Georgia Tech researchers made a four-day voyage from Chile, across the Drake Passage, to Anvers Island and Palmer Station, Antarctica. Led by Jeannette Yen, a professor in the School of Biology, the team traveled aboard the research vessel Laurence M. Gould, which the team used to explore the waters around Antarctica during their time on the continent. The research vessel carried the scientists past icebergs, leopard seals, and thousands of penguins during the journey to and from Antarctica.

Photograph by Ryan Wallace
Georgia Tech researchers traveling aboard the research vessel Laurence M. Gould witnessed this stunning sight. Thousands of Gentoo penguins frolicked in the frigid waters of Le Maire Channel, near Palmer Station, Antarctica. There was even more action under the water, which the scientists captured by dunking a waterproof camera overboard. To see the penguins at play, visit http://b.gatech.edu/1pzmyk. Photography by Michiel Gitzels.
Explorers and scientists from the United States have been traveling to Antarctica since 1830. This past spring, scientists from Georgia Tech — led by Jeannette Yen, a professor in the School of Biology — traveled to Palmer Station, Antarctica (seen here), to explore the frozen continent’s frigid waters. They were searching for tiny organisms called pteropods, which could be a canary in the coal mine of climate change. Photograph by Ryan Wallace
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If you’re a regular subscriber to Research Horizons magazine, you’ve surely noticed that this issue is very different from what you’re used to receiving. And I hope those of you seeing our magazine for the first time will be impressed with our new look and new content.

Georgia Tech has been publishing Research Horizons since 1983. During that time, it has become a trusted vehicle for sharing compelling stories about Georgia Tech’s groundbreaking research.

As the center of a vibrant innovation ecosystem, Georgia Tech has been working to facilitate transformative opportunities, strengthen collaborative partnerships, and maximize its economic and societal impact.

Georgia Tech research is powered by ideas, led by faculty and supported by a diverse group of professionals, including talented research communicators committed to sharing our life-changing research with the world. Reporting on this research is critical to advancing scientific knowledge. It also solidifies our reputation as one of the nation’s leading research universities.

We value your time. That’s why this publication now includes a better mix of news briefs, short stories, and longer features. You’ll also notice a difference in our photos and illustrations – a dynamic assortment, truly bringing our stories to life. We think this newly designed magazine powerfully captures and embraces our collaborative research culture, as well as the excitement and relevance of our innovative work.

Finally, in response to requests from subscribers, we have added a list of key research contacts to the publication. You’ll find this inside the back cover. This will make it easier to connect with Georgia Tech experts who can help you solve tough technical problems or gain that competitive edge.

As always, I welcome your feedback.

Steve Cross
Executive Vice President for Research
October 2014
A driver traveling to New York City might take I-95, I-78, I-87, or any number of alternate routes. Most cancers begin similarly, with many possible routes to the disease. A new study has found that assessing the route to cancer on a case-by-case basis might make more sense than basing a patient’s treatment on commonly disrupted genes and pathways.

The study found little or no overlap in the most prominent genetic malfunction associated with each patient’s disease compared to malfunctions shared among the group of patients as a whole.

“This paper argues for the importance of personalized medicine, where we treat each person by looking for the etiology of the disease in patients individually,” said John McDonald, a professor in Georgia Tech’s School of Biology. “The findings have ramifications for how we might best optimize cancer treatments as we enter the era of targeted gene therapy.”

McDonald and his team of researchers collected cancer and normal tissue samples from four patients with pancreatic cancer and analyzed data that had previously been reported from eight other pancreatic cancer patients. The team compiled a list of the most aberrantly expressed genes in the cancer tissues isolated from the patients relative to adjacent normal pancreatic tissue.

The study found that, collectively, 287 genes displayed significant differences in expression in the cancers compared to normal tissues. Twenty-two cellular pathways were enriched in cancer samples, with more than half related to the body’s immune response. The researchers ran statistical analyses to determine if the genes most abnormally expressed on an individual patient basis were the same as those identified as most abnormally expressed across the entire group of patients.

The researchers found that the molecular profile of each individual cancer patient was unique in terms of the most significantly disrupted genes and pathways. The research was published in the journal *PANCREAS* and was funded by the St. Joseph’s Mercy Foundation.
MOVER SHAKER

PABLO VEGA IS HELPING SAVE OLDER BUILDINGS FROM EARTHQUAKES

Pablo Vega is a fifth-year graduate student in the Georgia Tech School of Civil and Environmental Engineering. He studies how older buildings are damaged during earthquakes. Vega works at the Structures Lab, where engineers have intentionally damaged a two-story building frame through forced vibrations using a hydraulic shaker. But Vega’s doing more than just breaking buildings. He’s working with other scientists to develop a bracing retrofit system that helps reduce the risk of earthquake damage in older buildings.

WHERE ARE YOU FROM?
San Juan, Puerto Rico.

WHERE DID YOU GET YOUR UNDERGRADUATE DEGREE?
At the University of Puerto Rico at Mayagüez. Actually, I got both my bachelor’s and master’s degrees in civil engineering there.

WHY DID YOU COME TO GEORGIA TECH?
Georgia Tech has a big earthquake research program, so that was the deciding factor. I’m also a city boy, and Georgia Tech being in the middle of a big city played a major role in my decision. Also, I have family members who graduated from Georgia Tech.

WHAT ARE YOUR POST-GRADUATE PLANS?
I’ve been hired by a firm called Arup. They were at the career fair last year. I start working in January in their New York office. Starting out, it’s going to be similar to what I’ve been doing at Georgia Tech: a lot of seismic response studies on new construction as well as on existing buildings.

WHAT ARE SEISMIC RESPONSE STUDIES?
We analyze buildings to find probabilities of failure during an earthquake. We then look at ways of enhancing the building’s structure so we can lower the probabilities of failure.

Traditionally, the structural engineering community has focused on collapse prevention during earthquakes. We want people to survive, which is good if you’re a building occupant. But this focus doesn’t tell us anything about the level of damage the building will sustain. Will the damage be irreparable? If you’re a building owner, will you lose your entire investment? What we’re moving to now is being able to quantify what’s going to happen given the intensity of an earthquake.

HOW DOES YOUR BUILDING BRACE WORK?
With our bracing system, we’ll stiffen up older buildings enough that there should be little to no damage during small-to-medium earthquakes. During a larger earthquake, we’re going to allow the building to move more. But the brace has a smart material called shape-memory alloy that’s going to pull the building back into place, so even if there’s damage, it’s going to be repairable damage.

WHERE DO YOU SEE YOURSELF IN 10 YEARS?
I see myself working in the industry but still connected to the academic world and encouraging engineers to become leaders.
Vaccinate Yourself

Visiting your doctor’s office each year to receive a flu shot may soon be outdated, thanks to the findings of a study published in the journal *Vaccine*.

The study, which involved nearly 100 people, found that test subjects could successfully apply a prototype vaccine patch to themselves. That suggests the self-administration of vaccines with microneedle patches may one day be feasible, potentially reducing administration costs and relieving an annual burden on health care providers.

The study also suggested that the use of vaccine patches might increase the rate at which the population is vaccinated against influenza. After comparing simulated vaccine administration using a patch against the conventional injection, researchers found that the percentage of test subjects who said they’d be vaccinated grew from 46 percent to 65 percent.

“Our dream is that each year there would be flu vaccine patches available in stores or sent by mail for people to self-administer,” said Mark Prausnitz, a Regents Professor in Georgia Tech’s School of Chemical & Biomolecular Engineering. “People could take them home and apply them to the whole family.”

In addition to Georgia Tech researchers, the project included scientists from Emory University and the Centers for Disease Control and Prevention. Research into the use of microneedle patches for influenza vaccination has been supported by the National Institutes of Health.

The study is believed to be the first published report of a head-to-head comparison between microneedle patches and traditional intramuscular injection for the administration of vaccines in humans.

INTERGRAPH ACQUIRES GT STRUDL

A structural engineering software system developed at Georgia Tech has been acquired by Intergraph®, a leading producer of engineering enterprise software. GT STRUDL®, a computer-aided structural engineering software system that assists engineers in the structural analysis and design process, was developed in the 1970s and has been maintained and updated by Georgia Tech for nearly 40 years.

Developed by the CASE Center within the Georgia Tech School of Civil and Environmental Engineering, GT STRUDL integrates graphical modeling, frame and finite element linear and nonlinear static and dynamic analysis, structural frame design, graphical analysis and design result display, and structural database management all into a menu-driven information processing system.

The system is used in a variety of areas such as nuclear power and nuclear defense industries, conventional power generation, offshore structures, marine applications, and general civil engineering.
THE MULTITASKING BRAIN

Study shows neural circuits can rapidly switch tasks

Imagine driving on a dark road. In the distance, you see a single light. As the light approaches, it splits into two headlights. That's a car, not a motorcycle, your brain tells you.

A new study has found that neural circuits in the brain rapidly multitask between detecting and discriminating sensory input, such as headlights in the distance. That's different from how electronic circuits work, where one circuit performs a very specific task. The brain, the study found, is wired in a way that allows a single pathway to perform multiple tasks.

“We showed that circuits in the brain change or adapt from situations when you need to detect something versus when you need to discriminate fine details,” said Garrett Stanley, a professor in the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University.

The findings were published in the journal *NEURON*. The research was supported by the National Institutes of Health (NIH) and the National Science Foundation.

“Every day, we are bombarded with sensations, and the brain automatically chooses which ones to detect. This study may help scientists answer fundamental questions about how neurological disorders may disrupt the brain circuits that make those choices,” said Jim Gnadt, program director at the National Institute of Neurological Disorders and Stroke, part of the NIH.

