Research Horizons

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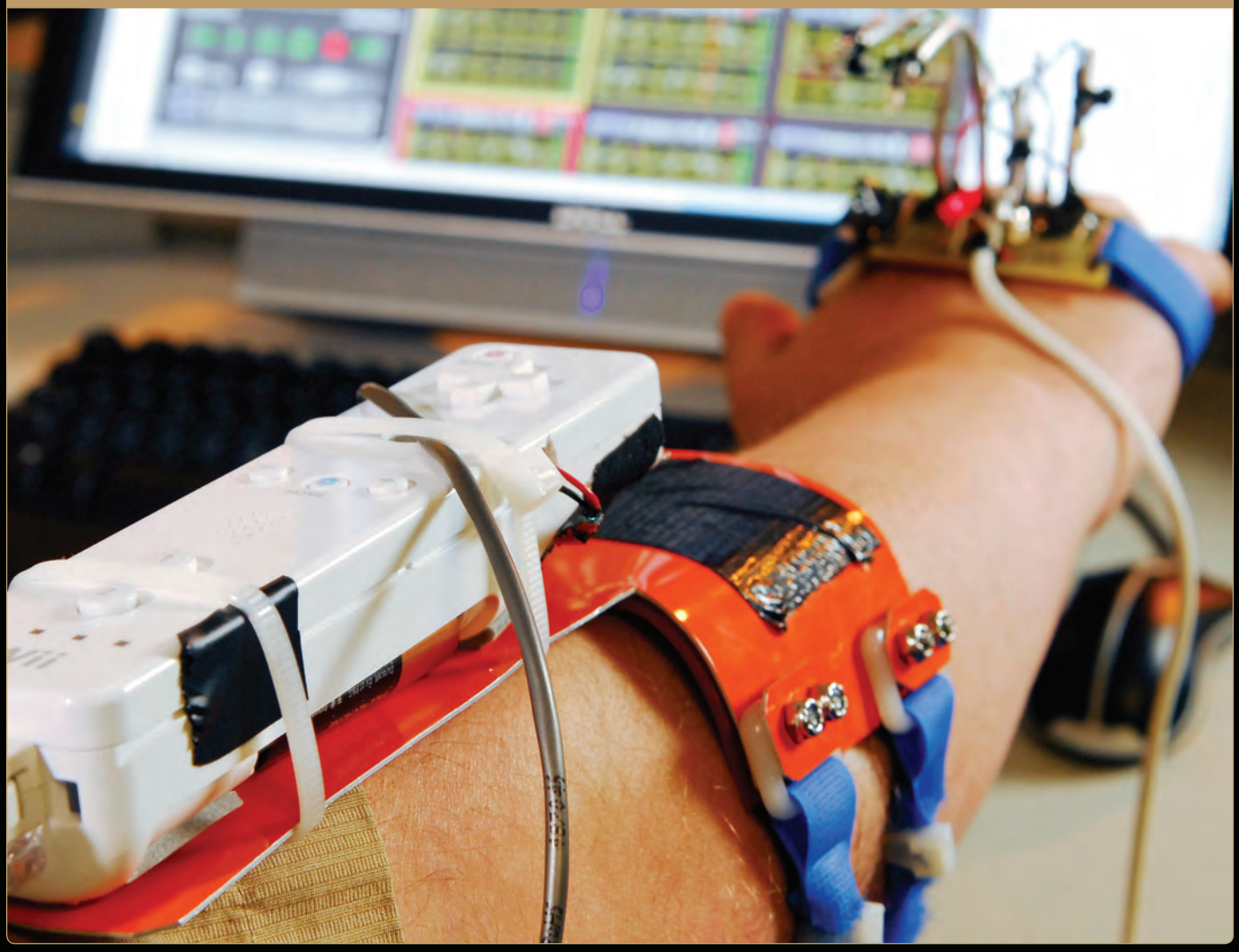
SERIOUS GAMING YIELDS RESEARCH RESULTS



Georgia Institute of Technology

- *Ice Radar*
- *Nano Defense*
- *Killer Seaweed*
- *Using Social Media*
- *Blast Protection*

"To design micro-autonomous systems, we first need to explore in a virtual way how they might behave in the real world and interact with one other. And a good way to start exploring them is with game engines, because you can examine robotic systems using the synthetic entities found in many game worlds."

– Lora Weiss, Georgia Tech Research Institute (GTRI) principal research engineer

COVER STORY

"This aerial approach would greatly facilitate environmental remote sensing of ice, allowing us to map larger areas of interest to better understand location, quantity and composition. This mapping ability is very important because we need to know about ice accumulation, consistency and stability."

– John Papapolymerou, professor in the Georgia Tech School of Electrical and Computer Engineering

"We need to start developing strategies now to be able to lessen the potential for malfeasant applications of these technologies. People have thought about this at a very high level, but what we need to do is dive more deeply into it and explore the potential nanotechnology threat in a much more analytical and systematic way."

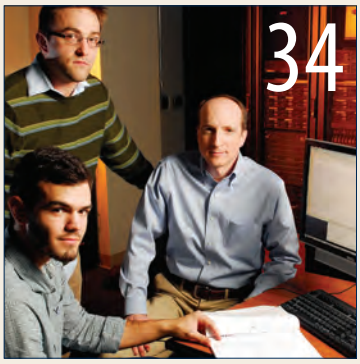
– Margaret Kosal, assistant professor in the Sam Nunn School of International Affairs at Georgia Tech

"This work provides proof that at least from a molecular point of view we can identify and produce materials that have the right properties for all-optical processing. This opens the door for looking at this issue in an entirely different way."

– Seth Marder, professor in the Georgia Tech School of Chemistry and Biochemistry

"This study shows that bio-artificial materials are suitable for promoting vasculature growth and remodeling. Because hydrogels are very compatible with biological tissues, they are a promising therapeutic delivery vehicle to improve treatment of peripheral artery disease, ischemic heart disease, and survival of cell and tissue transplants."

– Andrés García, professor and Woodruff Faculty Fellow in Georgia Tech's Woodruff School of Mechanical Engineering and the Petit Institute for Bioengineering and Bioscience



"We've been using a commonly available graphics processor to test the integrity of typical passwords of the kind in use here at Georgia Tech and many other places. We can confidently say that a seven-character password is hopelessly inadequate – and as GPU power continues to go up every year, the threat will increase."

– Richard Boyd, senior research scientist at the Georgia Tech Research Institute (GTRI)

"Development of a novel approach to producing hierarchical anode or cathode particles with controlled properties opens the door to many new directions for lithium-ion battery technology. This is a significant step toward commercial production of silicon-based anode materials for lithium-ion batteries."

– Gleb Yushin, assistant professor in the Georgia Tech School of Materials Science and Engineering

Georgia Tech *Research Horizons* Magazine

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Cover: Georgia Tech researchers have adapted a game controller made for the Nintendo Wii to analyze physical stresses on the arms of workers in poultry processing plants.

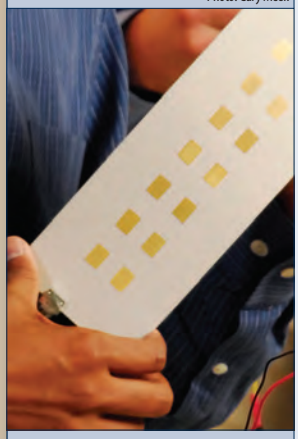
NASA has awarded $2.4 million to develop a new type of radar system that will be used to study the Earth's ice and snow formations from the air. The system could provide new information about the effects of global climate change.

Ice Radar:

NASA Grant Enables Development of Novel Radar to Map Ice Formations Remotely

By Rick Robinson

Photo: Gary Meek



Radar sub-arrays developed by Georgia Tech researchers John Papapolymerou, John Cressler and Ted Heath use a multi-layer substrate made of liquid crystal polymer and Duroid to house silicon-germanium integrated circuits.

The National Aeronautics and Space Administration (NASA) has awarded $2.4 million to Georgia Tech to develop a new type of radar system that will be used to study the Earth's ice and snow formations from the air. The system could provide new information about the effects of global climate change.

The research will create a technological first: a small, lightweight, low-cost, phased-array radar that uses silicon-germanium (SiGe) chips in tandem with radio-frequency micro-electromechanical systems (RF MEMS). The system being developed could be mounted on aircraft or satellites to enable high-quality mapping of ice and snow formations.

Traditionally, research on frozen areas has required bulky radar equipment that must be operated on the surface, said John Papapolymerou, a professor in Georgia Tech's School of Electrical and Computer Engineering who is principal investigator on the project. The lightweight radar approach could allow unmanned aerial vehicles (UAVs) to gather information by flying over a large area such as Greenland, using the radar system to map ice sheets in three dimensions.

"This aerial approach would greatly facilitate environmental remote sensing of ice, allowing us to map larger areas of interest to better understand location, quantity and composition," said Papapolymerou, who will work with another Georgia Tech professor, John Cressler, and Ted Heath, a Georgia Tech Research Institute (GTRI) senior research scientist. "This mapping ability is very important because we need to know about ice accumulation, consistency and stability," added Papapolymerou.

Phased-array radar technology uses fixed, interconnected antenna elements to send and receive multiple radar signals almost simultaneously. This approach employs a technique called phase-shifting to electronically steer the radar-signal beam.

By contrast, a conventional radar antenna changes the direction of the signal beam mechanically; the antenna moves physically among set positions, sending and receiving signals at each position. The serial approach used by conventional radar generally offers slower and less-effective performance than the more parallel technique of phased-array radar.

The basic sub-array unit under development consists of a flat grid with eight antenna elements on a side – 64 elements in all. These sub-arrays, measuring about 8.5 by 7 inches, can be combined to create a far larger radar array capable of high-quality 3-D mapping.

The sub-arrays are constructed using polymers as the substrate, which is the board-like structure in which the electronics are embedded. Polymers have numerous advantages; robust, flexible and low cost, they also offer good electrical performance.

The researchers have produced and successfully tested an eight-by-two-element sub-array mounted on a multi-layer substrate. This substrate

consists of a layer of liquid crystal polymer (LCP), which is a robust organic polymer, and a layer of a composite material called Duroid.

The LCP/Duroid substrate houses integrated circuits made from silicon-germanium (SiGe). The SiGe chips transmit and receive the radar signals via the sub-array's multiple interconnected antenna elements.

The researchers chose silicon-germanium because it offers high-performance signal amplification that is also low in noise and power consumption, said Cressler, who is a Ken Byers professor in the School of Electrical and Computer Engineering. SiGe chips are also robust, low in cost and highly resistant to weather and to radiation encountered in space.

"Using silicon-germanium allows much higher levels of integration, which older radar systems don't give you," Cressler said. "It enables you to go from a system which is much larger and more expensive, and less robust, to a chip that is only a few millimeters on a side and costs far less."

Silicon-germanium circuits also interface well with RF-MEMS systems, which are tiny micro-electromechanical devices capable of movement on a very small scale. The team is using RF-MEMS devices, embedded in the substrate, to perform two functions – switching between the transmit and receive circuits, and activating phase-shifters that electronically guide the radar signals sent by the sub-array's 64 antenna elements.

GTRI's Heath and his team are developing the hardware that controls the electronic components, such as the field-programmable gate arrays used by the phase-shifters to electronically steer the signal beam. The GTRI team is also designing the power supplies required by the system.

"GTRI is tasked with taking the silicon-germanium MEMS transmit-receive elements and putting them into a functioning radar system," Heath said. "These back-end electronics supply the power to those chips, as well as provide the signal processing and conditioning that steer the signals, and the processing of the raw data coming back."

Papapolymerou added that this approach to phased-array technology is expected to have uses in a variety of defense and commercial applications. rh

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"This aerial approach would greatly facilitate environmental remote sensing of ice, allowing us to map larger areas of interest to better understand location, quantity and composition. This mapping ability is very important because we need to know about ice accumulation, consistency and stability."

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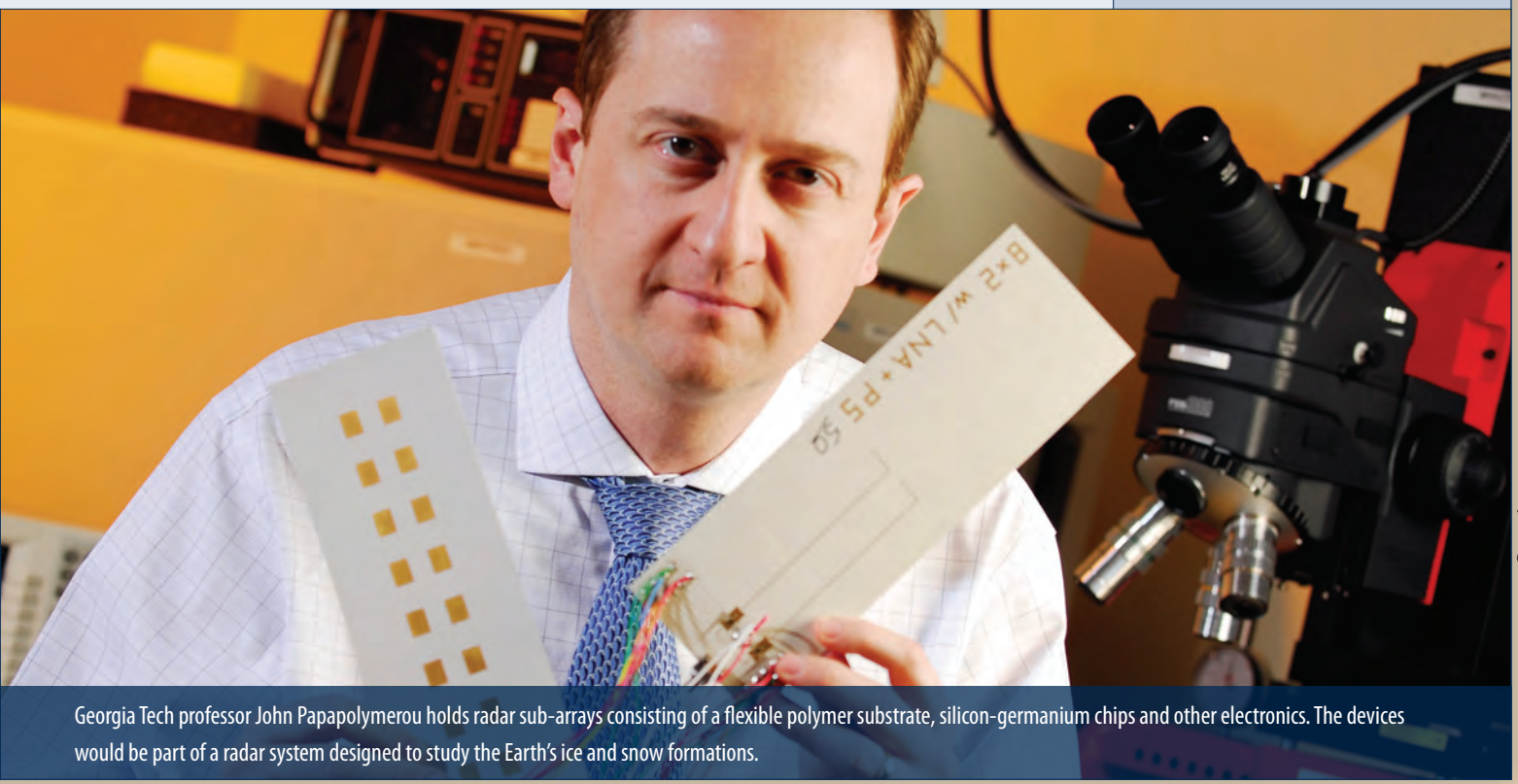

Georgia Tech professor John Papapolymerou holds radar sub-arrays consisting of a flexible polymer substrate, silicon-germanium chips and other electronics. The devices would be part of a radar system designed to study the Earth's ice and snow formations.

Photo: Gary Meek

Powerful processors and flexible software developed to power computer and video games are being adapted for a broad range of "serious" uses that include defense, education, industrial safety and therapy. In many cases, use of this entertainment technology facilitates applications that might not otherwise be practical or cost-effective.

Serious Gaming:

Entertainment Technology Yields Results for Research Ranging from Defense to K-12 Education

By Rick Robinson

In a laboratory at Georgia Tech, researchers gaze intently into a line of large flat-screen monitors. Using hand-held devices and famous-name gaming software, they guide on-screen vehicles through winding streets and around or over obstacles. Groans can be heard when a vehicle doesn't make the grade.

No, it's not break time in the lab. The gaming activity here is serious, aimed at investigating ways in which a robot might move through complex environments. Its ultimate purpose is to provide the U.S. military and other government agencies with tiny autonomous devices that could carry

Photo: Gary Meek

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

out combat or disaster-relief missions.

The term serious gaming might seem to be an oxymoron, like "static electrons." But in today's pragmatic research world, investigators from numerous Georgia Tech units are appropriating technologies, practices and even equipment from both digital and real-world games. Then they're applying those gaming techniques to defense, industry, education, health care and more.

Definitions of serious games and gaming vary. Still, most definitions cite the use of gaming technologies for purposes other than entertainment.

On-screen games such as Pong go back to the 1970s, but during the past 20 years the computer- and video-game world has expanded very rapidly. This digital revolution has produced powerful game "engines" – the basic code underlying a digital game – that are now widely available to aspiring game developers.

The result is that today's game technologies are often highly user-configurable, a process called "modding" (short for modification); that adaptability helps make them useful for research purposes. Even gaming hardware is being modified for use in applications that its designers probably never envisioned.

This article provides a look at a variety of Georgia Tech research efforts related to serious games.

Using Games for Robotics Research

At the Georgia Tech Research Institute (GTRI), a research team is using game-engine technology to support an ambitious program to develop tiny mobile robots that are both intelligent and interactive.

The overall effort is called the Micro Autonomous Systems and Technology (MAST) Collaborative Technology Alliance Program. It's hoped that this five-year effort will result in rolling, hopping and even flying devices that could aid the military and other agencies in combat, disaster relief and other tasks.

The MAST research program, which includes Georgia Tech, 13 other universities and BAE Systems Inc., is sponsored by the U.S. Army Research Laboratory. GTRI and the College of Computing are among several Georgia Tech units involved in the program.

To date, no truly autonomous robots actually exist, much less tiny ones that can move cooperatively through unpredictable environments. To gain insight into the many challenges involved in such technology, researchers are turning to game-development techniques, said GTRI principal research engineer Lora Weiss.

"To design micro-autonomous systems, we first need to explore in a virtual way how they might behave in the real world and interact with one other," she said. "And a good way to start exploring them is with game engines, because you can examine robotic systems using the synthetic entities found in many game worlds."

By combining a widely available computer-game engine with open-source software called USARSim – short for urban search and rescue simulation – the GTRI engineers can simulate many challenges that robotic hardware might encounter. Modifying game parameters to suit their purposes, engineers can rapidly construct a three-dimensional world – complete with reasonably accurate 3-D physics – to test a variety of concepts.

