The research magazine of *Florida Institute of Technology*

DISCOVERY

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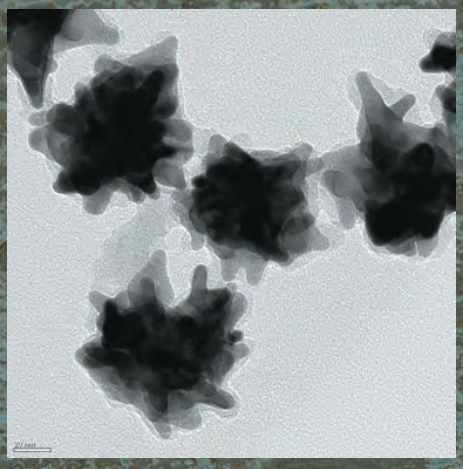
Spring/Summer 2016

•THE NEW•

GOLD RUSH

Gold nanoparticles may not be flashy, but Florida Tech researchers are using this treasured metal to make important discoveries.



MESSAGE FROM THE PRESIDENT AND CHIEF EXECUTIVE OFFICER

What is education, if not discovery?

And what fuels discovery? Experience.

For our students, experience means extraordinary hands-on learning, like having the opportunity to work with the world's most complex machine, the Large Hadron Collider, deep below the ground in Switzerland, or developing ways to keep barnacles and other unwanted guests off the hulls of ships at our lab at Port Canaveral.

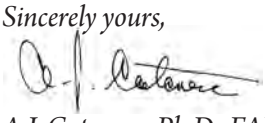
And our world-renowned faculty are about experience, too, whether illuminating minds with their passion in the classroom or illuminating new corners of the research world, from the mysteries of space-time to the majesty and power of sprites and upward lightning.

The magazine you are holding captures the spirit of these experiences, as well as the work and, as happens in science from time to time, the good fortune that made it all possible.

They are among the discoveries, large and small, that unfold on our campus every day.

I am delighted to give you the opportunity to learn about them yourself. Happy reading!

Sincerely yours,



A.J. Catanese, Ph.D., FAICP
President & Chief Executive Officer

MESSAGE FROM THE EXECUTIVE VICE PRESIDENT AND CHIEF OPERATING OFFICER

While gold may be best known as the stuff of treasure, jewelry and the commodities market, it is also an increasingly common part of research at a growing number of leading universities, including Florida Tech.

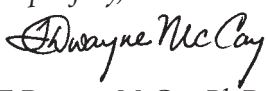
As we detail in the pages of this issue of Discovery, gold nanoparticles are an exceptional and essential component in work our faculty are doing in critical areas of science, from curing cancer to safeguarding our soldiers.

Exploring this new gold rush is just one journey you'll take. What about glimpsing a future that would allow us to 3-D print a new organ that would eliminate the need for donation waiting lists? Students at Florida Tech are getting closer to making that possible.

We could look skyward with one of our newest faculty members, legendary moonwalker Buzz Aldrin, whose new institute here at Florida Tech will further study a pathway to Mars.

Different as they are, these stories all reflect what makes our university so strong: passion, curiosity, creativity and hard work.

Respectfully,



T. Dwayne McCay, Ph.D.
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PRESIDENT AND CHIEF EXECUTIVE OFFICER Anthony James Catanese, Ph.D., FAICP
EXECUTIVE VICE PRESIDENT AND CHIEF OPERATING OFFICER T. Dwayne McCay, Ph.D.
VICE PRESIDENT FOR RESEARCH Frank Kinney
VICE PRESIDENT FOR MARKETING AND COMMUNICATIONS Wes Sumner
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EDITOR Adam Lowenstein, *adam@fit.edu*
ASSOCIATE EDITOR Shelley Preston, *spreston@fit.edu*
ART DIRECTOR/DESIGNER Judi Tintera, *jtintera@fit.edu*
COPY EDITOR Christena Callahan, *ccallaha@fit.edu*
CONTRIBUTING WRITERS Adam Lowenstein, Shelley Preston, Emily Roberge
PRODUCTION Kristie Kwong
WEB LAYOUT Joshua Culver
PHOTOGRAPHY Dominic Agostini, Mike Brown, CERN, Michael Fenn, Peter Finger, Kelly Hunsucker, Shelley Preston
HOW TO KEEP IN TOUCH
Florida Tech, Office of Marketing and Communications, 150 W. University Blvd., Melbourne, FL 32901-6975, 321-674-8548, Fax 321-674-8598, *wsumner@fit.edu*

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Cover: Inset photo of gold nanoparticles courtesy of Michael Fenn.

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On a Collision Course

Florida Tech professors and students are involved in international experiments at the Large Hadron Collider.

SPRING/SUMMER 2016 ISSUE

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WE'RE LISTENING. *Please send any comments or suggestions to Adam Lowenstein at adam@fit.edu.*

The student team behind the project known as "Biofabrications: 3-D Printing for Tissue Engineering." They are, from left, Michael Weng Kwan, Victoria Gilchrist Anderson, Ian McClure, Scott Baskerville and Ryan Bailey. Their project won the President's Cup as the top engineering entry at the 2015 Northrop Grumman Engineering and Science Student Design Showcase.

A New Spin on Tissue Fabrication

Student Project Could Lead to Key Advancements in Biomedical Engineering

"Whoa."

It certainly wasn't the most scientific thing Mike Fenn could say, but given what the assistant professor of biomedical engineering at Florida Tech was seeing in his fluorescent microscope, it was appropriate. Students Victoria Gilchrist Anderson and Scott Baskerville, who had brought Fenn the sample of 3-D-printed tissue he was now looking at, were having a moment, too.

"We had tears in our eyes," said Anderson, who graduated in May 2015 cum laude with a bachelor's degree in biomedical engineering. "I was hysterical."

What they saw in the image from Fenn's machine was that the living cells they had inserted into that artificial tissue as part of a senior design project had migrated to a network of wispy polymer fibers the team manufactured via a process called electrospinning.

The cells had adhered concentrically around the biodegradable fibers, where the fibers would begin to degrade over time. It is what was left behind that had everyone so excited: the makings of microvascular channels.

The holy grail of tissue engineering via 3-D printer—imagine being able to print a new kidney for someone facing a lifetime of dialysis—is to create a vascular network inside the structure that would provide the necessary nutrition to the cells that comprise it.

"In biomanufacturing, maintaining the viability of deep cells in the structure was one of the major challenges," said Ted Conway, head of Florida Tech's department of biomedical engineering and an advisor to these students. Before coming to the Melbourne, Florida, university, Conway served as program director for several National Science Foundation programs, including bioengineering. "You need a vascular network for that to happen."

Until now, attempts to create such a system of arteries and veins have failed—attempts often by companies with seven-figure research and development budgets. But here, in a project that cost under $5,000, Anderson, Baskerville

The holy grail of tissue engineering via 3-D printer ... is to create a vascular network inside the structure that would provide the necessary nutrition to the cells that comprise it.

and fellow students Ryan Bailey, Ian McClure and Michael Weng Kwan seemingly succeeded.

"This has huge potential," Conway said. "They made a huge step in that direction."

Settling on a Project

It wasn't the plan to take their science in this direction.

In the early discussions of their project, which would go on to win the team the President's Cup award as the top engineering project at Florida Tech's prestigious senior design showcase, faculty advisors proposed that the students use a 3-D printer to create an ear or nose.

"Then we thought, 'Nah, that's been done,'" Anderson said.

So the team then decided to take on a major problem in fabricated tissue by exploring how to maintain cell viability after the tissue was printed. Also included in this project, which was to be known as "Biofabrications: 3-D Printing for Tissue Engineering," was what Anderson called a "reach-for-the-stars" goal: create a vascular network within the printed tissue.

Spinning Success

As is often the case in key scientific discoveries, there was some fortunate happenstance involved in this work.

In October 2013, McClure, then a sophomore at Florida Tech, began building an electrospinner powered by alternate current, or AC. Electrospinners use an electrical charge to create extremely small—often nano-level—strands from a liquid. McClure was seeking to produce carbon nanotubes, and building his own device was nothing new.

"I have built bio labs, electronics and everything in between," he said. Over the next nine months, he built four prototypes.

Right about the time that fourth version was complete, Baskerville, who has since graduated, had the idea of using electrospinning to produce the capillary structures needed within the 3-D-printed tissue. He and the others began looking into the more common method of direct current, or DC, electrospinning.

In September 2014, Bailey and McClure, who hadn't met before, found themselves in the same biomechanics/biomaterials lab. They chatted easily and soon became friends. Not long after they began talking, McClure mentioned AC electrospinning.

He showed Bailey images of his nanotubes captured by a scanning electron microscope.

"This is when I saw the control and vascular patterns that could be created with AC electrospinning," Bailey said.