The distance at which a person can discern two headlights from a single light is controlled by the acuity of the body's sensory pathway. Neuroscientists had assumed that the level of one's acuity was controlled by the distance between areas in the brain that are triggered by the sensory input. If these two areas of the brain closely overlap, then two sensory inputs – two headlights in the distance – will appear as one, the thinking went.

The new study used animal models and optical imaging to directly assess how acuity is controlled in the brain, and how acuity can adapt to the task at hand. One neuronal circuit can do different things and do them in a robust way, the study found.
Chemist Stanley Miller, whose landmark experiment published in 1953 showed how some of the molecules of life could have formed on a young Earth, left behind boxes of samples, some of which he never analyzed, from his 1950s experiments. The first-ever analysis of some of these old samples has revealed another way that important molecules could have formed on early Earth.

The study discovered a path from simple to complex compounds amid Earth’s prebiotic soup. More than 4 billion years ago, amino acids could have been attached together, forming peptides. These peptides ultimately may have led to the proteins and enzymes necessary for life’s biochemistry.

In the new study, scientists analyzed samples from an experiment Miller performed in 1958. To the reaction flask, Miller added the chemical cyanimide, which at the time wasn’t widely thought to have been available on early Earth. The new study found that the 56-year-old reaction had successfully formed peptides.

“It was clear that the results from this old experiment weren’t some sort of artifact. They were real,” said Jeffrey Bada, distinguished professor of marine chemistry at the Scripps Institution of Oceanography at UC San Diego. Bada was a former student and colleague of Miller’s.

The study was supported by the Center for Chemical Evolution at Georgia Tech, which is jointly supported by the National Science Foundation and the NASA Astrobiology Program. The study was published in the journal _Angewandte Chemie International Edition_ and resulted from collaboration spearheaded by UC San Diego and Georgia Tech. Scientists from NASA’s Johnson Space Center and Goddard Space Flight Center were also involved in the analysis.

Eric Parker, the study’s lead author, was an undergraduate student in Bada’s laboratory and is now a graduate student at Georgia Tech.

The 1958 reaction samples were analyzed by Parker and his current mentor, Facundo M. Fernández, a professor in the Georgia Tech School of Chemistry and Biochemistry. Liquid chromatography and mass spectrometry showed that the reaction samples from 1958 contained peptides.

In addition to analyzing the 1958 samples, Parker designed a way to conduct the experiment using modern equipment and confirmed that the reaction created peptides.

“We found some of the same products of polymerization that we found in the original samples,” Parker said. “This corroborated the data we collected from analyzing the original samples.”

**NEW STUDY ANALYZES UNKNOWN SAMPLES FROM FAMOUS CHEMIST, STANLEY MILLER**

Chemist Stanley Miller, pictured with the experimental setup he used to show how the peptides necessary for life could have originated on early Earth.

**FILE**

Chemist Stanley Miller is pictured with the experimental setup he used to show how the peptides necessary for life could have originated on early Earth.

**UNIVERSITY OF CALIFORNIA, SAN DIEGO**
ICEQUAKES

Seismic events aren’t rare on Antarctica, where sections of the frozen desert can experience hundreds of micro-earthquakes an hour due to ice deformation. Some scientists call them icequakes. But in March 2010, the ice sheets in Antarctica vibrated a bit more than usual because of something more than 3,000 miles away: the 8.8-magnitude Chilean earthquake. A study published in the journal *Nature Geoscience* is the first to indicate that Antarctica’s frozen ground is sensitive to seismic waves from distant earthquakes.

To study the quake’s impact on Antarctica, a team from Georgia Tech looked at seismic data from 42 stations in the six hours before and after the 3:34 a.m. event. The researchers used the same technology that allowed them to “hear” the seismic response to the devastating 2011 magnitude 9 Japan earthquake as it rumbled through the Earth. They removed the longer-period signals as the seismic waves spread from the distant epicenter to identify high-frequency signals from nearby sources. Nearly 30 percent of the stations showed clear evidence of high-frequency seismic signals as the surface wave arrived on Antarctica.

“We interpret these events as small icequakes, most of which were triggered during or immediately after the passing of long-period Rayleigh waves generated from the Chilean main shock,” said Zhigang Peng, an associate professor in Georgia Tech’s School of Earth and Atmospheric Sciences who led the study.

TINY TWEEZERS AID BIOMED RESEARCHERS

A new type of biomolecular tweezers could help researchers study how mechanical forces affect the biochemical activity of cells and proteins. The tweezers, too small to see without a microscope, use opposing magnetic and electrophoretic forces to precisely stretch the cells and molecules, holding them in position so the activity of receptors and other biochemical activity can be studied.

Arrays of tweezers could allow the study of multiple molecules and cells simultaneously, providing a high-throughput capability for assessing the effects of mechanical forces.

“Our lab has been very interested in mechanical-chemical switches in the extracellular matrix, but we currently have a difficult time interrogating these mechanisms and discovering how they work in vivo,” said Thomas Barker, an associate professor in the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University. “This device could help biologists and biomedical engineers answer questions that cannot be answered right now.”

For example, a cell in the extracellular matrix may bind with one receptor while the matrix is being stretched, and with a different receptor while not under stress. Those binding differences could drive changes in cell phenotype and affect processes such as cell differentiation.

“Having a device like this will allow us to interrogate what the specific binding sites are and what the specific binding triggers are,” Barker explained.

Details of the devices were published in the journal *Technology*.

Measuring Graphene’s Limits

Graphene is strong, but new research could prompt engineers to look a little deeper as they consider the miracle material for applications.

The atom-thin sheet of carbon is touted not just for its electrical properties but also for its physical strength and flexibility. The bonds between carbon atoms are the strongest in nature, so a perfect sheet of graphene should withstand just about anything, which is why reinforcing composite materials is among the material’s potential applications.

Researchers Jun Lou at Rice University and Ting Zhu at Georgia Tech have measured the fracture toughness of imperfect graphene for the first time and found it to be somewhat brittle, however. While it’s still very useful, graphene is really only as strong as its weakest link, which they determined to be substantially lower than the intrinsic strength of graphene.

Researchers reported in the journal *Nature Communications* the results of tests in which they physically pulled graphene apart to see how much force it would take.

“Graphene has exceptional physical properties, but to use it in real applications, we have to understand the useful strength of large-area graphene, which is controlled by the fracture toughness,” said Zhu, an associate professor in Georgia Tech’s George W. Woodruff School of Mechanical Engineering.

Imperfections in graphene drastically lessen its strength. That’s important for engineers to understand as they think about using graphene for applications in which stresses on microscopic flaws could lead to failure.
Using a novel high-throughput screening process, scientists have, for the first time, identified molecules with the potential to block the accumulation of a toxic eye protein that can lead to the early onset of glaucoma.

Glaucoma is a group of diseases that can damage the eye’s optic nerve to cause vision loss and blindness. Elevated eye pressure is the main risk factor for optic nerve damage.

Previous research in the field identified a mutant form of a protein called myocilin as a root cause of this increased eye pressure in some patients. Mutant myocilin is toxic to the cells in the part of the eye that regulates pressure. These genetically inherited mutants of myocilin clump together in the front of the eye, preventing proper fluid discharge from the eye, which then raises eye pressure. This cascade of events can lead to early onset glaucoma, which affects several million people before age 35.

To find molecules that bind to mutant myocilin and block its aggregation, researchers designed a simple, high-throughput assay and then screened a library of compounds. They identified two molecules with potential to treat early onset glaucoma.

“These are really the first specific drug targets to treat glaucoma,” said Raquel Lieberman, an associate professor in the Georgia Tech School of Chemistry and Biochemistry. Lieberman presented her findings at the Society for Laboratory Automation and Screening Conference in San Diego, California, and published them in the journal *ACS Chemical Biology* earlier this year.

The National Institutes of Health and the Pew Scholars Program in the Biomedical Sciences provided support for the research. The work was a collaboration involving Georgia Tech, Emory University, and the University of South Florida.

At the heart of the study was an assay created to take advantage of the fundamental principles of ligand binding.

**CUTTING MEMBRANE COSTS**

Researchers have developed a microfluidic technique for fabricating a new class of metal-organic framework (MOF) membranes inside hollow polymer fibers that are just a few hundred microns in diameter. The process, believed to be the first to grow MOF membranes inside hollow fibers, could change the way large-scale energy-intensive chemical separations are done.

By replacing energy-intensive distillation or cryogenic techniques, these molecular-sieving membranes could cut the cost of gaseous and liquid separations, reduce energy consumption, and lead to industrial processes that generate less carbon dioxide. The researchers have demonstrated that membranes produced with the new technique can separate hydrogen from hydrocarbon mixtures, and propylene from propane.

“This work opens up new ways of fabricating molecular-sieving separation membranes using microscopic hollow fibers as a platform,” said Sankar Nair, a professor in Georgia Tech’s School of Chemical & Biomolecular Engineering. “Many of the separations that currently are done with energy-intensive techniques could one day be performed with membranes fabricated by a scaled-up version of our methodology.”

Energy-intensive separation processes are widely used in the industrial production of petro-based and bio-based fuels and chemicals, as well as a variety of other technological materials. The most common separation technique is distillation, which applies heat to chemical mixtures to drive off specific molecules according to their boiling points.

In contrast, molecular-sieving membranes use semipermeable materials to separate molecules from mixtures that are produced by chemical reactions or found in raw material feed stocks. The process may be driven by a pressure gradient, and relies on the membranes to preferentially pass certain molecules through their pore structures. Crystalline materials known as zeolites have been fabricated into membranes, but high membrane fabrication costs and a limited selection of materials have prevented their widespread use.

