancer cells. Intensity-modulated radiation therapy (IMRT) is an advanced type of radiation treatment that utilizes computer-controlled linear accelerators to deliver precise radiation doses to tumors while avoiding critical organs. Clinicians can use IMRT to treat difficult-to-reach tumors – such as tumors in the brain, head, neck, prostate, lung and liver – with new levels of accuracy.

“Constructing an IMRT treatment plan that radiates the cancerous tumor without impacting adjacent normal structures is

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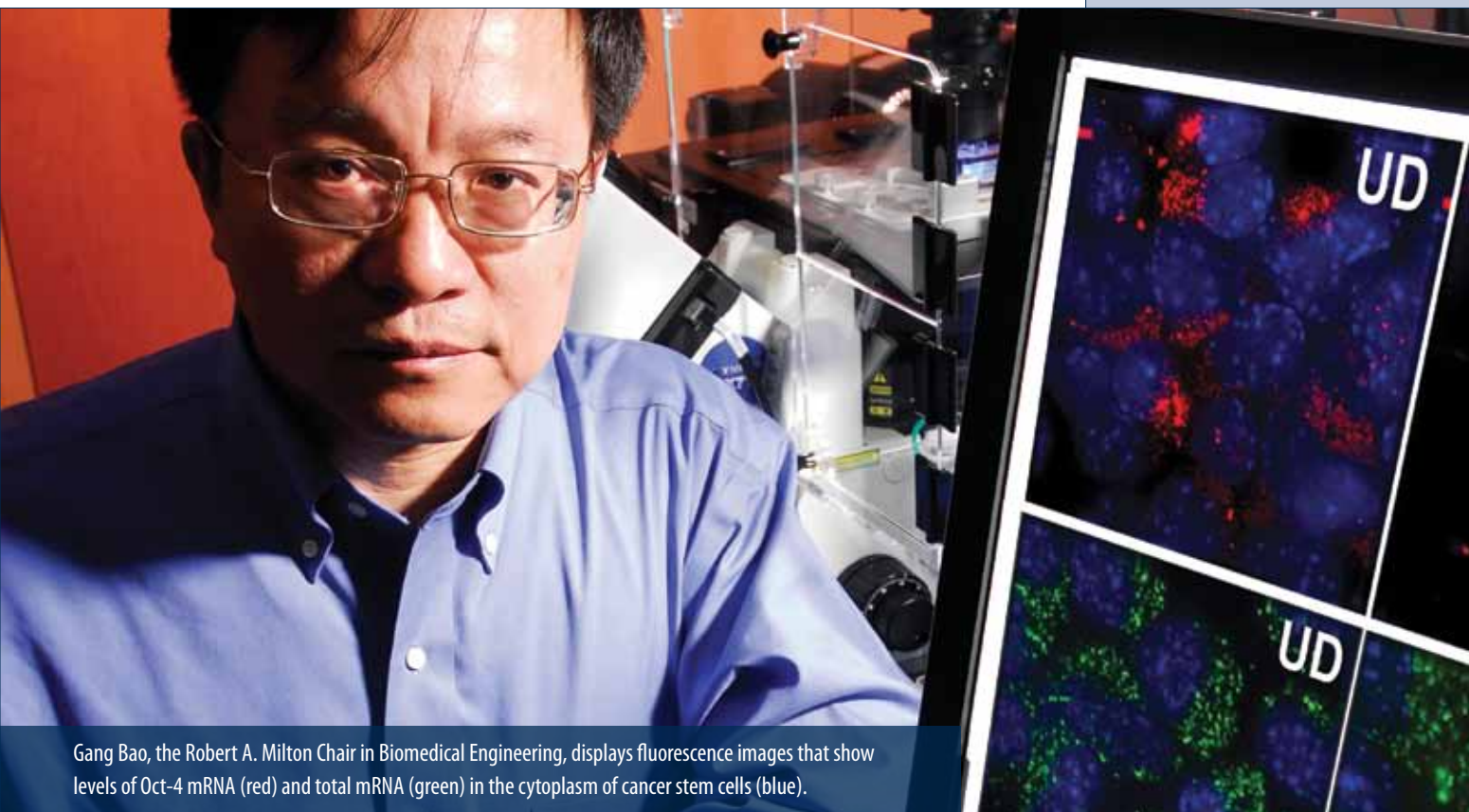
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Gang Bao, the Robert A. Milton Chair in Biomedical Engineering, displays fluorescence images that show levels of Oct-4 mRNA (red) and total mRNA (green) in the cytoplasm of cancer stem cells (blue).

Timothy Fox, Shabbir Ahmed, Halil Ozan Gozbasi and Eduard Schreibmann (left to right) are improving intensity-modulated radiation therapy treatment plans to minimize damage to critical organs.



challenging,” explained Shabbir Ahmed, an associate professor in the Stewart School of Industrial and Systems Engineering at Georgia Tech. “Because of the many possible beam geometries and the range of intensities, there are an infinite number of treatment plans and many metrics to assess their quality.”

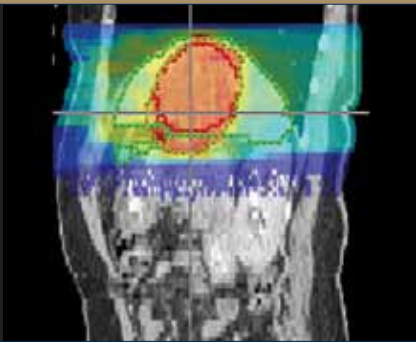
To develop better treatment plans faster, Ahmed began working with School of Industrial and Systems Engineering professor Martin Savelsbergh and graduate student Halil Ozan Gozbasi, as well as collaborators Ian Crocker, Timothy Fox and Eduard Schreibmann from the Emory University School of Medicine’s Department of Radiation Oncology. Funding for this research was provided by Emory University.

The Georgia Tech researchers built on an existing model and developed a fully automated program that simultaneously generates several high-quality treatment plans satisfying the

clinician-provided requirements. The optimization program uses three-dimensional computed tomography images of the patient and information about (1) the type, location and size of the tumor; (2) maximum allowable doses to non-cancerous organs; and (3) the patient’s health.

“Previous models would produce one treatment plan in an hour and then if it was not exactly what the clinician wanted, someone would have to change the requirements and rerun the program to create a new treatment plan,” explained Ahmed. “Our program produces several optimized solutions in a fraction of the time.”

The technology, which has been tested successfully on real brain, head/neck and prostate cancer cases, produces clinically acceptable treatment plans in less than 15 minutes.



A cross-sectional computed tomography slice shows a four-dimensional IMRT treatment plan. Note the tight red contours of the dose around the tumor. Compared to the clinical plan, this plan provided superior tumor coverage and reduced the average dose to the normal liver and non-liver tissues.

## Including Motion and Biological Information in Treatment Planning

Intensity-modulated radiation therapy (IMRT) treatment planning is challenging because some organs, such as the prostate, move due to normal daily volume changes in the bladder and rectum. In addition, a tumor can change shape during radiation treatment, which typically lasts five days a week for five to 10 weeks.

By collecting computed tomography images over time, the researchers can track every spatial point of interest in the tumor and surrounding area during each phase of the breathing cycle. This allows them to develop treatment plans that account for breathing, motion and shape changes throughout the treatment regimen.

"Accounting for motion in the image-guided treatment planning dramatically improves under-dosing the tumor tissue and even reduces the dose to normal tissue and critical organs," noted Lee, who is also director of the Center for Operations Research in Medicine and HealthCare at Georgia Tech.

In lung cancer cases, that means reducing the average dose of radiation to the normal lung tissue, heart and esophagus. For liver cancer, the researchers have reduced the radiation delivered to normal liver and non-liver tissues.

In another project, Lee and Marco Zaider, an attending physicist and head of brachytherapy physics in medical physics at Memorial Sloan-Kettering Cancer Center in New York, are incorporating biological information into treatment planning for prostate cancer IMRT and brachytherapy – the placement of radioactive "seeds" inside a tumor.

Using magnetic resonance spectroscopy, the researchers identified regions of the prostate that had denser populations of tumor cells. These areas could then be targeted with an escalated radiation dose, while maintaining a minimal dose to critical and normal tissues.

"One of our main concerns is avoiding normal tissue toxicity, so by targeting only the 'bad' pockets of tumor cells, we hope

to improve the outcome," said Zaider. "Biological optimization attempts to target tissue that is potentially responsible for metastatic spread."

Lee's research has been supported by the National Science Foundation (NSF), the National Institutes of Health (NIH) and the Whitaker Foundation.

*This project was partially supported by Award No. 0800057 from the NSF and Award No. 5UL1RR025008-02 from the NIH. The content is solely the responsibility of the principal investigator and does not necessarily represent the official views of the NSF or NIH.*

## Assessing a Tumor's Ability to Create New Blood Vessels

Cancer manifests itself in different ways – some cancers proceed slowly, while others spread aggressively. These differences have led clinicians to believe that personalized cancer therapies might be the best solution for treating the disease.

Now, new research, published in the June 2009 issue of the journal *PLoS ONE*, is providing insight into the aggressiveness of tumors. This information could facilitate development of a personalized treatment regimen.

Because aggressive tumors create more new blood vessels to sustain their growth, researchers designed long-circulating nanoprobes that were 100 nanometers in diameter and contained a contrast agent that could only seep into tumors from blood vessels that were growing and therefore leaky.

"We exploited the fact that the nanoprobes are too big to leak out of normal blood vessels, but they can leak out of newly forming tumor vessels because these immature vessels have bigger holes in them," explained lead author Ravi Bellamkonda, a professor in the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University.

The study showed that the degree of "leakiness" of tumor blood vessels to the nanoprobe correlates to its expression of vascular endothelial growth factor (VEGF), a protein that stimulates the growth of new blood vessels in tumors.

