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Florida Tech's College of Engineering is truly engineering the future, as our slogan goes. The college's faculty is currently deeply entrenched in cutting-edge research that will soon shape our country's technological foundation.

This report contains five exciting stories about five of our COE faculty who have accepted the challenge to engineer the future. In one of the stories, you will find out about a new wireless communications network approach to improve the performance of wireless network systems; another story is about our chemical engineering department head whose research agenda involves the development of mathematical models and computer simulations for estimating the nuclear magnetic resonance properties of porous, fibrous and composite materials. Our biomedical engineering interim department head is busy these days finding an interface between biomedical engineering and space applications, and in the mechanical and aerospace engineering department, a relatively new faculty member is gaining an understanding of the anatomy of an explosion. Finally, unmanned aerial vehicles (UAVs) are what one faculty member in the engineering systems department is using to inspect bridges and other structures.

I hope you enjoy these stories about our college's faculty whose expertise is engineering the future.

Fredric M. Ham, Ph.D.
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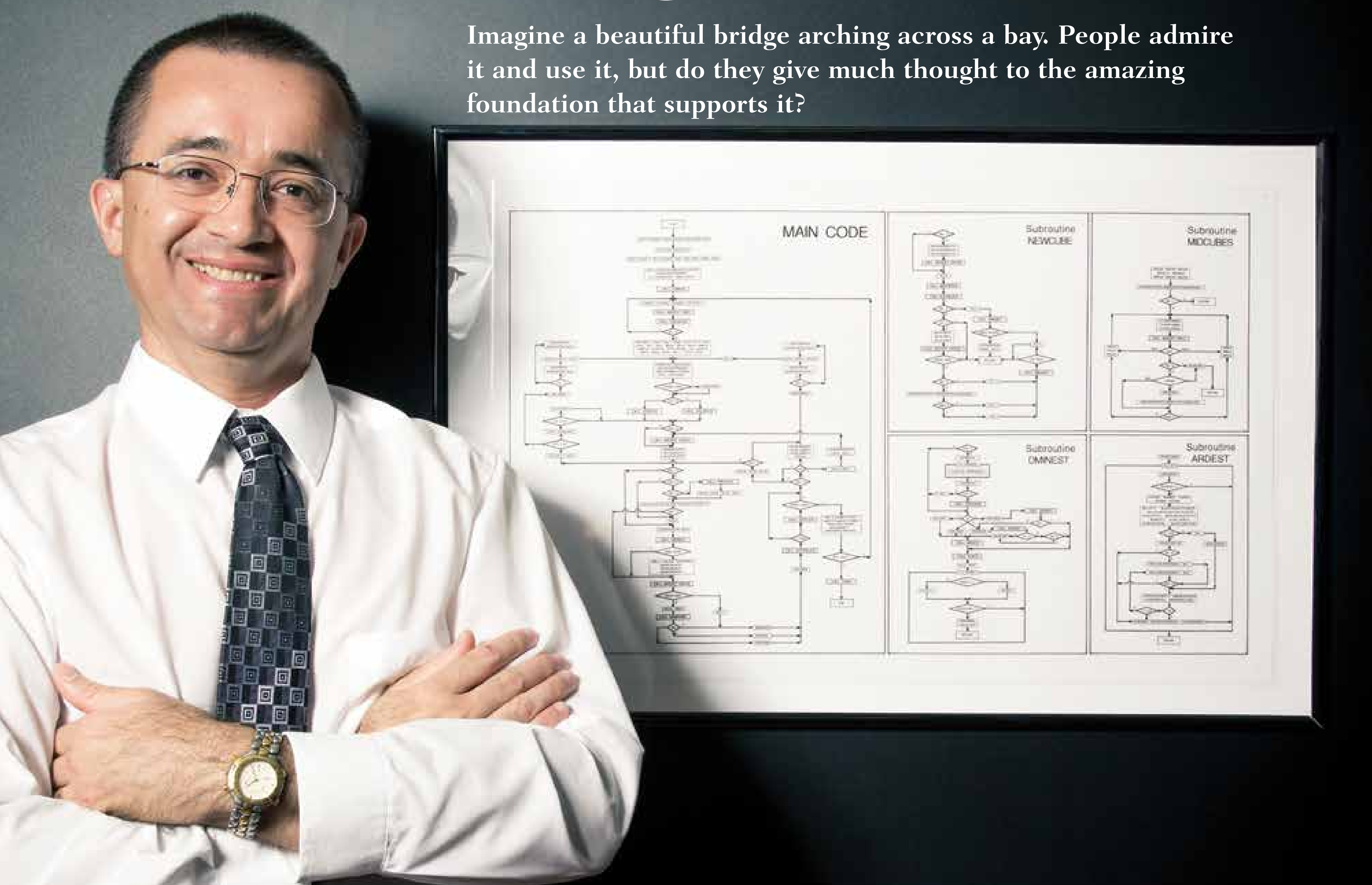
On the cover: Hua Mu (right) and electrical engineering graduate student Shah Niraja create advanced algorithms for wireless systems of the future.