That was important: the control just wasn't the same using the DC electrospinning; nor was the final product, which was more linear in form. With the AC version, the team could create the fibrous, web-like mesh needed to ultimately establish networks of micron-level capillaries.

"The more we learned about what AC electrospinning could do with other materials, we began to get excited about the possibilities with biological tissue," Anderson said.

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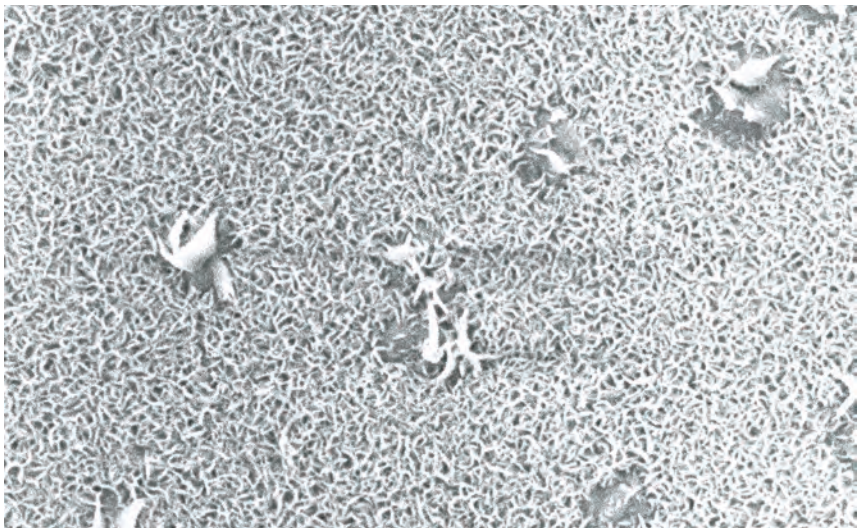
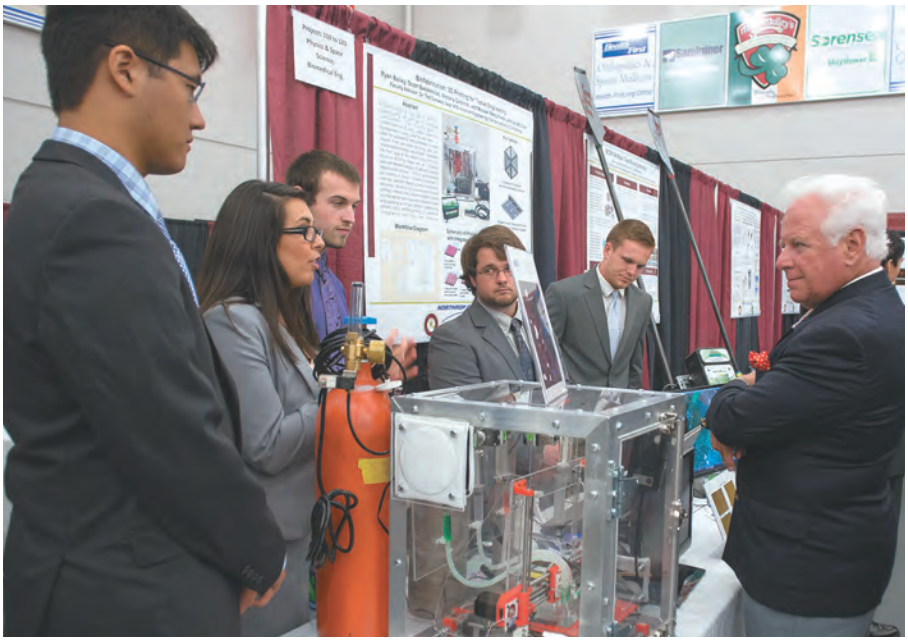


A nanometer-scale mesh of interwoven, interconnected iron, with high levels of carbon, from the first AC electrospinner tests conducted by Ian McClure. AC electrospinning became key to the success of the students' experiment into creating artificial tissue with a vascular system.



Florida Tech President and CEO Anthony Catanese, right, looks over the tissue biofabrication project at the senior design showcase last year.

Continued from page 5

The team also had to fine-tune the 3-D-printed hydrogel that holds the cells before they migrate to the capillary-like network. Anderson focused on that, and it took many experiments to get the viscosity right: it can't be so dense that the cells cannot move, nor so fluid that the structure is not retained. "Not toothpaste, not water," she said.

Once the hydrogel "bio-ink" was perfected, the custom-designed extrusion printing system was built, and the AC electrospinner was operational, it was time to print the tissue sample. The printer, housed in its own incubator, laid a 3-D structure of cell-embedded hydrogel while the AC electrospinner wove a dissolvable polymer mesh throughout. The printed tissue sample was then left to incubate.

After 36 hours, the sample was treated with a fluorescent stain that binds to the DNA in living cells. Anderson and Baskerville were with Mike Fenn and his microscope. Hysteria ensued when they saw the images: Not only had the cells survived the printing process, but they had also migrated through the hydrogel to aggregate around the electrospun fibers.

For an organ to survive, its cells need to be fed. And for them to be fed, especially the cells below the surface, there must be a means for liquid-based nutrients to spread among this newly growing tissue. The network of capillaries formed in the team's experiment seem to allow that "feeding" to happen.

"It was exactly what we were hoping for," Anderson said.

'So Many Possibilities'

Working with Florida Tech, the team filed a provisional patent application with the U.S. Patent and Trademark Office.

And there is much work to be done in the coming years.

Bailey, Baskerville and McClure are interested in developing versions of the biofabrication apparatus used in the project for markets such as aerospace, military and automotive.

And with the overall system, future tasks would include developing a tissue structure that includes capillary "channels" that would allow the delivery of nutrients to continue even after the cells have consumed the hydrogel.

And studying and using different types of cells could allow for different end uses and different manufactured organs.

Taking this to its logical conclusion many years from now, the potential impact of the team's work is breathtaking. Tissue and organs could be produced for a patient with his or her own cells, thus eliminating the chance of rejection and a lifetime of taking anti-rejection drugs.

"The wait-list for organs that so many people die on would no longer be an issue," McClure said.

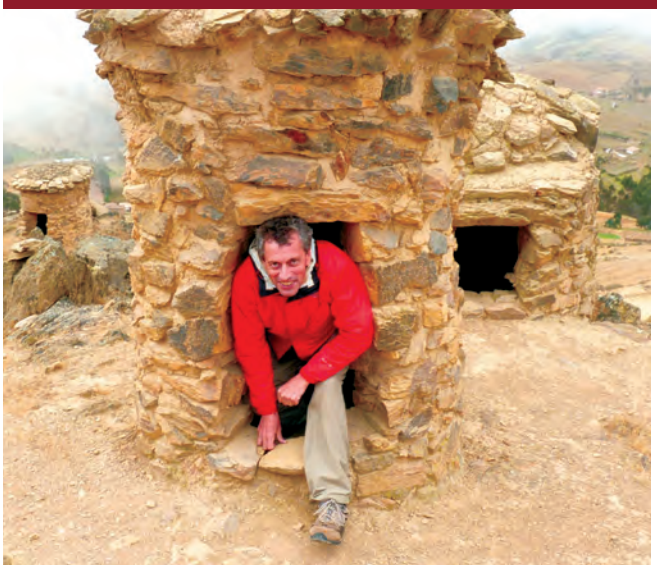
Also, he pointed out, scientists in many fields could use tissue manufactured by this method for highly accurate and extremely detailed analysis and testing of new medications and other applications.

"This opens the door to so many possibilities," said Conway.

Anderson said, "We are so grateful to Florida Tech for giving us this opportunity. We created something bigger than ourselves."

Adam Lowenstein

SPOTLIGHT ON TOP RESEARCHERS



Mark Bush

Professor and chair, Conservation Biology and Ecology Program

Department of Biological Sciences, College of Science

General research focus: conservation biology, paleoecology, fossil pollen, plant community ecology

Current research funding: $2,460,365

What has you excited about your current research?

For many years we have been working at the nexus of ecology, archaeology and climate change. There are many unanswered questions about the paleoecology of South and Central America, and it's answering these questions that makes me want to come to work every day. In our latest research venture, we have taken on a more applied project to support forensic investigations. Best of all, the new work feeds back into our long-term academic research and helps us to produce better quality data.

Why is it important to conduct research?

Solving riddles, getting completely new insights and having that sense of discovery is absolutely addictive. It is this excitement that makes a career in academia really fulfilling. At the larger scale, the reputation of the university is a sum of its research. With stronger research, we attract more and better students. A stronger research program triggers a snowball effect that is wholly positive.

Marco Carvalho

Associate professor; executive director, Harris Institute for Assured Information; director, Intelligent Communication and Information Systems Laboratory

Harris Center for Science and Engineering

General research focus: computer security, computer networks, information systems

Current research funding: $3,732,533

What has you excited about your current research?