"What we're trying to do here is look at high level – but not high-fidelity – interactions of dynamic systems," Weiss said. "We're using this approach on several robotics projects."

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GTRI principal research engineer Lora Weiss is using game engines to simulate the many challenges that robotic hardware may encounter.

Photo: Gary Meek

Photo: Gary Meek

Assistant professor Mark Riedl of the Georgia Tech School of Interactive Computing has utilized a popular computing-gaming engine to develop cultural role-playing simulations for soldiers who may soon face challenging situations overseas.

High-level analysis, she explains, focuses only on behavior. For example, can a robot with certain attributes move successfully across an intersection, or might a car hit it on the way?

At this level, the high-fidelity physical details of robot motion or car damage are not vital. What's most important is understanding whether the robot can apply reason to the situation and then activate an avoidance behavior.

"Game engines and virtual worlds allow exploring these interactions in ways that, until we understand the issues, are much safer than building systems and identifying problems the hard way," Weiss said.

However, once behavioral basics have been worked out, researchers will likely leave the game world and move to more high-fidelity simulations. Such simulations offer greater accuracy and rigor that would help investigators understand the complex physics necessary to design and build a robot prototype.

Those future hardware prototypes will have their functionality evaluated by computer-based test equipment, a process known as hardware-in-the-loop. Once a prototype seems to be working properly, final steps will involve rigorous field testing.

Getting small robots to operate collaboratively with humans will be another hurdle, Weiss acknowledges. That's a problem being addressed not only by Weiss, but by researchers in other Georgia Tech units, including College of Computing professors Charles Isbell and Mark Riedl (see "Applying Games to Complex Environments" on page 12 of this article).

"High-level modeling of humans collaborating with groups of robots will be particularly important as robots become more independent and less remote-controlled," Weiss said. "If robots are to exist with people and operate in shared spaces, then they must cooperate."

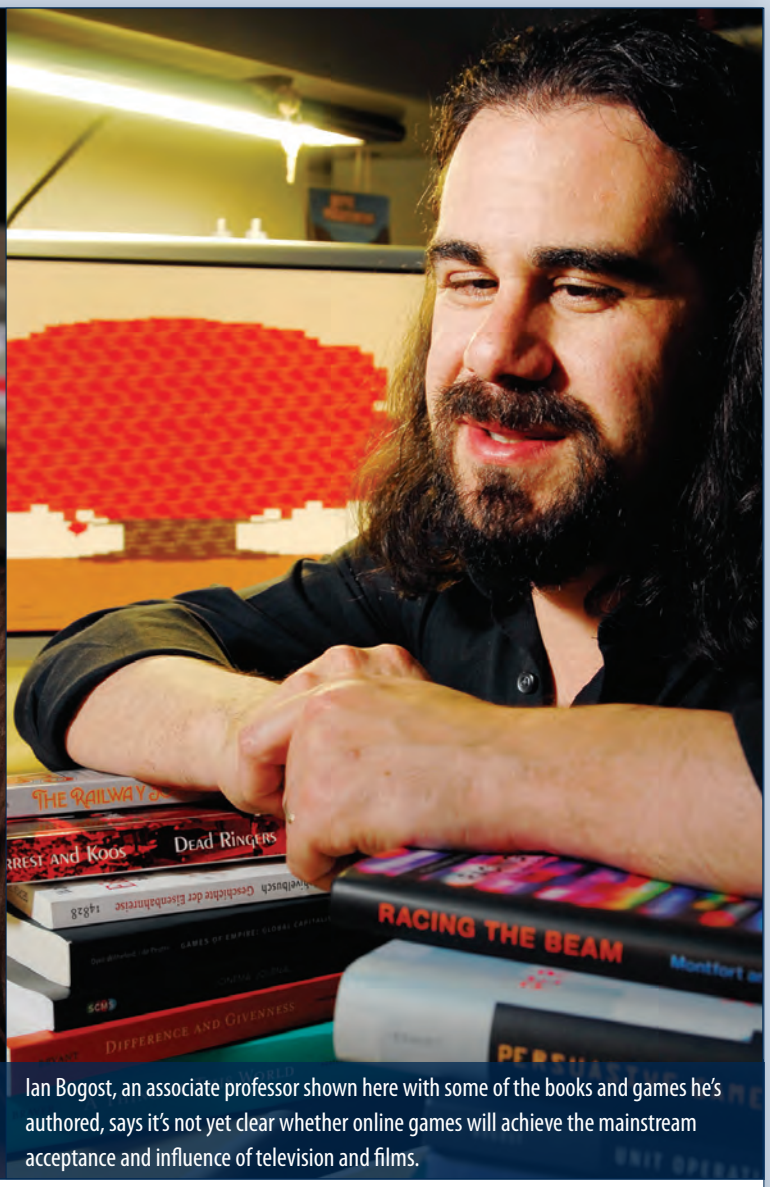
Pursuing Industrial Research with Game Hardware

Digital gaming equipment has become highly sophisticated – so much so that some investigators are using off-the-shelf game accessories for serious research and applications.

Photo: Gary Meek

Associate professor Charles Isbell, a specialist in statistical machine learning, is studying ways in which gaming elements can help improve machine-learning technology, and vice-versa.

Photo: Gary Meek



Ian Bogost, an associate professor shown here with some of the books and games he's authored, says it's not yet clear whether online games will achieve the mainstream acceptance and influence of television and films.

At GTRI, a team of engineers is developing a research device capable of analyzing physical stresses on the arms of workers in poultry plants. Critical to their approach is a Nintendo Wii game-console remote controller, known popularly as the Wiimote. This inexpensive controller's capabilities include advanced motion-sensing.

"Poultry workers typically stand and make the same cuts eight hours a day, and they have a risk of developing repetitive-stress syndrome," said GTRI research scientist Clayton J. Hutto. "There's a real need to study the ergonomics of poultry work to make it less physically stressful."

Existing motion-capture devices cost thousands of dollars, Hutto explained. In the wet environment of a poultry plant, their expensive electronics can be damaged quickly.

But motion capture based on the $30 Wiimote would be affordable even if the capture devices didn't last long. Moreover, at such reduced cost researchers could outfit multiple workers with capture devices, greatly increasing the amount of motion data gathered.

GTRI's work with the Wiimote goes back to 2006, the year the device was introduced. Intrigued by the Wiimote's capabilities, GTRI research engineer Donnie Smith developed the open-source CWiid library (pronounced seaweed) as an interface to the Wiimote's low-level message format. CWiid, programmed in the C language with bindings to an open-source language called Python, allows a Wiimote to work in a variety of platforms and uses beyond traditional games.

In 2007, supported by research scientist Josh Davis, Smith worked with fellow research scientist Nick Bollweg to develop a Wiimote-based head-tracking system. This system, pyWiiVR, consists of a Wiimote, a computer, wireless headphones and goggles that have been modified with inexpensive infrared sensors.

Connected to a computer via Bluetooth, the system provides immersive 3-D visualization and audio that changes realistically with a user's head movements. Such technology could have several military applications including training and mission preparation, the researchers said.

Collaborating with Jonathan Holmes, a researcher with GTRI's

Photo: Gary Meek

Georgia Tech Research Institute researchers Donnie Smith, Clayton Hutto and Nick Bollweg (l-r) are using commercially available gaming hardware to develop a device that measures physical stresses encountered by poultry industry workers.

Ergonomic Work Assessment System program, and Jessica Pater of GTRI's Office of Policy Analysis and Research, Hutto and his team have developed a Wiimote-enabled device that mounts on a poultry worker's lower arm. A Wiimote detects the location of four infrared LEDs and then transmits data gathered to a computer. Software transforms this information into arm and wrist angle data, which can be visualized and stored for analysis.

"So far, we're on track, and it's working very well," said Hutto. "We're also working on a feedback capability that instantly alerts a worker when he or she exceeds the recommended physical limits. If we can change worker behavior during the performance of an actual task, then we're really onto something."

Creating Environments for Training and Therapy

Game developers work hard to make electronic games more engaging. In fast-moving shooting games, computer-generated adversaries increasingly behave with human-like cunning. They can even take cues from human players' gaming styles to make the action more competitive.

In other digital amusements, such as role-playing games, programmers use artificial intelligence (AI) techniques to help create "drama managers." Working either in the background or as actual game characters, drama managers monitor player behavior and can quickly alter events to enhance a player's experience.

Mark Riedl, an assistant professor in the Georgia Tech School of Interactive Computing, is using the drama-manager approach to develop simulations for certain types of military training. For this application, he has developed the Automated Story Director, software that uses a drama manager as a kind of coach.

For example, he has used simulations created by the Automated Story Director to develop cultural role-playing scenarios for soldiers who may soon experience similar situations on real foreign streets. The work was sponsored by the U.S. Army Research, Development and Engineering Command.

"We create virtual characters with certain cultural qualities, and the user's goal is to pick up on what is happening in this foreign environment and to respond accordingly," Riedl said. "The virtual coach watches what you're doing, and if you're not picking up on things, it might, for example, send a character to talk to you to make it more obvious."

Riedl crafted this simulation using the software engine of a well-known shooting game. When he was finished with modifications, the carnage was gone; in its place, a role-playing game filled with edgy socio-cultural exchanges had emerged.

Photo: Gary Meek

Jessica Pater, a GTRI research associate, says immersive online environments such as Second Life and ActiveWorlds are performing increasingly useful roles in many K-12 classrooms.

Riedl – collaborating with School of Interactive Computing colleagues associate professor Charles Isbell and associate professor Ashwin Ram – is also working on AI-enhanced, scenario-generation software. This kind of software can model the learner and then automatically craft a customized interactive experience, catering to the learner's particular needs and abilities.

Using such scenario-generation software, learners enter an interactive, multiplayer virtual world. The software assigns roles to players, coaches them on how to play their roles – and can change the scenario on the fly depending on how things go.

"This technology could be useful in almost any area in which you might want to use a game or a simulated environment to educate," Riedl said.

In another education-related effort called Refl-ex, Riedl is developing software to aid children with autism. He is collaborating on Refl-ex with Rosa Arriaga, a senior research scientist in the Georgia Tech School of Interactive Computing, and L. Juane Heflin, an associate professor in the Department of Educational Psychology and Special Education at Georgia State University.

Refl-ex uses a game-like environment to repeat and reinforce interactions between the child and a therapist or teacher. Riedl explains that game experiences tend to be a hit with autistic youngsters, who sometimes prefer interacting with computers rather than humans.

"We have people with autism who go to therapy several times a week, and yet it's not enough," he said. "If they can play this game at home, it could add five or 10 hours per week of valuable interaction for them."

Applying Games to Complex Environments

Charles Isbell sees serious gaming as a two-way street.

An associate professor in Georgia Tech's School of Interactive Computing and an associate dean in the College of Computing, Isbell is a specialist in statistical machine learning – software that allows computers to learn and change based on incoming data.

Isbell's research goals include using gaming elements to improve machine-learning technology. He's also doing the reverse – employing machine-learning approaches to improve serious-gaming applications.

"I'm very interested in large, complex problems where communication is difficult, your goals change, and you need to work with other people or even other agents such as robots," he said. "Serious gaming has much to offer here, because these kinds of problems occur in a variety of social and other games."

Isbell's research includes three areas related to gaming:

- **Finding techniques to influence how people behave, especially in groups**.

In one recently initiated project, Isbell and his team are investigating ways to influence human subjects to adopt goals without obvious coercion – what Isbell calls "computational models of influence." This effort is related to Lora Weiss's work with the robotics program (see "Using Games for Robotics Research" on page 7 of this article).

Entertainment games, Isbell notes, typically limit players to a specific area until they've accomplished a given task. He wants players to pursue tasks on their own, and have a sense that they're acting of their own free will.

- **Developing tools to let non-programmers quickly build game-like environments for training simulations, modeling or other purposes**.

Working with School of Interactive Computing colleague Mark Riedl and others, Isbell is building tools to allow rapid development of models or game-like programs by non-programmers. The team is developing a language called A^2BL, which is an adaptation of a well-known programming language called A Behavior Language, or ABL.

"With A^2BL, you as a user can describe in simple terms what you're trying to accomplish, and with that information we can build a system for you," Isbell said.

- **Using gaming concepts to improve tools for statistical machine learning**.

Isbell and his team are using gaming concepts such as narrative to help re-envision approaches to machine learning. He sees a strong connection between mathematical sequences and the process of narrative.

Traditionally, machine learning focuses on immediate tasks rather than on sequences. In other words, it doesn't matter where you've been, it only matters where you are.

But narrative can help make machine learning more flexible, Isbell explains. "With a story, it matters very much where you've been and those of us in machine learning have something to learn from that."

Adapting Gaming Environments for the Classroom

Can the gaming worlds that keep kids anchored to computers for hours also help them in the classroom?

Jessica Pater, a GTRI research associate, has been investigating the use of gaming in education for several years. She believes that digital gaming technology can be a serious teaching tool.

"In K-12 education, there has been hesitation about using gaming in classrooms," she said. "But now, quite a number of schools are starting to use immersive environments to create experiences that kids otherwise wouldn't have."

One example: game-like environments that let students manipulate molecules in real time. This kind of technology, limited to supercomputers only a few years ago, can allow youngsters to look at the actual bonds between different atoms, offering them a better understanding of how things work at the nanoscale level.

CONTINUED ON PAGE 15

Empowering Players to Create Their Own Games

Photo: Erik Lesser

Chris Klaus, founder of the online multiplayer environment Kaneva, wants to enable users to create their own 3-D web-based applications and serious games. He is shown here speaking at the FutureMedia Conference held in Atlanta in October 2009.

Atlanta-based Kaneva, which has created a unique online environment, wants participants to generate their own 3-D casual games and other content for the Kaneva community.

Kaneva was founded by Georgia Tech alumnus Chris W. Klaus, who sold his Internet Security Systems company to IBM for $1.3 billion in 2006. Kaneva is definitely MMO – massively multiplayer and online – but it views itself as more of an environment, an enabling tool for its users.

"Kaneva is Latin for canvas, and our mission has always been to provide a digital canvas for our online community with 3-D game graphics and video technology," Klaus said. "Now we're entering into the phase of empowering these environments with gaming mechanics, so that ultimately our community will create its own 3-D games, serious and otherwise."

Klaus said he's already seeing users exploit the Kaneva space to achieve their own goals. When singer Michael Jackson died, site members immediately used the website's tools to create a variety of 3-D graphical memorial spaces.

And Klaus points to the more than 20,000 churches created by Kaneva users as another means of self-expression.

"If you go into one of these online churches, you will see immediately that this is definitely not a game," he said.

One area where Klaus particularly expects game-like environments to develop involves Kaneva's home decorator application. The website lets users upload their own photos and other graphics and then use Kaneva's 3-D tools to produce a multitude of design variations.

"If you then add some game mechanics such as points, prizes and levels," Klaus said, "you're well on your way to creating a serious online game that many users would also find fun and satisfying."

— Rick Robinson

Using Games to Broaden Participation in Computing

Digital games are basically computer software programs. When users look under the hood at how games are put together, they start to see how software programming works.

A games-oriented introduction to programming was one goal of a project completed in summer 2009 by Amy Bruckman, an associate professor in the Georgia Tech School of Interactive Computing, and Betsy DiSalvo, a doctoral candidate. Called Glitch Gametesters, the project employed 12 Atlanta-area minority high school students to test computer games.

The program, sponsored by the National Science Foundation, was not all fun and games. The students' paid positions required them to work in a computer lab seven hours a day for eight weeks.

Their work involved finding malfunctions in computer games that are under development. The group was supervised by DiSalvo and by several computer science majors from Georgia Tech and from Atlanta-based Morehouse College.

"Essentially, we're taking entertainment games and using them for more serious applications," DiSalvo said. "Our larger goal is to broaden participation in computing."

Computer scientists, she said, often report that their interest in computing started with digital games. Yet, although African-American youth are often intensely involved in video-game competition, they don't enter computer science in a ratio that's proportionate to their interest in gaming.

DiSalvo and Bruckman are using the students' gaming enthusiasm to help them uncover the computation beneath computer games. Summer and after-school job programs as game testers bring the students together with games that still need plenty of work.

"They test the games," said DiSalvo, "which basically means they break them. In other words, they're trying to figure out where the computation is breaking down and where the developers need to go back in and fix the software code."

Bruckman stresses that the programs being tested are real games being developed by commercial companies.

"The kids find a bug, send a report to the developers, and then they get a new version of the game back the next week with the bug fixed," she said. "So they watch the feedback that they're giving to the game company have a real impact."

When the students began their 2009 summer jobs, two of the 12 said they wanted to be computer science majors in college. By the end of the session, eight favored such a major.

The student game testers continued to work part time during the 2009-2010 school year. And 23 high school students are participating in the program during summer 2010.

Bruckman, who directs Georgia Tech's Electronic Learning Communities Group, believes that gaming will become even more popular in the future. More work needs to done on creating games that are enjoyable yet productive. She admits that's a tall order, but adds that future research could show how it can be done.

"I see many people spending a lot of time on games – sometimes staggering amounts of time," she said. "If we could enhance ways to make that time productive, and productive for society, I think that would be a big win."

— Rick Robinson

Researchers in the School of Interactive Computing initiated the Glitch Gametesters program, in which Atlanta-area students pursue summer and after-school jobs that involve pinpointing software errors in commercial digital games. The Glitch program's ultimate aim is to increase students' interest in computer science.

Photo: Rick Robinson

Also useful, Pater said, are immersive online environments such as Second Life and ActiveWorlds, also known as massively multiplayer online environments. These applications support development of simulations that can dramatize scientific subjects for middle school and high school students.

"Historically, schools have lacked the bandwidth to support these applications," Pater said. "As the price of bandwidth continues to fall, more of these opportunities are starting to take hold in schools."

Working with Georgia's DeKalb County schools, Pater and colleagues are developing a learning environment within the Teen Second Life application. Using a Second Life island – a secure area only students can access – the GTRI-DeKalb team is creating a project called "Small Fry To Go."

Based on a real-world DeKalb project where students raise trout at school-based hatcheries, Small Fry To Go extends that trout-growing venture into an immersive virtual world. In this world, students can investigate the underwater environment of trout fry (hatchlings) and make critical decisions about hatchery conditions.

"The intent is to teach environmental responsibility and show the impact of our decisions on the environment," Pater said.

One downside to using immersive spaces for online education is the unevenness of funding for classroom technology, she said. Less-affluent school districts may lack the money to install the required equipment, to buy space in online environments or to maintain the immersive domain.