"Clinical studies have shown that VEGF expression varies among tumors, with higher levels of VEGF expression correlating with unfavorable prognosis, but scientists haven't been able





Biomedical engineering professor Ravi Bellamkonda has developed nanoprobes that enable the use of CT imaging to quantify the proteins responsible for new blood vessel formation in tumors.

to non-invasively determine VEGF expression levels in individual tumors until now," said Bellamkonda, who is also a Georgia Cancer Coalition Distinguished Scholar.

After injecting the contrast-containing nanoprobes into rats with six-day-old breast cancer tumors, the research team visualized the levels of nanoprobe accumulation in the tumor using digital mammography. The results showed increased "leakiness," nanoprobe accumulation and tumor growth rates in tumors with higher levels of VEGF. Similar-size tumors showed various degrees of angiogenesis and blood vessel permeability, which caused them to behave differently, emphasizing the inherent variability in tumors and the need for a personalized approach to each tumor.

"In the future, instead of just measuring the size of a tumor, clinicians can quantify the leakiness of tumor blood vessels to determine the extent of angiogenesis in each tumor and de-

cide which patients should undergo anti-angiogenic therapy or other aggressive treatment regimens," added Bellamkonda.

Collaborators on this research include Efstathios Karathanasis, formerly a Coulter Department postdoctoral fellow and currently an assistant professor in the Department of Biomedical Engineering at Case Western Reserve University; Carl D'Orsi and Ioannis Sechopoulos of the Department of Radiology and Winship Cancer Institute at the Emory University School of Medicine; and Ananth Annapragada, an associate professor of health information sciences at the University of Texas, Houston.

*This project is supported by the National Science Foundation (NSF) (Award Nos. 0401627 and ERC-EEC-9731643), the Nora Reed Foundation, the Wallace H. Coulter Foundation and the Georgia Cancer Coalition. The content is solely the responsibility of the principal investigator and does not necessarily represent the official view of the NSF.*



Adegboyega "Yomi" Oyelere (center), an assistant professor in the School of Chemistry and Biochemistry, discusses compound design principles with graduate students Vishal Patil (left) and William Guerrant.

## Developing a New Approach to Targeted Cancer Therapy

A new therapeutic strategy for cancer treatment is to inhibit enzymes called histone deacetylases, which play an important role in the regulation of gene expression. Vorinostat (SAHA) – a histone deacetylase inhibitor – was approved by the U.S. Food and Drug Administration in 2006 to treat an immune system cancer called cutaneous T-cell lymphoma.

While these inhibitors are clinically valuable, they typically inhibit many of the 18 different histone deacetylase subtypes, a process that can be harmful to essential cell functions throughout the body.

"Our goal is to create inhibitors for these enzymes that target specific cancerous organs so that we can exploit their anti-cancer activity in the cancerous tissue areas only and not nega-

tively affect other areas of the body," said Adegboyega "Yomi" K. Oyelere, who holds the Blanchard Assistant Professorship in the Georgia Tech School of Chemistry and Biochemistry.

In the January 22, 2009, issue of the *Journal of Medicinal Chemistry*, Oyelere and Georgia Tech biology assistant professor Yuhong Fan described a new class of potent non-peptide histone deacetylase inhibitors that can be selectively accumulated in the lungs.

To create them, the researchers modified the amine sugar portion of common antibiotics such as azithromycin and clarithromycin with a histone deacetylase inhibiting structure. Experiments have shown that the new compounds are more potent than SAHA and are lung-specific. As a result of these preliminary findings, Oyelere was recently awarded a five-year, \$1.5 million grant from the National Institutes of Health to continue this lung cancer research.

Oyelere is also designing histone deacetylase inhibitors that





Chemical and biomolecular engineering assistant professor Lakeshia Taite is investigating ways to smuggle powerful chemotherapeutic drugs and chemical compounds into tumor cells, thus increasing the drugs' cancer-killing activities and reducing their toxic side effects on healthy cells.

Photo: Rob Felt



can be taken up by the hormones expressed on the surface of hormone-positive breast cancer cells to stop the cells from dividing. For this project, he is working with Donald Doyle, an associate professor in the Georgia Tech School of Chemistry and Biochemistry.

"A majority of hormone-positive breast cancers develop resistance to anti-cancer hormone drugs, so if we can exploit the ability of our compounds to be accepted by hormone-positive breast cancers, whether they're resistant or not, this could lead to the identification of new, broad anti-cancer agents for targeted cancer therapy," explained Oyelere.

Next up on Oyelere's list of cancers to tackle with this approach is prostate cancer.

*This work is funded by grant number R01CA131217 from the National Institutes of Health (NIH). The content is solely the responsibility of the principal investigator and does not necessarily represent the official view of the NIH.*

## Increasing Responses to Chemotherapy

Lakeshia Taite is investigating ways to smuggle powerful chemotherapeutic drugs and chemical compounds into tumor cells, thus increasing the drugs' cancer-killing activities and reducing their toxic side effects on healthy cells.

As an assistant professor in the Georgia Tech School of Chemical and Biomolecular Engineering, Taite is developing cancer drug delivery vehicles composed of a gold nanoshell core with dendrimers attached to the surface. Dendrimers are polymers that exhibit a tree-like structure with many branches and cavities where chemotherapy drugs can be encapsulated.

The dendrimers are synthesized with targeting molecules on their surfaces that can seek out and bind to cancer cells. Introduced into the body, they bind to cancer cells, and when near-infrared light shines on the body, the gold nanoshell heats up. That heat leads the dendrimers to shrink, the drug to be released, and the tumor cells are exposed to both the heat and drug therapies.

"In some cases, ablation takes place at temperatures that can be uncomfortable to the patient, so we are trying to develop dendrimers that require lower transition temperatures to release the drug," said Taite. "We believe that even if the lower temperature does not kill all of the cancer cells, it will still damage them enough that they will become extremely vulnerable to the drug, ultimately still leading to cell death."

Amanda Lowery, a research fellow in radiation oncology at Vanderbilt University, is collaborating with Taite on this research.

Taite is also designing another delivery vehicle to carry and release nitric oxide for the treatment of aggressive brain tumors. She is focusing on nitric oxide because it has the ability to cross

the blood-brain barrier and help other molecules cross both the blood-brain barrier and the blood-tumor barrier.

"Nitric oxide has been shown to increase the sensitivity of certain tumors to chemotherapeutics and radiation, so we are working to form materials that can be attached to imaging particles and a chemotherapeutic that can be targeted to specific tumors. That would significantly enhance current tumor treatment approaches," explained Taite.

The targeted nitric oxide delivery system will be used to study the efficacy of using nitric oxide to sensitize brain tumors to treatment and improve patient prognosis.

"My ultimate goal in designing all of these drug delivery systems is to improve patient quality of life and reduce cancer recurrence," added Taite.

## Enabling Personalized Drug Delivery

The search is on for drug delivery systems that allow treatment to be tailored to an individual patient and a particular tumor. Researchers at Georgia Tech are contributing to the pursuit by developing ways to program the assembly and disassembly of multi-particle drug delivery vehicles.

"Cancer is a complicated disease, and we wanted to find a way that we could simultaneously deliver many different particles to the tumor site as a package and, upon arrival, break open the packages so that the individual particles could then carry out their particular functions," said Valeria Milam, an assistant professor in the Georgia Tech School of Materials Science and Engineering.

Individuals benefit from this type of personalized treatment through the increase in the drug's cancer-killing power and the reduction of its toxic side effects.

Milam and her students are using short nucleic acid polymers called oligonucleotides to connect the particle surfaces for simultaneous delivery of different therapeutic and diagnostic agents to the tumor site.

"To assemble the pieces, we are using short oligonucleotides as the glue because they have a weak, yet sufficient affinity for their partner strand," explained Milam, who is also a Georgia Cancer Coalition Distinguished Cancer Scholar. "This allows us to direct particles A and B to attach to particle C through oligonucleotide linkages, while keeping particles A and B unconnected to one another."

Then, to disassemble the particle package, a competitive oligonucleotide – one with a stronger affinity as a partner strand – is introduced into the system. These competitive strands displace the original partner strands, allowing the package to break open. Milam and her team are further improving the drug delivery vehicle so that

it can be initially camouflaged to avoid any host response that would clear it out of the body before arriving at the tumor site.

“Our ongoing work involves initially masking the presence of the therapeutic carriers by applying a stealth coating to the vehicle surface,” noted Milam. “Then, after the desired circulation time, the coating will be shed to reveal cancer-targeting ligands.”

While Milam’s experiments are still at the laboratory stage, her ultimate goal is to develop materials that can be used in the clinical setting to treat cancer. Former Georgia Tech students Christopher Tison and Sonya Parpart, and current graduate students James Hardin and Bryan Baker, also worked on this research. This work is currently supported by the Georgia Cancer Coalition, a National Science Foundation CAREER award, and the U.S. Army. It was previously supported by the Emory-Georgia Tech National Cancer Institute Center for Cancer Nanotechnology Excellence (CCNE).