Some of our current research efforts are focused on self-adaptive and resilient command and control infrastructures and algorithms for cyber operations. Under the sponsorship of the Department of Defense, we are working on ways to allow multiple cyber defenses to coordinate with one another and with humans, to better monitor and protect enterprises and critical infrastructures against cyber attacks.

Why is it important to conduct research?

Research is a critical part of the academic life. It enables innovation and the generation of knowledge with a great return on investment to society in the long term; but it also has an immediate return, which is the impact it brings to education and faculty development. Engaged research-minded faculty are generally more akin of the way their disciplines are evolving and some of the open challenges and trends in their areas. They tend to be more familiarized with state-of-the-art tools and techniques, and aware of current applications of the concepts taught in their disciplines. This kind of experience is invaluable to students and has a transformational effect on the way they see their studies and future careers.

Smooth Sailing

Geoffrey Swain and His Research Team Keep Ship Hulls—and our Environment—Clean

At the end of Dock C at Cape Marina in Port Canaveral on Florida's Atlantic coast, a huge Disney cruise ship looming in the distance, a group of scientists and engineers was examining experiments just pulled from the seawater.

Attached to a series of secured frames were several panels—some covered in barnacles, sponges and mussels, others free of any sort of clinging creature or plant. The Static Immersion Test Platform, designed and fabricated by Florida Institute of Technology with funding from the Office of Naval Research, is dedicated to helping research methods to eliminate those hangers-on and their ilk from the hulls of Navy ships, a process called anti-fouling.

Leading the team is Professor Geoffrey Swain, one of the world's most respected anti-fouling scientists. For 30 years, he and his researchers have made a global impact by improving the fuel efficiency and lessening the environmental impact of huge, ocean-going ships like the one moored across the water.

Applying anti-fouling coatings to a vessel makes it difficult for plant and animal life to become established. This can dramatically affect how efficiently a ship slices through the water. Smooth, streamlined progress is imperative to a ship's performance, and less resistance from barnacles and other marine life means better fuel economy and fewer greenhouse gasses spewed into the atmosphere. (World shipping is estimated to be the source of as much as 3 percent of total global carbon dioxide output.)

But it's not that simple.

Anti-fouling paints may contain biocides that are detrimental to the environment. One such biocide, tributyltin, or TBT, was extremely effective, but at a cost: it was found to adversely affect non-target organisms such as oysters and other marine life in waters near ports, shipping lanes and marinas. Introduced in the 1960s, TBT is now banned worldwide. Scientists are now faced with the challenge of developing alternative methods to keep hulls clean and ships fuel-efficient without damaging marine life.

Swain and his team help develop new formulations that function with reduced or no biocides, and they are also developing underwater robots to proactively groom and maintain surfaces free from fouling.

Emily Ralston, a research assistant professor, looks at marine organisms living on Florida Tech's Static Immersion Test Platform. The test program, funded by the Office of Naval Research, is spearheaded by professor Geoffrey Swain.

Geoffrey Swain, right, professor of oceanography and ocean engineering, stands beneath a ship hull with Kelli Hunsucker, a research assistant professor.

Swain has received more than $8 million in funding for this work, much of it from the Office of Naval Research. He has also contracted with industry leaders such as Dow Corning Corp., DuPont Canada, General Electric, International Paint, Pittsburg Paint and Glass and Royal Caribbean Cruise Lines.

Recently, three members of Swain's team became faculty members. With their new titles of research assistant professor, Kelli Hunsucker, Emily Ralston and John Hearin pursue anti-fouling science under Swain's direction, but they also have the ability to apply for their own research grants.

The research assistant professors are also key to implementing the research at the test sites. In one area of Cape Marina at Port Canaveral are the Static and Dynamic Test Facilities, where surfaces are evaluated for their ability to control fouling. The static immersion represents conditions a ship experiences when in port and the dynamic while the ship is at sea. The dynamic immersion is conducted from a rotating disk deployed off the stern of a catamaran simulating a boat cruising at 10 knots, all while secured to the dock.

"We are one of only a few test facilities in the world to have this capability," Hunsucker said. "We are leaders in pushing this research forward and making others realize the importance of incorporating dynamic immersion into anti-fouling testing."

Observing fouling on a moving vessel is important because the researchers have found that microscopic plants called diatoms prefer to grow on ships that are on the move more often than they are docked, such as cruise ships. These form layers of slime that can increase drag by up to 20 percent over a clean, smooth surface.

Hunsucker's specialty is studying this plant life. The slime or biofilm is resistant to some of the newer coatings, so she is interested in looking at ways to prevent the buildup of these microscopic plants from attaching and creating costly drag penalties.

Ralston, who recently secured a grant to develop methods to prevent fouling on parts of boats that are not easily protected by coatings (such as propellers), studies settlement and recruitment of animals that attach to hulls, like barnacles and mussels.

"We want to protect surfaces that need to be protected, like boat hulls, but make it work with biology," she said.

Ralston is interested in seeing parts of harbors and piers that don't come into contact with boat surfaces be allowed to attract filter feeders such as bivalves to help purify the water. Copper, an effective biocide, can have its place, too, she said, but only if it's managed well and balanced by healthy ports that attract organisms such as native oysters.

The in-water maintenance of coatings is also an important area of study, and it's the specialty of John Hearin, an ocean engineer. He runs a Florida Tech test facility at Port Canaveral that is developing an autonomous underwater robot equipped with rotating brushes that gently and proactively maintain coatings in a smooth and fouling-free condition. Other endeavors include capturing real-time video of biofouling and measuring a coating's hydrodynamic performance.

Besides the lab at Port Canaveral, Swain and his team run two other labs, collectively known as the Center for Corrosion and Biofouling Control, at the Sebastian Inlet, and a testing facility on the Florida Tech campus in Melbourne. Between the three sites, Swain's team is able to provide services to clients from all over the world, advising them on methods that help them prevent corrosion and control fouling.

Hunsucker says the team is dedicated to carrying anti-fouling science forward for a new generation of researchers at Florida Tech, with the end goal being environmentally friendly anti-fouling coatings.

"We are starting to see the marriage between silicon-based fouling-release coatings, similar to non-stick cookware in your kitchen, and underwater hull grooming. This would reduce the need for biocides, save on fuel and costs, and help ships reduce greenhouse gas emissions," Hunsucker said. "Our goal is to see these coatings and hull grooming become standard practice for both the Navy and industry."

Shelley Preston

The CMS detector at the Large Hadron Collider. The detector is about the size of a five-story building.

On a Collision Course to Explain Our Universe

Research from Florida Tech professors and students using the Large Hadron Collider may provide insight on dark matter, extra dimensions and more.

With a 17-mile-long underground tunnel housing thousands of superconducting magnets under the border of France and Switzerland, the Large Hadron Collider (LHC) is the world's biggest and arguably most complex machine.

Operated by the European Organization for Nuclear Research, known as CERN, the powerful particle accelerator, built to smash counter-rotating beams of protons, requires extreme conditions for its operation: it contains the coldest place on Earth at 1.9 degrees Kelvin, colder than interstellar space; a vacuum that qualifies as the emptiest place on Earth; and when heavy particles collide the impact point can become 100,000 times hotter than the center of the sun.

Perhaps more amazing than the machine itself is its purpose: The LHC was built to answer the most profound questions of physics: What is the origin of mass? What is dark matter?

Florida Tech faculty members Marc Baarmand, Marcus Hohlmann and Francisco Yumiceva, along with their students, are helping to find the answers.

"These are big questions, fundamental questions of our time," said Baarmand.

Big questions require "big science," and the LHC does not disappoint: With a recent $1.2 million grant from the U.S. Department of Energy, secured by Hohlmann and Yumiceva, the Florida Tech team is a part of a coalition of 4,300 scientists from 42 countries working on the Compact Muon Solenoid (CMS) detector, which records the data from the collisions. And CMS is one of four similar-size international collaborations studying LHC data.

In 2012 CMS and another experiment, called ATLAS, found evidence for the elusive Higgs boson, a particle involved in the mechanism giving mass to all elementary particles. The Higgs boson is the final particle of the Standard Model to be experimentally verified, which brought in another Nobel Prize for particle physics. Recently, CERN announced a reading was found that deviates slightly from what's expected from known physics. Scientists are hoping it may be another significant finding but are waiting for more data to confirm or dismiss it.

With numerous trips to CERN's headquarters outside of Geneva, Switzerland, recent jobs performed by Florida Tech researchers ranged from improving the CMS detector while the collider was shut down for scheduled upgrades, to evaluating the plethora of data from the machine's first run that included data taken from 2009–12. This summer, Florida Tech scientists geared up for LHC's second run to continue the quest for understanding the most basic materials of the universe. "This new run is at much higher energy—13 TeV—than the previous run, which was 7 and 8 TeV. That's a big deal," says Hohlmann. "More energy allows you to make massive particles more easily. So the CMS experiment will be more sensitive to new-physics particles that make up massive dark matter."