Other Georgia Tech units are also investigating the educational potential of online environments. The Center for Education Integrating Science, Mathematics, and Computing (CEISMC) is sharing in a new five-year, $3 million NASA grant to Georgia Tech aimed at supporting science, technology, engineering and math (STEM) education in K-12 schools. Mike Ryan, CEISMC's program director, will lead a course that uses Second Life to help develop online environments.

"Being online doesn't replace the curriculum – it augments it in a way that gets kids excited," Pater said. "It's basically an immersive space where teachers can go and create rich content for their kids."

Weighing the Seriousness of Games

What makes one game serious and another just entertainment?

Ian Bogost believes that distinction is in the eye of the beholder. He suggests any game or environment that affects people's lives should be viewed as serious, regardless of its original intent.

Bogost's research often focuses on the cultural roles played by the fast-growing gaming field. He's interested in mainstream commercial video games, but also in games that go beyond entertainment to address politics, advertising, learning or art.

"I'm interested in upsetting the solid line between seriousness and entertainment," said Bogost, an associate professor in the Georgia Tech School of Literature, Communication and Culture. "Can you really label a game as pure commercial entertainment if, in fact, it has tremendous influence in the cultural sense?"

He points to SimCity, a popular game that lets users design urban areas from scratch. This hit game, he said, was not conceived as a serious tool for urban planning.

"But it has clearly created a certain interest in urban planning as a concept," he argued. "And that has probably been responsible for inspiring an entire generation of potential urban planners – or at least aware citizens who attend their local city council meetings."

Second Life and other online environments are increasingly used formally in education, Bogost observes. But, he asks, what about more casual uses? Couldn't such environments also be viewed as serious if users find friendships and a sense of satisfaction online?

Even real-world games involve serious elements, Bogost notes. Basketball was devised as a way to keep poor children amused and out of trouble. Football is often touted for its character-building influence.

And, he points out, the issue of serious games is on the minds of many in the game-development world. For instance, the annual Game Developers Conference has for six years included a sub-conference that focuses squarely on serious-gaming issues.

Bogost's 2007 book, *Persuasive Games: The Expressive Power of Video Games,* looks at the capacity of both commercial and other games to act as an influential medium. In particular, the book examines three areas where video-game persuasion shows potential: politics, advertising and education.

Bogost has published a large number of other books, articles and games. In 2007, *The New York Times* took the novel step of publishing a number of Bogost-developed games online.

One example is a game dealing with the failed McCain-Kennedy immigration bill of 2005. This game, playable online, offered a fictional competition between immigration agents. It conveyed details about this complex piece of legislation and made critical points about the nature of immigration politics.

Bogost's most recent book, *Newsgames: Journalism at Play*, written with students Simon Ferrari and Bobby Schweizer, examines the potential role of video games in journalism. His current research also includes a project sponsored by the Knight Foundation that examines the developing relationship between journalism and gaming.

"News is changing, and the media are going to have different roles to play," he said. "I don't believe for a minute that reading will go away, but I think there will be new roles for tools such as video games."

Bogost is working on a book that focuses on the diverse uses of digital gaming.

"Today, video gaming is a hot medium, though it's been around for 30 years already," he said. "It could turn out to be more or less a child's toy or a fad, or it could achieve the mainstream acceptance and influence of television and movies. What we're going to do with gaming is an open question."

Photos: Gary Meek

Assistant professor Celia Pearce, seated, works with students to develop games that tackle real-world themes such as current environmental practices or the experiences of American immigrants.

Celia Pearce, an assistant professor in the School of Literature, Communication and Culture, in interested in games that push the boundaries of online play. Her Emergent Game Group develops games that offer a viewpoint on the real world – such as this one where players assume the roles of new immigrants to the United States.

Merging Game Worlds with the Real World

Serious games don't have to be solemn. Some researchers are investigating the potential for online games to be constructive and social and also appealing to a broad range of people.

Celia Pearce, an assistant professor in the Georgia Tech School of Literature, Communication and Culture, is interested in games that push the boundaries of online play. Working with her Emergent Game Group, she develops large-scale multiplayer game worlds that offer a viewpoint on the real world.

"I'm not sure I like the term 'serious gaming' – it could imply that a game is belaboring a point or is didactic," she said. "Other terms that might work better are 'activist games' or 'games for change.'"

Among the projects that Pearce and her team are working on is "Mermaids," an experimental multiplayer game set underwater among the ruins of an extinct mermaid culture. Players must rebuild this lost culture while trying to avoid their ancestors' fatal mistakes, which are unknown.

"This isn't a blatantly activist game, but it has a very green subtext," Pearce said. "Teachers have told us it could be a good way to teach about environmentalism."

Project Passage is a suite of historical digital and board games. The digital game of the group, called "Five Boroughs," takes place in the New York City of 1928, where players assume the roles of new immigrants.

Unlike many commercial games, where players lock themselves into a fully fledged character from the start, Project Passage players must familiarize themselves with their new world before they make important choices, Pearce said. Moreover, they even get opportunities to back out of those decisions if they want.

"If you look at the narrative of many games, everything is oversimplified – you're either good or bad, a criminal or a cop," she said. "Our game introduces nuances and ambiguities that often don't get included in games, and are more similar to how the real world operates."

These experimental games are developed under Pearce's direction by students who get credit for each project studio they participate in.

"It's kind of a market-driven program," Pearce said. "We announce each semester what projects we're doing, and the students work on the projects they're interested in."

Pearce – author of *The Interactive Book* (Macmillan 1997) and *Communities of Play: Emergent Cultures in Multiplayer Games and Virtual Worlds* (MIT 2009) – has also created games that blend the digital world with real-world activity.

In one game created by students in her group, participants are contacted by an international cast of characters from the future who report on the damage caused by current environmental practices. Players help one another complete real-world missions aimed at cleaning up today's biosphere.

Pearce, who is also involved in independent game development, laments that the commercial gaming industry generally isn't interested in funding projects that push the envelope.

"But who knows," she adds. "If some of the more experimental games found a substantial following, that could change." rh

FutureMedia: Getting Serious About Georgia's Media Potential

Serious gaming is one part of the digital media landscape that's of interest to FutureMedia[sm], a Georgia Tech initiative that seeks to help the state of Georgia become a global pioneer and leader in the future of digital, social, and mobile media.

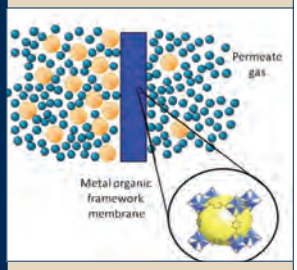
Business and technology professionals in the state believe that goal can be achieved, says Renu Kulkarni, executive director of the initiative for Georgia Tech. But, she adds, they agree that it will require focus and determination – and sustained collaboration among universities, corporations, venture capitalists, entrepreneurs and government.

The FutureMedia initiative was kicked off in October 2009 during a day-long conference hosted by Georgia Tech. The conference, initiated by the Georgia Tech Research Institute (GTRI) and sponsored by Turner Broadcasting and Motorola, attracted 260 participants from as far away as South Korea.

A four-day FutureMedia Fest 2010, slated for October in Atlanta, is expected to include keynote speakers and expert panels from throughout industry and academia, as well as demonstrations of media-related research at Georgia Tech and other Georgia institutions. For more information, see www.futuremediaglobal.com.

Computational modeling tools could accelerate development of a new type of membrane technology that will boost the efficiency of energy-related gas separations. The tools will help researchers identify the best candidate materials for use in new metal-organic framework (MOF)membranes now under development.

Illustration: Seda Keskin



This illustration shows how a metal-organic framework membrane would work with large-scale energy-related separations.

Energy-Efficient Separations:

Researchers Use Computational Modeling to Design Improved Membrane Technology

By John Toon

Computational modeling tools developed at Georgia Tech could accelerate development of a new type of membrane technology that will boost the efficiency of energy-related gas separations. The tools will help researchers identify the best candidate materials for use in new metal-organic framework (MOF) membranes now under development.

MOF membranes offer an alternative to more energy-intensive processes for separating gases such as carbon dioxide, methane, nitrogen and hydrogen. The technology has generated significant interest because of the broad range of crystalline structures that can be synthesized, but development of new MOF membranes is still at an early stage.

"Metal-organic framework membranes will be useful for doing large-scale, energy-related separations in an efficient way," said David Sholl, a professor in the Georgia Tech School of Chemical and Biomolecular Engineering. "We are trying to accelerate their development to help move the world's energy economy toward a more sustainable path."

A publication on the use of atomically detailed calculations for designing metal-organic framework membranes was cited by *ScienceWatch* as its "fast-breaking paper in engineering" for February 2010. Details of the work were published in the journal *Industrial Engineering Chemical Research* in Jan. 2009. The research was funded in part by the National Science Foundation (NSF).

Metal-organic framework materials are nanoporous crystals that combine metal-organic complexes with organic linkers to create highly porous frameworks. They offer advantages such as high surface area, porosity, low density and both thermal and mechanical stability – all important for separation membranes.

There are many possible material combinations that could be used in the membranes. By comparing such properties as binding strength and flow rates, the computational modeling could give researchers a way to rapidly identify the materials that will work best in high-volume industrial applications.

"The extra challenge with using metal-organic frameworks is that there are literally thousands of different materials that could be considered for use," said Sholl, who is a Georgia Research Alliance eminent scholar in energy sustainability. "This is where computational modeling really helps. We are doing the materials screening problem computationally to guide us in attacking the actual fabrication problem experimentally."

Sholl hopes the technique will narrow the list of candidate materials from thousands down to as few as 10. Researchers would then fabricate the membranes and test them in real-world conditions.

"If we were testing all of these in the lab without the computational guidance, it's unlikely that we would ever choose the right material," he said. "The biggest challenge for making a new membrane is that it really requires a lot of work to make a functioning device. Even if we know exactly what material to use, there is a very long development path."

At Georgia Tech, Sholl's modeling group is working with experimentalists such as Sankar Nair and Christopher Jones – both professors in the School of Chemical and Biomolecular Engineering – to produce prototype membranes for evaluation.

"The big push right now is to make some devices and get test data," Sholl said. "In particular, we want to do this within a technology framework that we know can scale up to real-world industrial levels quickly."

In addition to colleagues at Georgia Tech, the group is also working with industrial partners to help ensure that the membranes work in industrial conditions.

"If we can go from the idea in the academic lab to a serious field test within five years, that would be a real success," said Sholl, who holds the Michael Tennenbaum Family Chair in the School of Chemical and Biomolecular Engineering. "We can't afford for this to take 25 years because there is a need for this technology now."

The new membrane technology could be used to address environmental issues such as cost-effective removal of carbon dioxide from stack gases of coal-burning facilities. The technology could also make it economically attractive to use natural gas supplies that are contaminated with carbon dioxide, potentially expanding supplies of that fuel.

The researchers, including graduate student Seda Keskin, have modeled how the membrane technology would operate in separating methane from carbon dioxide, hydrogen from carbon dioxide, nitrogen from carbon dioxide, hydrogen from methane, nitrogen from hydrogen and methane from nitrogen.

"The common thread of this work is that we are interested in very large-scale, large-volume applications that can only be economical with very low energy input," Sholl added. rh

This research was supported in part by the National Science Foundation (NSF) under grants CTS-0413027 and CTS-0556831. The content of this article is solely the responsibility of the principal investigator and does not necessarily represent the official view of the NSF.

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"Metal-organic framework membranes will be useful for doing large-scale, energy-related separations in an efficient way. We are trying to accelerate their development to help move the world's energy economy toward a more sustainable path."

— David Sholl, professor in the Georgia Tech School of Chemical and Biomolecular Engineering

A research team headed by Prof. David Sholl has developed computational modeling tools that could accelerate development of a new type of membrane technology that would be useful in energy-related separations.

Photo: Georgia Research Alliance

Could the unique properties of nanometer-scale materials be used by rogue nations or organizations to create a global security threat? Margaret E. Kosal explores that possibility – and potential countermeasures – in her new book, *Nanotechnology for Chemical and Biological Defense*, published by Springer Science Academic Publishers.

Nano Defense:

New Book Explores Potential Chemical and Biological Threats from Nanoscience and Nanotechnology

By John Toon

Nanoscience and nanotechnology promise clever new ways to target cancer cells, novel materials with amazing properties, smaller and more powerful computers, new approaches for cleaning up the environment and a host of other advances.

But could the unique properties of nanometer-scale materials be used by rogue nations or organizations to create a global security threat? Margaret E. Kosal explores that possibility – and potential countermeasures – in her new book, *Nanotechnology for Chemical and Biological Defense,* published by Springer Science Academic Publishers.

An assistant professor in the Sam Nunn School of International Affairs at Georgia Tech, Kosal argues that the unique concerns raised by nanotechnology must be part of the threat scenarios considered by the U.S. defense and homeland security communities. Strategies to address the threats could include developing a better understanding of their real potential and fostering improved international cooperation.

"We are moving away from many of the limiting conventional assumptions about warfare to incorporate insurgencies and asymmetrical warfare, including the potential for non-state actors and substate actors to appropriate technology in ways they haven't before," she said. "Part of the nature of nanotechnology is that it is fundamentally dual use. Much about its applications depends on the intent of the individuals pursuing it."

Ironically, the mechanisms that make nanotechnology beneficial could also be part of its dark side.

For instance, the ability to target cancer cells by recognizing their specific genetic sequences could also potentially be used to deliver toxins to harm healthy cells. Carbon nanotubes, useful in electronics and other technology areas, could also be used to circumvent vaccines by delivering protein cargoes directly into cells. Magnetic nanoparticles developed to draw therapeutics to diseased areas of the body could also be bombarded with electromagnetic energy to create excessive heat in the brain or other organs.

Of course, such evil application of nanotechnology would require research and development capabilities beyond those of non-Hollywood terror organizations. But as the proliferation of nuclear weapons enabled by Pakistani nuclear scientist A.Q. Khan demonstrated, state-developed technology can sometimes find its way into the wrong hands.

"We are thinking about a rogue scientist working at some level below official channels to pursue something that could have negative impacts," explained Kosal. "This is not something that terrorists are going to be using soon, but it is a threat we need to anticipate when looking forward 15 or 20 years."

Kosal's book is based on her own independent research, field work and case studies – and on concerns and scenarios developed in a January 2007 workshop she organized and chaired. The event was attended by more than 100 U.S. experts, in-

Magnetic nanoparticles, shown here, could be used to improve chemical separations or to localize drugs in the body. Could they also be used for harmful purposes?

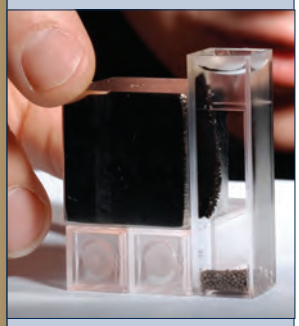

Photo: Gary Meek

cluding scientists and engineers involved in nanoscience and nanotechnology, researchers from defense laboratories, social scientists concerned about policy issues, policy-makers, members of the intelligence community, and "operators" – soldiers, sailors, Marines and others who might actually use the technologies.

The groups considered what the threats might be, what kinds of countermeasures might be needed, and what strategies should be developed to counter the threats. They considered scenarios that have been published in scientific journals, ignoring the "science fantasy" ideas that have been popularized in the general media.

"We need to start developing strategies now to be able to lessen the potential for malfeasant applications of these technologies," said Kosal, who has a Ph.D. in chemistry and served for two years as a science and technology advisor in the Pentagon's Office of the Secretary of Defense. "People have thought about this at a very high level, but what we need to do is dive more deeply into it and explore the potential nanotechnology threat in a much more analytical and systematic way."

The work was supported in part by the Defense Threat Reduction Agency's Chemical and Biological Technologies Directorate.

Nanoscience and nanotechnology differ from earlier technological revolutions because they are global and interdisciplinary, and therefore cannot be readily restricted through conventional arms control methods, noted Kosal, who is a member of Georgia Tech's Center for International Strategy, Technology and Policy (CISTP). In their first decades, atomic bomb technology and even biotechnology could be limited to just a few nations and their courses set by a handful of scientists and political leaders. But nanotechnology isn't like that.

"We can't be sure where the nanotechnology weapons may arise," Kosal said. "There are programs in every developed nation to pursue nanotechnology, and a lot of developing nations have them, too. The reality of the globalized world is that we can't just pull together a hundred scientists and engineers to decide what will be the norms for this new technology." rh

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— Margaret Kosal, assistant professor in the Sam Nunn School of International Affairs at Georgia Tech

Assistant professor Margaret Kosal, shown here in Georgia Tech's Nanotechnology Research Center, warns that nanoscale materials could be used by rogue nations or organizations to create security threats. Beyond analyzing the threats, her new book also suggests potential countermeasures.

Photo: Gary Meek

Field studies have shown for the first time that several common species of seaweeds in both the Pacific Ocean and Caribbean Sea can kill corals upon contact using chemical means. While competition between seaweed and coral is just one of many factors affecting the decline of coral reefs worldwide, this chemical threat may provide a serious setback to efforts aimed at repopulating damaged reefs.

Photo shows an experimental coral that had been in contact with the green seaweed *Chlorodesmis*. The white area of the coral is where contact with the seaweed has caused damage or death in the coral.

Photo: Douglas Rasher

Killer Seaweed:

Researchers Offer First Proof That Chemicals from Seaweeds Damage Coral on Contact

By John Toon

Field studies have shown for the first time that several common species of seaweeds in both the Pacific Ocean and Caribbean Sea can kill corals upon contact using chemical means.

While competition between seaweed and coral is just one of many factors affecting the decline of coral reefs worldwide, this chemical threat may provide a serious setback to efforts aimed at repopulating damaged reefs. Seaweeds are normally kept in check by herbivorous fish, but in many areas overfishing has reduced the populations of these plant-consumers, allowing seaweeds to overpopulate coral reefs.

A study documenting the chemical effects of seaweeds on corals was published May 10, 2010, in the early edition of the journal *Proceedings of the National Academy of Sciences* (PNAS). The research was supported by the National Institutes of Health, the National Science Foundation, and the Teasely Endowments at the Georgia Institute of Technology.

"Between 40 and 70 percent of the seaweeds we studied damaged corals," said Mark Hay, a professor in the School of Biology at Georgia Tech. "We don't know how significant this is compared to other problems affecting coral, but we know this is a growing problem. For reefs that have been battered by human use or overfishing, the presence of seaweeds may prevent natural recovery from happening at all."

Coral reefs are declining worldwide, and scientists studying the problem had suspected that proliferation of seaweed was part of the cause – perhaps by crowding out the coral or by damaging it physically.

Using racks of coral being transplanted as part of repopulation efforts, Hay and graduate student Douglas Rasher compared the fate of corals of two different species when they were placed next to different types of seaweed common around Fijian reefs in the Pacific and Panamanian reefs in the Caribbean. They planted the seaweeds next to coral being transplanted, and also placed plastic plants next to some of the coral to simulate the effects of shading and mechanical damage. Other coral in the racks had neither seaweeds nor plastic plants near them.