Development of the MOF fabrication methodology was described in the journal *Science*. This work was supported by the Phillips 66 Company.
My ceramics research group at the Georgia Tech School of Materials Science and Engineering investigates novel methods for making body armor strike faces for use by the military and others. We currently study boron carbide, the third-hardest material on Earth, and our research has resulted in patented techniques for making highly effective armor. One outcome of our efforts is Verco Materials LLC, an Atlanta-based startup that produces strike-face armor for personnel protection as well as for ongoing research and development.

The most critical quality of effective body armor strike faces is hardness, meaning resistance to permanent shape change when a focused compressive force is applied. Hardness is the key to preventing the armor from flowing out of the way when struck by high-speed projectiles. We have produced lightweight ceramic plates that can stop an armor-piercing rifle round traveling on the order of 2,000 mph—a capability that affords a high degree of protection for U.S. soldiers in battle zones.

Robert Speyer is a professor in the Georgia Tech School of Materials Science and Engineering.

Energy from the bullet damages the armor, but stops the bullet. The armor plate must be replaced, but has protected its wearer.

1. When a bullet hits the strike face, it’s stopped momentarily during the “dwell period,” in which it is forced to collapse upon itself and mushroom out.

2. During that time, the bullet’s energy travels as a compressive wave and then rebounds as a tensile wave that pulverizes the ceramic.

3. The bullet, or its fragments, is further degraded as the pulverized ceramic ablates it as it penetrates through. What remains is caught by the fiber-reinforced backing.

This armor consists of two parts: a ceramic strike face and a fiber-reinforced polymer backing. The exceptional degree of hardness of the strike face was developed using a process that sinters (consolidates) boron carbide powder compacts under carefully controlled thermal and atmospheric conditions. That phase is followed by compressing with a high pressure/high temperature gas. The end result is a boron carbide ceramic with no remaining porosity and very high hardness.
BLOOD CELLS ON A MICROCHIP

Researchers are studying how nanoparticles behave in blood vessels

Designing nanomedicine to combat diseases is a hot area of research, but little is known in the context of atherosclerotic disease. Scientists have now engineered a microchip coated with blood vessel cells to learn more about the conditions under which nanoparticles accumulate in the plaque-filled arteries of patients with atherosclerosis, the underlying cause of myocardial infarction and stroke.

In the research, microchips were coated with a thin layer of endothelial cells, which make up the interior surface of blood vessels. In healthy blood vessels, endothelial cells keep foreign objects out of the bloodstream. But at sites prone to atherosclerosis, the endothelial barrier breaks down, allowing things to move in and out of arteries that shouldn’t.

In a new study, nanoparticles were able to cross the endothelial cell layer on the microchip under conditions that mimic the permeable endothelium of a microvessel in atherosclerosis. The results on the microfluidic device correlated well with nanoparticle accumulation in the arteries of an animal model with atherosclerosis, demonstrating the device’s capability to help screen nanoparticles and optimize their design.

“It’s a simple model — a microchip, not a cell culture dish — which means that a simple endothelialized microchip with microelectrodes can show some important predictions of what’s happening in a large animal model,” said YongTae (Tony) Kim, an assistant professor in Georgia Tech’s George W. Woodruff School of Mechanical Engineering.

The research was published in the journal Proceedings of the National Academy of Sciences. It represents a multidisciplinary effort of researchers who are collaborating within the Program of Excellence in Nanotechnology funded by the National Heart, Lung, and Blood Institute of the National Institutes of Health. The team included researchers at the David H. Koch Institute for Integrative Cancer Research at MIT, the Icahn School of Medicine at Mount Sinai, the Academic Medical Center in Amsterdam, Kyushu Institute of Technology in Japan, the Boston University School of Medicine, and Harvard Medical School.
Flock Together

Today’s unmanned aerial vehicles (UAVs) typically fly alone with a team of ground operators controlling their activities through tele-operation or waypoint-based routing. But one aircraft can only carry so many sensors, limiting its capabilities. That’s one reason a fleet of autonomous aircraft can be better than one flying alone.

In one of the world’s first autonomous demonstrations, the Georgia Tech Research Institute (GTRI) successfully commanded three fully autonomous, collaborating UAVs. The machines flew in close formation at the same altitude, separated by approximately 50 meters as they executed figure-eight patterns.

The three UAVs operated in the air over Fort Benning, near Columbus, Georgia. A single plane was initially designated as the leader and commanded to fly autonomous orbits. The two “follower” UAVs joined the orbits, flying with rotational offsets of 15 and 30 degrees, respectively, from the leader.

“For autonomous systems to scale effectively, future systems will need the ability to perform with a higher level of autonomy,” said GTRI Chief Scientist Lora Weiss, who leads GTRI’s UAV research. “Human operators must be able to provide high-level task descriptions, allowing the systems to figure out for themselves how to dynamically form teams and autonomously collaborate to complete tasks.”

UAVs working in teams could have many applications. For example, two UAVs could provide different camera angles while searching for a missing person. When checking on a wildfire, one vehicle could assess temperature, while another measures the fire’s extent.

The research is part of GTRI’s efforts to improve the capabilities for autonomous systems collaborating as teams, thereby reducing the load on human operators.

FLIP THE SWITCHGRASS

Although fuel cells powered by methanol or hydrogen have been well studied, existing low temperature fuel cell technologies cannot directly use biomass because of the lack of an effective catalyst system for polymeric materials.

Now, researchers have developed a new type of low-temperature fuel cell that directly converts biomass to electricity with assistance from a catalyst activated by solar or thermal energy. The hybrid fuel cell can use a wide variety of biomass sources, including cellulose, lignin – and even switchgrass, powdered wood, algae, and waste from poultry processing.

The device could be used in small-scale units to provide electricity for developing nations, as well as for larger facilities to provide power where significant quantities of biomass are available.

“We have developed a new method that can handle the biomass at room temperature, and the type of biomass that can be used is not restricted,” said Yulin Deng, a professor in Georgia Tech’s School of Chemical and Biomolecular Engineering and the Renewable Bioproducts Institute. “This is a very generic approach to utilizing many kinds of biomass and organic waste to produce electrical power without the need for purification of the starting materials.”

The challenge for biomass fuel cells is that the polymer chains in the biomass cannot be easily broken down by conventional catalysts. To overcome that challenge, scientists have developed microbial fuel cells in which microbes or enzymes break down the biomass. But that process has drawbacks: Power output is limited, microbes or enzymes can selectively break down only certain types of biomass, and the microbial system can be deactivated by many factors.

Deng and his research team overcame those challenges by altering the chemistry to allow an outside energy source to activate the fuel cells’ oxidation-reduction reaction.

The work has been described in the journals Nature Communications and Angewandte Chemie International Edition.

Factoid

The new Renewable Bioproducts Institute at Georgia Tech conducts research aimed at transforming biomaterials into new products, including traditional and novel forest products, renewable energy, chemicals, advanced materials, and pharmaceuticals.

GTRI researchers are using quarter-scale Piper Cub aircraft to study how UAVs can work together.

Hybrid fuel cells that use a catalyst activated by solar or thermal energy could directly utilize a range of biomass materials, including switchgrass.

GTRI researchers are using quarter-scale Piper Cub aircraft to study how UAVs can work together.
A combined computational and experimental study of self-assembled silver-based structures known as superlattices has revealed an unexpected behavior: arrays of gear-like molecular-scale machines that rotate in unison when pressure is applied to them.

The superlattice structures, self-assembled from smaller clusters of silver nanoparticles and organic-protecting molecules, form in layers, with the hydrogen bonds between their components serving as “hinges” to facilitate the rotation. Movement of the “gears” is related to another unusual property of the structures: Increased pressure on the superlattice softens it, allowing subsequent compression to be done with less force.

Materials containing the gear-like nanoparticles – each composed of nearly 500 atoms – might be useful for molecular-scale switching, sensing, and even energy absorption. The complex superlattice structure is among the largest solid ever mapped in detail using a combination of X-ray and computational techniques.

“As we squeeze on this material, it gets softer and softer and suddenly experiences a dramatic change,” said Regents Professor Uzi Landman, the F.E. Callaway professor in the Georgia Tech School of Physics. “When we look at the orientation of the microscopic structure of the crystal in the region of this transition, we see that something very unusual happens. The structures start to rotate with respect to one another, creating a molecular machine with some of the smallest moving elements ever observed.”

The gears rotate as much as 23 degrees and return to their original position when the pressure is released. Supported by the Air Force Office of Scientific Research and the Department of Energy’s Office of Basic Energy Sciences, the research was reported in the journal *Nature Materials*. The University of Toledo also contributed to the project.
THE AGILE APERTURE FLIES HIGH

The Georgia Tech Research Institute’s (GTRI) software-defined, electronically reconfigurable Agile Aperture Antenna has now been tested on land, sea — and air.

Two of the low-power devices, which can change beam directions in a thousandth of a second, were demonstrated in an aircraft during flight tests held in Virginia in February. One device, pointed up, maintained a satellite data connection as the aircraft changed headings, banked, and rolled. The other antenna, pointed down, tracked electromagnetic emitters on the ground.

“We were able to sustain communication with the commercial satellite in flight as the aircraft changed headings dramatically,” explained Matthew Habib, a GTRI research engineer. “At the same time, we were maintaining communication with a device on the ground.”

In addition to rapidly altering its beam direction, the antenna’s frequency and polarization can also be changed by switching active components. The prototype used in the test operated from 500 to 3,000 megahertz with a plus or minus 60-degree hemispherical view.

Beyond its ability to be easily reconfigured, the antenna’s low power consumption and flat form make it ideal for unmanned aerial vehicles (UAVs) that have small power supplies and limited surface area for integrating antennas. Composed of printed circuit boards, the antenna components weigh just two or three pounds.