The Big Smash

The Large Hadron Collider's superconducting magnets accelerate protons (and occasionally heavy ions) until they are moving at close to the speed of light. Then they are guided into head-on collisions.

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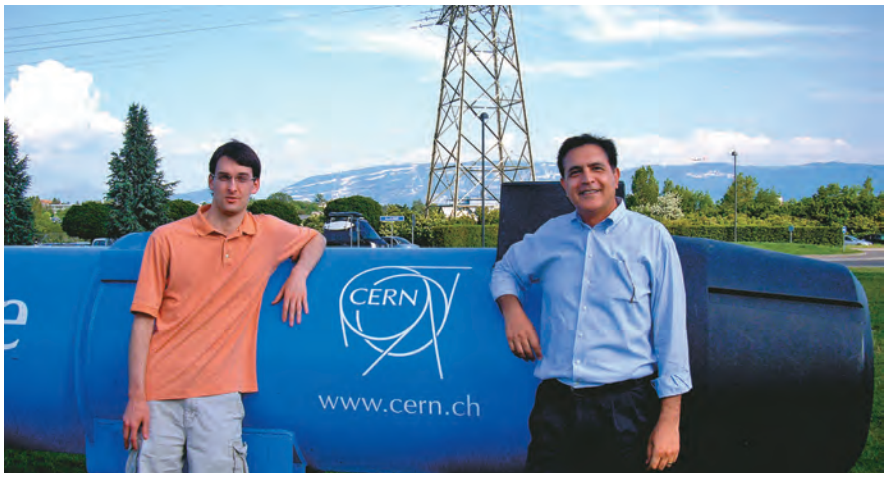


Florida Tech faculty and students, including Brian Dorney, left, and Marc Baarmand, are working on the CMS experiment.

Continued from page 11

Through these collisions, scientists are studying the complex and mysterious behavior of the building blocks of matter—particles even smaller than atoms—and the forces that govern them. Everything from unraveling dark matter to the discovery of extra spatial dimensions is contingent on discovering the as-yet unknown particles produced by these collisions.

Currently, what scientists know about the building blocks of matter is laid out in the Standard Model of Particle Physics, a collection of theories explaining what experimental evidence suggests about the fundamental particles and forces in our universe. Even though the Standard Model is well supported, it may not be complete or even entirely correct. By studying high-energy collisions using the LHC, scientists may discover evidence that further supports the Standard Model, or that might challenge some of its assumptions.

Ultimately, the LHC is meant to unlock secrets about the origin and nature of our universe.

Beyond physics, Florida Tech's work with LHC also involved some technical upgrades. This summer, for the sixth year in a row and with at least another five to go, Hohlmann and his students focused on improving instrumentation for the CMS experiment, while Yumiceva and his students worked on the detector's electronics.

"Detectors work like digital cameras to take pictures of collisions," Yumiceva said. "Ultra-fast digital cameras … because there are 40 million collisions per second." New components in place for the second run allow these "cameras" to look deeper into the properties of known particles and perhaps even discover new particles.

Baarmand and Yumiceva also continue to analyze data from the first run. Specifically, they're studying a particle called the "top quark," the heaviest elementary particle discovered thus far and one with peculiar properties. These qualities can be used as a tool for discovering new phenomena, such as dark matter (which remains unexplained by the Standard Model) or extra dimensions of space.

The discovery of the Higgs boson in 2012 was mainly based on observing its decay into other bosons, i.e., photons, W and Z particles that are the force carrier particles. Hohlmann and his Ph.D. student Vallary Bhopatkar are now trying to see if the Higgs boson also decays into fermions, the matter particles of the universe. They are sifting through new data from the second run to see if these other decays, firmly predicted by the Standard Model, really exist.

Unlocking Secrets

Scientists estimate that the composition of our universe is only about five percent regular matter as described by the Standard Model; another 25 percent is dark matter, and 70 percent is dark energy that propels the expansion of our universe. That means there is a lot we don't understand, and scientists hope the LHC will provide clues.

The LHC may provide evidence for many particles predicted by theories beyond the Standard Model—or it might lead scientists down a different path. "As good as our theoretical models are, maybe that's not how nature works," Baarmand said. "We may get the final word from the next few runs of the LHC."

We may not yet be able to see how these discoveries will impact society, but examples of "everyday" technology coming out of CERN include the World Wide Web, the touchscreen, and contributions to healthcare instrumentation, alternative energy and industrial processes.

"The things we're doing now for sure will find application in the future," Yumiceva said, "but it's hard to tell how."

Back at Florida Tech

Baarmand, Hohlmann and Yumiceva are all proud of the work being done both at CERN and back at Florida Tech analyzing the CMS experiment's data. Nine Ph.D. students have come out of the

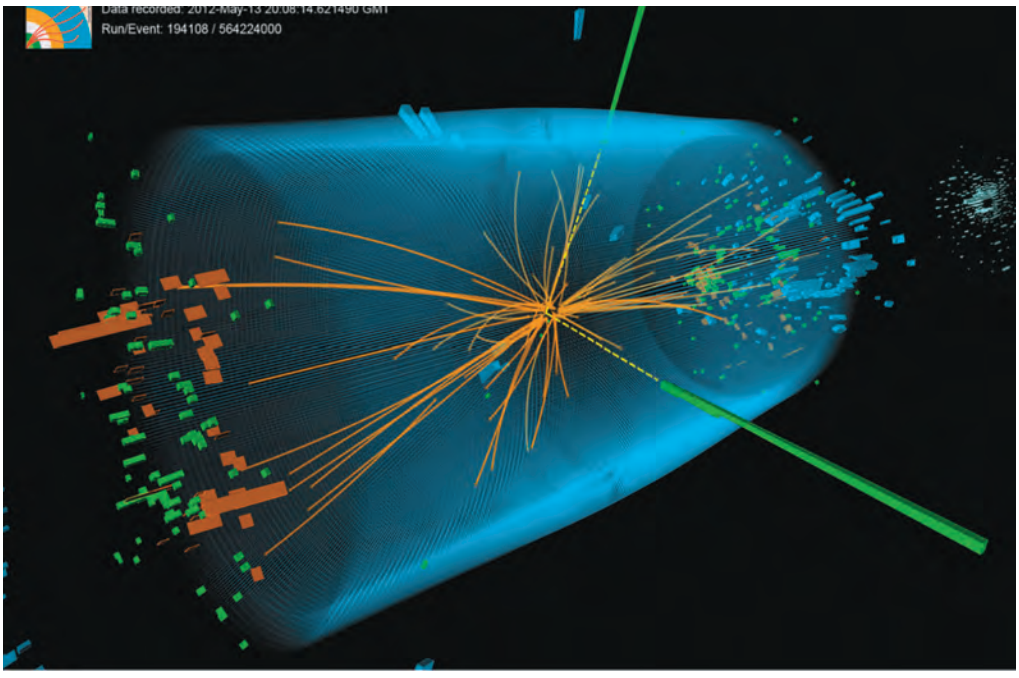
Above, from back to front: Florida Tech faculty members Marc Baarmand, Marcus Hohlmann and Francisco Yumiceva join Igor Vodopiyanov in a lab in the Olin Physical Sciences Center on the Florida Tech campus.

program and gone into successful careers, and another student was awarded a prestigious fellowship at CERN—rare for a U.S. candidate. The team effort has produced many publications in prestigious journals.

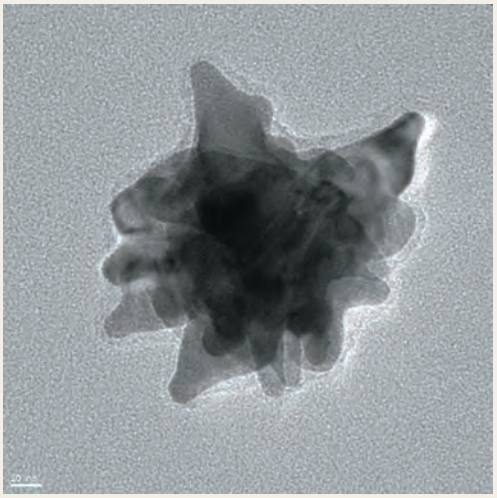
Our understanding of the universe is not complete, and the LHC may be the gateway to dark matter, extra dimensions, exotic particles, supersymmetry and more.

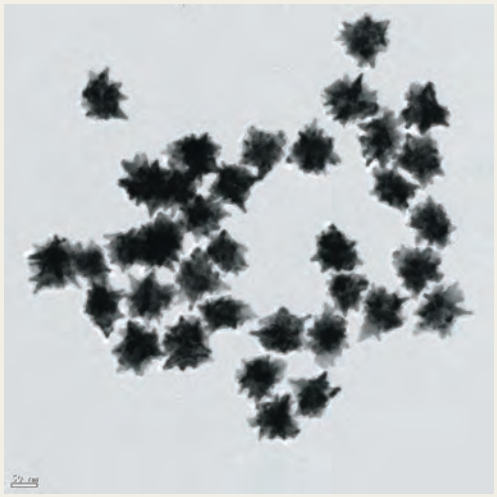
"We may even have preliminary results by next summer," Baarmand said. "Stay tuned."