The researchers revisited the coral two days, 10 days and 20 days later. In as little as two days, corals in contact with some seaweed species bleached and died in areas of direct contact. In other cases, the effects took a full 20 days to appear – or for some seaweed species, no damaging effects were noted during the 20-day period. Up to 70 percent of the seaweed species studied turned out to have harmful effects, but only when they were in direct contact with the coral.

To confirm that chemical factors were responsible, Hay and Rasher extracted chemicals from the seaweeds – and from only the surfaces of the seaweeds. They then applied both types of chemicals to corals by placing the chemicals into a gel matrix bound to a strip of window screen, forming something similar to a gauze bandage, and applying that directly to the corals. To a control group of corals, they applied the gel and screen without the seaweed chemicals. The ef-

fects confirmed that chemicals from both the surface of certain seaweeds and extracts from those entire plants killed corals.

"In all cases where the coral had been harmed, the chemistry appeared to be responsible for it," said Hay. "The evolutionary reasons why the seaweeds have these compounds are not known. It may be that these compounds protect the seaweeds against microbial infection, or that they help compete with other seaweeds. But it's clear now that they also harm the corals, either by killing them or suppressing their growth."

The researchers studied coral of different species in the Pacific and Caribbean, matching them up against different species of seaweed common to their geographic areas. The coral species chosen – *Porites porites* near Panama and *Porites cylindrica* near Fiji – are among the hardiest of coral.

In the Caribbean, five of the seven seaweeds studied caused bleaching of the coral, while in the Pacific, three of eight species studied caused the effect.

The study reinforces the importance of maintaining a healthy ecosystem that includes enough herbivorous fish to keep seaweed under control.

"Removing the herbivorous fishes really sets up a cascade of effects," said Hay, who holds the Harry and Linda Teasley Chair in the Georgia Tech School of Biology. "The more you fish, the more seaweeds there are. The more seaweeds there are, the more damage is done to the coral. The less coral there is, the fewer fish will be recruited to an area. If there are fewer fish, the seaweeds outgrow the coral. It's a downward death spiral that may be difficult to recover from." rh

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"Between 40 and 70 percent of the seaweeds we studied damaged corals. We don't know how significant this is compared to other problems affecting coral, but we know this is a growing problem. For reefs that have been battered by human use or overfishing, the presence of seaweeds may prevent natural recovery from happening at all."

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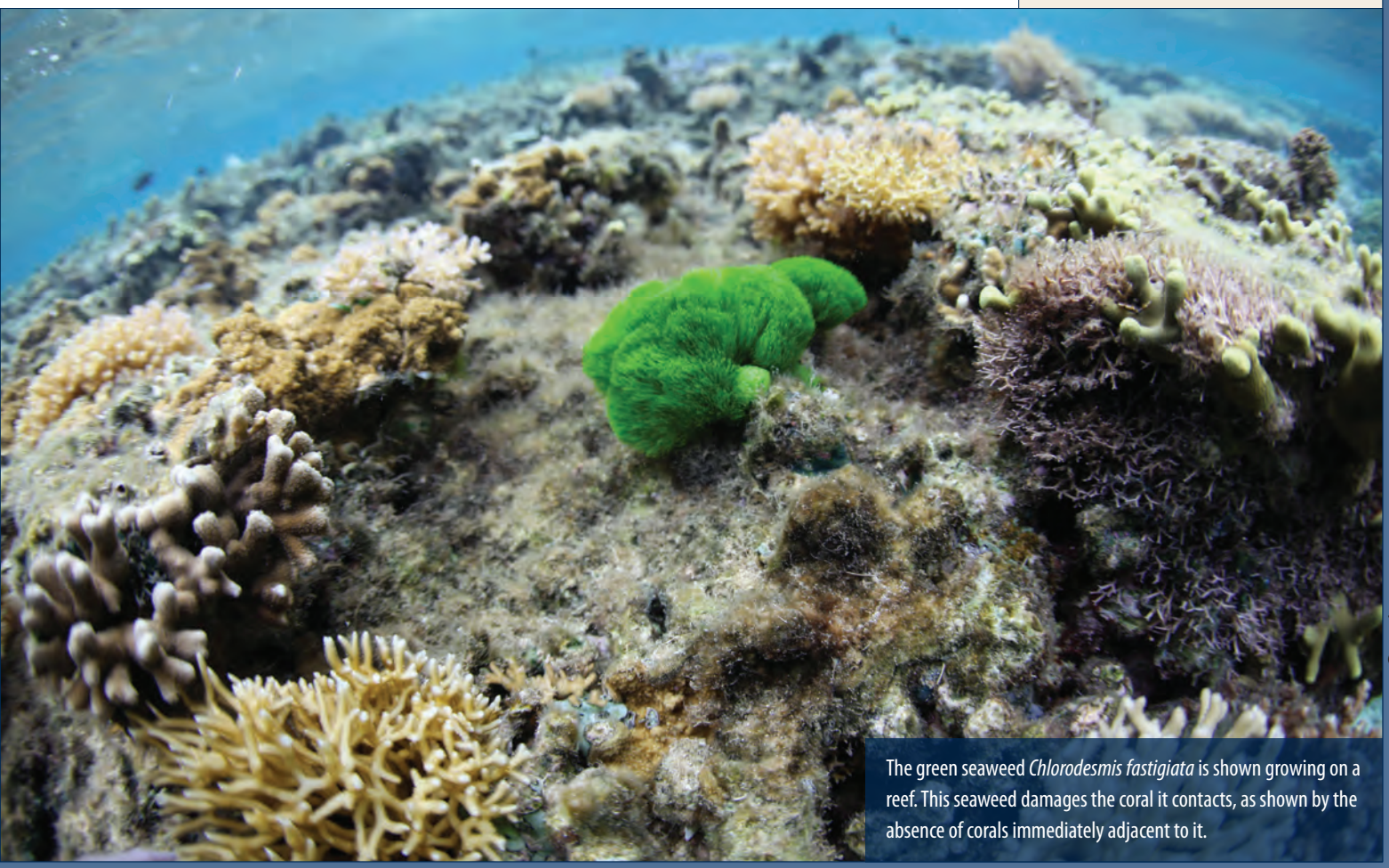


The green seaweed *Chlorodesmis fastigiata* is shown growing on a reef. This seaweed damages the coral it contacts, as shown by the absence of corals immediately adjacent to it.

Photo: Mark Hay

Work of Georgia Tech Researchers is Covered in the News Media

Field studies by Georgia Tech biologists have shown for the first time that several common species of seaweeds in both the Pacific Ocean and Caribbean Sea can kill corals upon contact using chemical means. While competition between seaweed and coral is just one of many factors affecting the decline of coral reefs worldwide, this chemical threat may provide a serious setback to efforts aimed at repopulating damaged reefs. Dozens of media outlets worldwide have picked up this news, including the *Christian Science Monitor*, *Discover Magazine*, MSNBC.com, the National Science Foundation's website, the *Sydney Morning Herald*, *The Telegraph* (United Kingdom), and WABE-FM, Atlanta's public broadcasting affiliate. (See the article on page 22 of this issue of *Research Horizons* magazine).

A new high-performance anode structure based on silicon-carbon nanocomposite materials and developed by materials researchers at Georgia Tech could significantly improve the performance of lithium-ion batteries used in a wide range of applications. The structure is produced with a "bottom-up, self-assembled" technique, using nanotechnology to fine-tune its materials properties. Dozens of media outlets have reported on this advance, including *Electronic Engineering Times*, Gizmag, *Industry-Week*, Maximum PC and *Popular Science*. (See the article on page 36 of this issue of *Research Horizons* magazine).

NASA has awarded $2.4 million to a team of Georgia Tech researchers to develop a new type of radar system that will be used to study the Earth's ice and snow formations from the air. The system could provide new information about the effects of global climate change. Among the media outlets reporting on this project were the *Atlanta Business Chronicle*, *Compound Semiconductor*, *National Defense*, *InTech*, *Semiconductor Today*, and WABE-FM, Atlanta's public broadcasting affiliate. (See the article on page 4 of this issue of *Research Horizons* magazine).

Technology Review, *Scientific Computing*, *R&D Magazine*, Photonics.com and *Popular Science* were among the outlets reporting on development of a class of molecules whose size, structure and chemical composition have been optimized for photonic use. Developed at Georgia Tech, the materials could provide the demanding combination of properties needed to serve as the foundation for low-power, high-speed, all-optical signal processing. All-optical processing could allow dramatic speed increases in telecommunications by eliminating the need to convert photonic signals to electronic signals – and back – for switching. (See the article on page 26 of this issue of *Research Horizons* magazine).

A national competition aimed at quickly locating 10 red weather balloons tethered at locations across the United States netted a second-place finish for a Georgia Tech team – along with a set of new insights into the use of social networks for gathering information. Sponsored by the U.S. Defense Advanced Research Projects Agency (DARPA), the DARPA Network Challenge attracted hundreds of teams to tackle the problem. Among the media outlets reporting on the Georgia Tech team were *Men's Journal*, *R&D Magazine*, *Scientific American* and *TechJournal South*. (See the article on page 30 of this issue of *Research Horizons* magazine).

Photo: Mark Hay

(Top) Georgia Tech graduate student Doug Rasher is shown with a rack holding corals transplanted into concrete cones for experiments on reefs off the Fiji Islands.

(Bottom) Graduate students Tushar Thrivikraman and Chad Patterson, and Georgia Tech professor John Papapolymerou (l-r), hold radar sub-arrays consisting of a flexible polymer substrate, silicon-germanium chips and other electronics.

Photo: Gary Meek

(Bottom) Georgia Tech School of Chemistry and Biochemistry professor Seth Marder is part of the team that developed a new photonic material that could facilitate all-optical signal processing.

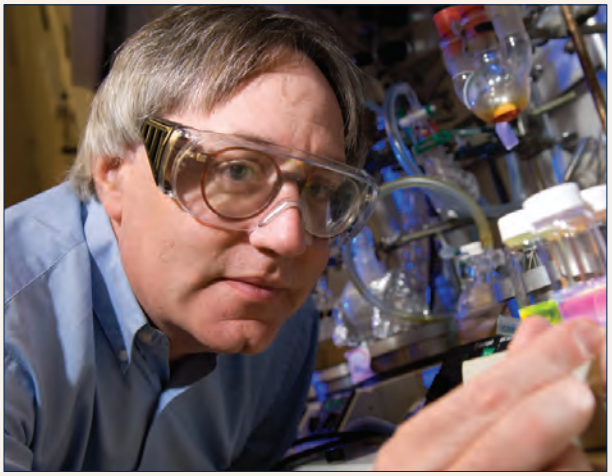


Photo: Rob Felt

Georgia Tech Faculty and Staff Receive Recognition

GTRI principal research scientist **Gary Gimmestad**, biomedical engineering professor **Gang Bao**, and civil and environmental engineering professor **Armistead Russell** were named Fellows of the American Association for the Advancement of Science.

Civil and environmental engineering associate professor **Kimberly Kurtis** was named a 2010 Fellow of the American Concrete Institute.

GTRI senior research engineer **Daniel Leatherwood** was selected as a Senior Member of the American Institute of Aeronautics and Astronautics.

Margaret Loper, a GTRI principal research scientist, was selected as a Senior Member of the Association of Computing Machinery.

Interactive computing professor **Gregory Abowd** received the Association for Computing Machinery's Eugene L. Lawler Award for Humanitarian Contributions within Computer Science and Informatics.

Electrical and computer engineering assistant professor **Maysam Ghovanloo** received the Barrier Breaker Award for Innovation from the Tommy Nobis Center.

John "Jack" Landgren, GTRI principal research scientist, was selected for the Association of Old Crows Technology Hall of Fame.

Chemical & biomolecular engineering chair **Ronald Rousseau** received an honorary degree from l'Institut Polytechnique, Toulouse, France.

Mathematics assistant professor **Maria Westdickenberg** and interactive computing assistant professor **C. Karen Liu** received 2010 Sloan Research Fellowships.

Biomedical engineering assistant professor **Todd McDevitt** was awarded the 2010 Young Investigator Award from the Society of Biomaterials.

Konstantinos Konstantinidis, assistant professor in civil and environmental engineering, received the 2010 Skerman Award from the World Federation for Culture Collections.

College of Architecture professor **Craig Zimring** was named #8 of the 25 most influential people in health care design by *Healthcare Design* magazine.

Ajay Kohli, professor of marketing in the College of Management, received the Vijay Mahajan Award from the American Marketing Association Foundation.

Civil & environmental engineering professor **Donald White** received the 2010 Raymond C. Reese Research Prize from the American Society of Civil Engineers.

Fumin Zhang, an electrical and computer engineering assistant professor, received an Office of Naval Research Young Investigator Award and a 2010 Lockheed Inspirational Young Faculty Award.

Leroy Emkin, a civil and environmental engineering professor, was named 2010 Engineer of the Year in Education by the Georgia Engineering Alliance.

Electrical and computer engineering professor **John Papapolymerou** won the 2010 John Kraus Antenna Award from the IEEE Antennas and Propagation Society.

Senior research engineer **Benny Bing** received a Technology Innovation Award from the National Association of Broadcasters.

Electrical and computer engineering chair **Gary May** received the 2010 Outstanding Alumni Award from the Department of Electrical Engineering and Computer Sciences at the University of California at Berkeley.

Biomedical engineering assistant professor **Johnna Temenoff** received the 2010 ASEE Meriam/Wiley Distinguished Author Award in recognition of her textbook, *Biomaterials: The Intersection of Biology and Materials Science.*

Santanu Dey, assistant professor in the School of Industrial and Systems Engineering, received an IBM Faculty Award.

President Barack Obama appointed **Willie Pearson**, professor of sociology in the School of History, Technology, and Society, to serve on the newly reestablished Board of Advisors on Historically Black Colleges and Universities.

Computer science associate professor **Alessandro Orso** received a Microsoft Research Software Engineering Innovation Foundation Award.

Interactive computing associate professor **Beki Grinter** received a Distinguished Alumni award from the University of California-Irvine's Donald Bren School of Information and Computer Sciences.

Joel Sokol, associate professor in the School of Industrial and Systems Engineering, received the 2010 Annual Award for Excellence in the Teaching of Operations Research from the Institute of Industrial Engineers' Operations Research Division.

Mechanical engineering professor emeritus **Jerry Ginsberg** received the 2010 Rossing Prize in Acoustics Education from the Acoustical Society of America.

Tim Lieuwen, an associate professor in aerospace engineering, received the American Society of Mechanical Engineers George Westinghouse Silver Medal.

Biomedical engineering assistant professor **Melissa Kemp** was awarded the Council for Systems Biology in Boston's Prize for Innovative Measurement Methods.

Mechanical engineering professor **Mardi Hastings** is president-elect of the Acoustical Society of America.

Aerospace engineering professor **Anthony Calise** received the American Institute of Aeronautics and Astronautics Aerospace Guidance, Navigation, and Control Award for 2010.

Materials science Regents professor **Z.L. Wang** was elected as a foreign member into the Chinese Academy of Sciences.

Aerospace engineering professor **Robert Loewy** was inducted in the Rensselaer Polytechnic Institute Alumni Hall of Fame.

Civil and environmental engineering professor **Peter Webster** was elected president of the atmospheric sciences section of the American Geophysical Union.

Civil and environmental engineering professor **Bruce Ellingwood** was awarded the Senior Research Prize in the area of risk analysis and decision making by the International Association for Structural Safety and Reliability.

The American Institute of Aeronautics and Astronautics 2010 Lawrence Sperry Award was awarded to aerospace engineering assistant professor **Mitchell Walker**.

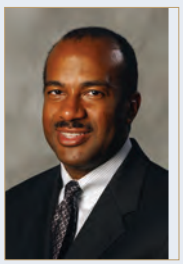
GTRI senior research engineer **Ron Ogan** received an award from the IEEE Huntsville Section.

— compiled by Abby Vogel


Ajay Kohli


Beki Grinter


Gary Gimmestad


Gary May


Maria Westdickenberg


Santanu Dey


Todd McDevitt

A class of molecules whose size, structure and chemical composition have been optimized for photonic use could provide the demanding combination of properties needed to serve as the foundation for low-power, high-speed, all-optical signal processing. All-optical processing could allow dramatic speed increases in telecommunications by eliminating the need to convert photonic signals to electronic signals – and back – for switching.

Designing Molecules:

New Photonic Material May Provide Properties Needed for All-Optical Switching and Computing

By John Toon

A class of molecules whose size, structure and chemical composition have been optimized for photonic use could provide the demanding combination of properties needed to serve as the foundation for low-power, high-speed, all-optical signal processing.

All-optical processing could allow dramatic speed increases in telecommunications by eliminating the need to convert photonic signals to electronic signals – and back – for switching. All-optical processing could also facilitate photonic computers with similar speed advances.

Details of these materials – and the design approach behind them – were reported in the March 19, 2010, issue of the journal *Science*. The research was funded by the National Science Foundation (NSF), the Defense Advanced Research Projects Agency (DARPA) and the Office of Naval Research (ONR).

"This work provides proof that at least from a molecular point of view we can identify and produce materials that have the right properties for all-optical processing," said Seth Marder, a professor in the Georgia Tech School of Chemistry and Biochemistry and co-author of the paper. "This opens the door for looking at this issue in an entirely different way."

The polymethine organic dye materials developed by the Georgia Tech team combine large nonlinear properties, low nonlinear optical losses, and low linear losses. Materials with these properties are essential for optical engineers to develop a new generation of devices for low-power and high-contrast optical switching of signals at telecommunications wavelengths. Keeping data all-optical would greatly facilitate the rapid transmission of detailed medical images, development of new tele-presence applications, high-speed image recognition – and even the fast download of high-definition movies.

But the favorable optical properties of these new materials have only been demonstrated in solution. For their materials to have practical value, the researchers will have to incorporate them in a solid phase for use in optical waveguides – and address a long list of other challenges.

"We have developed high-performing molecules by starting with highly polarizable molecules and getting the combination of needed molecular properties right," said co-author Joseph Perry, also a professor in the Georgia Tech School of Chemistry and Biochemistry. "Now we have to figure out how to pack them together so they have a high concentration and useful physical forms that would be stable under operation."

Marder, Perry and collaborators in Georgia Tech's Center for Organic Photonics and Electronics have been working on the molecules for several years, refining their properties and adding atoms to maximize their length without inducing symmetry breaking, a phenomenon in which the molecules become less polarizable and the nonlinear properties are reduced. This molecular design effort, which builds on earlier research with smaller

Photo: Georgia Tech

Researchers Joel Hales (left) and Joe Perry were part of the team that developed a new photonic material that could facilitate all-optical signal processing.

molecules, included both experimental work and theoretical studies done in collaboration with Jean-Luc Brédas, also a professor in the School of Chemistry and Biochemistry.