Beyond aircraft, ships, and ground vehicles, the antenna’s concept could also be used in mobile devices, where its ability to be tuned dynamically could help cut through congestion on cellular networks.

MISSILE MAN

The AN/AAR-57 Common Missile Warning System helps protect Army aircraft from attack by shoulder-launched missiles and other threats. To keep this defensive system operating at maximum effectiveness, the Army periodically updates the software on the more than 1,000 units in use around the world.

Before new updates are fielded, however, they must be thoroughly tested to make sure the software performs as expected. Thanks to collaboration between researchers at the Georgia Tech Research Institute (GTRI) and the Army Reprogramming Analysis Team (ARAT), that testing can now be done in a new integrated support station (ISS) that puts the software through its paces under conditions simulating actual aircraft operation.

Using a standard AN/AAR-57 system unit and associated sensors, the ISS tests software updates under a wide range of scenarios and conditions to make sure they will perform as expected.

“The ISS creates an environment by feeding data to the sensors, simulating threats, and monitoring the responses the unit makes to the simulated threats,” said William Miller, a GTRI senior research scientist who leads the project. “The ISS then correlates the results to make sure the system’s responses are what should be expected from the threat information fed into the system.”

The ISS development was part of a multi-phase program that transferred sustainment of the AN/AAR-57 software from the system’s original equipment manufacturer to the Army. GTRI has been involved in the effort since 2010, working closely with ARAT program staff and managers housed on the Georgia Tech campus in Atlanta.

Factoid

Hi
How Can I Help You?

CO-ROBOTS TEAM UP WITH HUMANS
BY JOHN TOON PHOTOGRAPHS BY ROB FELT
Charlie Kemp is giving robots common sense. And that's good news for Californian Henry Evans.

Ten years ago, Evans suffered a stroke that left him with limited mobility. Over the past two years, he's been working with Kemp, an associate professor in the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University, to develop and test robots that help him shave, adjust a blanket when he's cold, and even scratch an annoying itch.

"We did things with the robots that I never could have imagined," said Evans, who contacted Kemp after seeing him on a CNN broadcast about health care robots.

Robots working directly with people – even helping them shave – is both challenging and unusual. Most robots today work in manufacturing facilities where, for safety reasons, they stay far away from humans. But Georgia Tech robotics researchers believe people and robots can accomplish much more by working together – as long as the robots have common sense to know, for instance, how much force humans apply when shaving.

"A major challenge for health care robots is that they lack so much of the knowledge and experience that people take for granted," said Kemp. "To us, it's just common sense that everybody has; for robots, it's a serious impediment."

Giving robots common sense is just one milestone on the path to the kinds of collaboration that will be required to meet the needs of a growing population of older persons. Beyond personal care, the benefits of co-robotics are many. To produce better products more efficiently, manufacturing robots will need to team up with humans, each contributing unique abilities. And in defense and homeland security, robots will increasingly have to take on the dangerous jobs, leveraging people's skills while protecting them from harm.

Robots as Appliances

For co-robotics to become reality, robots will have to be easy enough for ordinary people to use.

"We can’t make the assumption that potential home users of robots have even used an iPad," said Henrik Christensen, a professor in Georgia Tech’s School of Interactive Computing and executive director of the Institute for Robotics and Intelligent Machines (IRIM). “Instead of looking at the technology and the technological capabilities of robots, we need to look at making this as simple as possible for the person at the other end. If we don’t, people just won’t use robots.”

Christensen believes robots will one day be more like home appliances. Unpack them, turn them on, and start using them. Fortunately, computing power, sensing, vision, speech recognition, and other technologies have advanced in power and fallen in cost to the point where it will be possible to produce inexpensive, but highly capable home robots.

“We are at a point where we can make technology that is fluent enough that people can use it,” added Christensen, who holds the title of KUKA Chair of Robotics and Distinguished Professor. “We need to reach the level of fluency where getting a robot is like getting a new assistant in the home. It needs to be as easy as turning on the television.”

Beyond ease of use, having robots work directly with people will require both human and machine to understand each other better. Robots will have to recognize what humans are trying to do so they can anticipate their needs – and avoid inadvertently harming them.

Mathematics Tutors

As class sizes increase, teachers are busier than ever – and so are parents. So who’s going to help kids understand critical math concepts?
“If you buy your kids an Xbox,” she reasoned, “you should be able to buy them a robotic tutor.”

FACTORY FLOOR COLLABORATION

Most robots today work with other robots on the factory floor, welding parts, painting or handling other repetitive jobs. Meanwhile, human workers handle tasks that are too complicated for robots or require significant judgment.

Aaron Bobick sees a potential partnership there.

In a project being done for BMW in South Carolina, Bobick is helping robots anticipate the needs of human workers building sub-assemblies for automotive consoles. Right now, humans must fetch the parts needed for each step, scanning them first to ensure that they are the right components for each vehicle before installing them.

“We have split the task up so the machine does the fetching and scanning, while the human does the inserting and installing,” said Bobick, a professor in Georgia Tech’s School of Interactive Computing. “The idea is for a fluid interaction – a fluid choreography, with the robot continually aware of what the human is doing.”

Among the key issues in teaming robots with people: helping robots anticipate what people intend to do so the human-robot team can produce a better product more efficiently.

“The robots need to clearly understand what the human is doing – and be able to anticipate the next action,” he said. “If the robot has to fetch the next part, the sooner it can know what part the human is going to need, the more in advance it can start, so that by the time the part is needed, the robot has it ready.”

Safety is another obvious consideration. Like a good assistant, robots can be programmed to stop what they are doing or get out of the way if the human does something unexpected. “The robot always has to be aware of the human’s presence,” Bobick noted.

In many ways, manufacturing is the easiest environment for a robot. An entire factory floor or warehouse can be engineered for automation, with any variables – lighting or floor obstacles – eliminated. Robots working in health care settings or the home don’t have such advantages.

FLYING FARMERS

Lora Weiss is taking robotics to new heights – thousands of feet up into the air. Working with bright-yellow, propeller-driven unmanned aerial vehicles (UAVs) that serve as test beds, she’s facilitating collaboration between humans and the flying robots – and even among the machines themselves.

The goal is for robots to protect humans from dangerous tasks while leveraging their capabilities. One example is monitoring forests for the early signs of fire. UAVs carrying sensors can quickly cover large areas and easily distinguish a Boy Scout campfire from a growing wildfire. Other examples include search and rescue missions and military tasks that can be accomplished by robots – instead of risking a human pilot.

“Anything that is dangerous, you want the robots to do,” said Weiss, who is chief scientist in the Georgia Tech Research Institute (GTRI). “You want the human to be as far away as possible, which means the robots have to go farther on their own.”

Like others pursuing co-robotics at Georgia Tech, Weiss sees robots and humans as complementary. “Machines don’t get bored like people do,” Weiss noted. “Humans know how to put information into context, so we can ask robots to conduct the tedious searches and let people know when they see something unusual.”

To be effective, robots will have to be more than mobile sensor systems. Instead of sending a video stream back to an operator who must watch it continuously, an agricultural robot could scan fields, armed with the knowledge of what diseased plants looks like. Only when it sees signs of disease would it...
alert a human collaborator. Having that level of sophistication will require powerful on-board computing able to sense the environment, merge and interpret data, and decide whether the information should be shared.

The robots Weiss works with are fully autonomous, no longer guided by remote pilots. Humans will continue to set mission parameters and oversee the robots, but their involvement will be much less than in the past.

Of course, allowing robots to operate on their own raises ethical questions, particularly in military domains. Just how independent can they be?

“It’s like the decisions parents make with teenagers,” Weiss said. “You want to give them independence, but only if they’re ready for it. When you have confidence that the robot is behaving responsibly, you’ll allow it to do more.”

Beyond human-robot collaboration, GTRI is also helping teams of UAVs work together. One aircraft may carry a heat sensor, while another will have a video camera. The aircraft work together using their complementary capabilities to provide better information. Recently, GTRI demonstrated that three UAVs could maintain formation while flying together.

“Getting humans and robots to interact the way humans work together is an exciting challenge,” said Weiss. “Traditionally, we have had humans commanding the robots and having constant oversight of them. We want to start loosening that control to let the robots do more on their own.”

**ROBOTIC CAREGIVERS**

In Charlie Kemp’s lab, a robotic arm with sensors in its skin reaches through a table covered with plants. It rustles the leaves as it moves between them, a task unthinkable for robots until recently. Being able to touch objects – and people who need help – through such cluttered environments will be essential to personal care robots of the future.

“If you decide that the robot’s arm shouldn’t touch anything, which has been the standard approach, you greatly limit the robot’s capabilities,” said Kemp. “With these limitations, the robot couldn’t reach to the back of a cluttered refrigerator or shelf. Many of the things it could have done for a person with disabilities would be out of reach.”

But modern robots can learn and understand much more than earlier generations. Today’s robots can know how to avoid harming people, how much force is reasonable to open a door, and how to operate amidst clutter. And research has already shown that people are comfortable with robots touching them. With our intelligent control system, we have shown it can be fine for the robot’s arm to make contact with people because it keeps the forces low,” Kemp explained. “Humans are accustomed to touching the world. We want to give that capability to robots because it can dramatically increase their ability to provide assistance.”

Over the past two years, Kemp has been working with Henry and Jane Evans to explore the bounds of personal care robots. When he was just 40 years old, Henry suffered a stroke that left him with the ability to move just his head and a finger. Among their goals for the effort: to make operating a robot simple enough for people without specialized training.

“You shouldn’t need a Ph.D. in robotics to be able to program a robot to do these things,” said Kemp, who also works with ALS researchers at Emory University in Atlanta. “We want to give robots more intelligence and more autonomy so they’ll be easier to use and more useful.”