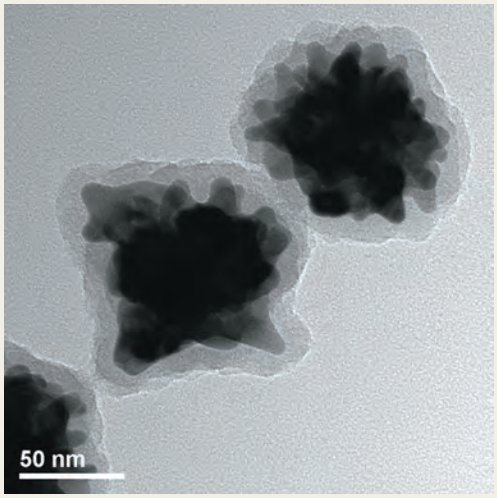
Emily Roberge

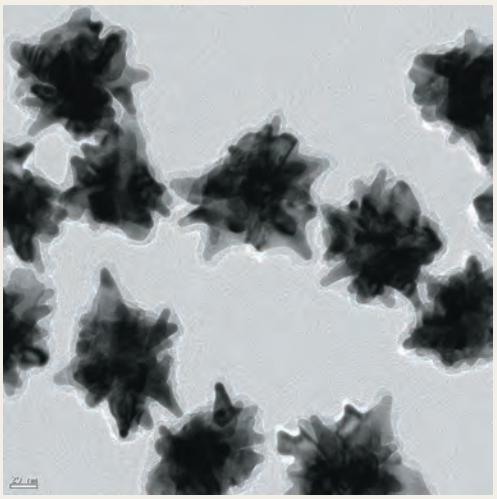


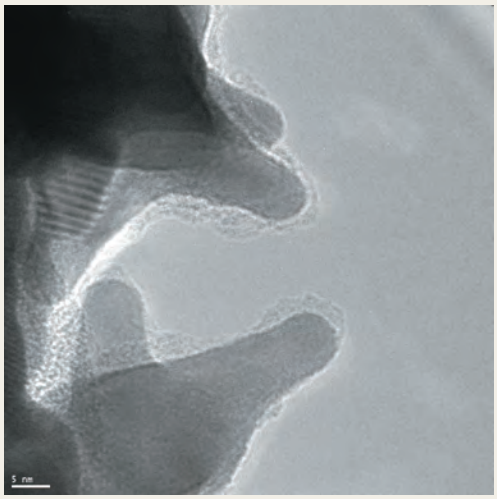
An electronic image of a collision showing production of a Higgs boson and its decay into two photons (represented by the two large green bands).

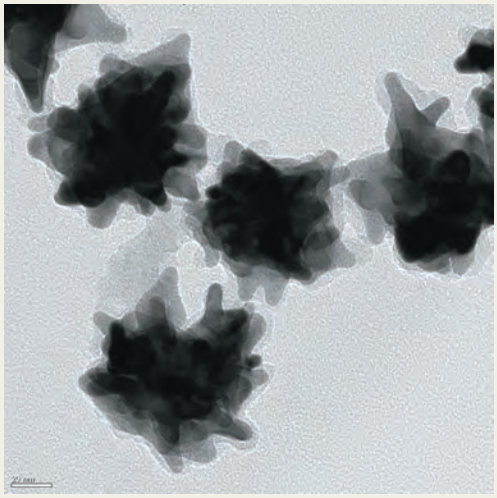






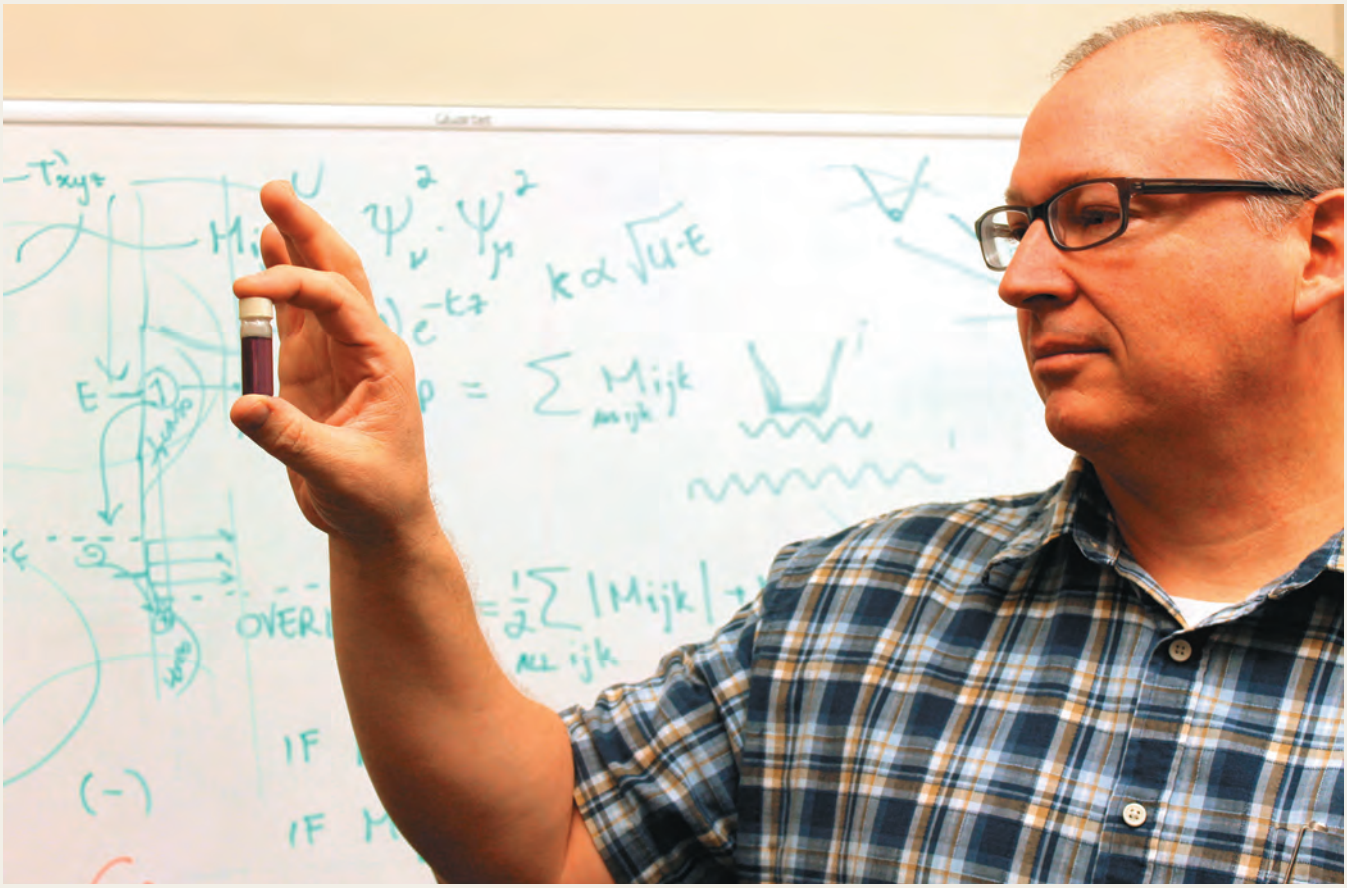






THE NEW GOLD RUSH

Florida Tech Researchers Prospect Nanotech for Science Breakthroughs



Joel Olson

When Florida Institute of Technology chemistry professor Joel Olson casually picked up a small vial of what looked like purple Kool-Aid off a shelf in his office, the liquid didn't register as something precious. Nor was there an obvious indication, as he held the container up between thumb and forefinger to catch the light, that this was one of the most promising tools being used for a range of critical scientific research, from medical to military.

But it is, in fact, both.

The gold nanoparticles in Olson's vial, purple because of reflected light, are allowing faculty members at Florida Tech to get closer to breakthroughs that could fundamentally change the world around us.

"Think about this," said Olson. "What an amazing world it would be if a cancer patient simply received an injection of functionalized gold nanoparticles drawn specifically to cancer cells. A little while later, he stands in front of a light that energizes the gold nanos and they kill the cancer cells."

Or another incredible scenario being studied at Florida Tech: A soldier in the field gets hit with nerve gas. His carbon nanotube body armor is coated with specialized gold nanoparticles that break down the gas faster than anything now known to man, potentially neutralizing any threat to the soldier.