*This material is based upon work supported by the U.S. Army (Award No. W911NF-09-1-0479), National Institutes of Health (NIH) (Award No. U54CA119338) and National Science Foundation (NSF) (Award No. DMR-0847436). Any opinions, findings, conclusions or recommendations expressed are those of the principal investigator and do not necessarily reflect the views of the U.S. Army, NIH or NSF.*

## Analyzing Gene Expression Data to Predict Drug Response

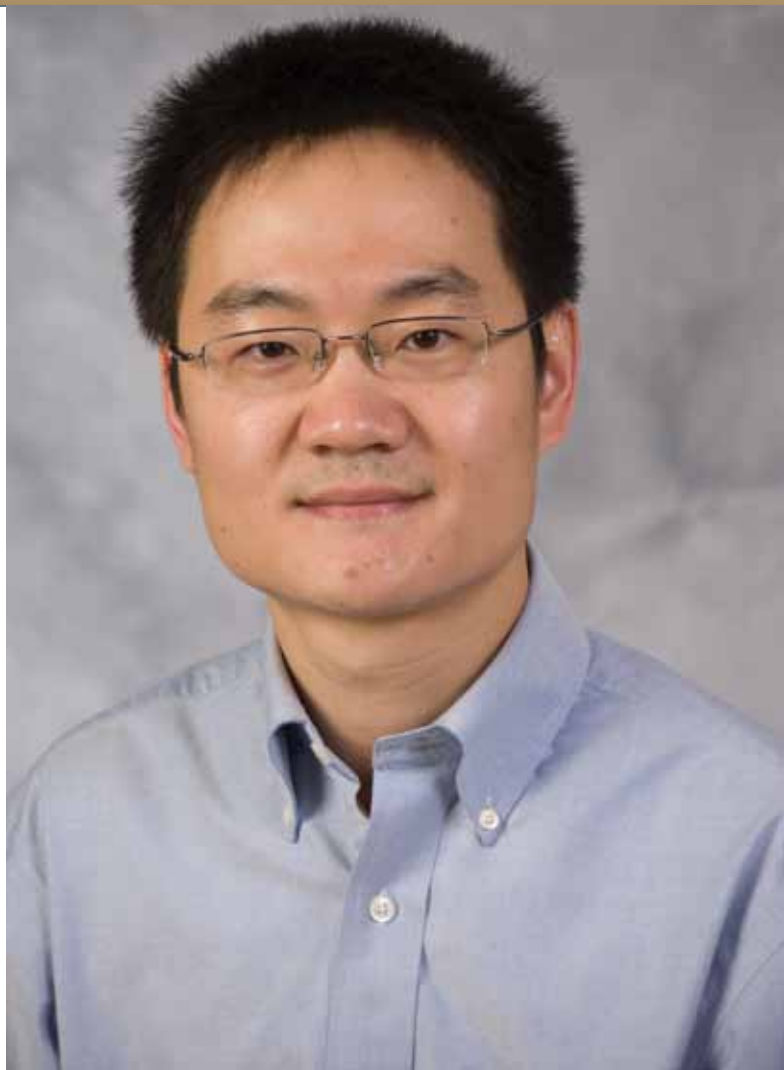
The major clinical goals in applying gene expression profiling to cancer are to develop predictors of drug response that will guide more individualized therapies.

Ming Yuan, an associate professor in the Stewart School of Industrial and Systems Engineering at Georgia Tech, is using computational and mathematical approaches to analyze how gene expression evolves over time in individuals with breast cancer and whether these patterns can predict treatment outcome. Specifically, Yuan is studying how gene expression evolves during the menstrual cycle and whether there is any association between these patterns and cancer relapse.

“Our goal is to weed out the genes that just change expression level due to a woman’s menstrual cycle and not because of tumor progression or treatment,” explained Yuan, who is also a Georgia Cancer Coalition Distinguished Cancer Scholar. “We want to know which genes are abnormally expressed over time and behave differently than the majority of genes because that would make them likely drug targets.”

Better predictors of relapse risk could help cancer patients make better treatment decisions in consultation with their physicians. Yuan is working with William Hrushesky of the University of South Carolina and the Dorn Veterans Affairs Medical Center on this research.

In another project, Yuan is collaborating with two University of Wisconsin professors, Alan Attie and Christina Kendzierski, to conduct expression quantitative trait loci (eQTL) studies. This



Ming Yuan, an industrial and systems engineering associate professor, is using computational and mathematical approaches to analyze how gene expression evolves over time in individuals with breast cancer.

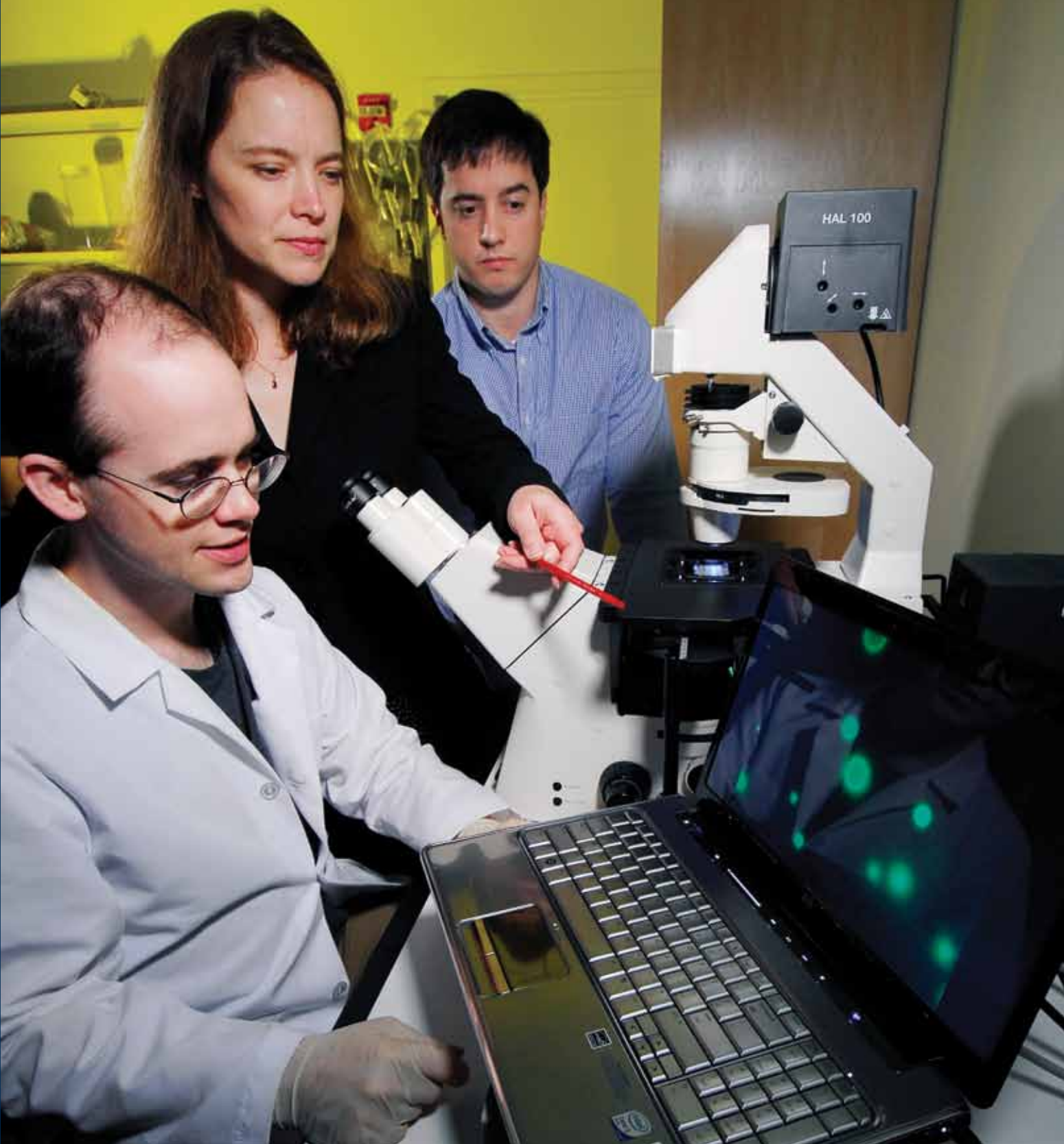
analysis allows the researchers to identify genomic hot spots that regulate gene transcription and expression on a genome-wide scale. “We want to determine which regions of the genome are most predictive of expression variations, but it’s challenging because there are a vast range of possible regulatory loci and many of them are correlated, making it hard to differentiate which is actually responsible for a given effect,” said Yuan.

Yuan’s analysis will determine the hot spots as well as how those genes are connected to each other, but ultimately, the proposed genes will need to be studied further by biologists.

Yuan’s research is supported by the National Science Foundation and the Georgia Cancer Coalition. 

*This work was partly funded by grant number DMS-0846234 from the National Science Foundation (NSF). The content is solely the responsibility of the principal investigator and does not necessarily represent the official view of the NSF.*

James Hardin, Valeria Milam and Bryan Baker (left to right) display multi-particle drug delivery vehicles designed to allow cancer treatment to be tailored to an individual patient and a particular tumor.





Using zinc oxide nanostructures grown on optical fibers and coated with dye-sensitized solar cell materials, researchers have developed a new type of three-dimensional photovoltaic system. The approach could allow PV systems to be hidden from view and located away from traditional locations such as rooftops.

Close-up image shows the brown light-absorbing material for the solar generators grown on optical fiber by Georgia Tech researchers.



Photo: Gary Meek

# Hidden Solar Cells:

## Three-Dimensional System Based on Optical Fiber Could Provide New Options for Photovoltaics

By John Toon

Converting sunlight to electricity might no longer mean large panels of photovoltaic (PV) cells atop flat surfaces like roofs.

Using zinc oxide nanostructures grown on optical fibers and coated with dye-sensitized solar cell materials, Georgia Tech researchers have developed a new type of three-dimensional photovoltaic system. The approach could allow PV systems to be hidden from view and located away from traditional locations such as rooftops.

"Using this technology, we can make photovoltaic generators that are foldable, concealed and mobile," said Zhong Lin Wang, a Regents professor in the Georgia Tech School of Materials Science and Engineering. "Optical fiber could conduct sunlight into a building's walls where the nanostructures would convert it to electricity. This is truly a three-dimensional solar cell."