Cost is still an issue, and will be until the price of robotic arms drops further, Kemp said. But through working with more than 200 people, one conclusion is clear:

“People are extremely excited about this technology across the board, even when they have worked with technology that isn’t very polished yet,” added Kemp, who has funding from the National Science Foundation (NSF) and the National Institute on Disability and Rehabilitation Research (NIDRR). “You can have great technology that could potentially help a lot of people, but if people don’t choose to adopt it, it won’t do much good.”

**CONDUCTING A SWARM**

Magnus Egerstedt works with lots of robots – all at the same time. He’s studying how humans can interact with swarms of inexpensive robots that individually have different capabilities. Swarms offer redundancy and the ability to get big jobs done quickly, but humans aren’t very good at managing multiple robots at the same time.

“You have to interact with robots at the team level,” explained Egerstedt, the Schlumberger Professor in Georgia Tech’s School of Electrical and Computer Engineering. “The questions I’m exploring revolve around how people should be embedded in these swarms and the ways people can direct the robots – much like how a single person conducts an entire orchestra.”

The swarms are composed of robots that aren’t so capable or talented on their own. But together with other members of the team, they can figure out how to carry out complex tasks – much like swarms of insects. Egerstedt is fond of showing videos in which robot teams form letters of the alphabet, with the team members negotiating among themselves to accomplish the tasks.

“With swarms, you have robots that are autonomous in the sense that they can make their own decisions even if, individually, they are sometimes rather ill-informed,” he said. “They have to come together to do things. No single robot is in charge, so they have to negotiate among themselves and with the human operator. The beauty of this is that results emerge.”

To make this happen, Egerstedt has to give the robots an ability to think differently than robots have in the past. For instance, a high priority for robots has always been avoiding collisions with other robots or humans. But with dozens, hundreds, or thousands of robots working together, that may no longer be practical.

“When people walk through crowds, we bump into each other all the time,” he noted. “We don’t run straight into each other, but there are little nudges here and there. Fish and birds also do this. So I’m letting the robots bump into each other. If you allow graceful collisions, you get less conservative solutions and can get more done.”

Other challenges will include scaling up the control algorithms from the 15 aerial and ground robots Egerstedt currently has in his lab. He believes that swarms of robots could be useful in search and rescue missions, farming, homeland security, and military operations.

Co-robotics offers benefits in many areas of society. The level of enthusiasm is high, but the potential beneficiaries are tempering their enthusiasm with a dose of reality.

“Like most new technologies, robots will turn out to be extremely useful for some things, and not so useful for others,” said Evans. “The point of the current research is to determine what they are best at.”

Georgia Tech robotics research is supported by a broad range of organizations, including the National Science Foundation, National Institutes of Health, DARPA, Army Research Office, BMW, Boeing, and John Deere & Company.

John Toon is director of research news at Georgia Tech and editor of Research Horizons magazine. He’s been writing about Georgia Tech research and economic development activities for more than 30 years.
The amazing ability of sidewinder snakes to quickly climb sandy slopes was once something that puzzled biologists and that roboticists only dreamed of replicating. But, by studying the snakes in a unique bed of inclined sand and using a snake-like robot to test ideas spawned by observing the real animals, both biologists and roboticists have now gained long-sought insights.

In a study published in the journal *Science*, researchers from Georgia Tech, Carnegie Mellon University, Oregon State University, and Zoo Atlanta report that sidewinders improve their ability to traverse sandy slopes by simply increasing the amount of their body area in contact with the granular surfaces they’re climbing. As part of the study, the researchers used a modular snake robot to test principles used by the sidewinders. Before the study, the snake robot was unable to climb the inclined sand trackway the real snakes could gracefully ascend. However, when the robot was programmed with the unique wave motion discovered in the sidewinders, it was able to climb slopes it would have been unable to otherwise.

“Our initial idea was to use the robot as a physical model to learn what the snakes experienced,” said Daniel Goldman, an associate professor in Georgia Tech’s School of Physics. “By studying the animal and the physical model simultaneously, we learned important general principles that allowed us to not only understand the animal, but to also improve the robot.”

The detailed study showed that both horizontal and vertical motion had to be understood and then replicated on the snake-like robot for it to be useful on sloping sand.

“During sidewinding, the snake lifts a section of its body and moves it forward, places it down on the sand, then repeats the motion,” explained Henry Astley, a postdoctoral fellow in Goldman’s lab. “This allows the snake to move with a stepping motion, even though the animal doesn’t have legs, and the belly never slides against the substrate. As the slope increases, the snake places more body in contact with the sand.”

Using high-speed video cameras, the researchers observed several sidewinders at Zoo Atlanta as they moved in a large enclosure containing sand from the Arizona desert.

“We realized that the sidewinder snakes use a template for climbing on sand, two orthogonal waves that they can control independently,” said Hamid Marvi, a postdoctoral fellow at Carnegie Mellon who conducted the experiments while he was a graduate student in the laboratory of Associate Professor David Hu in Georgia Tech’s School of Mechanical Engineering. “We used the snake robot to systematically study the failure modes in sidewinding.”

The modular snake robot used in this study was specifically designed to pass horizontal and vertical waves through its body to move in three-dimensional spaces. The Carnegie Mellon robot is 2 inches in diameter and 37 inches long; its body consists of 16 joints that allow it to move using a variety of gaits – some similar to those of a biological snake.

“This type of robot often is described as biologically inspired, but too often the inspiration doesn’t extend beyond a casual observation of the biological system,” said Howie Choset, a Carnegie Mellon professor of robotics. “In this study, we got biology and robotics, mediated by physics, to work together in a way not previously seen.”

The robot could be used in search and rescue operations, for archaeological explorations, and for inspecting piping in facilities such as nuclear power plants.

Many people dislike snakes, but in this study, the venomous animals were easy study subjects that provided knowledge that may one day benefit humans, noted Joe Mendelson, director of research at Zoo Atlanta.

“If a robot gets stuck in the sand, that’s a problem, especially if that sand happens to be on another planet,” he said. “Sidewinders never get stuck in the sand, so they are helping us create robots that can avoid getting stuck. These venomous snakes are offering something to humanity.”

For Goldman’s team, the work builds on earlier research on how turtle hatchlings, crabs, sandfish lizards, and other animals move on complex surfaces such as sand. In its research, the team tested what it learned from the animals on robots, often gaining additional insights into how the animals move.

Co-authors of the *Science* article included Chaohui Gong and Matthew Travers from Carnegie Mellon University, and Nick Gravish from Georgia Tech. The research was funded by the National Science Foundation, the Army Research Office, and the Army Research Laboratory.

*The opinions expressed are those of the authors and do not necessarily represent the official views of the sponsoring agencies.*
VventureLab Hatches Sustainable Faculty and Student Startups

BY T.J. BECKER  ILLUSTRATIONS BY HARRY CAMPBELL
Becoming an entrepreneur was never on Ayanna Howard’s to-do list. “In fact, it wasn’t even a remote thought in my mind,” said Howard, a professor in Georgia Tech’s School of Electrical and Computer Engineering. Today, however, Howard is the founder and chief technology officer of Zyrobotics LLC. Launched in September 2013, the company is commercializing assistive technology that enables children with limited mobility to operate tablet computers, smartphones, toys, gaming apps, and interactive robots.

With eight employees, Zyrobotics introduced three gaming apps earlier this year and expects to begin shipping its first smart toy in December. By 2016, Howard believes the company could be generating $4 million in annual revenue, with 30 employees.

**MARKET POSSIBILITIES TO PROBABILITIES**

What changed Howard’s mind about commercialization? “Two things,” she said. “I-Corps opened my eyes to the possibility – and VentureLab provided a safe haven to launch a startup.”

A unit within Georgia Tech’s Enterprise Innovation Institute (EI²), VentureLab helps Georgia Tech faculty, students, and staff transform innovations into sustainable companies. Among its many programs is I-Corps, which VentureLab administers for the National Science Foundation (NSF) to validate market opportunities for technologies developed by NSF-sponsored researchers.

Howard went through I-Corps in summer 2012, and then incorporated Zyrobotics with VentureLab’s assistance. “VentureLab is a solid bridge to transition technology from the lab into the market. You’re not swimming with the sharks,” Howard said, noting the incubator helped her:

- Find manufacturers and electronic vendors to produce Zyrobotics’ products.
- Navigate through the licensing process by sharing insights about how other licensing agreements have been structured.
- Obtain $50,000 in grants from the Georgia Research Alliance (GRA) to develop a revised prototype.
- “The GRA funding was a big help,” Howard said. “Going through I-Corps gave us critical information about what we needed to change on our device, but we still had to implement those changes. It’s hard to get that kind of money because you’re not doing academic research, and you’re not really a business yet.”

For Suman Das, a professor in the George W. Woodruff School of Mechanical Engineering, VentureLab has been instrumental in his strategic thinking. As CEO of DDM Systems Inc., Das is commercializing two technologies for additive manufacturing. The first, known as large area maskless photopolymerization, reduces the time and cost to make ceramic components, cores, and molds used in metal-forming processes. The second technology, scanning laser epitaxy, can produce metal components directly from powder as well as repair existing components.

Launching two disruptive technologies at the same time greatly complicates the challenges of a startup, Das explained. “VentureLab’s advice has been very important in how we approach this, what kind of infrastructure we need, and how to build a cross-functional team that can contribute to the launch of both technologies.”

In addition to mentoring, VentureLab has helped raise DDM’s visibility. Das points to the ability to secure $350,000 in GRA grants and loans, along with $3 million from private investors. “VentureLab has taken every opportunity to promote us and vouch for us,” he said. “And, because of its reputation, that gives our company additional credibility. When VentureLab speaks, people listen.”