It turns out that when gold is broken down into small clusters of just a few dozen atoms each, it takes on properties that may have substantial ability to heal the body or fend off dangerous chemicals. Add to this the fact that gold is considered to be relatively safe within the human body, and it is understandable why gold nanoparticles are particularly interesting to researchers looking to use them for human applications.

This is leading to a new kind of gold rush.

The gold nanoparticle industry is expected to grow from its current $1 billion market to nearly $5 billion by 2020, according to the market research firm Radiant Insights. A reason for that anticipated growth is that today's scientists are confident in the material's potential for diagnostics and therapeutics, such as targeted cancer

Continued on page 16

Continued from page 15

imaging and therapy, because of its "high biocompatibility and selective accumulation in tumor cells," the report says.

Gold nanoparticles are not new, not really. Consider that ancient Romans figured out glass infused with gold could appear as a rosy red or jade green depending on how the light hit it. The word "nanoparticle" didn't exist then, of course, but they probably understood that the addition of gold created something unexpected.

The color-shifting that ancient artists prized is also prized in the lab, not for cosmetic reasons but for the way it absorbs light energy. Gold nanoparticles can amplify light energy or be tuned to a certain wavelength and react in a prescribed way. Depending on their size and shape, gold nanoparticles in a colloid solution can be nearly any color in the rainbow.

Golden Era of Biotech

"Gold nanoparticles are one of the most promising new materials for biomedical applications," said Professor Kunal Mitra, a biomedical engineer at Florida Tech who is working on several projects aimed at diagnosing and treating cancer.

Mitra's work is focused on injecting formulated gold nanoparticles into a tumor. With an ultra-short light pulse shined on the particles, a high-resolution image of the cancer can be achieved. One of his research projects is specifically targeted at skin cancer. Mitra's non-invasive method could be used instead of a biopsy, which can be costly and produce results that can take a week or more to process.

Beyond detection, gold nanoparticles inside a cancer cell could possibly kill the cancer when energized by a laser.

Olson, the chemistry professor, explained the science like this: "If you have ever put your hand in front of a flashlight, you realize red and orange light makes it through human tissue. If we can get gold nanoparticles tuned to orange light, meaning they will absorb the light that makes it through our tissue and inside a cancer cell, you can aim light energy at them. They become very hot at that small scale. The idea is you could boil a cancer cell from the inside out."

The hard part, Olson said, is getting those gold nanoparticles to selectively enter only cancer cells. Florida Tech's Michael Fenn, an assistant professor in biomedical engineering, is working toward that goal.

"My biggest interest is finding micrometastasis," Fenn explained. "These are rogue cells that get out from the primary tumor and are the ones that actually end up killing 95 percent of patients, depending on the type of cancer. This is where the technology we are developing can be the most powerful."

Fenn uses a technique called surface-enhanced Raman spectroscopy (SERS), which greatly amplifies Raman signals from molecules absorbed onto specially prepared gold nanoparticles. With the data from SERS, different components in a mixture can be identified, whether cells or chemicals. "We want to distinguish different types of cancer or even cancer cells from normal tissue," Fenn said.

Fenn's process is a very complex undertaking that will likely take years to bring into a human study and to the clinic. But the ultimate, tantalizing goal is to turn specialized gold nanoparticles into a combined diagnostic and therapeutic platform that can not only seek out cancer, but then deliver a drug directly into the sickly cells.

Chemistry's Gold Standard

Kurt Winkelmann, associate professor of chemistry, says chemists are drawn to nanoparticles for properties only found at such a minute scale. When a material such as gold is ground down to less than a micron across a micron—that's 0.000039 inch—one of the most important changes is that the combined surface area increases. "That's a valuable property for industry because a lot of chemical reactions occur on the surface," Winkelmann said. "The smaller the particles, the faster your reaction performs."

It's this property that is useful for chemistry professor Andrew Knight and graduate student Rafaela Nita. They have shown that gold nanoparticles are a promising catalytic delivery system that can quickly break down pesticides, which are model compounds of chemical warfare agents.

Nita, with Knight's guidance, discovered a way to synthesize a copper catalyst and attach it onto the surfaces of gold nanoparticles. They then looked at how it could neutralize compounds similar to a nerve agent such as Sarin.

"If you were to use the catalyst by itself, it would take hours to

break down a nerve agent," Nita said. "If you have a catalyst on the surface of a gold nanoparticle, you are looking at about 60 minutes, which is still not good enough, but it's still pretty fast. But once you irradiate those gold nanoparticles with a laser, it can break down a nerve agent in minutes."

The discovery could be used in military applications as a preventive measure against chemical warfare attacks in air and soil and as a decontamination protocol.

"A plus about using a shield made of carbon nanotubes is that they can be chemically functionalized," Nita said. A coating of specialized gold nanoparticles, such as the one that Knight and Nita developed, could speed up the degradation of the nerve agent before it reaches the skin. Another intriguing possibility is adding specialized gold nanoparticles to tainted water to neutralize dangerous warfare chemicals or toxic insecticides and pesticides such as methyl parathion.

The Future of Gold Nanoparticles

Human trials using gold nanoparticles as a cancer therapy are still in the future, but indications seem to suggest the Food and Drug Administration will eventually give the green light for use in the human body.

"There's a very real possibility that my children or maybe their children will be in a world where getting cancer will be akin to having an infection today," Olson said.

As for chemistry, gold nanoparticles used as a catalyst could have a range of uses from fuel cells to pollution controls. "When you're working with gold nanos in the lab," Nita said, "it's a bit of a routine, but when you start talking to people about what they can do, it gets you more excited about the possibilities."

Shelley Preston

A New Generation of Nanotech Scholars

While faculty and graduate students are using nanomaterials for their research at Florida Tech, undergrads also have a chance to explore materials that might one day aid their own endeavors. Joel Olson, along with chemical engineering assistant professor James Brenner and Kurt Winkelmann, started a nanotech minor at Florida Tech five years ago. The idea was to create a new generation of students interested in entering the ever-growing nanotech field. One of the experiments Winkelmann likes to do in his lab is to have students make gold nanoparticles. "From the very beginning, we get them involved in making materials that are being used on the cutting edge of medical research and industrial applications."

Graduate student Rafaela Nita works with gold nanoparticles to study how they may play a role in breaking down chemical warfare agents.

Buzz Aldrin Space Institute Launches at Florida Tech

Famed Moonwalker Leads Quest for Mars Colonization

Florida Tech's summer campus became an international media sensation within 24 hours last August. That was when Buzz Aldrin, the Apollo 11 astronaut and second man on the moon, announced he would become a research professor and founder of the Buzz Aldrin Space Institute.

At a press conference inside the Board of Trustees Room packed with reporters and Florida Tech executives, faculty members and staff, Aldrin made it clear his legacy would include a push to inhabit Mars. Flanked by Florida Tech President and CEO Anthony Catanese and Executive Vice President and COO T. Dwayne McCay, Aldrin enthusiastically waved his arms as he outlined Cycling Pathways to Occupy Mars, his personal vision for humans arriving on the red planet.

The institute, he said, will support commercial and international development of lunar resources to support an eventual Mars settlement. His proposed architecture establishes pathways of progressive missions to cis-lunar space, asteroids, Phobos and eventually the surface of Mars.

The news was quickly broadcast on National Public Radio and written about in The *New York Times, Newsweek* and hundreds of other media outlets around the world.

"Florida Tech has long been at the forefront of exploration—since the days of our founding in 1958 serving as the 'night school for missilemen' when America began the race for space at Cape Canaveral," Catanese told the crowd. "Having Dr. Aldrin build this new initiative at Florida Tech is indeed an honor. We look forward to meaningful collaboration as humankind's new vision for space unfolds."

Aldrin joins the university faculty as Florida Tech Research Professor of Aeronautics and will serve as senior faculty advisor for the institute, which will be

> "I am proud of my time at NASA with the Gemini 12 and Apollo 11 programs, but I hope to be remembered more for my contributions to the future."
>
> Buzz Aldrin

(Top left) Buzz Aldrin talks with astronauts Winston Scott, center, and Sam Durrance, right, both faculty members at Florida Tech. (Above) Aldrin is joined by Florida Tech President and CEO Anthony Catanese, left, and Executive Vice President and COO T. Dwayne McCay at the signing ceremony for the new space institute.

based at the university's Center for Aeronautics and Innovation.

"I'm thrilled to be partnering with FIT in my new home state of Florida," Aldrin said. "I am proud of my time at NASA with the Gemini 12 and Apollo 11 programs, but I hope to be remembered more for my contributions to the future. FIT will play a key role in my ongoing legacy and Cycling Pathways to Occupy Mars. You ain't seen nothing yet!"

Since retiring from NASA and the U.S. Air Force, Aldrin, who earned a Doctorate of Science in Astronautics from Massachusetts Institute of Technology before being named an astronaut in 1963, has remained at the forefront of efforts to ensure America's continued leadership in human space exploration. He began to devise a master plan in 1985 for missions to Mars known as the "Aldrin Mars Cycler"—a spacecraft system with perpetual cycling orbits between Earth and Mars. He has refined the concept over the years and continues research on it.