Details of the research were published in the early view of the journal *Angewandte Chemie International* on Oct. 22, 2009. The work was sponsored by the Defense Advanced Research

Projects Agency (DARPA), the KAUST Global Research Partnership and the National Science Foundation (NSF).

Dye-sensitized solar cells use a photochemical system to generate electricity. They are inexpensive to manufacture, flexible and mechanically robust, but their tradeoff for lower cost is conversion efficiency lower than that of silicon-based cells. But using nanostructure arrays to increase the surface area available to convert light could help reduce the efficiency disadvantage, while giving architects and designers new options for incorporating PV systems into buildings, vehicles and even military equipment.

Fabrication of the new Georgia Tech PV system begins with optical fiber of the type used by the telecommunications industry to transport data. First, the researchers remove the cladding layer, then apply a conductive coating to the surface of the fiber. Next, they use established solution-based techniques to grow aligned zinc oxide nanowires around the fiber, much like the bristles of a bottle brush. The nanowires are then coated with

the dye-sensitized materials that convert light to electricity.

Sunlight entering the optical fiber passes into the nanowires where it interacts with the dye molecules to produce electrical current. A liquid electrolyte between the nanowires collects the electrical charges. The result is a hybrid nanowire/optical fiber system that can be up to six times as efficient as planar zinc oxide cells with the same surface area.

"In each reflection within the fiber, the light has the opportunity to interact with the nanostructures that are coated with the dye molecules," Wang explained. "You have multiple light reflections within the fiber, and multiple reflections within the nanostructures. These interactions increase the likelihood that the light will interact with the dye molecules, and that increases the efficiency."

Wang and his research team have reached an efficiency of 3.3 percent and hope to reach 7 to 8 percent after surface modification. While lower than silicon solar cells, this efficiency would be useful for practical energy harvesting. If they can do that, the potentially lower cost of their approach could


make it attractive for many applications. By providing a larger area for gathering light, the technique would maximize the amount of energy produced from strong sunlight, as well as generate respectable power levels even in weak light. The amount of light entering the optical fiber could be increased by using lenses to focus the incoming light.

"This will really provide some new options for photovoltaic systems," Wang said. "We could eliminate the aesthetic issues of PV arrays on building. We can also envision PV systems for providing energy to parked vehicles, and for charging mobile military equipment where traditional arrays aren't practical or you wouldn't want to use them."

Wang and his research team, which includes Benjamin Weintraub and Yaguang Wei, have produced generators on optical fiber up to 20 centimeters in length. "The

longer the better," said Wang, "because the longer the light can travel along the fiber, the more bounces it will make and the more it will be absorbed."

Traditional quartz optical fiber has been used so far, but Wang would like to use less expensive polymer fiber to reduce the cost. He is also considering other improvements, such as a better method for collecting the charges and a titanium oxide surface coating that could further boost efficiency. Though it could be used for large PV systems, Wang doesn't expect his solar cells to replace silicon devices any time soon. But he does believe they will broaden the potential applications for photovoltaic energy.

"This is a different way to gather power from the sun," Wang said. "To meet our energy needs, we need all the approaches we can get." 

## CONTACT

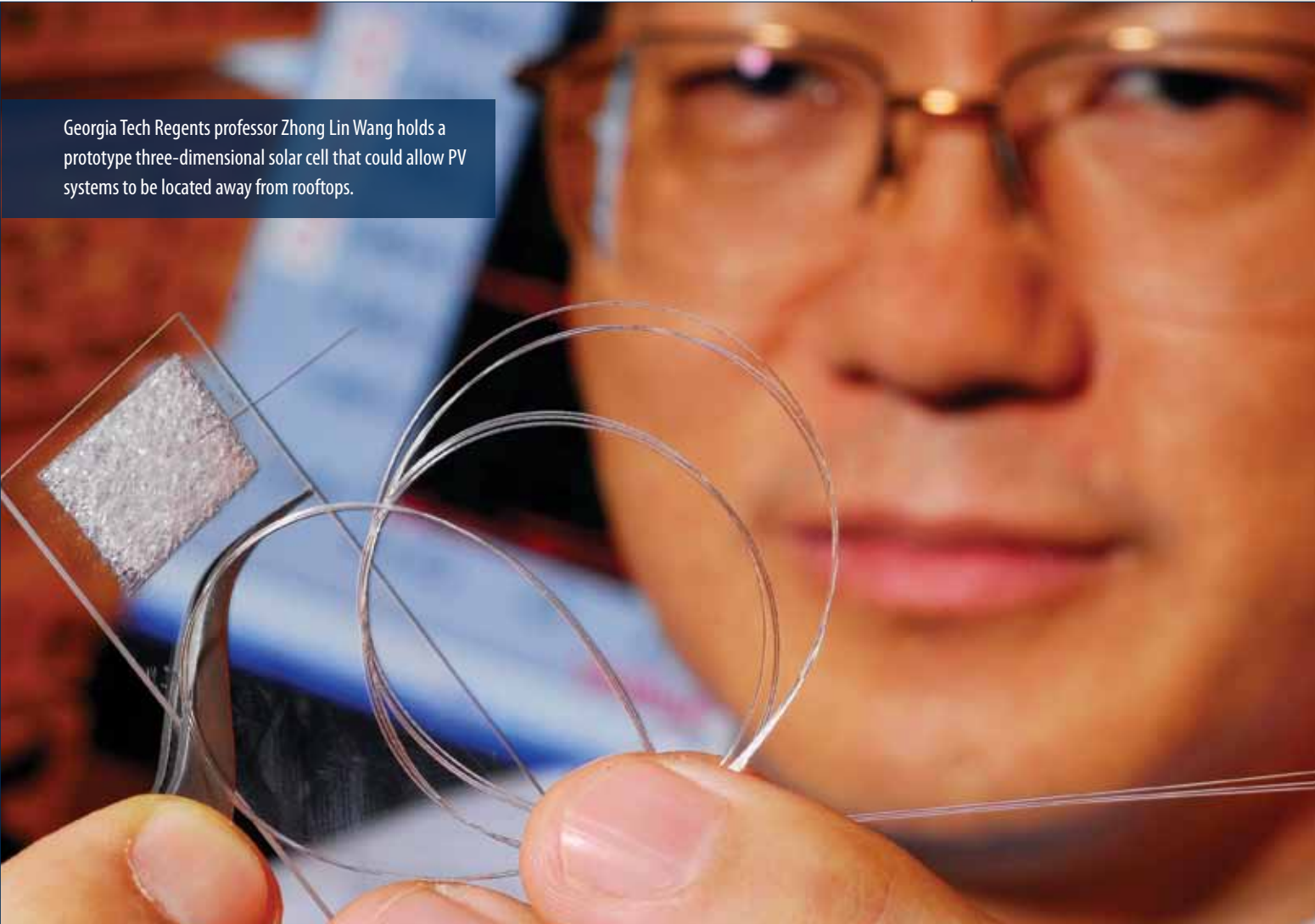
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**“Using this technology, we can make photovoltaic generators that are foldable, concealed and mobile. Optical fiber could conduct sunlight into a building’s walls where the nanostructures would convert it to electricity.”**

**—Zhong Lin Wang,  
Regents professor in the  
School of Materials Science  
and Engineering**



Georgia Tech Regents professor Zhong Lin Wang holds a prototype three-dimensional solar cell that could allow PV systems to be located away from rooftops.

Researchers have completed the first thorough, system-level assessment of the diversity of an environmentally important family of microbes known as *Shewanella*. Results of the study could help scientists choose the best strain for remediation projects based on each site's environmental conditions and contaminants.

Georgia Tech assistant professor Kostas Konstantinidis displays *Shewanella* microbes that have the ability to "inhale" certain metals and compounds and convert them to an altered state.

Photo: Gary Meek



# Bioremediation Bacteria:

## Systems Biology Reveals Diversity in Key Environmental Cleanup Microbes

By Abby Vogel

Researchers have completed the first thorough, system-level assessment of the diversity of an environmentally important family of microbes known as *Shewanella*. Microbes belonging to that genus frequently participate in bioremediation by confining and cleaning up contaminated areas in the environment.

A team of researchers from Georgia Tech, Michigan State University and the Pacific Northwest National Laboratory analyzed the gene sequences, proteins expressed and physiology of 10 strains of *Shewanella*. They believe the study results will help scientists choose the best strain for bioremediation projects based on each site's environmental conditions and contaminants.

The findings, which further advance the understanding of the enormous microbial biodiversity that exists on the planet, appeared Sept. 1, 2009, in the early online issue of the journal *Proceedings of the National Academy of Sciences*. This research

was supported by the U.S. Department of Energy through the *Shewanella* Federation consortium and the Proteomics Application Project.

Similar to a human breathing in oxygen and exhaling carbon dioxide, many *Shewanella* microbes have the ability to "inhale" certain metals and compounds and convert them to an altered state, which is typically much less toxic. This ability makes *Shewanella* very important for the environment and bioremediation, but selecting the best strain for a particular project has been a challenge.

"If you look at different strains of *Shewanella* under a microscope or you look at their ribosomal genes, which are routinely used to identify newly isolated strains of bacteria, they look identical. Thus, traditional microbiological approaches would suggest that the physiology and phenotype of these *Shewanella* bacteria are very similar, if not identical, but that is not true," explained Kostas Konstantinidis, an assistant

professor in the Georgia Tech School of Civil and Environmental Engineering.

Using the traditional method for determining interrelatedness between microbial strains – sequencing of the 16S ribosomal gene – the researchers determined that the 10 strains belonged to the same genus. However, the technique was unable to distinguish between most of the strains or define general properties that would allow the researchers to differentiate one strain from another. To do that, they turned to genomic and whole-cell proteomic data.