**STARTUP THERAPY**

Indeed, VentureLab ranked No. 2 among U.S. university business incubators, according to a recent study by UBI Index, a Stockholm-based consulting group. VentureLab also placed 17th globally, scoring high for both the success of its companies and their diverse technologies.

These technologies run the gamut from computer science and Internet technologies to life science and engineering-based innovations.

Take Inmondo Tech, founded by David Sholl and Krista Walton, both of Georgia Tech’s School of Chemical & Biomolecular Engineering. The company is commercializing metal-organic frameworks (MOFs), a class of nanomaterials with numerous real-world uses, such as capturing contaminants from the air or liquids.

I-Corps helped Sholl and Walton confirm market interest, and then VentureLab picked up from there, working with them to refine Inmondo Tech’s business model, win GRA funding, and prepare to go to market. The company has already sold initial products for air purification and refrigeration applications.

In addition to business mentoring, the moral support VentureLab provides is invaluable, Sholl said, likening conversations with incubator advisers to “startup therapy.”

“Because Krista and I are faculty members and have a variety of other things going on, it’s easy to get distracted or feel overwhelmed by all the details of commercialization,” explained Sholl, who is the school chair. “VentureLab is a friendly ally that helps us evaluate where we are – and where we need to be next. It helps us stay accountable and keep moving ahead.”
EXPERTS AT CREATING COMPANIES
Although Georgia Tech has numerous programs to support startup activity, one of VentureLab’s hallmarks is its client base.

“We’re white and gold,” said Keith McGreggor, director of the incubator since 2008. “VentureLab will help anyone who is actively affiliated with Georgia Tech, whether they’re a student, faculty member, researcher, or staff. If a building custodian has developed an intriguing innovation, they can come to us.”

People sometimes confuse VentureLab with ATDC, another entrepreneur-support unit at EI2. Although the groups work together, VentureLab focuses on technology developed within the Georgia Tech community whereas ATDC serves entrepreneurs throughout the state not necessarily affiliated with the Institute. Another distinction, VentureLab gets involved with innovations at a much earlier stage. “We work with the companies for a while, then they move into ATDC and go out into the world,” McGreggor said.

In most academic institutions, licensing and commercialization services are housed under one roof. Yet, VentureLab is separate from the Georgia Tech Research Corp., the university’s licensing arm.

“I think it’s one of our super powers,” McGreggor said. “Because our group doesn’t take any equity or royalties from the entities we help create, we can give unvarnished advice. What’s more, our group is filled with entrepreneurs — super-geeks who have launched companies, raised money, lost money, hired, and fired. We’re experts at creating companies.”

Indeed, McGreggor has founded or co-founded six software firms, including the first artificial intelligence company in the Southeast. Roberto Casas, VentureLab’s associate director, and its five other principals (Colin Ake, Paul Freet, Ben Hill, Harold Solomon, and James Stubbs) are seasoned entrepreneurs who have launched companies, raised money, lost money, hired, and fired. We’re experts at creating companies.”

Ken Johnson and Dan Campbell, who helped develop the technology at GTRI. Although Slawson is a serial entrepreneur and former venture capitalist, he praises VentureLab for helping identify blind spots.

“I’ve been exposed to a lot of markets, but they know more about some than I do — and they know some that I don’t,” Slawson explained. “It’s been very helpful to discuss the pros and cons of different markets we want to pursue, along with their sequencing.”

I think it’s one of our super powers. Because our group doesn’t take any equity or royalties from the entities we help create, we can give unvarnished advice.

Slawson also credits Freet for providing introductions that led to two rounds of funding, totaling $3.65 million, from angel investor Leland Strange of Intelligent Systems Corp., and The Coca-Cola Company. The money is helping Lumense refine its sensor platform for high-volume, low-cost manufacturing, and Slawson expects to deliver initial units in early 2015.

“Our technology is simple but powerful,” Slawson said. “In my venture capital career, I’ve seen that a cutting-edge technology doesn’t always win the battle. What’s more important is to have a product that’s well timed for the market.”

GETTING OUT OF THE LAB
Under McGreggor’s aegis, VentureLab has evolved from traditional commercialization services to an intense focus on customer discovery. The first order of business for startup teams is to contact 100 potential customers and verify interest in their product.

In addition, VentureLab wants entrepreneurs to understand the customer’s purchasing motivation. “Why would they buy a product from your company?” McGreggor asked. “That’s different than identifying a customer segment, and you can’t Google it. You have to go out and talk to actual living, breathing people.”

These conversations can be eye-opening for academic researchers. “We saw customers were interested in features different from what the research community focuses on,” said Sholl. “Researchers win credit for devising a brand new material. But potential customers want to know about more mundane features: Is it stable? Is it cheap? Can you give this to me in the form of a powder or a pellet? Such things don’t get addressed in research literature.”

VentureLab makes the innovation process more efficient, observes Bernard Kippelen, a professor in Georgia Tech’s School of Electrical and Computer Engineering and director of the Center for Organic Photonics and Electronics.
No stranger to commercialization, Kippelen holds more than 15 patents and has been involved in several startups. He equates VentureLab’s customer discovery process with the methodology scientific researchers use: First conduct experiments, and then draw conclusions from the resulting data. “It’s important to go through that process in the business world,” Kippelen said. “You need to be able to generate data to validate your assumptions about customers before you raise millions of dollars and spend years of your time only to find out that your great technology is not so great.”

Case in point: Kippelen is working on an optical technology he originally thought would help manufacturers who use lasers to achieve cleaner, more precise cuts. After four weeks of talking to potential customers, Kippelen saw little enthusiasm from manufacturers. Yet, discussions with vascular surgeons identified a completely new application for his technology: an ultra-fast camera shutter that makes medical imaging safer and less invasive than the current method of ionizing radiation.

“VentureLab is real partnership,” observed Kippelen. “It’s a constant exchange of ideas and best practices about how to commercialize innovations. They help you through a process where you forget about the technology for a while, get out of the lab, and really listen to potential customers. It completely changes how you think about your research; it’s no longer about publishing the next paper but truly finding solutions to people’s problems.”

Customer discovery also helps establish relationships in large companies at the senior level, pointed out VentureLab’s Harold Solomon. “Even if faculty members don’t move ahead with a startup, they may get sponsored-research opportunities. It’s a no-lose proposition.”

Sholl believes that VentureLab brings a different nuance to the university’s intellectual environment: “Even if my grad students end up working for a giant petrochemical company, they can use their entrepreneurial skills to develop new ideas, think about who their customers are, and connect with them.”

For Howard, commercialization has been gratifying on multiple levels. “For one thing, it’s rewarding because it’s challenging,” she explained. “Being a business owner is forcing me to learn a whole new set of skills.” Like Kippelen, commercialization has made Howard look at academic research differently. Instead of thinking about “the next great paper and citations,” she now focuses on how her research could ultimately help someone.

Today’s jobs didn’t exist 20 years ago and won’t exist 20 years from now.
THE
BIRD’S
EYE

Upgrades Mark 20th Anniversary of FalconView Mapping Program

BY RICK ROBINSON
PHOTOGRAPHS BY ROB FELT
A specialized mapping software program along with late-breaking intelligence to plan an upcoming combat mission. At a stateside surveillance center, an intelligence analyst is running the same software on a desktop PC, tracking a suspicious vehicle at a U.S. border. And half a world away, the mapping tool is helping the pilots of a massive military cargo aircraft navigate home.

Using a single software program for a broad range of mission planning, mapping, and surveillance tasks isn’t a new concept. It’s a strategy that U.S. forces and agencies have followed for two decades, and it’s become an essential part of multiple military and intelligence operations. Consistently, the core software used is FalconView®, first developed in 1994 by the Georgia Tech Research Institute (GTRI) for the U.S. Air National Guard (ANG).

“Our current numbers on FalconView’s distribution are in the 80,000-user range—it’s used today by the military, federal agencies, and allied countries for a wide variety of intelligence, planning, and operational tasks,” said John Pyles, the principal research scientist who leads FalconView development for GTRI. “Both aircrew and analysts routinely use FalconView to help gather intelligence, and that intelligence can then become part of a FalconView mission package that pilots can rehearse almost like a video game.”

This year—FalconView’s 20th anniversary—two new editions of the program are being developed to extend the original Microsoft Windows-based 2-D version of the software:
• FalconView 3-D adds capabilities to better support surface missions carried out by ground units, ships, and others.
• FalconView Mobile extends these capabilities to tablets and smartphones.

In addition to Windows, the new FalconView versions will run on a variety of other operating systems. The work is sponsored by the U.S. Special Operations Command (USSOCOM).

The FalconView of today serves as the interface for a varied group of mission planning software tools known as the Portable Flight Planning System (PFPS), the Joint Mission Planning System (JMPS), and XPlan—all of which analyze and display vital geographical data. For the sake of convenience, users often refer to the graphical portion of these tools as FalconView.

FalconView can display many types of maps, including aeronautical charts, satellite images, and elevation maps. It also supports multiple types of overlays, allowing them to be displayed and printed over any map background.

Combined with global positioning systems (GPS), FalconView supports the use of aircraft by moving-map displays, which are more complex versions of now familiar consumer applications in which a symbol representing a cellular phone or other GPS device remains stationary on a display screen while a route map moves underneath. FalconView can also aid combat operations by displaying incoming tactical data in real time.

“FalconView serves as the framework for a wide variety of tools and increases their interconnectivity,” said Pyles. “It’s the glue that helps provide broad situational awareness to the operator.”

Major Functionality Upgrade
FalconView 3-D is designed to give surface-based military units an improved battlefield perspective. Unlike the traditional 2-D version of FalconView, which was developed primarily for aviation and other bird’s-eye view applications, FalconView 3-D can give those operating on the ground or water a first-person view of the surrounding area, complete with incoming intelligence data that updates the battlefield situation in real time.