But his work in the realm of space and aeronautics is varied. Aldrin has received three U.S. patents for his schematics of a modular space station, Starbooster reusable rockets and multi-crew modules for space flight. He founded Starcraft Boosters Inc., a rocket design company, and Buzz Aldrin's ShareSpace Foundation, a nonprofit devoted to addressing science literacy for children by igniting their passion for science, technology, engineering, arts and math (STEAM) through delivering hands-on activities and inspirational messages.

As part of Aldrin's new partnership with Florida Tech, The Buzz Aldrin Special Collection and Archives will be established at the university's Evans Library.

Aldrin joins two other astronauts on the Florida Tech faculty—Winston Scott and Sam Durrance, who both flew during the space shuttle program.

Shelley Preston

The Sprite Stuff

Florida Tech Professors Illuminate Science Behind Lightning High in the Atmosphere

Lightning discharges high in the Earth's atmosphere have unusual qualities and looks nothing like those jagged streaks usually seen during a storm. Fittingly, scientists gave them otherworldly names such as sprites, blue jets and elves, each with their own set of specific conditions, shapes and durations.

Florida Institute of Technology professors Ningyu Liu and Hamid Rassoul and their team have improved our understanding of several of these luminous curiosities that happen above thunderstorms, including sprites and lightning that moves upward to space.

Sprites are fireworks-like electrical discharges that are sometimes preceded by halos of light in Earth's upper atmosphere. Predicted by Nobel laureate C. T. R. Wilson in 1924 but not discovered until 1989, they are triggered by intense cloud-to-ground lightning strikes. They typically last a few to tens of milliseconds; they are bright enough to be seen with dark-adapted naked eyes at night; and only the most powerful lightning strikes can cause them.

Unproven until now, Liu and his team's recent publication in *Nature Communications* provided convincing arguments for a long-standing theory that atmospheric gravity waves play an important role in the initiation of sprites. Their research includes comprehensive computer-simulation results from a novel sprite initiation model and dramatic images of a sprite event, providing a clearer understanding of the physical mechanism that leads to sprite formation.

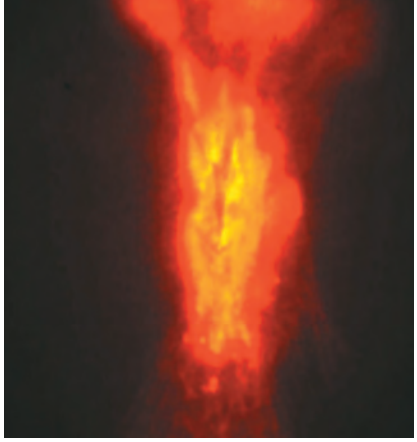
"Understanding the conditions of sprite formation is important, in part, because sprites can interfere with long-range communication signals by changing the electrical properties of the lower ionosphere," said Rassoul, a veteran lightning physicist and Florida Tech's dean of the College of Science.

Liu's outside collaborators for the study included Joseph Dwyer, a former professor at Florida Tech now at University of New Hampshire, Hans Stenbaek-Nielsen from University of Alaska Fairbanks and Matthew McHarg from the United States Air Force Academy.

According to Liu, the perturbations in the upper atmosphere created by atmospheric gravity waves can grow in the electric field produced by lightning and eventually lead to sprites.

"Perturbations with small spatial scale and large amplitude are best for initiating sprites," Liu said. "If the spatial scale of the perturbation is too large, sprite initiation is impossible; if the magnitude of the perturbation is small, it requires a relatively long time for sprites to be initiated."

To validate their model, the team analyzed a sprite event captured simultaneously by high-speed, high-sensitivity cameras on two aircraft during an observation mission sponsored by the Japanese broadcasting



corporation NHK. The high-speed images show that a relatively long-lasting sprite halo preceded the fast initiation of sprite elements, exactly as predicted by the model.

Upward-Moving Lightning from Thunderstorms to Space

Sprites aren't the only lightning-related research that the Florida Tech lightning team pursued this year. They also captured rare and hard-to-predict upward-moving lightning discharges of all known types on video, which makes it possible for scientists to study these phenomena in greater depth.

The study and accompanying video, published in another *Nature Communications* paper, focused on the electrical activities of Tropical Depression Dorian in August 2013, which featured seven upward-moving lightning events, each with unique optical and radio signatures. (An in-depth study of the meteorological properties of Dorian, led by another Florida Tech lightning team member, Steven Lazarus from the department of marine and environmental Systems, was later published in the *Journal of Geophysical Research*.)

Upward electrical discharges from thunderstorms to space are classified into three types, based on their terminal altitudes: starters (20-30 km), jets (40-50 km) and gigantic jets (70-90 km). Prior to Liu's work, typical observations of

(Left) A sprite captured by a high-speed, high-sensitivity camera.

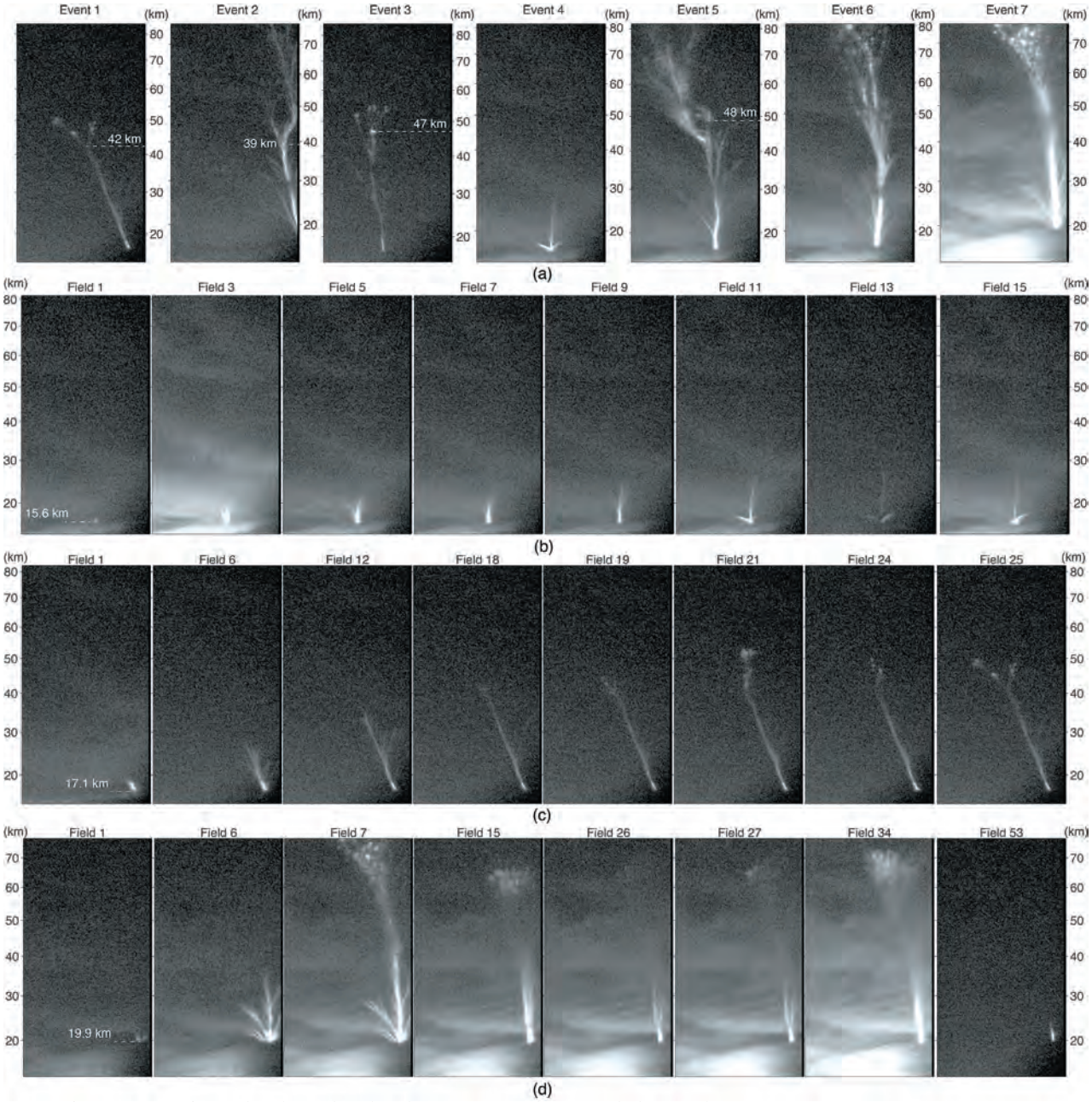
these discharges had been limited to one type for a single storm.