By comparing the 10 *Shewanella* genomes, which were sequenced at the Department of Energy's Joint Genome Institute, the research team found that while some of the strains shared 98 percent of the same genes, other strains only shared 70 percent. Of the almost 10,000 protein-coding genes in the 10 strains, nearly half – 48 percent – of the genes were strain-specific, and the differences in expressed proteins were con-



sistently larger than their differences at the gene content level.

"These findings suggest that similarity in gene regulation and expression constitutes an important factor for determining phenotypic similarity or dissimilarity among the very closely related *Shewanella* genomes," noted Konstantinidis. "They also indicate that it might be time to start replacing the traditional microbiology approaches for identifying and classifying new species with genomics- or proteomics-based methods."

Upon further analysis, the researchers found that the genetic differences between strains frequently reflected environmental or ecological adaptation and specialization, which had also substantially altered the global metabolic and regulatory networks in some of the strains.

The *Shewanella* organisms in the study appeared to gain most of their new functions by acquiring groups of genes as mobile genetic islands, selecting islands carrying ecologically important genes and losing ecologically unimportant genes.


The most rapidly changing individual functions in the *Shewanellae* were related to "breathing" metals and sensing mechanisms, which represent the first line of adaptive response to different environmental conditions. *Shewanella* bacteria live in environments that range from deep subsurface sandstone to marine sediment and from freshwater to saltwater.

All but one of the strains was able to reduce several metals and metalloids. That one exception had undertaken a unique evolution resulting in an inability to exploit strictly anaerobic habitats.

"Let's say you have a strain of *Shewanella* that is unable to convert uranium dissolved in contaminated groundwater to a form incapable of dissolving in water," noted Konstantinidis, who also holds a faculty position in the Georgia Tech School of Biology. "If you put that strain in an environment that contains high concentrations of uranium, that microbe is likely to acquire the genes that accept uranium from a nearby strain, in turn

preventing uranium from spreading as the groundwater flows."

This adaptability of bacteria is remarkable, but requires further study in the bioremediation arena, since it frequently underlies the emergence of new bacterial strains. Konstantinidis' team at Georgia Tech is currently investigating communities of these *Shewanella* strains in their natural environments to advance understanding of the influence of the environment on the evolution of the bacterial genome and identify the key genes in the genome that respond to specific environmental stimuli or conditions, such as the presence of heavy metals.

Ongoing studies should broaden the researchers' understanding of the relationship between genotype, phenotype, environment and evolution, Konstantinidis said. 



Kostas Konstantinidis, an assistant professor in Georgia Tech's School of Civil and Environmental Engineering, used genomics and proteomics to identify hidden diversity in the *Shewanella* family of bioremediation microbes.

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**“These findings suggest that similarity in gene regulation and expression constitutes an important factor for determining phenotypic similarity or dissimilarity among the very closely related *Shewanella* genomes. They also indicate that it might be time to start replacing the traditional microbiology approaches for identifying and classifying new species with genomics- or proteomics-based methods. ”**

**— Kostas Konstantinidis,  
assistant professor  
in the School of Civil  
and Environmental  
Engineering**

A new ceramic material could help expand the applications for solid oxide fuel cells – devices that generate electricity directly from a wide range of liquid or gaseous fuels without the need to separate hydrogen. The new mixed ion conductor material could address three issues facing the solid oxide fuel cells: tolerance of sulfur, resistance to carbon build-up known as coking, and the requirement for high operating temperatures.

Georgia Tech researchers analyze a Raman spectrum that shows material composition information for the new mixed ion conductor.

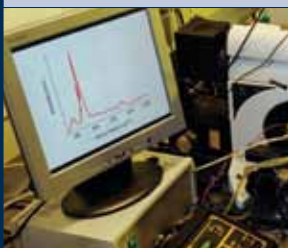


Photo: Gary Meek

# Cutting Fuel Cell Cost:

## New Sulfur- and Coking-Tolerant Material Could Expand Applications for Solid Oxide Fuel Cells

By John Toon

**A** new ceramic material described in the Oct. 2, 2009, issue of the journal *Science* could help expand the applications for solid oxide fuel cells – devices that generate electricity directly from a wide range of liquid or gaseous fuels without the need to separate hydrogen.

Though the long-term durability of the new mixed ion conductor material must still be proven, its development could address two of the most vexing problems facing the solid oxide fuel cells: tolerance of sulfur in fuels and resistance to carbon build-up known as coking. The new material could also allow solid oxide fuel cells – which convert fuel to electricity more efficiently than other fuel cells – to operate at lower temperatures, potentially reducing material and fabrication costs.

“The development of this material suggests that we could have a much less expensive solid oxide fuel cell, and that it could be more compact, which would increase the range of potential applications,” said Meilin Liu, a Regents professor in the Georgia Tech School of Materials Science and Engineering. “This new material would potentially allow the fuel cells to run with dirty hydrocarbon fuels without the need to clean them and supply water.”

The research was supported by the U.S. Department of Energy’s Basic Energy Science Catalysis Science Program.

Like all fuel cells, solid oxide fuel cells (SOFCs) use an electrochemical process to produce electricity by oxidizing a fuel. As the name implies, SOFCs use a ceramic electrolyte, a material known as yttria-stabilized zirconia (YSZ).

The fuel cell’s anode uses a composite consisting of YSZ and the metal nickel. This anode provides excellent catalytic activity for fuel oxidation, good conductivity for collecting current generated, and compatibility with the cell’s electrolyte – which is also YSZ.

But the material has three significant drawbacks: (1) even small amounts of sulfur in fuel “poisons” the anode to dramatically reduce efficiency, (2) the use of hydrocarbon fuels creates carbon build-up which clogs the anode, and (3) because YSZ has limited conductivity at low temperatures, SOFCs must operate at high temperatures.

As a result, fuels used in SOFCs, such as natural gas or propane, must be purified to remove sulfur, which increases their cost. Water in the form of steam must also be supplied to a reformer that converts hydrocarbons to hydrogen and carbon monoxide before being fed to the fuel cells, adding complexity to the overall system and reducing energy efficiency. And the high-temperature operation means the cells must be fabricated from exotic materials, which keeps SOFCs too expensive for many applications.

The new material developed by the Georgia Tech team – which also included Lei Yang, Shizhong Wang, Kevin Blinn, Mingfei Liu, Ze Liu and Zhe Cheng – addresses all three of those anode issues. Referred to as BZCYYb as shorthand for its complex composition, the material tolerates hydrogen sulfide in concentrations as high as 50 parts per million, does not accumulate carbon – and can operate efficiently at temperatures as low as 500 degrees Celsius.

The BZCYYb (Barium-Zirconium-Cerium-Yttrium-Ytterbium Oxide) material could be used in a variety of ways: as a coating on the traditional Ni-YSZ anode, as a replacement for the YSZ in the anode and as a replacement for the entire YSZ electrolyte system. Liu believes the first two options are more viable.


So far, the new material has provided steady performance for up to 1,000 hours of operation in a small laboratory-scale SOFC. To be commercially viable, however, the material will have to be proven in operation for up to five years – the expected lifespan of a commercial SOFC.

In addition to its tolerance of sulfur and resistance to coking, the BZCYYb material's conductivity at lower temperature could also provide a significant advantage for SOFCs.

"If we could reduce operating temperatures to 500 or 600 degrees Celsius, that would allow us to use less expensive metals as interconnects," Liu noted. "Getting the temperature

down to 300 to 400 degrees could allow use of much less expensive materials in the packaging, which would dramatically reduce the cost of these systems."

He believes that solid oxide fuel cells offer the greatest potential for directly converting a variety of fuels to electricity.

"Solid oxide fuel cells offer high energy efficiency, the potential for direct utilization of all types of fuels including renewable biofuels, and the possibility of lower costs since they do not use any precious metals," said Liu. "We are working to reduce the cost of solid oxide fuel cells to make them viable in many new applications, and this new material brings us much closer to doing that." 