“I can sit in my office and have big 3-D displays around me, but I can’t take them with me when I’m out in the field,” said David Millard, a GTRI principal research engineer who helps test FalconView products. “I want something that shows me my situational awareness in perspective, so that I can see the good guys and the bad guys relative to my position.”

This 3-D capability, Millard adds, is important to surface forces as varied as Army and Marine infantry units, tank units, and naval vessels—even Navy Seals. Compared to a two-dimensional view from above, it can give them a more intuitive picture of their situation.

“With these tools, you can first reconnoiter the mission area on screen and basically go there before you go there,” said George Menhorn, a GTRI senior research scientist and lead engineer for FalconView. “And that usually helps a lot in locating your objective.”

THE MOBILE ADVANTAGE
FalconView Mobile has the potential to support both aircraft and surface units. It brings the core features of FalconView 2-D and 3-D to highly portable tablets, considered easier to handle than laptops by many users.

FalconView on a mobile device can be an important tool for surface units engaged in missions, Millard said. It provides ready access to graphics that show combat situations at a glance. Moreover, tablet computers can provide those in the field real-time access to intelligence that predicts probable enemy behavior.

Intelligence can then become part of a FalconView mission package that pilots can rehearse almost like a video game.

Adapting FalconView to tablets can also benefit aviators, Millard explained. Mobile computing devices are currently replacing a time-honored pilots’ tool: the black flight bag. This bulky item is typically stuffed with emergency manuals, maps, and other reference materials.
“Paper is stale the day you print it,” said Millard. “But updates for pilots come out every five minutes, and an electronic flight bag can go out and get the most recent notices for airmen right before takeoff.”

**20 YEARS OF EXPERIENCE**

Acting on a request from the ANG, GTRI completed the first FalconView programs in 1994. The original GTRI development team – led by John Pyles and including Rob Gue, Jim Rhodes, and Vinny Sollicito – produced the first FalconView PC version for the MS-DOS operating system, followed shortly by a Windows 3.1 version.

Pyles said the idea for a mission-planning program that would run on the familiar PC came from a pilot named Bobby Sandford, then a captain in the ANG. Sandford wanted basic software that would give him and fellow F-16 pilots in the ANG a convenient, lower-cost alternative to the then dominant Unix mission-planning platforms.

“I wanted to avoid complexity; I wanted to provide mission-planning software that anyone could use, which would also be rock-solid and very cost-effective,” said Sandford, now a colonel and still flying fighter jets. “The engineering and the effort we got from GTRI was impressive.”

The initial version of FalconView – named after the “F-16 Fighting Falcon,” the fighter’s full name – was a set of routines that displayed scanned maps with simple stick routes drawn on top. Improved functionality followed, as the product was fleshed out by collaborations between the GTRI development team and mission planners who soon adopted the software as part of their daily activities.

As FalconView matured, USSOCOM adopted it as the framework for the entire PFPS. Important capabilities were added such as moving-map functionality, which shows aircraft location dynamically and helps provide pilots with hands-off navigation.

In 1997, the Air Force adopted PFPS, followed by the Navy in 1998, and the Army in 2002. Working with the military, GTRI gradually upgraded the program to support many platforms, including transport aircraft, helicopters, naval vessels, unmanned aerial vehicles (UAVs), and PC-based intelligence operations.

**USER-DRIVEN SOFTWARE**

Today, FalconView utilizes a range of programmer interfaces that lets multiple applications combine their information into a single coherent picture of a user’s area of interest. Moreover, the existence of the widely used FalconView standard helps users share data with other branches of the armed services and with coalition partners.

Jon R. Lindsay, a research scientist with the University of California Institute on Global Conflict and Cooperation in La Jolla, California, has written that the introduction of FalconView created strong interest among many in the military. In an article titled “War upon the Map,” published in the July 2010 edition of the journal *Technology and Culture*, Lindsay said of FalconView:

“Networks of enthusiastic users drove its functional evolution and diffusion into a de facto standard for geospatial information processing in the U.S. military, all for a total cost of about $20 million ... FalconView is a striking example of sustained and successful bottom-up innovation in a military environment.”

FalconView users continue to influence the program’s list of features, said GTRI researcher Menhorn. In some cases, he explained, pilots or intelligence analysts will spot a function they like in commercial flight-planning or geospatial programs and then request that it be added to FalconView.

“Adding new capabilities to FalconView is arguably an economical choice, as well as convenient,” Menhorn said. “The federal government owns FalconView, so there’s no license or update fees involved in adding upgrades, beyond GTRI’s one-time upgrade cost.”

**NEW OPERATING SYSTEMS**

GTRI is currently porting FalconView to a variety of platforms, in addition to Windows. These platforms include Apple Computer tablets, which use the Apple iOS operating system, and several tablets and smartphones that use the Android operating system. A version for the Linux operating system is also being developed.

The new versions will be solely for use by the U.S. military and allied nations. An open-source edition of FalconView exists; it can be downloaded by registered users in certain countries, but this edition has reduced functionality.

Development plans call for FalconView to become core to the main framework of the JMPS, the mission-planning program used by many U.S. combat aircraft, Pyles explained. FalconView maps have been a part of the JMPS system since 2002. Now JMPS will plug into FalconView, increasing JMPS’ ability to connect to a number of mission-planning software tools.

Added Sandford: “I’ve been stationed all over the world, and I can tell you that wherever you go, you’re going to see FalconView. It’s not only being used by pilots, but by the planners and the intel folks as well.”

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*Rick Robinson is a science and technology writer in Georgia Tech’s Institute Communications. He has been writing about defense, electronics, and other technology for more than 20 years.*
Biomedical engineering at Georgia Tech has risen from a handful of projects to national prominence in just two decades. Today, more than half of all incoming freshman pursue a degree in biomedical engineering, biochemistry, or biology. These students want to both understand living systems and make things that improve people’s lives.

Now, more than ever, those opportunities are plentiful in biosciences at Georgia Tech, where researchers are creating medical devices for children, understanding how diseases occur, improving vaccines, and building better biomaterials for drug delivery. Georgia Tech’s unique blend of engineering, biology, chemistry, and computing — along with partnerships with world-class medical facilities in Atlanta, such as Emory University and Children’s Healthcare of Atlanta — has transformed the Institute’s campus into a magnet for bio-minded scientists.

“What we bring to the table is a new perspective in the biological sciences that is data driven, that is quantitative, that focuses on devices and techniques and on being unafraid to ask fundamental questions,” said Ravi Bellamkonda, the chair and professor of the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University. “It’s a different approach to biology as an engineer.”

“The rise of biomedical engineering...
at Georgia Tech has created a ripple effect across the biosciences on campus. Biologists studying genetics, ecology, and personalized medicine are collaborating with engineers to solve challenging medical problems. The bio quad, home to the Parker H. Petit Institute for Bioengineering and Bioscience (IBB); the U.A. Whitaker Biomedical Engineering Building; the Ford Environmental Science and Technology (ES&T) Building; and the Molecular Science and Engineering (M) Building, already forms a hub of interdisciplinary research. Soon, other collaboration-oriented buildings will be added, solidifying the Institute’s commitment to developing its bioscience portfolio, which touches everything from mechanical engineering, to electrical engineering, to materials science and engineering.

Bioscience the Georgia Tech way has attracted high-profile faculty, such as M.G. Finn, pioneer of click chemistry and rumored Nobel Prize candidate. Also flocking to campus are fresh young minds, such as Susan N. Thomas, an assistant professor in the new field of immunoengineering. These researchers and others, who might not have come to Georgia Tech even 10 years ago, say that the Institute is already making a dent in some of the world’s biggest medical challenges, and is poised to do more. Nascent fields of research, such as immunoengineering, systems biology, pediatric bioengineering, chemical biology, and biomanufacturing, are emerging strengths on campus, positioning Georgia Tech to help define what these fields become. Georgia Tech is already recognized as a leader in regenerative medicine, cardiovascular engineering, neuroengineering, and mechanobiology.

“Considering what had been done in the past 10 years, I thought the next 10 years at Georgia Tech would be pretty exciting,” said Finn, the interim chair and professor of the School of Chemistry and Biochemistry. “Very few places in the world—if anywhere—will embed fundamental science in with applications science and technology better than we do here.”

RISK TAKERS

Building a bioscience community from scratch was a big risk, especially at a top-ranked engineering school. Visionaries such as Ajit Yoganathan, Robert Nerem, and Don Giddens took a chance and formed a partnership with Emory University in the late 1990s. They started the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and
Emory University, a rare joint department between a public and a private university. The partnership has been an overwhelming success, with the graduate program ranked second in biomedical engineering, according to U.S. News & World Report’s 2015 Best Colleges Rankings.

“There’s no doubt in my mind, we wouldn’t have a top biomedical engineering program if we didn’t have embedded within our DNA the risk-taking and vision evident from this bold partnership between Emory and Georgia Tech,” Bel-lamkonda said.

Michael Davis, an Emory associate professor in the biomedical engineering department and director of the Pediatric Center for Cardiovascular Biology at Emory, said the joint department is the model for how new therapies are made – with engineers and biomedical scientists working together to solve problems. For example, a scientist may be trying to get a cell to live longer and stay where it is needed; an engineer may have a great material that cells can survive in and that gels quickly in the body. Separately, these may be interesting, but put together, you have potential cures, Davis said.

“In the next 10 years, with the right funding, the sky could be the limit,” Davis said. “As the successes mount, so will the opportunities.”