One of the key findings from the new observation is that all seven events originated in the same thundercloud region, suggesting that these different types of events can be generated by the same physical mechanism. This has presented scientists with new challenges in understanding the underlying formation mechanism(s) of these events.

Liu said that the upward electrical discharges transfer a large amount of electric charge into the upper atmosphere. This charge transfer can potentially modify the global atmospheric electrical circuit and possibly affect cloud formation and weather. Understanding these discharges is also important because they can disrupt radio signals for long-range communication.

"Since 2001 our research team has been probing the mysteries of lightning. The latest observations represent exciting discoveries that will help us better understand the properties of lightning in all of its diverse forms," Rassoul said.

Shelley Preston and Adam Lowenstein



Freeze-frame images from Florida Tech video showing upward-moving lightning during a storm.

Research in Brief

A look at recent science and engineering highlights from Florida Tech faculty and staff.

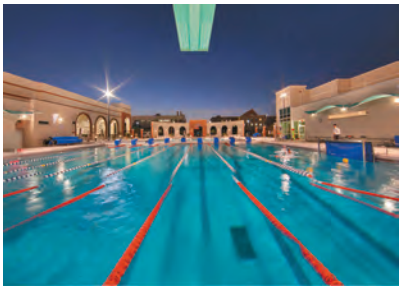
The Scott Center Offers Online Resource for Parents With Autistic Children

Florida Tech's Scott Center for Autism Treatment launched AutismAdvisor.org, an online resource for parents of and caregivers for children with Autism Spectrum Disorder (ASD). AutismAdvisor.org features more than 100 videos featuring experts from The Scott Center and Florida Tech's Applied Behavior Analysis Program, as well as parents discussing challenges, experiences and successes with ASD family members.

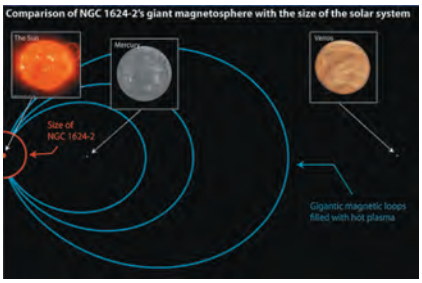
AutismAdvisor.org

"AutismAdvisor.org is dedicated to providing parents and caregivers fast, free access to information they need to improve the lives of their children and families," said **Mary Beth Kenkel,** dean of the College of Psychology and Liberal Arts. "There are videos and other resources on early diagnosis, evaluating therapy options, teaching living skills and many other topics."

Students Help Secure LEED Certification for the Panther Aquatic Center



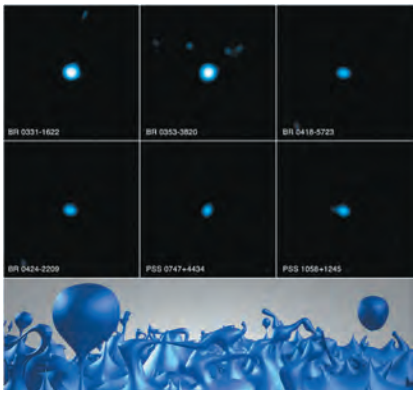
The Green Building Certification Institute (GBCI) this year awarded the Leadership in Environmental and Energy Design (LEED) certification to Florida Tech's Panther Aquatic Center. Student projects played a key role in obtaining performance credits from the GBCI, according to **Ken Lindeman**, chair of the sustainability program in Florida Tech's department of education and interdisciplinary studies. The endeavor was challenging because swimming pools have high energy and water demands, but student teams worked over several years with both Florida Tech Facilities Operations and outside contractors to help earn the LEED certification, which is the pinnacle of national green building design. "We are proud of the students who helped achieve this," Lindeman said. "The student-staff project model is novel for university LEED certifications, and our campus should benefit further as we move forward."



Hot, Dense Material Surrounds O-type Star with Largest Magnetic Field Known

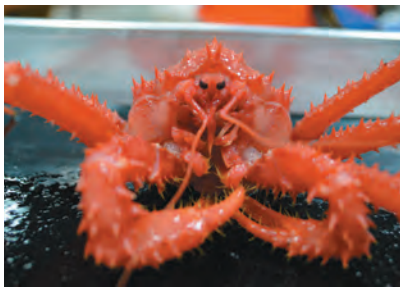
Observations using NASA's Chandra X-ray Observatory revealed that the unusually large magnetosphere around an O-type star called NGC 1624-2 contains a raging storm of extreme stellar winds and dense plasma that gobbles up X-rays before they can escape into space. The findings, led by assistant professor of physics and space sciences **Véronique Petit,** may help scientists better understand the lifecycle of certain massive stars. Her findings were published this summer in the journal *Monthly Notices of the Royal Astronomical Society* from Oxford University Press. NGC 1624-2's powerful stellar winds are three to five times faster and at least 100,000 times denser than our sun's solar wind. "The magnetic field isn't letting its stellar wind get away from the star, so you get these big flows that are forced to collide head-on at the magnetic equator,

creating gas shock-heated to 10 million Kelvin and plenty of X-rays," said Petit. "But the magnetosphere is so large that nearly 80 percent of these X-rays get absorbed before being able to escape into free space." Petit and her team, including Florida Tech graduate student **Rebecca MacInnis**, are currently studying observations of NGC 1624-2 from the Hubble Space Telescope to better understand the dynamics of the massive star's trapped wind.



Space-Time: Foamy? Or, Not so Much?

Research by associate professor **Eric Perlman** gleaned new insights about the texture of space-time, which quantum theory predicted as being "foamy" instead of a smooth, featureless highway on which light travels. Using the brightest beacons in the universe—quasars—as a way to indirectly measure fluctuations of light over vast distances, Perlman and fellow researchers from Massachusetts Institute of Technology and the University of North Carolina were able to rule out two quantum foam models, pointing to a smoother universe than anticipated. Their findings were published in *Astrophysical Journal*. "Being able to eliminate those two models of space-time foam gets us closer to understanding the structure of space-time on the smallest scales and how gravity might eventually be unified with quantum mechanics," Perlman said.



Study Finds Predator's Arrival to the Antarctic Could Radically Alter Marine Life

King crabs may soon become high-level predators in Antarctic marine ecosystems where they haven't played a role in tens of millions of years, according to a new study led by **Richard Aronson**, professor and head of Florida Tech's department of biological sciences. "No Barrier to Emergence of Bathyal King Crabs on the Antarctic Shelf," published in the *Proceedings of the National Academy of Sciences* this fall, ties the reappearance of these crabs to global warming. Aronson found the rising temperature of the ocean west of the Antarctic Peninsula—one of the most rapidly warming places on the planet—should make it possible for king crab populations to move to the shallow continental shelf from their current deep-sea habitat within the next several decades. No barriers, such as salinity levels, types of sediments on the sea floor or food resources were found that would prevent the predatory crustaceans from arriving if the water became warm enough. Their arrival would have a huge impact. "Because other creatures on the continental shelf have evolved without shell-crushing predators, if the crabs moved in they could radically restructure the ecosystem," said Aronson.

Study Finds Pacific Ocean Reef Growth Can Match Rising Sea

The coral reefs that have protected Pacific Islanders from storm waves for thousands of years could grow rapidly enough to keep up with escalating sea levels if ocean temperatures do not rise too quickly, according to a new study led by **Rob van Woesik**, a professor in the department of biological sciences. His research was recently published in the journal, *Royal Society Open Science*. The study provides the first evidence that well-managed reefs will be able to keep up with sea-level rise through vertical growth. But that can happen only if carbon dioxide levels in the atmosphere stay below 670 parts-per-million (ppm). Today, the level of carbon dioxide is 400 ppm. "Reefs will continue to keep up with sea-level rise if we reduce our emission of greenhouse gases," said van Woesik. "If reefs lose their capacity to keep up with sea-level rise they will drown."

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DISCOVERY

HARRIS STUDENT DESIGN CENTER

The Harris Student Design Center was unveiled on Nov. 20, 2015. The 11,500-square-foot, single-story structure, made possible by a $1 million gift from Harris Corporation, will serve College of Engineering and College of Science seniors completing capstone design projects. The Harris Student Design Center is located on the south side of campus, not far from the Harris Center for Science and Engineering that opened in 2009. In the design center's high bay space, student teams will fabricate and assemble a variety of projects, from unmanned submersibles and Baja cars to lunabots.

Left to right: Greg Tsark, vice president for facilities operations; Alton Romig Jr., executive officer, National Academy of Engineering; Bill Brown, Harris Corp. chairman, president and CEO; Anthony Catanese; Florida Tech president and CEO; T. Dwayne McCay, Florida Tech executive vice president and COO; Martin Glicksman, dean, College of Engineering; Hamid Rassoul, dean, College of Science; and Pierre Larochelle, associate dean, College of Engineering.

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