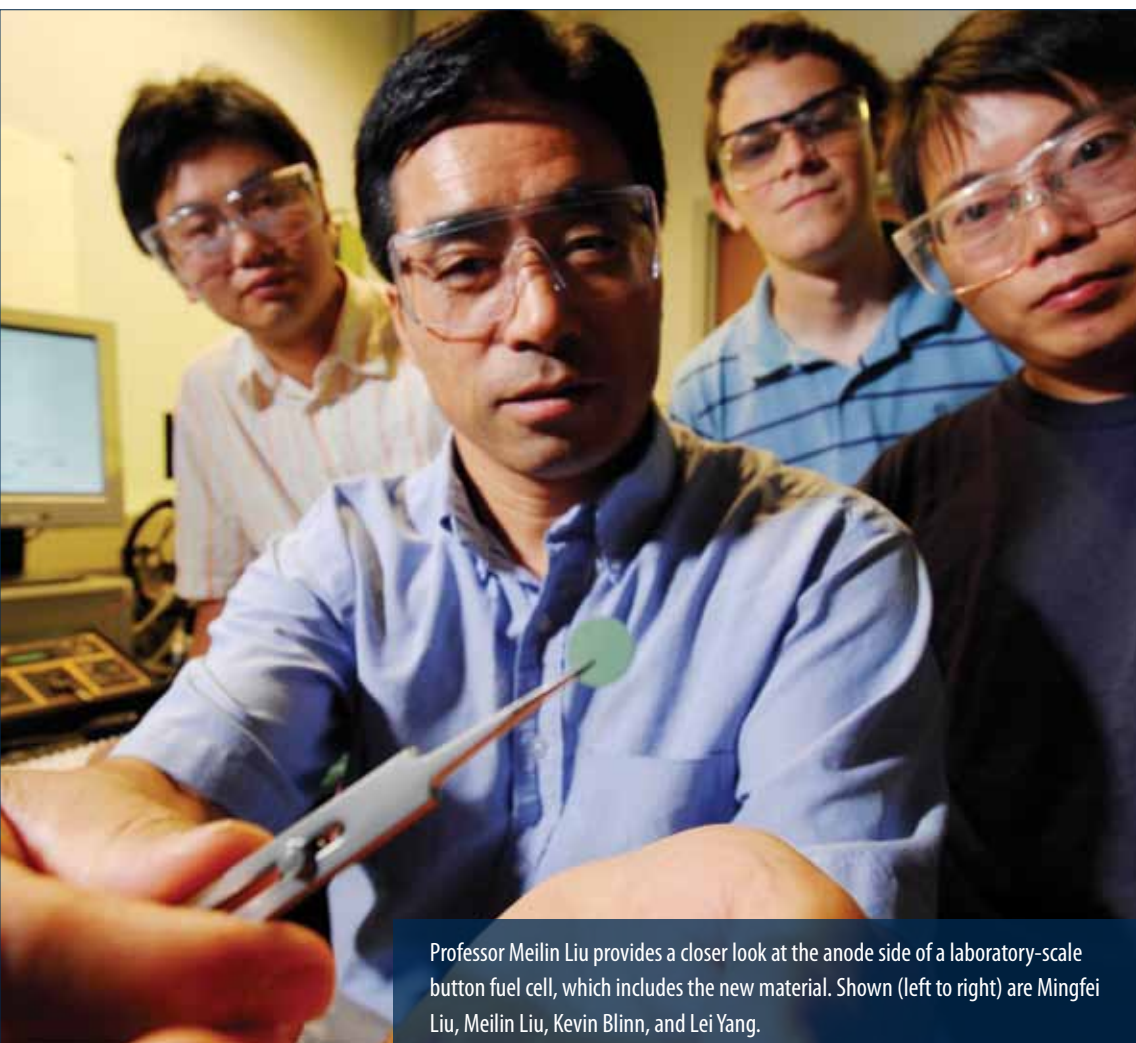
*This research was supported by the U.S. Department of Energy's Basic Energy Science Catalysis Science Program under grant DE-FG02-06ER15837. The comments and conclusions in this document are those of the researchers and do not necessarily represent the views of the U.S. Department of Energy.*

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**“Solid oxide fuel cells offer high energy efficiency, the potential for direct utilization of all types of fuels including renewable biofuels, and the possibility of lower costs since they do not use any precious metals. We are working to reduce the cost of solid oxide fuel cells to make them viable in many new applications, and this new material brings us much closer to doing that. ”**

**— Meilin Liu, Regents professor in the School of Materials Science and Engineering**



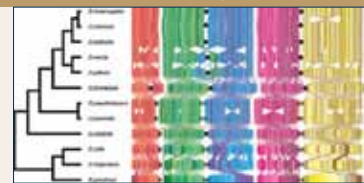
Professor Meilin Liu provides a closer look at the anode side of a laboratory-scale button fuel cell, which includes the new material. Shown (left to right) are Mingfei Liu, Meilin Liu, Kevin Blinn, and Lei Yang.

Photo: Gary Meek



## Petascale Tools Could Revolutionize Genomics Knowledge

Image: Stephen Schaeffer



*This plot shows microscale rearrangements of genes from 12 *Drosophila* species. Each gene is indicated by a colored line.*

Technological advances in high-throughput DNA sequencing have opened up the possibility of determining how living things are related by analyzing the ways in which their genes have been rearranged on chromosomes. However, inferring such evolutionary relationships from rearrangement events is computationally intensive on even the most advanced computing systems available today.

Research recently funded by the American Recovery and Reinvestment Act of 2009 aims to develop computational tools that will utilize next-generation petascale computers to understand genomic evolution. The four-year, \$1 million project, supported by the National Science Foundation's PetaApps program, was awarded to a team of universities that includes the Georgia Institute of Technology, the University of South Carolina and the Pennsylvania State University.

"Genome sequences are now available for many organisms, but making biological sense of the genomic data requires high-perfor-

mance computing methods and an evolutionary perspective, whether you are trying to understand how genes of new functions arise, why genes are organized as they are in chromosomes, or why these arrangements are subject to change," said lead investigator David A. Bader, a professor in the School of Computational Science and Engineering in Georgia Tech's College of Computing.

Even on today's fastest parallel computers, it could take centuries to analyze genome rearrangements for large, complex organisms. That is why the research team – which also includes Jijun Tang, an associate professor in the Department of Computer Science and Engineering at the University of South Carolina; and Stephen Schaeffer, an associate professor of biology at Penn State – is focusing on future generations of petascale machines, which will be able to process more than a thousand trillion, or  $10^{15}$ , calculations per second. Today, most personal computers can only process a few hundred thousand calculations per second.

The researchers plan to develop new algorithms in an open-source software framework that will utilize the capabilities of parallel, petascale computing platforms to infer ancestral rearrangement events. The starting point for developing these new algorithms will be GRAPPA, an open-source code co-developed by Bader and released in 2000 that reconstructed the evolutionary relatedness among species.

The researchers will test the performance of their new algorithms by analyzing a collection of fruit fly (*Drosophila*) genomes. The analysis of genome rearrangements in *Drosophila* will provide a relatively simple system to understand the mechanisms that underlie gene order diversity, which can later be extended to more complex mammalian genomes, such as primates.

The researchers believe these new algorithms will make genome rearrangement analysis more reliable and efficient, while potentially revealing new evolutionary patterns. In addition, the algorithms will en-

able a better understanding of the mechanisms and rate of gene rearrangements in genomes, and the importance of the rearrangements in shaping the organization of genes within the genome.

"Ultimately this information can be used to identify microorganisms, develop better vaccines, and help researchers better understand the dynamics of microbial communities and biochemical pathways," added Bader.

This material is based upon work supported by the National Science Foundation (NSF) under Award Nos. OCI-0904461, 0904179 and 0904166. Any opinions, findings, conclusions or recommendations expressed in this publication are those of the researchers and do not necessarily reflect the views of the NSF.

— Abby Vogel

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## Researchers Work to Improve the Security of Mobile Devices

Smart phones – like BlackBerrys and iPhones – have become indispensable to today's highly mobile workforce and tech-savvy youngsters. While these devices keep friends and colleagues just a few thumb-taps away, they also pose new security and privacy risks.

"Traditional cell phones have been ignored by attackers because they were specialty devices,

but the new phones available today are handheld computers that are able to send and receive e-mail, surf the Internet, store documents and remotely access data – all actions that make them vulnerable to a wide range of attacks," said Patrick Traynor, assistant professor in the Georgia Tech School of Computer Science.

Traynor and Jonathon Giffin, also an assistant professor in

the School of Computer Science, recently received a three-year, \$450,000 grant from the National Science Foundation to develop tools that improve the security of mobile devices and the telecommunications networks on which they operate. These Georgia Tech faculty members, together with a team of graduate students, are developing methods of identifying and remotely repairing mobile devices

that may be infected with viruses or other malware.

Malware can potentially eavesdrop on user input or otherwise steal sensitive information, destroy stored information, or disable a device. Attackers may snoop on passwords for online accounts, electronic documents, e-mails that discuss sensitive topics, calendar and phone book entries, and audio and video media.

"Since mobile phones typically lack security features found on desktop computers, such as antivirus software, we need to accept that the mobile devices will ultimately be successfully attacked. Therefore our research focus is to develop effective attack recovery strategies," explained Giffin.

The researchers plan to investigate whether cellular service providers are capable of detecting infected devices on their respective networks. Because infected devices often begin to over utilize the network by sending a high volume of traffic to a known malicious Internet server or by

suddenly generating a high volume of text messages, monitoring traffic patterns on the network should allow these infected phones to be located, according to the researchers. "While a single user might realize that a phone is behaving differently, that person probably won't know why. But a cell phone provider may see a thousand devices behaving in the same way and have the ability to do something about it," said Traynor.

Once infected devices are located, those phones will need to be cleared of the malicious code. To accomplish this, the researchers are developing remote repair

methods, which will allow service providers to assist in the cleaning of infected devices without requiring that the phones be brought to a service center. The methods will also have to work without much effort on the part of the customer.

This repair may require disabling some functionality on the phone, such as the ability to use downloaded programs, until the malicious program is located and removed. While the repair is under way, phone calling and text messaging functionality would continue to operate.

"Using this remote repair strategy, the service provider no longer has to complete-

ly disable a phone. Instead they just put the device into a safe, but reduced, mode until the malware can be removed," said Giffin.