The design strategies identified by the research team – which also included Joel Hales, Jonathan Matichak, Stephen Barlow, Shino Ohira, and Kada Yesudas – could be applied to development of even more active molecules, though Marder believes the existing materials could be modified to meet the needs of all-optical processing

"For this class of molecules, we can with a high degree of reliability predict where the molecules will have both large optical nonlinearities and low two-photon absorption," said Marder. "Not only can we predict that, but using well-established chemical principles, we can tune the structure of the molecules to have the properties optimized so that people can work at telecommunications wavelengths."

Switching of optical signals carried in telecommunications networks currently requires conversion to electrical signals, which must be switched and then converted back to optical format. Existing electro-optical technology may ultimately be able to provide transmission speeds of up to 100 gigabits-per-second. However, all-optical processing could theoretically transmit data at speeds as high as 2,000 gigabits-per-second, allowing download of high-definition movies in minutes rather than hours.

"While we have not made all-optical switches, what we have done is provide a fundamental understanding of what the systems are that could have the combined set of properties that would make this possible," Marder said. "Conceptually, we have probably made it over the hump with this class of molecules. The next part of this work will be difficult, but it will not require a fundamental new understanding of the molecular structure." rh

This article is based on work supported in part by the STC program of the National Science Foundation under agreement DMR-0120967, the DARPA MORPH Program and ONR (N00014-04-0095 and N00014-06-1-0897) and the DARPA ZOE Program (W31P4Q-09-1-0012). The comments and opinions expressed are those of the researchers and do not necessarily represent the views of the NSF, DARPA or ONR.

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"This work provides proof that at least from a molecular point of view we can identify and produce materials that have the right properties for all-optical processing. This opens the door for looking at this issue in an entirely different way."

— Seth Marder, professor in the Georgia Tech School of Chemistry and Biochemistry

Photo: Rob Felt

Georgia Tech professor Seth Marder, center, is part of the team that developed a new photonic material that could facilitate all-optical signal processing. The work was reported in the journal *Science*.

Using synthetic polymers called hydrogels, researchers have been able to induce significant vasculature growth in areas of damaged tissue. The work could boost regenerative medicine therapies that often require the growth of functional, stable blood vessels at the site of an injury.

Photo: Gary Meek

Growing Blood Vessels:

Bio-engineered Materials Promote the Growth of Functional Vasculature, New Study Shows

By Abby Vogel

Regenerative medicine therapies often require the growth of functional, stable blood vessels at the site of an injury. Using synthetic polymers called hydrogels, Georgia Tech researchers have been able to induce significant vasculature growth in areas of damaged tissue.

"This study shows that bio-artificial materials are suitable for promoting vasculature growth and remodeling," said lead author on the study Andrés García, professor and Woodruff Faculty Fellow in Georgia Tech's Woodruff School of Mechanical Engineering and the Petit Institute for Bioengineering and Bioscience. "Because hydrogels are very compatible with biological tissues, they are a promising therapeutic delivery vehicle to improve treatment of peripheral artery dis-

Georgia Tech graduate student Ed Phelps displays hydrogel samples he engineered by tailoring their biochemical and mechanical properties to enable the growth of functional vasculature in small animals.

ease, ischemic heart disease, and survival of cell and tissue transplants."

Details of the research were published in the early edition of the journal *Proceedings of the National Academy of Sciences* on Dec. 21, 2009. The work was supported by the National Institutes of Health, the Atlanta Clinical and Translational Science Institute (ACTSI) through the Georgia Tech/Emory Center (GTEC) for the Engineering of Living Tissues, the Juvenile Diabetes Research Foundation, and the American Heart Association.

As part of the research, García and Georgia Tech graduate student Edward Phelps tailored the biochemical and mechanical properties of polyethylene glycol-based hydrogel matrices to enable vasculature to form in and around them. First, the researchers incorporated specific chemical cross-links into the gels so that they would maintain their structural integrity and only degrade in the presence of enzymes called matrix metalloproteinases that are typically expressed by invading cells. They also incorporated into the matrices a protein, vascular endothelial growth factor (VEGF), which stimulates the growth of blood vessels.

"Incorporating these cross-links controlled the release of VEGF from the matrix so that VEGF was only released as the matrix was digested by invading cells," explained García. "This was very important because if you have something solid such as a matrix that cannot degrade, you will not have any vasculature growth into that area."

Adhesive amino acid sequences were also added to the gel so that cells could spread within the gel and interact with nearby endothelial cells undergoing the blood vessel growth process called angiogenesis.

When the researchers implanted the preformed hydrogel constructs into small animals, the matrix exhibited constant levels of VEGF for two days followed by a gradual decrease during the following 12 days. When animals were injected with soluble VEGF, a steady decline of VEGF was recorded until 90 percent of the compound was lost within two weeks.

"With the degradable implant that included growth factors, after two weeks we saw that new vessels were growing into and around the implant," noted Phelps.

Additional studies with micro-CT imaging showed a six-fold increase in vascular density at two weeks and a 12-fold increase in vascular density at four weeks with the degradable matrix compared to unfunctionalized hydrogel. In addition, the hydrogel degraded in a controlled fashion and was replaced by normal tissue.

"We found that the vasculature was functional and connected to the host circulatory system, which we saw when a contrast agent injected through the aorta reached the vessels in the implant," added García.

To place the hydrogel deeper inside the body than the preformed matrix construct would allow and to be able to fill in an injured area of any shape, the researchers developed a liquid material that forms a gel inside the body when exposed to ultraviolet light.

The researchers injected the VEGF-containing matrix solution into mice suffering from restricted blood flow, known as ischemia, in one leg. After seven days, the animals exhibited a 50 percent increase in blood perfusion to the affected leg and a 100 percent increase in perfusion to the affected foot. The blood flow to the affected leg was greatly enhanced compared to treatment with a non-degradable hydrogel and injection of soluble growth factors alone.

"The engineered matrix containing VEGF performed much better than injecting soluble VEGF, indicating that the delivery vehicle acted synergistically to amplify the effect of the growth factor," noted Phelps.

Other researchers involved in the study include W. Robert Taylor, a professor in the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University, Emory's Division of Cardiology, and the Atlanta Veterans Affairs Medical Center; Peter Thulé, an associate professor in Emory University's Division of Endocrinology, Metabolism and Lipids, and the Atlanta Veteran's Affairs Medical Center; and Natalia Landázuri, a postdoctoral fellow in the Emory University Division of Cardiology. rh

This work was partly funded by grant number R01 EB004496 from the National Institutes of Health and by PHS Grant UL1 RR025008 from the Clinical and Translational Science Award program, National Institutes of Health (NIH), National Center for Research Resources. The content is solely the responsibility of the principal investigator and does not necessarily represent the official view of the NIH.

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"This study shows that bio-artificial materials are suitable for promoting vasculature growth and remodeling. Because hydrogels are very compatible with biological tissues, they are a promising therapeutic delivery vehicle to improve treatment of peripheral artery disease, ischemic heart disease, and survival of cell and tissue transplants."

— Andrés García, professor and Woodruff Faculty Fellow in Georgia Tech's Woodruff School of Mechanical Engineering and the Petit Institute for Bioengineering and Bioscience

A national competition aimed at quickly locating 10 red weather balloons tethered at locations across the United States netted a second-place finish for a Georgia Tech team – along with a set of new insights into the use of social networks for gathering information. Sponsored by the U.S. Defense Advanced Research Projects Agency (DARPA), the DARPA Network Challenge attracted hundreds of teams to tackle the problem.

The map below shows the locations where red balloons were reported by observers. The GTRI team had to carefully verify the reports.

I Spy A Red Balloon:

Georgia Tech Team Wins Key Insights and a Second-Place Finish in DARPA Network Challenge

By John Toon

A national competition aimed at quickly locating 10 red weather balloons tethered at locations across the United States netted a second-place finish for a Georgia Tech team – along with a set of new insights into the use of social networks for gathering information.

Sponsored by the U.S. Defense Advanced Research Projects Agency (DARPA), the DARPA Network Challenge attracted hundreds of teams to tackle the problem of how to locate the balloons, which were positioned Dec. 5, 2009, at locations ranging from San Francisco and Portland to Memphis and Miami.

A team from the Massachusetts Institute of Technology won the $40,000 prize for locating all 10 balloons. A team led by researchers at the Georgia Tech Research Institute (GTRI) found nine of the 10 balloons during the nine-hour competition.

DARPA's interest in the competition was in assessing how social networks could be used to address massive information-gathering tasks. In addition to its research component, the challenge also marked the 40th anniversary of the ARPANET, the forerunner of today's Internet.

GTRI researchers Erica Briscoe and Ethan Trewhitt began discussing the challenge in early November, and quickly organized a core team of seven co-workers. They established a website and began using Facebook™ and word-of-mouth communications to build a network that eventually included more than 1,000 people pledged to help.

One of their initial decisions was that if they should win, the prize would be donated to the American Red Cross rather than being split among the team members and balloon spotters. Team members believed that was important to attracting altruistic volunteers.

"One thing that surprised us was that many balloon reporters specifically chose our team because we had decided to donate the winnings," said Betty Whitaker, a GTRI principal research engineer who helped coordinate the team. "We pledged any winnings to charity to encourage recruitment and avoid complicated issues with money after the contest."

Another key was establishing the website "I Spy A Red Balloon," which built a high Google ranking thanks to references on established websites. That enabled the team to attract people who may have seen a red balloon on Dec. 5 and wondered what was going on.

"Though we focused on getting the word out to the public prior to launch day, our strong presence on that day made it possible for people who were unaware of the competition to find our team after running across a balloon," explained Trewhitt, a GTRI research engineer.

The team also connected established networks and used the news media to get information out to potential balloon-spotters. Beyond those who pledged to help, thousands more people knew about the effort and would have made contact had they seen a balloon.

But as with popular social networking services, not everybody could be trusted.

"Because teams were commonly infiltrated by members of competing teams, one of the toughest parts of this competition was not being able to trust

any particular members of the group," Trewhitt added. "This led us to realize that trust in large groups is a tricky issue – and a topic for future research."

On competition day, which began at 10 a.m. with balloons being raised in the 10 previously undisclosed locations, team members searched Twitter™ and Facebook for news of balloon sightings. They called friends, family and local businesses to validate alleged sightings, and analyzed incoming photographs to spot fakes and confirm the location of authentic red balloons.

Though the GTRI team didn't win the top prize, its leaders believe the effort established credibility and planted seeds for future research projects.

"We would like to study issues of trust in large social networks, as well as how to extract and validate useful and correct information from unmoderated online media such as Twitter," said Erica Briscoe, a GTRI research scientist. "Twitter is often the fastest medium for notification of real-time events because it is unfiltered and raw. It would be useful to research methods for determining the accuracy and authenticity of rumors in this type of environment."

For its part, the agency also seemed pleased with what the teams had done.

"[The DARPA Network] Challenge explored basic research issues such as mobilization, collaboration and trust in diverse social networking constructs, and could serve to fuel innovation across a wide spectrum of applications," the agency said in a news release. "DARPA plans to meet with teams to review the approaches and strategies used to build networks, collect information and participate in the Challenge."

Beyond those already mentioned, the team also included Stephen Cuzzort, Jessica Pater, Rick Presley and Miles Thompson, all from the Georgia Tech Research Institute.

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— Erica Briscoe, a GTRI research scientist

Team member Betty Whitaker, a GTRI principal research engineer, poses with the DARPA red balloon raised at Centennial Olympic Park in Atlanta, one of 10 balloon locations.

Photo: Red Balloon Team

A new study provides detailed information about the rates at which three of the most powerful greenhouse gases are destroyed by a chemical reaction that takes place in the upper atmosphere. The three compounds are potentially important because they absorb infrared energy in the so-called "atmospheric window" region – at wavelengths where other major greenhouse gases allow radiation to pass freely out into space.

Researchers have provided new information about the rate at which three greenhouse gases are destroyed by a chemical reaction that takes place in the upper atmosphere.

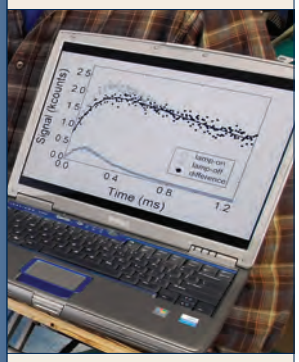

Photo: Gary Meek

Greenhouse Gases:

New Study Documents Reaction Rates for Three Chemicals with High Global Warming Potential

By John Toon

A new study provides detailed information about the rates at which three of the most powerful greenhouse gases are destroyed by a chemical reaction that takes place in the upper atmosphere.

The three compounds are potentially important because they absorb infrared energy in the so-called "atmospheric window" region – at wavelengths where other major greenhouse gases such as carbon dioxide allow radiation to pass freely out into space. Though these long-lived compounds now exist in relatively low concentrations, their ability to absorb energy at these wavelengths means their contributions to global warming could increase if their levels continue to rise.

Because the compounds are relatively inert chemically, information on how they react with electronically excited atomic oxygen – known as $O(^1D)$ – will help improve the accuracy of global climate models by providing a better estimate of how long these absorbers remain in the atmosphere. The information could also inform public policy debate about whether the chemicals, now used in industrial applications, should be replaced with compounds that have less potential climate change impact.

"This study will contribute to an understanding of the long-term effect of these compounds on climate," said Paul Wine, a professor in the Georgia Tech Schools of Chemistry and Biochemistry and Earth and Atmospheric Sciences. "There is significant interest in trying to establish the role of these heavy absorbers of infrared radiation, especially the compounds that absorb in the window region where other greenhouse gases are not factors."

Information on the reaction rates of sulfuryl fluoride (SO_2F_2), nitrogen trifluoride (NF_3) and trifluoromethyl sulfur pentafluoride (SF_5CF_3) was published in the April 13, 2010, issue of the journal *Proceedings of the National Academy of Sciences*. The research was funded by the National Aeronautics and Space Administration (NASA).

Sulfuryl fluoride is a fumigant widely used as a replacement for the ozone-depleting compound methyl bromide (CH_3Br). Nitrogen trifluoride is used in the electronics industry for plasma etching and equipment cleaning. Trifluoromethyl sulfur pentafluoride – the most powerful known greenhouse gas on a per-molecule basis – is believed to be a breakdown product of an insulating compound used in high-voltage equipment.

The three compounds have some of the highest global warming potentials (GWP) of any compounds in the atmosphere. Trifluoromethyl sulfur pentafluoride has a global warming potential approximately 18,000 times greater – on a per unit mass basis – than carbon dioxide when evaluated over a 100-year time period. Nitrogen trifluoride has a GWP of approximately 17,000, while sulfuryl fluoride is approximately 4,000 times more effective than carbon dioxide at trapping infrared radiation.

The presence of these compounds in the atmosphere and their potential contributions to climate change were only recently recognized. Reaction with electronically-excited oxygen atoms is the only known pathway by which these compounds are destroyed at atmospheric altitudes below the ionosphere. Though present at relatively low levels today, studies show that their concentrations are increasing

– with atmospheric levels of NF_3 growing at more than 10 percent per year.

"These chemicals are relatively inert, which makes them useful for specific applications," Wine said. "But because of their chemical inertness, they tend to have long lifetimes in the atmosphere and are available to trap radiation for a long time. That contributes to their high global warming potential."

To study the rate at which the compounds react with and deactivate the atomic oxygen species, Wine and Georgia Tech collaborators Zhijun Zhao, Patrick Laine and J. Michael Nicovich used laser flash photolysis in the laboratory to create $O(^1D)$ and expose it to the three compounds in controlled environments at temperatures ranging from about 200 to 350 degrees Kelvin.

$O(^1D)$ is produced in the atmosphere by the interaction of ozone (O_3) and molecular oxygen (O_2) with ultraviolet light. This electronically-excited oxygen interacts quickly with other molecules around it – such as N_2 and O_2 – to form ground-state atomic oxygen. Hence, its levels are higher in the upper atmosphere than in the lower atmosphere.

The researchers found that $O(^1D)$ interaction with trifluoromethyl sulfur pentafluoride destroys this compound in – at most – one out of a thousand interactions. That means amounts of that compound released into the atmosphere will remain there for long periods of time, probably around a thousand years.

For NF_3, the researchers found a reaction rate more than double one that had been reported in a previous study, meaning the material may have less warming impact than previously thought. For SO_2F_2, which also may be taken up by the ocean, the Georgia Tech findings agreed with one earlier study.

"If you put new molecules into the atmosphere that absorb infrared radiation where CO_2 and methane already absorb, they would have to be present in very large quantities to have any effect at all," Wine noted. "But because these molecules absorb in the window region at wavelengths between 8 and 12 microns, they don't have to be present at high levels to have an effect." rh

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"This study will contribute to an understanding of the long-term effect of these compounds on climate. There is significant interest in trying to establish the role of these heavy absorbers of infrared radiation, especially the compounds that absorb in the window region where other greenhouses gases are not factors."