IBB was launched around the same time as the Coulter Department, with the mission of accelerating Georgia Tech’s move into bio-related research. Today, the bioscience community is home to more than 150 faculty and more than 1,000 graduate students across 10 different academic units.

Georgia Tech’s funding from the Department of Health and Human Services, nearly all of which comes to Georgia Tech through the National Institutes of Health, has risen from $3 million in 1994 to $25 million in 2014. That acceleration shows no signs of stopping.

Opening in early 2015 is the Engineered Biosciences Building (EBB). The $113 million building will provide 220,000 square feet of multidisciplinary research space, allowing for enhanced partnerships with researchers at institutions including Emory University Hospital and Children’s Healthcare of Atlanta.

EBB will be organized into three research themes: chemical biology, cell and developmental biology, and systems biology. This creates a pathway for development and discovery that goes from the small molecule all the way up to the organism and its system. The building was designed to “promote collaborations and form teams that cut across

WITH THE ADVENT OF SYSTEMS BIOLOGY, IT BECOMES MATH WITH BIOLOGY, WHICH IS PERFECT FOR A PLACE LIKE GEORGIA TECH

MANU PLATT
Roy, who had been lured away from the University of Texas at Austin, told Finn that the Immunoengineering Research Center, a $15 million research initiative with the renowned immunologists at Emory University, had received the green light. Finn knew that immunology was key to the further development of high-impact discoveries in bioscience and was very excited to see this new initiative appear “as if by magic, but really by the efforts of forward-thinking colleagues and a supportive administration.”

Roy is now the director of Georgia Tech’s Immunoengineering Center, which is helping recruit more talent to Georgia Tech, another example of how the biosciences are continuing to grow at the Institute.

“What attracted me to Tech was the close relationship with Emory and the synergy between engineering, biology, and clinic,” Roy said. “That’s very, very rare at other institutions.”

Thomas, the assistant professor who specializes in immunoengineering, was also attracted to Georgia Tech’s research environment and the attitudes of its people. She said that the diversity and flavors on campus for engineering ideas in bioscience are “tremendously innovative and trendsetting.”

Immunoengineering is the application of engineering tools and principles to quantitatively study the immune system in health and disease. Researchers in the field develop new therapies or improve existing ones by controlling a patient’s immune response. It’s a field where engineering solutions have a clear path to improve patient care, Thomas said. Immunoengineering can impact autoimmune conditions such as multiple sclerosis, arthritis, and chronic bowel disease, as well as address challenges with infectious diseases, such as respiratory syncytial virus (RSV) in children, or HIV in adults. Immunoengineering at Georgia Tech is also focused on exploring how the immune system can be harnessed to combat cancer.

“Immunoengineering is an area Georgia Tech is poised to help define,” Thomas said. “Across the country, I hear people talking about us, how we’re leaders and how we’re ahead of everyone else in a field that everyone’s interested in.”

**TRENDING TOPICS**

Just a few months after Finn moved to Georgia Tech from The Scripps Research Institute in 2013, his decision to relocate was validated, he said, by the launching of an important new program. Roy, who had been lured away from the University of Texas at Austin, told Finn that the Immunoengineering Research Center, a $15 million research initiative with the renowned immunologists at Emory University, had received the green light. Finn knew that immunology was key to the further development of high-impact discoveries in bioscience and was very excited to see this new initiative appear “as if by magic, but really by the efforts of forward-thinking colleagues and a supportive administration.”

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**BETTING ON BIOLOGY**

When Manu Platt was a graduate student at Georgia Tech in the early 2000s, biology on campus was mostly ecology. With the rise of biomedical engineering, biology’s profile is growing, too, he said.
“They’ve brought in some big hitters, and with the advent of systems biology, it becomes math with biology, which is perfect for a place like Georgia Tech: mathematicians doing biology and vice versa,” said Platt, now an assistant professor in biomedical engineering.

The Integrative Biosystems Institute (IBSI) is a step in that direction. IBSI is a place where multi-scale, multidisciplinary systems approaches are applied toward solutions of grand-challenge problems in biology, such as developmental processes leading to cancer and the interactions between humans and microbial systems in the environment. Unraveling biological systems requires immense computing power, which Georgia Tech has no shortage of.

“I think where we could lead is in quantitative biology,” Platt said. “The more math you take, the better off you’ll be because biology is really going more quantitative.”

Melissa Kemp, an associate professor specializing in systems biology, agrees and sees Georgia Tech’s computing prowess as a big advantage, especially compared to bioscience programs housed at medical schools.

“You don’t see this level of computing infrastructure or computer science research elsewhere devoted to tackling some of the technical challenges that arise when you run large, complicated biological simulations,” Kemp said.

Kemp would like to see Georgia Tech’s broader biosciences community get the same level of recognition as its engineers. She thinks that’s not too far off due to the number of strong researchers being hired in the College of Sciences over the past two decades, and because of close collaboration with the College of Engineering.

“Everyone’s elevated with this team-science approach,” Kemp said.

Ravi Bellamkonda sees strengthening basic science at Georgia Tech as a big priority for the future.

“For strong engineering, I believe you need strong sciences also,” Bellamkonda said. “MIT’s biology department is fantastic, one of the best in the world. That doesn’t stop it from being a technology institute. I think we need to build excellence everywhere, and the opportunity to leverage our strong engineering brand to grow sciences on campus is compelling.”

He would love to see a building – maybe even two – on campus that is full of molecular biologists and life scientists who collaborate closely with engineers on campus. The strength of the School of Biology is in ecology, genetics, and data analysis, as recent publications in Science and Nature attest. But when it comes to basic science research in cell biology or traditional molecular biology, while these are on the rise at Georgia Tech, there is still plenty of room for growth.

Terry Snell, chair of the School of Biology, says that Georgia Tech has strengths in three broad areas of biology representing computational, ecology and evolution, and cell and molecular biology. Faculty have organized themselves into six interdisciplinary research centers focused on systems biology, bio-inspired design, aquatic chemical ecology, integrated cancer research, macromolecular complexes, and integrated genomics.
“I believe that the greatest opportunities for growing biosciences at Georgia Tech lie at the intersection of the fields of biology, chemistry, physics, engineering, and computation,” Snell said. “Strategic investments in these areas could rapidly advance biosciences at Georgia Tech into the ranks of the world’s leading research universities.”

DREAMING BIG
Georgia Tech boasts two world-renowned centers for the study of molecular evolution. The Ribo Evo Center, led by Loren Williams of the School of Chemistry and Biochemistry and sponsored by the NASA Astrobiology Institute, is investigating the origins of the ribosome, dubbed the operating system of life. At the Center for Chemical Evolution, led by Nick Hud, also of the School of Chemistry and Biochemistry and sponsored by a large multimillion-dollar grant from the National Science Foundation and NASA, scientists are investigating the chemical origin of life.

“The fact that there are so many people here thinking about evolution dovetails beautifully with my own plans,” Finn said. “This is where I see my own research moving in the next 10 years.”

From biomedical engineering, to physics, to mechanical engineering, researchers across campus are thinking about problems in an evolutionary context. They’re learning how to use molecular evolution to build things, or make machines or software that evolves. Finn said he sees a day where Georgia Tech is the center of the world for evolution-driven discovery.

“Using evolution to make useful stuff is something we’re going to lead the league in,” he said.

Whether in evolution or immuno-engineering, the same teamwork that helped build bioscience at Georgia Tech will help Georgia Tech scientists define the bioscience fields of tomorrow. The current investments in bioscience and the excellence led by Tech’s biomedical engineering experts are prompting some of the best scientists and students to converge at Georgia Tech as it continues to grow.

“Everyone talks about collaboration, but Georgia Tech really lives up to the promise,” Thomas said. “It’s easy and natural that everyone fits together. There’s a really open environment that makes it a special place.”

Brett Israel is a research news writer in Georgia Tech’s Institute Communications. He has degrees in biochemistry and molecular biology, as well in as journalism.
Co-Robots
(KŌ-RŌ’BŌTS)

Robots designed to work alongside humans on collaborative tasks, both safely and efficiently. The robots act in direct support of and in a symbiotic relationship with human partners. At Georgia Tech, this research is headquartered in the Institute for Robotics and Intelligent Machines, and focuses on applications including health care, manufacturing, and homeland security/national defense.

Seismic Analysis

PAGE 9, MOVER SHAKER
The study of the response of a building (or non-building) structure to the forces generated by earthquakes. At Georgia Tech, these studies are used as part of research in retrofitting older buildings to make them better able to withstand earthquake forces.

Biomolecule

PAGE 10, VACCINATE YOURSELF
A molecule produced by a living organism, including large macromolecules such as proteins, polysaccharides, and DNA. Georgia Tech researchers are studying how microneedle patches could be used to administer biomolecules, such as vaccines, into the outer layers of the skin to prompt an immune response.

Graphene

PAGE 13, MEASURING GRAPHENE’S LIMITS
Graphene is pure carbon in the form of a very thin, nearly transparent sheet, one atom thick. It is remarkably strong for its very low weight (100 times stronger than steel), and it conducts heat and electricity with great efficiency. Georgia Tech researchers are studying the electrical, mechanical and other properties of the material for a broad range of potential uses.

Metal-Organic Framework

PAGE 14, CUTTING MEMBRANE COSTS
Metal-organic frameworks (MOFs) are porous materials consisting of metal ions or clusters connected by rigid organic molecules. Georgia Tech researchers are using MOFs for a variety of applications, including membranes grown inside hollow polymer fibers for separating gases and liquids.

Superlattice

Page 18, GEAR HEADS
A superlattice is a crystalline ordered structure composed of stacked layers, each containing a periodic arrangement of nano-size crystallites. Georgia Tech researchers are studying the unique properties of silver superlattices, predicted to behave under compression like interlocking gears.
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