*This material is based upon work supported by the National Science Foundation (NSF) under Award No. CNS-0916047. Any opinions, findings, conclusions or recommendations expressed in this publication are those of the researcher and do not necessarily reflect the views of the NSF.*

— Abby Vogel

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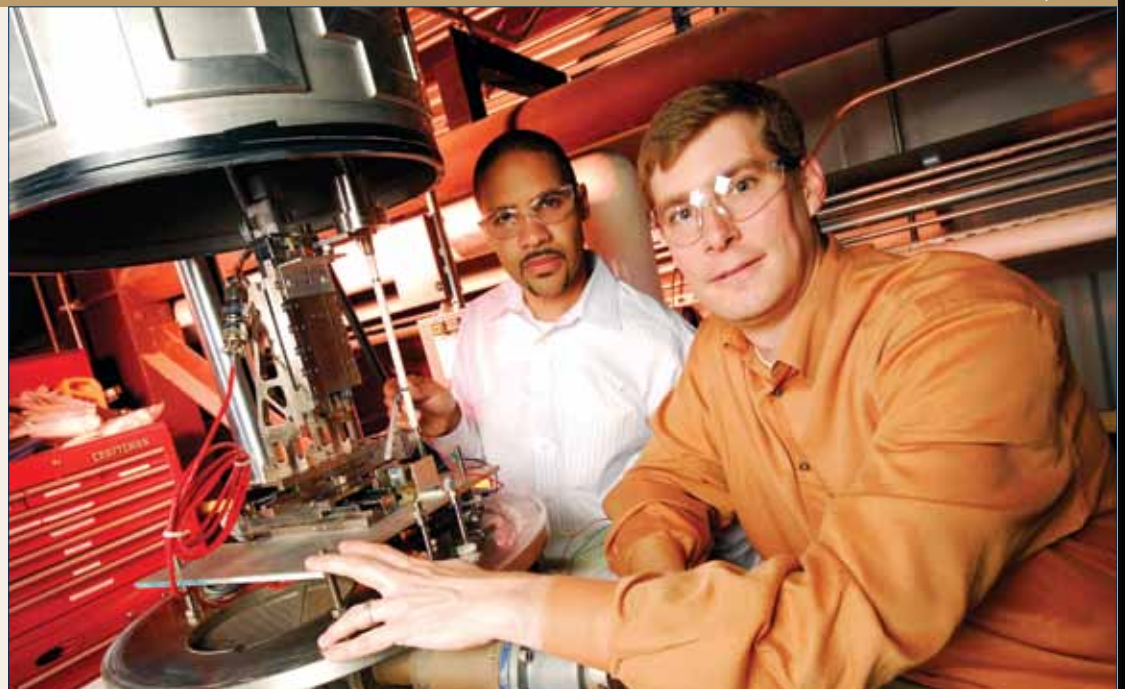
## Improved Electric Propulsion Could Boost Satellite Lifetimes

Photo: Gary Meek

Georgia Tech researchers have won a \$6.5 million grant to develop improved components that could boost the efficiency of electric propulsion systems used to control the positions of satellites and planetary probes.

Focusing on improved cathodes for devices known as Hall Effect thrusters, the research would reduce propellant consumption in commercial, government and military satellites, allowing them to remain in orbit longer, be launched on smaller or cheaper rockets, or carry larger payloads. Sponsored by the U.S. Defense Advanced Research Projects Agency Defense Sciences Office (DARPA-DSO), the 18-month project seeks to demonstrate the use of propellant-less cathodes with Hall Effect thrusters.

"About 10 percent of the propellant carried into space on satellites that use an electric propulsion system is essentially wasted in the hollow cathode that is part of the system," said Mitchell Walker, an assistant professor in Georgia Tech's School of Aerospace Engineering and the project's principal investigator. "Using field emission rather than a hollow cathode, we are able to pull electrons from cathode arrays made from carbon nanotubes without wasting



Researchers Jud Ready and Mitchell Walker prepare a carbon nanotube field emitter sample for measurements in the High-Power Electric Propulsion Laboratory of Georgia Tech's School of Aerospace Engineering.

propellant. That will extend the life of the vehicle by more efficiently using the limited onboard propellant for its intended purpose of propulsion."

To maintain their positions in space or to reorient themselves, satellites must use small thrusters that are either chemically or electrically powered. Electrically powered thrusters use electrons to ionize an inert gas

such as xenon. The resulting ions are then ejected from the device to generate thrust.

In existing Hall Effect thrusters, a single, high-temperature cathode generates the electrons. A portion of the propellant — typically about 10 percent of the limited supply carried by the satellite — is used as a working fluid in the traditional hollow cathode. The DARPA-funded research would

replace the hollow cathode with an array of field-effect cathodes fabricated from bundles of multi-walled carbon nanotubes. Powered by on board batteries and photovoltaic systems on the satellite, the arrays would operate at low power to produce electrons without consuming propellant.

Walker and collaborators at the Georgia Tech Research Institute (GTRI) have

already demonstrated field-effect cathodes based on carbon nanotubes. The additional funding will support improvements in the devices, known as carbon nanotube cold cathodes, and lead to space testing as early as 2015.

"This work depends on our ability to grow aligned carbon nanotubes precisely where we want them to be and to exacting dimensions," said Jud Ready, a GTRI senior research

engineer and Walker's collaborator on the project. "This project leverages our ability to grow well-aligned arrays of nanotubes and to coat them to enhance their field emission performance."

In addition to reducing propellant consumption, use of carbon nanotube cathode arrays could improve reliability by replacing the single cathode now used in the thrusters. The improved carbon nanotube

cathodes should advance the goals of reducing the cost of launching and maintaining satellites.

"Thrust with less propellant has been one of the major goals driving research into satellite propulsion," said Walker, who is director of Georgia Tech's High-Power Electric Propulsion Laboratory. "Electric propulsion is becoming more popular and will benefit from our innovation. Ultimately, we will

help improve the performance of in-space propulsion devices."

— John Toon

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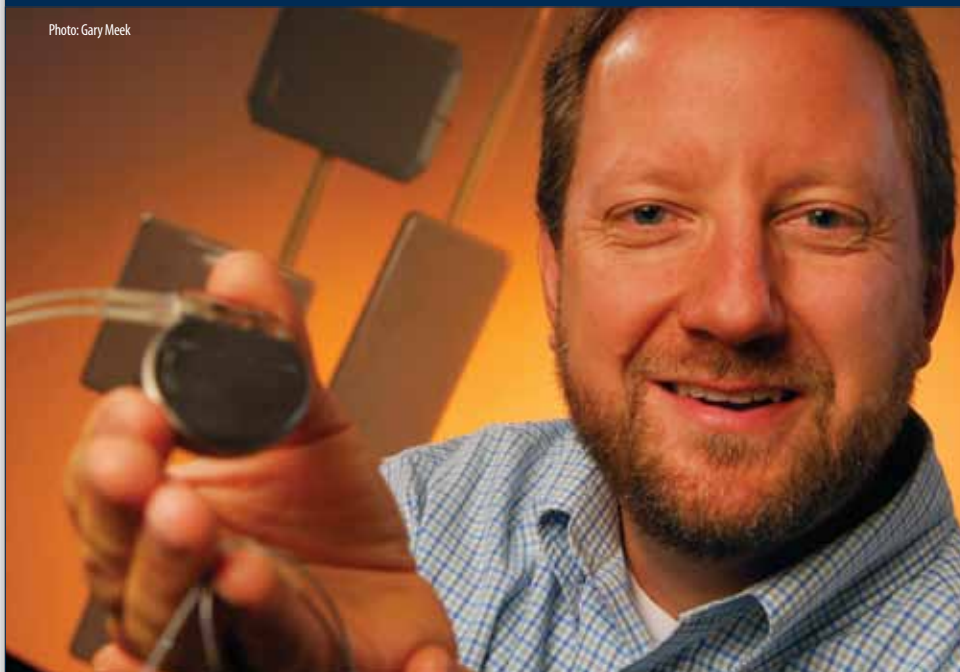
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## Establishing Protocols to Test RFID Systems and Medical Devices

Photo: Gary Meek



*Ralph Herkert, director of the Medical Device Test Center in the Georgia Tech Research Institute, holds a sample device under study at the center.*

Radio frequency identification (RFID) systems are widely used for applications that include inventory management, toll collection and airport luggage security. These systems have also found their way into medical environments to track patients, equipment and staff members.

However, there is currently no published standardized, repeatable methodology by which manufacturers of RFID equipment or medical de-

vices can assess potential issues with electromagnetic interference and evaluate means to mitigate them.

To resolve these concerns, the Georgia Tech Research Institute (GTRI) recently began developing testing protocols for RFID technology in the health care setting. The test protocol development is being overseen by AIM Global, the international trade association representing automatic identifica-

tion and mobility technology solution providers, and also includes MET Laboratories, a company that provides testing and certification services for medical devices.

"A comprehensive set of test protocols, which are sufficiently precise to permit repeatable results, is required to understand if there is an interaction between various types of RFID systems and active implantable medical devices,

electronic medical equipment, *in vitro* diagnostic equipment and biologics. Only after the protocols are developed will we be able to investigate the cause of any interactions, the result of any interactions, and ways manufacturers might eliminate or mitigate interactions," said Craig K. Harmon, president and CEO of Q.E.D. Systems and chairman of AIM Global's RFID Experts Group.

GTRI researchers will test how RFID systems affect the function of implantable and wearable medical devices, such as pacemakers, implantable cardioverter defibrillators, neurostimulators, implantable infusion pumps and cardiac monitors.

"The internal components, firmware and hardware of every company's devices are different, meaning that each device can respond differently to the same electromagnetic environment. Since there have been various preliminary tests and publications from different organizations indicating that there may or may not be issues with RFID system environments and these devices, it is important to standardize the way to test such de-



vices," said Ralph Herkert, director of GTRI's Medical Device Test Center.

The researchers will test whether radio frequency-emitting devices cause any negative effects on the medical devices, and under what conditions these effects might occur. Testing will also determine whether specific medical devices are particularly susceptible to certain radio frequency identification characteristics and if any corrective actions can be taken to mitigate such susceptibility.

GTRI established its Medical Device Test Center more than 14 years ago to en-

able manufacturers of implantable cardiac pacemakers and defibrillators to work with providers of electronic article surveillance (EAS) systems, used by retailers, libraries and other establishments to prevent theft and track inventory. In 2006, GTRI expanded the Center's operations and facilities to test new types of security and logistical systems, including RFID. To test the effects of RFID systems on medical devices, the researchers simulate real-world conditions by placing a medical device in a tank of saline solution that simulates the electrical characteristics of body tissue and fluid. The

medical device is then exposed to different RFID technologies. Several tests are performed with the device placed in different orientations to represent how people typically interact with the emissions.

"We think the testing procedure for RFID systems will be similar to the EAS system procedure, but there are a few more challenges with the RFID systems because a person doesn't always pass through a portal," noted Gisele Bennett, director of GTRI's Electro-Optical Systems Lab and a member of AIM Global's RFID Experts Group. "Medical devices can be affected

by active tags with stronger signals or RFID systems reading passive tag signals."