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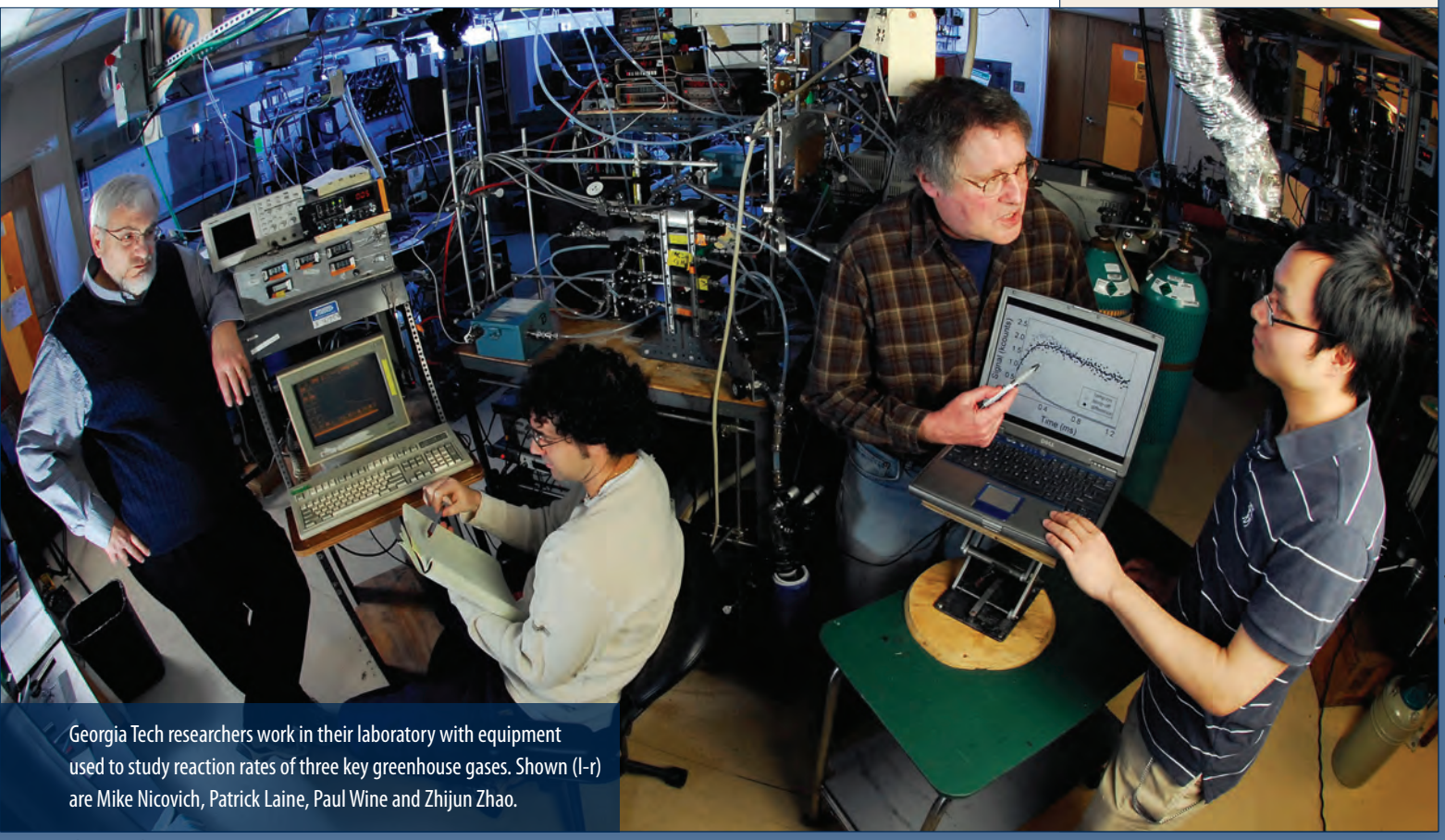


Georgia Tech researchers work in their laboratory with equipment used to study reaction rates of three key greenhouse gases. Shown (l-r) are Mike Nicovich, Patrick Laine, Paul Wine and Zhijun Zhao.

Photo: Gary Meek

Technology that lends supercomputer-level power to any desktop is becoming available in the form of graphics processing units (GPU) costing only a few hundred dollars. Georgia Tech researchers are investigating whether this new calculating power might change the security landscape worldwide by making existing password protection systems vulnerable.

Teraflop Troubles:

The Power of Graphics Processing Units May Threaten the World's Password Security System

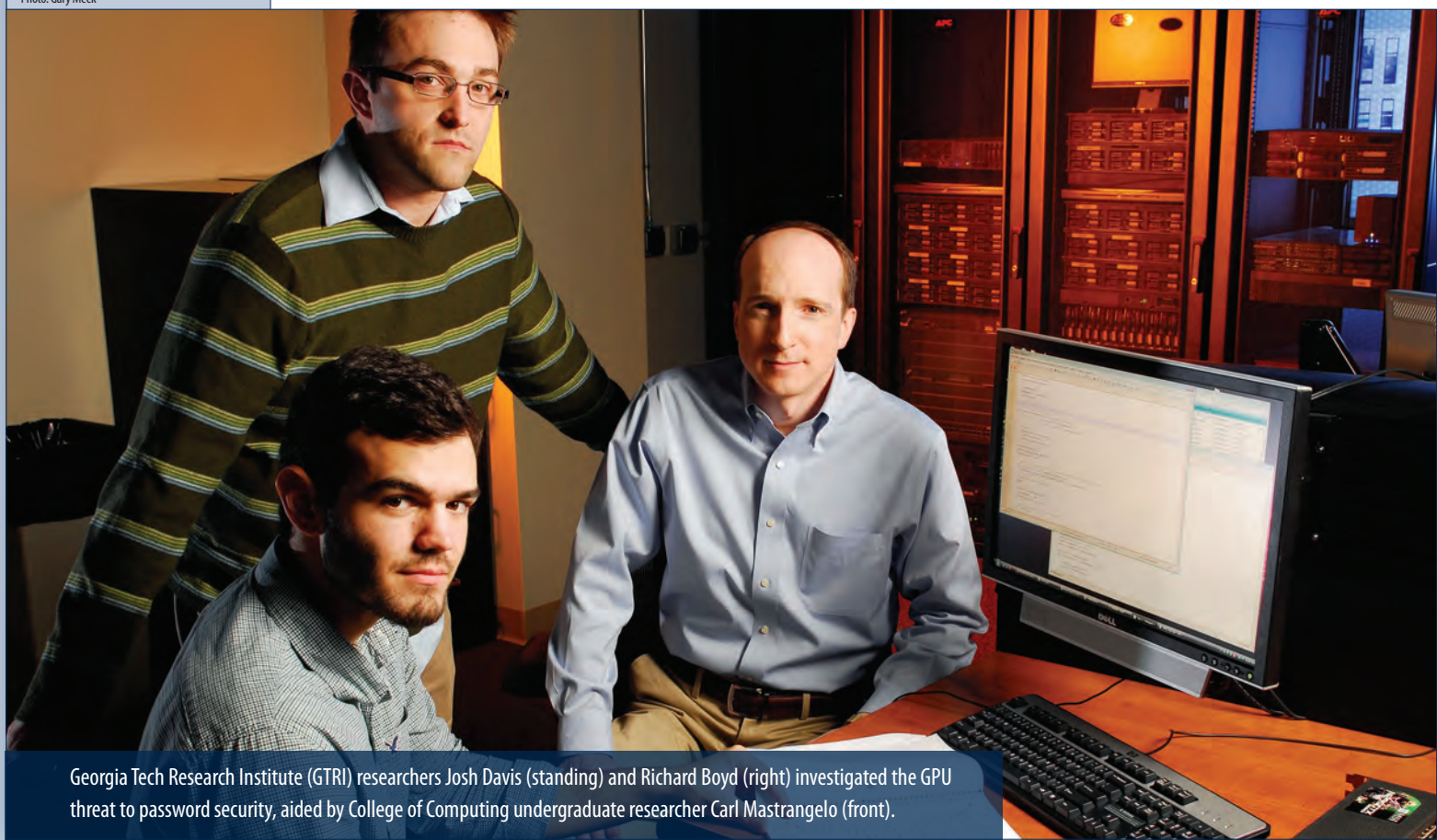
By Rick Robinson

It's been called revolutionary – technology that lends supercomputer-level power to any desktop. What's more, this new capability comes in the form of a readily available piece of hardware, a graphics processing unit (GPU) costing only a few hundred dollars.

Georgia Tech researchers are investigating whether this new calculating power might change the security landscape worldwide. They're concerned that these desktop marvels might soon compromise a critical part of the world's cybersecurity infrastructure – password protection.

"We've been using a commonly available graphics processor to test the integrity of typical passwords of the kind in use here at Georgia Tech and many other

Photo: Gary Meek



Georgia Tech Research Institute (GTRI) researchers Josh Davis (standing) and Richard Boyd (right) investigated the GPU threat to password security, aided by College of Computing undergraduate researcher Carl Mastrangelo (front).

places," said Richard Boyd, a senior research scientist at the Georgia Tech Research Institute (GTRI). "Right now we can confidently say that a seven-character password is hopelessly inadequate – and as GPU power continues to go up every year, the threat will increase."

Designed to handle the ever-growing demands of computer games, today's top GPUs can process information at the rate of nearly two teraflops (a teraflop is a trillion floating-point operations per second). To put that in perspective, in the year 2000 the world's fastest supercomputer, a cluster of linked machines costing $110 million, operated at slightly more than seven teraflops.

Graphics processing units are so fast because they're designed as parallel computers. In parallel computing, a given problem is divided among multiple processing units, called cores, and these multiple cores tackle different parts of the problem simultaneously.

Until recently, multi-core graphics processors – which are made by either Nvidia Corp. or by AMD's ATI unit – were hard to use for anything except producing graphics for a monitor. To solve a non-graphics problem on a GPU, users had to couch their problems in graphical terms, a difficult task.

But that changed in February 2007, when Nvidia released an important new software-development kit. These new tools allow users to directly program a GPU using the popular C programming language.

"Once Nvidia did that, interest in GPUs really started taking off," Boyd explained. "If you can write a C program, you can program a GPU now."

This new capability puts power into many hands, he says. And it could threaten the world's ubiquitous password-protection model because it enables a low-cost password-breaking technique that engineers call "brute forcing."

In brute forcing, attackers use a fast GPU (or even a group of linked GPUs) – combined with the right software program – to break down passwords that are blocking them from a computer or a network. The intruders' high-speed technique basically involves trying every possible password until they find the right one.

For many common passwords, that doesn't take long, said Joshua L. Davis, a GTRI research scientist involved in this project. For one thing, attackers know that many people use passwords comprised of easy-to-remember lowercase letters. Code-breakers typically work on those combinations first.

"Length is a major factor in protecting against brute forcing a password," Davis explained. "A computer keyboard contains 95 characters, and every time you add another character, your protection goes up exponentially, by 95 times."

Complexity also adds security, he says. Adding numbers, symbols and uppercase characters significantly increases the time needed to decipher a password.

Davis believes the best password is an entire sentence, preferably one that includes numbers or symbols. That's because a sentence is both long and complex, and yet easy to remember. He says any password shorter than 12 characters could be vulnerable – if not now, soon.

Would-be password crackers have other advantages, says Carl Mastrangelo, an undergraduate student in the Georgia Tech College of Computing who is working on the password research. A computer stores user passwords in an encrypted "hash" within the operating system. Attackers who locate a password hash can besiege it by building a rainbow table, which is essentially a database of all previous attempts to compromise that password hash.

"Generating a rainbow table takes a long time," Mastrangelo explained. "But if an attacker wants to crack many passwords quickly, once he's built a rainbow table it might then only take about 10 minutes per password rather than several days."

Software programs designed to break passwords are freely available on the Internet, Boyd says. Such programs, combined with the availability of GPUs, mean it's only a matter of time before the password threat will be immediate.

Boyd hopes his password work will increase awareness of the GPU's potential for harm as well as benefit. One result of this research, he says, could be GPU-based workstations that would offer rapid assessments of a given password's real-world security strength. rh

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— Richard Boyd, senior research scientist at the Georgia Tech Research Institute (GTRI)

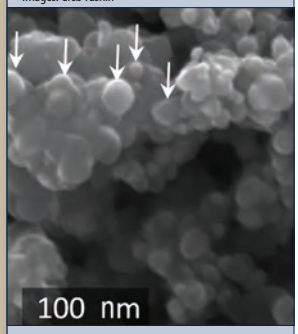
Battery Boost:

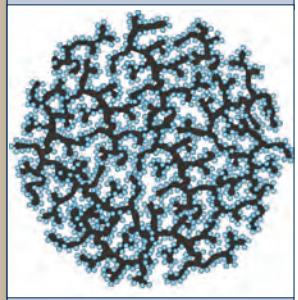
Lithium-Ion Anode Uses "Bottom-Up, Self-Assembled" Nanocomposite Materials to Increase Capacity

By John Toon

A new high-performance anode structure based on silicon-carbon nanocomposite materials could significantly improve the performance of lithium-ion batteries used in a wide range of applications. The structure is produced with a "bottom-up, self-assembled" technique, using nanotechnology to fine-tune its materials properties.

Images: Gleb Yushin





(Top) SEM image shows carbon-coated silicon nanoparticles on the surface of composite granules used to form the new anodes. (Bottom) Schematic shows a silicon-carbon nanocomposite granule formed through a hierarchical bottom-up assembly process in which annealed carbon black particles are coated by silicon nanoparticles and then assembled into rigid spheres.

A new high-performance anode structure based on silicon-carbon nanocomposite materials could significantly improve the performance of lithium-ion batteries used in a wide range of applications from hybrid vehicles to portable electronics.

Produced with a "bottom-up, self-assembled" technique, the new structure takes advantage of nanotechnology to fine-tune its materials properties, addressing the shortcomings of earlier silicon-based battery anodes. The simple, low-cost fabrication technique was designed to be easily scaled up and compatible with existing battery manufacturing.

Details of the new self-assembly approach were published online in the journal *Nature Materials* on March 14, 2009.

"Development of a novel approach to producing hierarchical anode or cathode particles with controlled properties opens the door to many new directions for lithium-ion battery technology," said Gleb Yushin, an assistant professor in the Georgia Tech School of Materials Science and Engineering. "This is a significant step toward commercial production of silicon-based anode materials for lithium-ion batteries."

The popular and lightweight batteries work by transferring lithium ions between two electrodes – a cathode and an anode – through a liquid electrolyte. The more efficiently the lithium ions can enter the two electrodes during charge and discharge cycles, the larger the battery's capacity will be.

Existing lithium-ion batteries rely on anodes made from graphite, a form of carbon. Silicon-based anodes theoretically offer as much as a 10-fold capacity improvement over graphite, but silicon-based anodes have so far not been stable enough for practical use.

Graphite anodes use particles ranging in size from 15 to 20 microns. If silicon particles of that size are simply substituted for the graphite, expansion and contraction as the lithium ions enter and leave the silicon creates cracks that quickly cause the anode to fail.

The new nanocomposite material solves that degradation problem, potentially allowing battery designers to tap the capacity advantages of silicon. That could facilitate higher power output from a given battery size – or allow a smaller battery to produce a required amount of power.

"At the nanoscale, we can tune materials properties with much better precision than we can at traditional size scales," said Yushin. "This is an example of where having nanoscale fabrication techniques leads to better materials."

Electrical measurements of the new composite anodes in small coin cells showed they had a capacity more than five times greater than the theoretical capacity of graphite.

Fabrication of the composite anode begins with formation of highly conductive branching structures – similar to the branches of a tree – made from carbon black nanoparticles annealed in a high-temperature tube furnace. Silicon nanospheres with diameters of less than 30 nanometers are then formed within the carbon structures using a chemical vapor deposition process. The silicon-carbon composite structures resemble apples hanging on a tree.

Using graphitic carbon as an electrically conductive binder, the silicon-carbon composites are then self-assembled into rigid spheres that have open, interconnected internal pore channels. The spheres, formed in sizes ranging from 10 to 30 microns, are used to create battery anodes. The relatively large composite powder size – a thousand times larger than individual silicon nanoparticles – allows easy powder processing for anode fabrication.

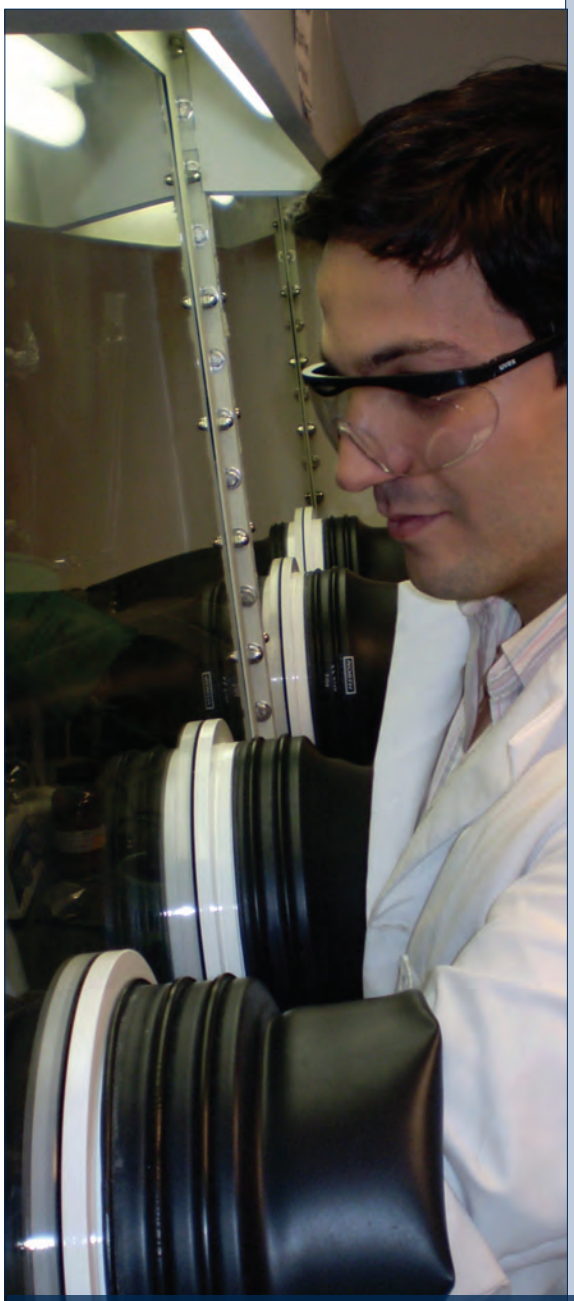
The internal channels in the silicon-carbon spheres serve two purposes. They admit liquid electrolyte to allow rapid entry of lithium ions for quick battery charging, and they provide space to accommodate expansion and contraction of the silicon without cracking the anode.

Production of the silicon-carbon composites could be scaled up as a continuous process amenable to ultra high-volume powder manufacturing, Yushin said. Because the final composite spheres are relatively large when they are fabricated into anodes, the self-assembly technique avoids the potential health risks of handling nanoscale powders, he added.

Once fabricated, the nanocomposite anodes would be used in batteries just like conventional graphite structures. That would allow battery manufacturers to adopt the new anode material without making dramatic changes in production processes.

In addition to Yushin, the paper's authors included Alexandre Magasinki, Patrick Dixon and Benjamin Hertzberg – all from Georgia Tech – and Alexander Kvit from the Materials Science Center and Materials Science Department at the University of Wisconsin-Madison, and Jorge Ayala from Chicago-based Superior Graphite Inc. The paper also acknowledges the contributions of Alexander Alexeev at Georgia Tech and Igor Luzinov from Clemson University.

The research was partially supported by a Small Business Innovation Research (SBIR) grant from the National Aeronautics and Space Administration (NASA) to Superior Graphite and Atlanta-based Streamline Nanotechnologies Inc.



Researcher Gleb Yushin works with prototype silicon-carbon battery anode materials in this glove box in Georgia Tech's School of Materials Science and Engineering.

Photo: John Toon

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"Development of a novel approach to producing hierarchical anode or cathode particles with controlled properties opens the door to many new directions for lithium-ion battery technology. This is a significant step toward commercial production of silicon-based anode materials for lithium-ion batteries."

— Gleb Yushin, assistant professor in the Georgia Tech School of Materials Science and Engineering

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 could improve safety for the occupants of future light armored patrol vehicles. GTRI researchers have designed and tested the concept, dubbed ULTRA II, for the U.S. Office of Naval Research (ONR).

Blast Protection:

Crew-Focused Design and Sacrificial "Blast Wedge" Could Improve Survivability in Light Armored Patrol Vehicles

By John Toon

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 could improve safety for the occupants of future light armored patrol vehicles.

Researchers from the Georgia Tech Research Institute (GTRI) have designed and tested the concept, dubbed ULTRA II, for the U.S. Office of Naval Research (ONR). The crew-protection concept builds on an earlier GTRI development for the ONR that evaluated new concepts for light armored vehicles. A blast test conducted with the ULTRA II full-sized crew compartment test article at the Aberdeen Test Center showed that the new concept could protect the vehicle crew from improvised explosions.

"Instead of up-armoring a standard vehicle or modifying an existing drive train, we built a bubble of force protection first and then addressed vehicle mobility," explained Vince Camp, a GTRI senior research engineer and the project's principal investigator. "The idea was to emphasize warfighter protection first by starting with design of an improved crew compartment, as opposed to starting with an existing vehicle and trying to add armor."

The ULTRA II crew compartment was designed to house six persons: a driver and commander facing forward, and two pairs of crew members behind them, each pair facing opposite sides of the vehicle. By putting their backs toward the center of the crew compartment, the concept moves the crew away from the outside walls to reduce the likelihood of injury from side blasts, provides better visibility for the crew to monitor their surroundings, allows blast-resistant seats to be frame-mounted – and facilitates faster egress from the vehicle.

The crew compartment envisioned by GTRI uses a "space frame" constructed of tubular steel – similar to civilian off-road racing vehicles. An armored steel "skin" provides added structure and moderate ballistic and blast protection. Additional armor is bolted onto the frame in a modular way, allowing varying levels of protection that could be easily modified in the field and changed as new high-performance armor concepts are developed.

An integral part of the protection is provided by a sacrificial "blast wedge" bolted onto the bottom of the vehicle. Constructed of welded steel armor, the wedge both deflects energy away from the vehicle and absorbs energy from a blast, performing a function similar to "crumple zones" in modern civilian vehicles.

Tests using a heavily-instrumented test article with instrumented dummies simulating the crew showed that the wedge deflected or

Mark Entrekin of GTRI welds a portion of the space frame for the crew compartment test article of the ULTRA II.

Photo: GTRI

absorbed nearly 70 percent of the energy from an explosion beneath it. Damage from the blast was primarily confined to the sacrificial blast wedge and there was no structural damage and no blast penetration to the crew compartment.

"Energy used up in crushing and tearing the metal in the blast wedge is energy that wouldn't go into injuring the crew," said Kevin Massey, a GTRI senior research engineer who was part of the project team. "Data from the instrumented dummies shows that we wouldn't have seen any spinal injuries, head trauma, neck trauma or leg injuries."

Because the wedge is removable, it could be replaced if damaged. Making the blast wedge removable also allows for an overall reduction of the vehicle's height for shipping, an important issue for rapid deployment.

The research team, which also included Burt Jennings, Cal Jameson, Jake Leverett and Mark Entrekin, combined nonlinear dynamics blast simulations and neural networks to study how blast forces would affect the vehicle. Conventional finite element analysis also provided valuable design feedback in development of the ULTRA II test article.

There were many tradeoffs to consider in designing the new concept, including vehicle height and resistance to blast forces that may come from many different angles.

"To survive the blast, you want to get as high off the ground as possible," Massey noted. "But the higher you are off the ground, the more likely you are to roll over. This is an example of the tradeoffs that have to be balanced."

GTRI has presented data from the test to the Office of Naval Research, and hopes to pursue additional refinements to the blast wedge and overall vehicle concept.

"We think that the concept of a space-frame design is a very viable one, and we want to take the lessons we've learned so far to improve on it," Massey added. "We'd also like to see if the concept of the energy-absorbing wedge can be applied to existing vehicles that are already out there. The bottom line is saving people's lives and protecting them from injury." rh

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"Instead of up-armoring a standard vehicle or modifying an existing drive train, we built a bubble of force protection first and then addressed vehicle mobility. The idea was to emphasize warfighter protection first by starting with design of an improved crew compartment, as opposed to starting with an existing vehicle and trying to add armor."

— Vince Camp, GTRI senior research engineer

The ULTRA II test article is transferred to a heavy truck for transportation to the Aberdeen Test Center in Maryland. There, it was subjected to blast testing designed to evaluate the concept for protecting vehicle occupants.

Photo: GTRI

Arthritis Gloves Help Companies Design Easy-to-Use Products

Photo: Gary Meek

While wearing GTRI's arthritis simulation gloves, which reproduce the reduction in functional capacity experienced by persons with arthritis, principal research scientist Brad Fain opens a medicine bottle.

As the U.S. population ages, manufacturers of consumer goods are realizing that many customers may not be as nimble-fingered or sharp-sighted as they once were. To help product designers and engineers address those changing requirements, researchers at the Georgia Tech Research Institute (GTRI) have been developing evaluation methods and design techniques to identify and address the needs of all consumers, including those with functional limitations.

GTRI's latest product is a pair of arthritis simulation gloves, which reproduce the reduction in functional capacity experienced by persons with arthritis. The gloves help those responsible for consumer products better understand how arthritis affects a person's ability to grasp, pinch, turn, lift and twist objects.

"A product manager or designer can put these gloves on and attempt to open their company's products or packaging," explained GTRI principal research scientist Brad Fain. "If they are unable to open a product or package, then chances are high that people with moderate-to-severe symptoms of arthritis will also have difficulty opening it."

The gloves can be used with a variety of consumer products, including medicine bottles, beverage containers, office supplies, medical devices, vehicles and cell phones. They can also be used with many different types of packaging, including clamshell packages, cardboard boxes, cereal containers and foil packages.

Three companies, including Kraft Foods, are currently using the gloves in-house.

The gloves were designed to reduce a wearer's functional ability to grasp something and either pull or rotate it by 33 to 50 percent. They also stiffen an individual's finger joints and restrict the range of motion of his or her fingers. To create the finger stiffness and reduced finger strength experienced by individuals with arthritis, the gloves were designed with metal wires between layers of neoprene and other fabrics.

In addition to identifying ease-of-use issues with products, the gloves are also intended to raise awareness about issues faced by people with disabilities and to support programs focused on ease of use in design. Currently, the Arthritis Foundation in the United States and Arthritis Australia are using the gloves for such educational purposes.

The gloves can be purchased alone or as part of GTRI's disability awareness kit, which also includes a low-vision simulation kit, a finger strength simulation kit and a CD training program. The finger strength simulation kit consists of finger exercises that are calibrated to certain amounts of force recommended for packaging, and the training program teaches individuals how to use the gloves.

The gloves were created through funding by GTRI's independent research and development program. To purchase the arthritis simulation gloves or the disability awareness kit, please visit: www.gtri.gatech.edu/facilities/aef.

— Abby Vogel

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Forbes Lists Georgia Tech Incubator Among the World's Best

Forbes magazine has named Georgia Tech's science and technology startup accelerator, the Advanced Technology Development Center (ATDC), to its new list of the "10 technology incubators that are changing the world." ATDC is the only incubator in the Southeast to be included on the *Forbes* list.

In its brief description of ATDC, *Forbes* noted that the program has graduated more than 120 companies since 1980 and that companies associated with ATDC have collectively raised more than $1 billion in outside financing. "The companies are heavy with Georgia Tech alumni," the magazine noted, "but that's not a requirement."

According to *Forbes*, the United States has more than 300 incubators that host approximately 6,000 companies. Many of them associated with universities, the incubators provide a broad range of support, from shared laboratory equipment to accounting and secretarial support, the magazine said.

Incubators like the ATDC, *Forbes* added, "are increasingly drawing intellectual capital from around the world." The magazine said it worked with CB Insights, a New York firm that tracks private-company funding trends – including venture capital private equity and government-backed deals – to select 10 "especially crackling innovation hubs."

Forbes is the third leading U.S. business publication to cite ATDC's record of success in helping Georgia entrepreneurs. *Inc.* magazine and *BusinessWeek* had earlier included ATDC on their lists of leading incubators.

Part of Georgia Tech's Enterprise Innovation Institute, the ATDC now has more than 300 companies in its program. ATDC helps Georgia technology entrepreneurs launch and build successful companies. As part of its incubation and acceleration services, ATDC helps Georgia Tech faculty members and researchers form new companies based on intellectual property developed in the Institute's $500 million-per-year research program. ATDC also helps companies compete for and win federal grants through the Small Business Innovation Research (SBIR) program.

"Startups play an essential role in creating new jobs and growing the economy," noted Stephen Fleming, Georgia Tech vice president and executive director of the Enterprise Innovation Institute. "We are proud of the many companies that have emerged from ATDC and those currently in our program that are Georgia's technology leaders of the future."

— John Toon

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Georgia Tech Awarded Air Force Center of Excellence

Photo: Dan Berrigan

Georgia Tech graduate student Taylor McLachlan is part of the team designing, fabricating, characterizing and modeling the performance of inorganic/organic nanocomposites for efficient, remote energy harvesting devices.

Georgia Tech has been awarded a U.S. Air Force Center of Excellence to design nanostructures for energy harvesting and adaptive materials, and to develop tools to optimize critical cognitive processes of the modern warfighter.

The $10.5 million center, known as the Bio-nano-enabled Inorganic/Organic Nanostructures and Improved Cognition (BIONIC) Center, is being led by Vladimir Tsukruk and Kenneth Sandhage, professors in Georgia Tech's School of Materials Science and Engineering.

"Advanced materials is an area of importance for the Air Force since the landscape of materials science is rapidly changing and bio-nano-materials are classes of pervasive materials that exhibit unique capabilities and have the potential to address Air Force needs," explained Rajesh Naik, a scientist in the U.S. Air Force Research Laboratory (AFRL) Materials and Manufacturing Directorate. "In addition, improved cognition tools are required for assessing the cognitive ability of the warfighter as we ask for more from our human operators in the most demanding environments."

The BIONIC Center includes a group of core members from six departments within the Georgia Tech Colleges of Sciences and Engineering, a researcher at The Ohio State University, and scientists and engineers at AFRL. Lockheed Martin Aeronautics Company is also an industrial collaborator.

Funding for the Center of Excellence is provided by the Materials and Manufacturing Directorate and Human Effectiveness Directorate of AFRL, the U.S. Air Force Office of Scientific Research and Georgia Tech. The initial award is for three years, with the possibility of an additional two-year extension.

"Georgia Tech was chosen to lead this Center of Excellence because of its investment in infrastructure development, including new facilities and instrumentation; its recruitment of high-caliber faculty members and students; and its emphasis in bio-nanotechnology and cognitive sciences," said Morley Stone, chief scientist of the Human Performance Wing of AFRL's Human Effectiveness Directorate.

There are three major research thrusts, called interdisciplinary research groups, within the BIONIC Center. Each group contains several collaborators from AFRL's Materials and Manufacturing Directorate or Human Effectiveness Directorate.

For the first thrust, which is led by Sandhage, researchers are designing, fabricating, characterizing and modeling the performance of inorganic/organic nanocomposites for efficient, remote energy-harvesting devices, such as photovoltaics and batteries.

Tsukruk is leading the second interdisciplinary research group, which is focused on designing, fabricating, characterizing and simulating the performance of inorganic/organic nanocomposites for tunable, adaptive materials.

The third thrust is being led by Eric Schumacher, an associate professor in the Georgia Tech School of Psychology. Schumacher and his team plan to develop tools and assessment methods to optimize critical cognitive processes of the modern warfighter.

This material is based upon work supported by the U.S. Air Force under Award No. FA9550-09-1-0162. Any opinions, findings, conclusions or recommendations expressed in this publication are those of the principal investigators and do not necessarily reflect the views of the U.S. Air Force.

— Abby Vogel

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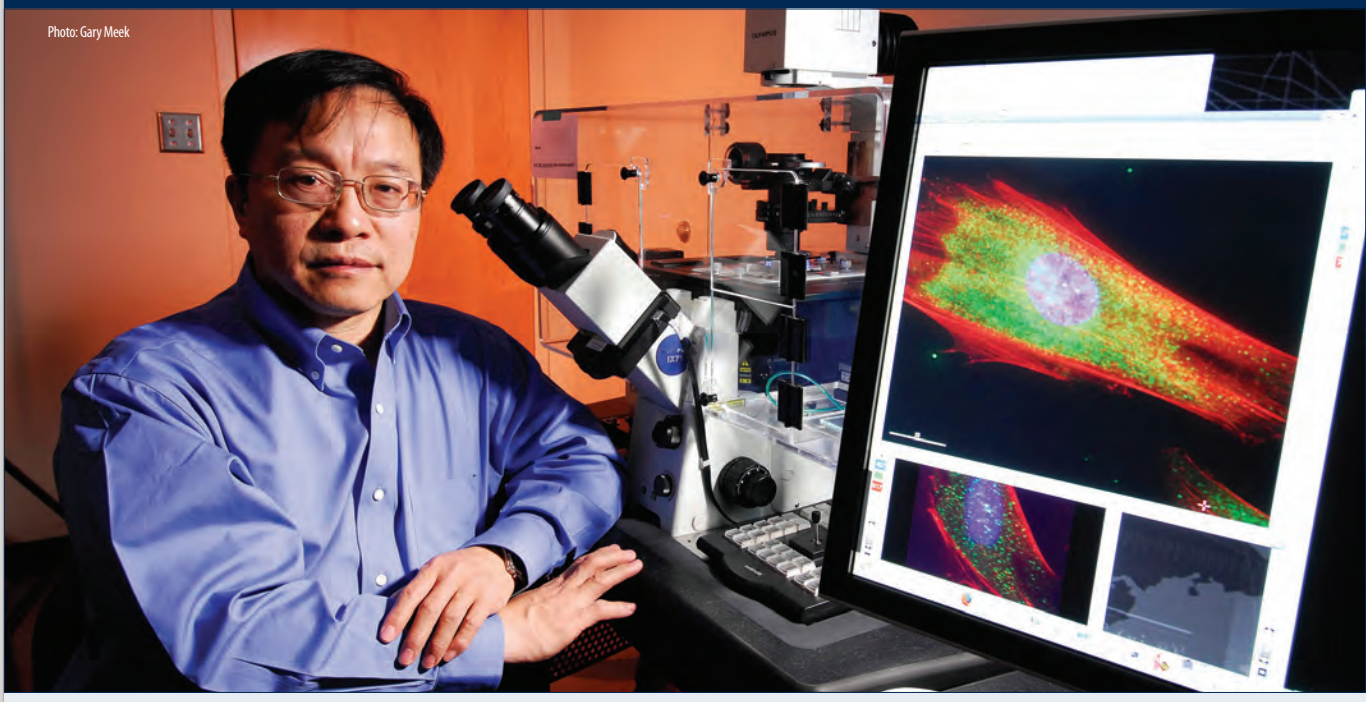
NSF Grant Supports Study into the Creation of Biological Machines



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, will coordinate the four research areas of the Emergent Behaviors of Integrated Cellular Systems Center.

While the behaviors of individual cells and the functions and properties of tissues and organs have been extensively studied, the complex interactions of cell clusters have not been examined in great detail.

The new $25 million Emergent Behaviors of Integrated Cellular Systems (EBICS) Center to be operated by the Massachusetts Institute of Technology (MIT), the University of Illinois at Urbana-Champaign, and Georgia Tech intends to change that.

The EBICS Center – established by the National Science Foundation (NSF) as part of its Science and Technology Centers Integrative Partnerships program – aims to advance research in complex biological systems, create new educational programs based on this research, and demonstrate leadership in its involvement of groups traditionally underrepresented in science and engineering.

"Ultimately, we envision being able to create biological modules – sensors, processors, actuators – that can be combined in various ways to produce different capabilities," said Roger Kamm, Germeshausen Professor of Mechanical and Biological Engineering at MIT, and the Center's founding director. "If we are successful, this will open up an entirely new field of research with wide-ranging implications, from regenerative medicine to developmental biology."

Georgia Tech will receive more than $1.6 million per year to support the research and educational efforts in the EBICS Center. Georgia Tech's participation in the Center will be administered through the Georgia Tech/Emory Center (GTEC) for Regenerative Medicine. Robert Nerem, an associate director of EBICS and the director of GTEC, will work closely with Kamm and the other associate directors to achieve the

Center's educational and research goals, and oversee its diversity objectives.

Georgia Tech faculty will contribute to the development of the knowledge, tools and technologies necessary to create these highly sophisticated biological machines.

"Critical to the successful design of engineered cellular systems is a fundamental understanding of interactions between cells and their environment, their control by biochemical and mechanical cues, and the coordinated behavior of functional biological machines," 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.

As director of research for EBICS, Bao will coordinate the Center's four research areas, which include:

- Investigating how individual cells integrate the various biological, biochemical and physical cues from their environments to determine their ultimate states and biological behaviors.
- Determining the emergent behaviors and interactions of cell clusters, including the transition from single-cell to multi-cell behavior, the nature of communication between cells, and how this leads to functional coordination among neighboring cells and cell populations.
- Creating and characterizing simple cellular machines that perform increasingly complex tasks, such as sensing, information processing, protein expression and transport.
- Developing enabling technologies to ensure the goals of the other three areas can be met.

Also contributing to the Center's research efforts are Georgia Tech researchers Yuhong Fan, an assistant professor in the School of Biology; Andrés García, a professor in the Woodruff School of Mechanical Engineering; and Melissa Kemp, Todd McDevitt and Manu Platt, all assistant professors in the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University.

— Abby Vogel

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First Georgia Tech Edison Prize Goes to Startup Company

A Georgia Tech startup company being formed to commercialize a new device that could help prevent pressure ulcers in hospital and nursing home patients has won the first Georgia Tech Edison Prize. The $15,000 prize will help launch the new company, which will be known as Multispectral Imagers.

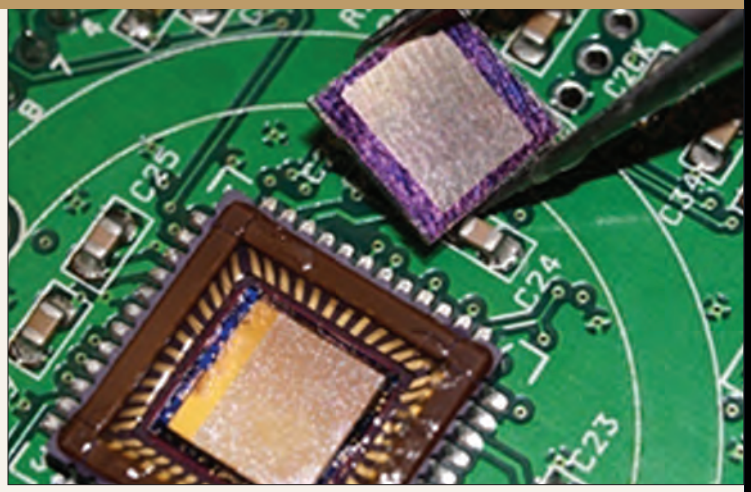
Treatment of pressure ulcers costs an estimated $8 billion each year in the United States alone, but the painful skin injury can be prevented if detected early. The device, a hand-held multispectral imaging system that provides data in real time, could be used by health care professionals to detect signs of pressure ulcers before they can be seen with conventional visual screening techniques, especially on patients with darker skin.