The test protocols developed by GTRI will be submitted to the U.S. Food and Drug Administration for concurrence, after which a worldwide certification program will be launched and other testing facilities will be invited to participate.

— Abby Vogel

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## Study Confirms Multidisciplinary Nature of Nano Research

Image: Alan Porter and Jan Youtie

The burgeoning research fields of nanoscience and nanotechnology are commonly thought to be highly multidisciplinary because they draw on many areas of science and technology to make important advances.

Research reported in the September 2009 issue of the journal *Nature Nanotechnology* found that nanoscience and nanotechnology indeed are highly multidisciplinary – but not much more so than other modern disciplines such as medicine or electrical engineering that also draw on multiple areas of science and technology.

With \$1.6 billion scheduled to be invested in nano-related research during 2010, assessing the multidisciplinary nature of the field could be important to policymakers, research managers, technology-transfer officers and others responsible for managing the investment and creating a supportive environment for it.

"Research in nanoscience and nanotechnology is not just a collection of isolated 'stove pipes' drawing knowledge from one narrow discipline, but rather is quite interdisci-

plinary," said Alan Porter, co-author of the paper and a professor emeritus in the Schools of Industrial and Systems Engineering and Public Policy at the Georgia Institute of Technology. "We found that research in any one category of nanoscience and nanotechnology tends to cite research in many other categories."

The study was sponsored by the National Science Foundation through the Center for Nanotechnology in Society at Arizona State University.

Porter and collaborator Jan Youtie, manager of policy services in Georgia Tech's Enterprise Innovation Institute, analyzed abstracts from more than 30,000 papers with "nano" themes that were published between January and July of 2008. They found that although materials science and chemistry dominated the papers, fields as diverse as clinical medicine, biomedical sciences and physics also contributed.

These "nanopapers" studied by the researchers appeared in more than 6,000 journals that were part of a database known as the Science Cita-

tion Index (SCI). The researchers found nanopapers in 151 of SCI's 175 subject categories, with 52 of the categories containing more than 100 such papers.

The researchers also used a metric they called an "integration score" to gauge the interdisciplinary nature of a particular paper or set of papers. The integration score ranged from zero for stand-alone disciplines that don't cite work from other disciplines to one for highly-integrated disciplines that heavily cite work from other areas.

Integration scores ranged from 0.65 for nanoscience and nanotechnology to 0.60 for electrical engineering and 0.64 for organic chemistry.

Understanding the interdisciplinary nature of nanoscience and nanotechnology could be important to creating the right environment for the field to produce results.

"There is a broad perspective that most scientific breakthroughs occur at the interstices among more established fields," said Youtie. "Nanotechnology R&D is believed to be an area where disciplines converge. If nanotechnology does have a strong multidisciplinary



*This figure shows the position of nanoscience and nanotechnology topics over a base map of science, with each node one of 175 subject categories.*

character, attention to communication across disciplines will be an important feature in its emergence."

This project was sponsored by the National Science Foundation (NSF) under awards 0531194 and 0830207. The findings and opinions contained in this article are those of the researchers and do not necessarily reflect the views of the National Science Foundation (NSF).

— John Toon

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# Athens Hospital Uses Lean Techniques to Improve Laboratory Processes

Implementing lean principles in a health care setting can be especially challenging. Developed for use in manufacturing, lean refers to an operational strategy derived from the Toyota Production System that focuses on eliminating waste while increasing value-added work to improve profitability, customer satisfaction, throughput time and employee morale.

"People involved in health care are about hands-on care-giving, comforting and healing," said Debbie Guzman, laboratory director at Athens Regional Medical Center in Athens, Ga. "We needed someone to help us who understood our language."

Fortunately, Guzman found an excellent translator in Georgia Tech's Enterprise Innovation Institute. Through its Healthcare Performance Group, project leaders work with health care professionals to conduct lean assessments, teach basic lean concepts, develop value stream maps to analyze the flow of materials and information, develop quality systems and implement rapid process improvement projects.

"We wanted the Healthcare Performance Group to provide the training, the structure and the facilitation for a period of time to do a 5S project in the lab. By using the 5S system — sort, straighten, shine, standardize and sustain — we thought we could significantly improve the efficiency and effectiveness of the laboratory," explained Jim Pirkle, Athens Regional's associate director of quality services. "Originally we were going to begin the project in one area, but we wanted each of the section supervi-



Photo: Nancy Fullbright

*As part of the lean implementation, team members removed sliding doors from shelving and storage cabinets and set up a visual inventory system to easily identify supplies.*

sors to be involved so it could be a whole lab culture change."

After years of inventory accrual and process adaptation, the lab was a physically dysfunctional environment. As the hospital expanded, team members had the opportunity to design a new lab that had the right supplies next to the right instruments, the appropriate amount of storage and counter space, equipment set up to facilitate testing processes and work processes arranged to minimize excess steps.

"The emphasis of the project was to get the right supplies where they were needed, within easy reach," said Kelley Hundt, a member of the Georgia Tech team. "This included implementing replenishment signals. So rather than have someone walk the lab each week to determine what they've run out of, cards in the storage area signal what needs to be reordered."

While the overall goal was to help design a highly functional

lab, the immediate project goals included making workspace more efficient, reducing inventory and supply costs, decreasing process steps and complexity and creating efficiencies. Participants included the lab director and supervisors, lab staff and quality support staff from Athens Regional, as well as Frank Mewborn, Tara Barrett and Kelley Hundt from Georgia Tech. Five teams of 21 people learned about lean and 5S methodologies, participated in brainstorming and planning exercises and completed a walk-through of the entire laboratory.

In the first phase of the project, team members sorted the useful from the unnecessary. They evaluated the necessity of all supplies and equipment, cleared away outdated equipment from the area and removed sliding doors from shelving and doors from storage cabinets to allow easy identification of supplies. Most importantly, each department developed a systematic and collaborative process for sorting obviously

misplaced items from useful ones.

Team members also relocated supplies, acquired supply bins and consolidated storage areas; set up a standard visual inventory system with red and green tape and developed cards to display the name of the supply, the name of the supplier, the desired number of units and the item's reorder point.

The project produced a 300 percent return on investment for the hospital. It increased the lab's storage capacity by 64 percent, freed up 30 percent of the counter space and reduced processing times from 12 to four minutes. Other results include reduced inventory and supply costs, decreased stock on hand and greater clarity in the lab environment.

— Nancy Fullbright

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# Device Designed to Measure Gorilla Blood Pressure

Photo: Zoo Atlanta

Zoo Atlanta recently became the first zoological institution in the world to obtain voluntary blood pressure readings from a gorilla. The accomplishment was made possible by the Gorilla Tough Cuff, a blood pressure reading system devised through a partnership with the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University.

Created as a senior design project by biomedical engineering undergraduates David Sotto, Nisha Bhatia, Stephanie Drewicz and Scott Seaman, the prototype has now been successfully tested on one of Zoo Atlanta's 22 western lowland gorillas. The students also had guidance from Hanjoong Jo, the Ada Lee and Pete Correll Professor in Biomedical Engineering and the Emory University Division of Cardiology; and Professor Franklin Bost, the Coulter Department director of design instruction.

"Zoo Atlanta is home to the nation's largest collection of gorillas, so there is an ongoing responsibility to contribute to the zoological community's understanding of their care," said Dennis Kelly, Zoo Atlanta's President and CEO. "We are proud to have spearheaded an effort that will ultimately benefit gorillas living in captive settings around the world."

The Gorilla Tough Cuff operates in the same manner as the mechanism familiar to humans, with the patient slipping an arm into a cuff. As the cuff inflates, the blood pressure reading is measured and displayed on a monitor. The student design team's biggest set of challenges, however, was constructing a durable, comfortable cuff large

enough to fit an adult male gorilla weighing upwards of 300 pounds.

The prototype system was comprised of a blood pressure cuff bolted to a casing made of acrylonitrile butadiene styrene (ABS) plastic. The casing was zip-tied to a rectangular mesh trap and the trap was temporarily attached to the gorilla cage. The pressure cuff tubing was connected to an off-the-shelf veterinary blood pressure monitor located outside of the gorilla cage.

"We also built a safety mechanism into the device so that the gorillas would not be injured if they became alarmed or frightened and tried to remove their arm from the cuff," said Sotto, who is currently a graduate student at Georgia Tech.

Once the prototype was complete, the Tough Cuff had its first tester: Ozzie, a 48-year-old male western lowland gorilla. Gorillas aren't typically keen on the idea of inserting their arms into inflatable cuffs: Ozzie's accomplishment is the result of months of positive reinforcement training on the part of Zoo Atlanta's Primate Team.

One of four geriatric gorillas living at the Zoo, Ozzie is at an age where he may be subject to health concerns similar to those experienced by mature humans. Cardiac disease is the leading cause of mortality in adult male gorillas living in captive settings, and the new system will enable veterinarians to more effectively monitor precursory signs such as high blood pressure.

"This is a great step forward in the medical management and care of captive gorillas," said Dr. Sam Rivera, associate veterinarian at Zoo Atlanta. "Our Veterinary and Pri-



*The Georgia Tech team that developed the Gorilla Tough Cuff and a Zoo Atlanta trainer position the pressure cuff casing inside the rectangular mesh trap so that a gorilla's blood pressure can be measured.*



*Ozzie slides an arm into the durable, yet comfortable, Gorilla Tough Cuff. As the cuff inflates, the blood pressure reading is measured and displayed on a monitor.*

mate Teams are extremely fortunate to have the biomedical engineering department at Georgia Tech and Emory University as a resource."

The Gorilla Tough Cuff has already been demonstrated for veterinarians and animal care profession-

als from numerous other accredited zoos. The device could ultimately prove valuable to the more than 100 institutions around the world currently housing the species.

— Abby Vogel





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