"We have developed a novel multispectral imager that can be integrated onto a chip," said Fengtao Wang, a Georgia Tech School of Electrical and Computer Engineering graduate student who explained the company's plan to a judging panel. "We can deliver a compact, real-time and low-cost multispectral imager to detect erythema at an early stage."

The device would be marketed to clinics, nursing homes, rehabilitation centers, hospitals and other facilities that treat patients whose mobility problems can result in development of pressure ulcers. In addition to the medical applications, Wang said the device may also have military, agricultural, manufacturing and environmental uses.

In addition to Wang, the company team includes Ali Adibi and Fuhan Liu in the Georgia Tech School of Electrical and Computer Engineering, and Linghua Kong and Stephen Sprigle of the Center for Assistive Technology and Environmental Access (CATEA) in the Georgia Tech College of Architecture. Adibi and Sprigle are both professors; Kong is a senior faculty engineer and Liu is research engineer.

The Georgia Tech Edison Prize was established to encourage formation of startup companies based on technology developed at Georgia Tech, and was made possible by a multi-year grant from the Charles A. Edison Fund, named for the famed inventor's son. Awarding of the first Georgia Tech Edison Prize was part of the Georgia Tech Graduate Research and Innovation Conference held Feb. 8, 2010.



A custom mosaic filter is integrated with a CMOS camera chip to form the multispectral imager used to detect pressure ulcers at an early stage. The device will be commercialized by a startup company.

"Thomas Edison often receives credit for inventing the electric light bulb, but his real accomplishment was in making that device – along with the phonograph and motion picture camera – commercially successful to create new companies and new industries," said Stephen Fleming, a Georgia Tech vice president and executive director of the Enterprise Innovation Institute. "Through the Edison Prize, we want to advance this kind of company-producing technology commercialization at Georgia Tech."

The Georgia Tech Edison Fund, which is managed by Fleming, provides seed funding to startup companies that have a close association with Georgia Tech.

— John Toon

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Imaging System Ensures Quality in Meat Cooking

Photo: Gary Meek

Georgia Tech Research Institute (GTRI) senior research engineer John Stewart and Georgia Tech undergraduate Chris McClanahan measure the three-dimensional shape and surface temperature of meat on a conveyor belt.

Fully cooked, ready-to-eat products continue to increase in popularity among consumers because of their convenience. However, cooking these products requires careful control to ensure that the product is not overcooked or undercooked. While overcooking can cause quality deterioration, undercooking can create an unsafe product.

"Food safety is a critical issue, so producers often compensate for natural variability in the product and variability in the measurement process by overcooking products," said John Stewart, a senior research engineer in the Georgia Tech Research Institute (GTRI). "But overcooking wastes energy, degrades product quality, lowers the maximum throughput rate of the production line and decreases product yield."

At typical production rates of 6,000 pounds per hour, the losses from overcooking can have a significant financial impact on producers. To minimize both undercooking and overcooking, Stewart and his colleagues at GTRI built a system that measures the three-dimensional shape and surface temperature of every piece of meat before it enters the oven.

Currently, after meat products travel through an oven for cooking, technicians randomly test samples with thermocouple insertion probes to ensure that the product reached the minimum required cooking temperature.

"We're focusing on analyzing the product before it goes into the oven because at that stage, there is still time to make changes in the cooking time or temperature to ensure that all pieces get cooked adequately," explained Stewart. "Once the product comes out of the oven, it's too late to correct any undercooking."

The system consists of two commercially available cameras – a wide-area, three-dimensional camera and an infrared camera – mounted above a 48-inch-wide processing conveyor belt. By measuring the three-dimensional profile of the meat, the screening system can identify individual products and detect arrangement issues such as overlapping product.

Locating individual pieces of meat on the conveyor belt can be challenging because producers often place products very close together to maximize throughput. In addition, thermal cameras sometimes view the product and conveyor belt temperatures as close to the same, which provides very little contrast.

Once individual product shapes have been measured, they are compared with a library of previously recorded cooking results for meat products with a similar shape and a cook profile that matches the current oven cook profile. Thermal heat and mass transfer models, along with the current oven cook profile, are used to determine whether a particular product will reach the desired end-point temperature.

"The system predicts the percentage of product that will be overcooked and identifies individual pieces of meat or arrangements of products that are likely to undercook," explained Stewart. "In the future, a producer might use this information to fine-tune the product arrangement before it reaches the oven."

The three-dimensional profiling system and models have been tested using chicken breast filets, and the researchers plan to test the system in a local plant this year. GTRI principal research engineer Wayne Daley and Georgia Tech undergraduate students Chris McClannahan and John Turgeson also contributed to this research.

— Abby Vogel

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Programming Handbook Helps Air Force Flight-Test Community

Effective flight testing of U.S. military aircraft and the subsystems they depend on is a complex and ongoing challenge, and it's important that every Air Force test facility use standardized approaches to in-flight testing.

Achieving and maintaining such flight-test standardization is the job of the Range Commanders Council (RCC), a group that oversees how testing is done on U.S. test ranges. Among the RCC's most important protocols are the Inter-Range Instrumentation Group (IRIG) standards, a broad group of procedures that includes the "IRIG 106 Chapter 10" standard, which covers digital flight-data recorders.

A digital flight data recorder consists principally of a hard drive that records a wide variety of information during flight testing. This data includes numerous functions such as instrument readings, along with video taken of instrument panels, cockpit displays or views outside the aircraft.

"Chapter 10 is an important and complex standard, really a de facto standard for how the Department of Defense does digital flight-data recording on test ranges," said Robert W. Baggerman, a research engineer at the Georgia Tech Research Institute (GTRI). "It describes how a digital flight-data recorder will work, what the resulting data will look like, and how you interface to it and interpret it."

To help support the Air Force's flight-test efforts, Baggerman has developed a handbook to aid those who deal with flight-test data. Known as the "IRIG 106-07 Chapter 10 Programming Handbook" – the Programmers Handbook for short – the 183-page document is now available in PDF format to the U.S. flight testing community and to others concerned with flight testing.

The work was funded by the Air Force. It was facilitated by the Military Sensing Information Analysis Center (SENSIAC), a Department of Defense information analysis center operated by Georgia Tech under contract to the Defense Technical Information Center.

"The handbook basically functions as a guide to the Chapter 10 standard," said Baggerman, who is a member of the Recorders and Reproducers Committee of the RCC's Telemetry Group. "It explains some areas of the standard that might need additional interpretation. It also provides applications useful for data analysis, as well as a considerable number of source-code examples to aid programmers."

Previously, Baggerman explained, U.S. aircraft relayed in-flight test information down to ground stations via wireless radio telemetry links. Telemetry is still used today, but increased data bandwidth requirements and the advent of miniaturized rugged storage have resulted in the development of on-board flight-data recording. After a test flight, the flight-data recorder's hard drive is plugged into a computer, and its information is analyzed to ensure that the systems under test are working correctly.

— Rick Robinson

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Grant Aims to Expand Use of Wind Turbines for Generating Electricity

Photo: iStockphoto.com

An aerodynamic technology originally developed to increase lift in aircraft wings and simplify helicopter rotors may soon help reduce the cost of manufacturing and operating wind turbines used for generating electricity.

This "circulation control" aerodynamic technology could allow the wind turbines to produce significantly more power than current devices at the same wind speed.

Research aimed at adapting circulation control technology to wind turbine blades will be conducted by a California company, PAX Streamline, in collaboration with Georgia Tech. The two-year project, which will lead to construction of a demonstration pneumatic wind turbine, will be supported by a $3 million grant from the Advanced Research Projects Agency-Energy – the federal energy research and development organization also known as ARPA-E.

"Our goal will be to make generation of electricity from wind turbines less expensive by eliminating the need for the complex blade shapes and mechanical control systems used in current turbines," said Robert J. Englar, principal research engineer at the Georgia Tech Research Institute (GTRI). "Because these new blades would operate effectively at lower wind speeds, we could potentially open up new geographic areas to wind turbine use. Together, these advances could significantly expand the generation of electricity from wind power in the United States."

Circulation control techniques use compressed air blown from slots on the trailing edges of wings or hollow blades to change the aerodynamic properties of those wings or blades. In aircraft, circulation control wings improve lift, allowing aircraft to fly at much lower speeds – and take off

Georgia Tech researchers are collaborating with a California company to help reduce the cost of manufacturing and operating wind turbines for generating electricity.

and land in much shorter distances. In helicopter rotor blades, the technique – also known as the "circulation control rotor" – both simplifies the rotor and its control system and produces more lift.

The ARPA-E project will apply the technique to controlling the aerodynamic properties of wind turbine blades, which now must be made in complicated shapes and controlled by complex control mechanisms to extract optimal power from the wind.

"The speed at which these turbines would begin to operate will be much lower than with existing blades," said Englar. "Places that wind maps have previously indicated would not be suitable locations for wind turbines may now be useful. This technology should also allow safe operation at higher wind speeds and in wind gusts that would cause existing turbines to be shut down to prevent damage."

Because they would produce more aerodynamic force, torque and power than comparable blades, these blown structures being developed by Georgia Tech and PAX could also allow a reduction in the size of the wind turbines.

"If you need a specific amount of wind force and torque generated by the wind turbine to generate electricity, we could get that force and torque from a smaller blade area because we'd have more powerful lifting surfaces," Englar explained.

A major question awaiting study is how much energy will be required to produce the compressed air the blown blades need to operate. Preliminary studies done by Professor Lakshmi Sankar in Georgia Tech's School of Aerospace Engineering suggest that wind turbines with the new blades could produce 30 to 40 percent more power than conventional turbines at the same wind speed – even when the energy required to produce the compressed air is subtracted from the total energy production.

— John Toon

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LaserFest Helps Interest K-12 Students in Science and Engineering

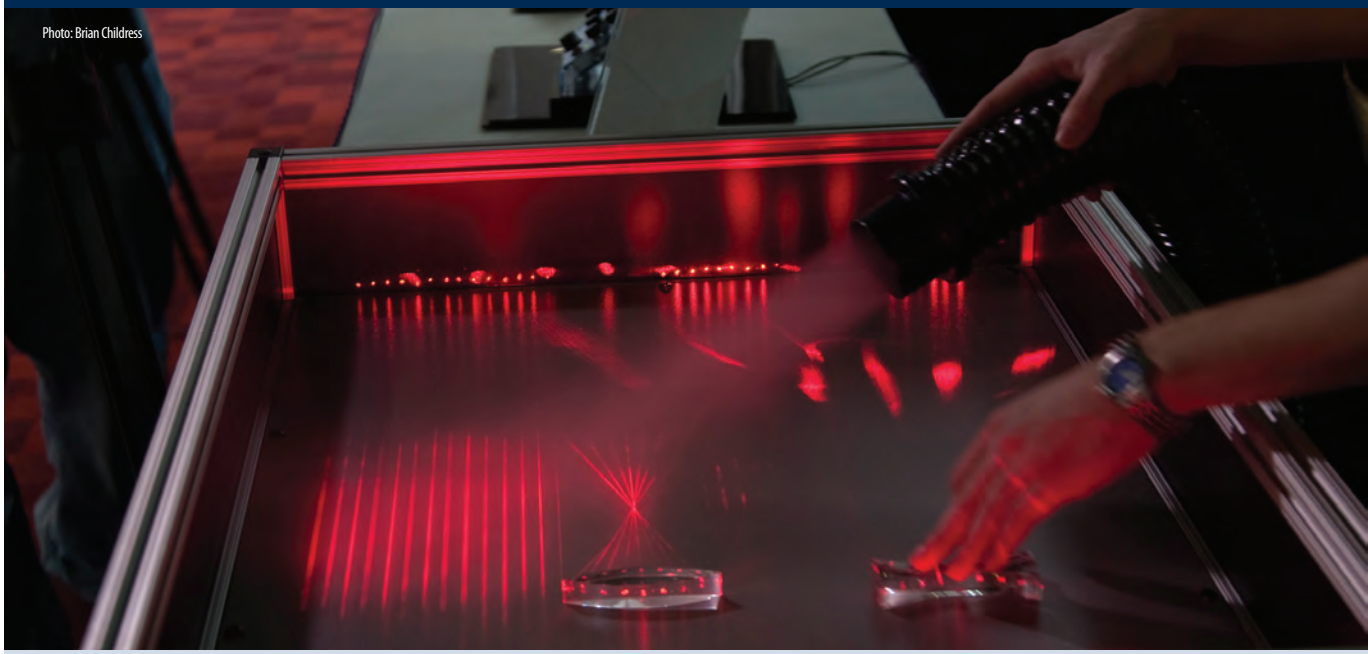

Photo: Brian Childress

GTRI researchers developed this demonstration showing how laser light can be bent. The project was part of LaserFest, a year-long celebration of the 50th anniversary of the invention of the laser.

Volunteers from the Georgia Tech Research Institute (GTRI) helped celebrate the 50th anniversary of the invention of the laser by creating a dozen hands-on, museum-quality exhibits for LaserFest, a year-long celebration of the ubiquitous device.

The volunteers hope that the exhibits will help attract more students to the STEM disciplines – science, technology, engineering and mathematics – a key part of efforts aimed at improving U.S. global competitiveness. The GTRI exhibits were displayed during WeatherFest, an American Meteorological Society event held recently at the Georgia World Congress Center in Atlanta.

"Our display at WeatherFest was met with significant enthusiasm," said Michael E. Knotts, a GTRI senior research scientist who led design of the laser exhibits. "We encountered strong interest in having our exhibits appear at other LaserFest events throughout the year, as well as at Atlanta-area schools."

WeatherFest and the LaserFest exhibition were visited by more than 5,000 children, parents, teachers and other interested individuals. GTRI had 11 researchers on hand as volunteers, presenters and booth personnel.

"We experienced tremendous positive feedback during the ex-

hibition," said GTRI senior research scientist Jack W. Wood. "Among the most satisfying parts of that feedback were the 'oohs' and 'ahs' from the kids as they approached our rather sizeable and eye-catching exhibition booth."

The GTRI laser exhibits will be available to travel to area schools for the indefinite future, Knotts said. Since the World Congress Center event, the exhibits have gone on tour to about a dozen metro-Atlanta schools, he added. By June 2010, more than 10,000 schoolchildren will have experienced them.

On April 24, 2010, one GTRI laser exhibit was shown at the Cambridge Science Festival in Massachusetts. That same day, 10 of the exhibits were displayed at the Atlanta's Fernbank Science Center as part of National Astronomy Day.

"The excitement of the children was thrilling," said Lon Pringle, director of GTRI's Signature Technology Laboratory.

After Fernbank, three of the exhibits were shown to Congress April 28 at the Rayburn House Office Building in Washington D.C.

Primary credit for GTRI's LaserFest effort belongs to Knotts and Wood. Knotts oversaw the design of exhibits, assisted by Wood and other GTRI personnel including Tedd Toler, Jon Swarner, James Fraley and Jeremy Wooten.

GTRI provided most of the funding for the laser exhibits. In addition, the Newport Corp., based in Irvine, Calif., donated some $4,000 worth of optical components used in the exhibits.

"The LaserFest effort indicates GTRI's commitment to public outreach that can foster education in science, technology, engineering, and mathematics," said Tom McDermott, interim GTRI director. "Budget cuts have forced many schools to curtail field trips and reduce spending on special programs. By taking our laser exhibits directly to schools, we can help make sure that science-related curriculum enhancement doesn't suffer."

— Rick Robinson

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Photo: Brian Childress

In this photo, children enjoy an exhibit demonstrating the applications of lasers. GTRI researchers developed the museum-quality exhibits and are making them available for loan to K-12 schools..

Georgia Tech Receives $100,000 Gates Foundation Grant

Image: Todd Sulchek

Georgia Tech has received a $100,000 Grand Challenges Explorations grant from the Bill & Melinda Gates Foundation to support an innovative global health research project led by Todd Sulchek, an assistant professor in Georgia Tech's School of Mechanical Engineering.

Known as "complement-based antibiotic microbeads," the project was one of 78 grants announced by the Gates Foundation in the fourth funding round of Grand Challenges Explorations, an initiative established to help scientists from around the world explore bold and largely unproven ways to improve health in developing countries.

Sulchek will work with David White, a microbiologist at the U.S. Centers for Disease Control and Prevention (CDC), to design multi-functional microparticles that can fight infectious diseases. "If we are successful, this technique may eventually be useful for battling many hard-to-treat diseases, like malaria and tuberculosis, which evade the immune system," said Sulchek.

The microparticles will be engineered to simultaneously accomplish two goals: target and bind infectious disease microorganisms, and activate the localized immune system. "The ultimate goal is to activate the immune system so that it can fight the microbe itself," White said.

Georgia Tech graduate students Patricia Pacheco and Daniel Potter, and several undergraduate students will also be involved in this project.

The Gates Foundation initiative is highly competitive, receiving almost 2,700 proposals in this round.

"The winners of these grants show the bold thinking we need to tackle some of the world's greatest health challenges," said Dr. Tachi Yamada, president of the Gates Foundation's Global Health Program. "I'm excited about their ideas and look forward to seeing some of these exploratory projects turn into life-saving breakthroughs."

Grand Challenges Explorations is a five-year, $100 million initiative of the Gates Foundation to promote innovation in global health. The program uses an agile, streamlined grant process – applications are limited to two pages, and preliminary data are not required. Proposals are reviewed and selected by a committee of foundation staff and external experts, and grant decisions are made within approximately three months of the close of the funding round. Successful projects have the opportunity to receive a follow-on grant of up to $1 million.

This microscope image shows immune cells activated by functionalized microbeads.

— Abby Vogel

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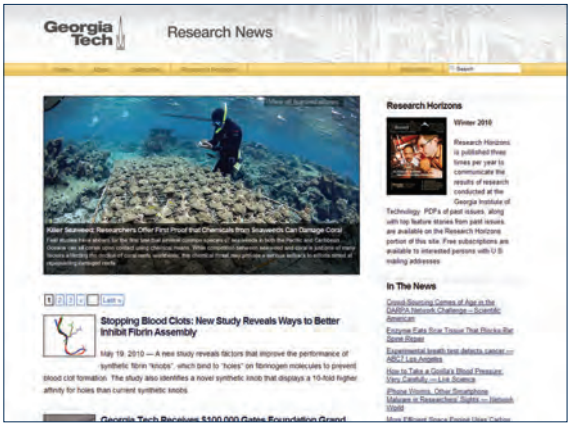

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