Laying a Strong Foundation for All Things Porous

Imagine a beautiful bridge arching across a bay. People admire it and use it, but do they give much thought to the amazing foundation that supports it?



So it goes with the research of Manolis Tomadakis, head of the department of chemical engineering. His work is the fundamental research that forms the underpinnings of applied research in, as he says, "anything porous." And a lot more is porous than might first be imagined.

Tomadakis builds advanced computer code. He develops mathematical models, computer simulation methods and algorithms for estimating mass and energy transport, reaction and the nuclear magnetic resonance properties of porous, fibrous and composite materials. We encounter these in a variety of modern technology applications and biological systems.

Mathematical modeling helps to understand in more depth why something happens as it does. It creates the root of a process to guide researchers in the right direction for their experiments.

"Most rewarding is when my work is applied in various R&D studies that contribute to technological advances and make a positive impact on our lives," Tomadakis says. Then, he has been well rewarded.

Tomadakis has witnessed his models and simulations tested, validated and applied by many other scientists around the world. He has seen applications in the U.S. space program, automobile industry, geochemistry, radiation oncology, biology, medicine and biotechnology.

The definitive honor for him is citations. When other scientists apply his research to their projects and credit his published work, he knows that "what we discovered on the computer is valuable and helps technology move forward."

Tomadakis has earned hundreds of citations from other researchers. He has had feedback from NASA, crediting him with positively affecting the properties of space shuttle tiles, made of fiber-reinforced composites. He was cited in *Science* for his contributions in improving composite manufacturing techniques for spacecraft applications.

His work has advanced nuclear magnetic resonance applications in oil extraction—assessing in real-time the feasibility of extracting oil from porous rock. Creating reliable models saves time and money, eliminating the need for extensive experimentation.

The ability to understand and predict the molecular transport and surface interactions in fibrous porous materials is valuable to the broader fields of textiles, filtration, paper, fuel cells and tissue engineering, for example. Today, hundreds of fuel cell researchers, including General Motors, use Tomadakis' models for the transport properties of fuel cell gas diffusion media in hybrid cars and other alternative energy systems.

The models he and his graduate students create, however, can only be known and used if they are published. It is his challenge to make time for that, while also meeting the day-to-day demands of heading one of the university's fastest-growing departments and concentrating on his and the department's main job—quality education.

Tomadakis, who usually works at least six days a week, has earned many teaching and service excellence awards and has been recognized by the American Institute of Chemical Engineers for his service to his profession.

"As much as I love the educational and leadership aspects of my job, I cannot imagine my professional life without research. What makes me happiest about my work is knowing that it is used in many applications all over the world."

Karen Rhine

Making Wireless Better

"Coming up with a wireless communication scheme that's completely new just makes me happy," said Hua (pronounced Wah) Mu. The recently minted Ph.D. and assistant professor creates advanced algorithms for wireless communication systems. Although this is her serious research, improving wireless technology is how Mu has some of the most fun.

New to the College of Engineering faculty in fall 2013, Mu taught digital signal processing to electrical engineering graduate students her first semester while devoting about half her time to research. Although she's ahead of her time in the wireless world, the rapidity of technological change will soon put her work right in step.

"Today, wireless networks might use up to eight antennas in an LTE-Advanced system. My work is designed for a system with many antennas," so, it can't be implemented quite yet, says Mu.

Her goal is to improve the performance of wireless communication networks, with their many demands caused by a variety of wireless applications such as video, Internet and traditional voice and text communication. This means higher spectrum efficiency, higher power efficiency and broader coverage.

The main objective of her research is to prompt a more efficient usage of underutilized spectrum resources using the cognitive radio concept and to design relay networks to support multi-users' concurrent transmissions.

A cognitive radio is an intelligent radio that can be programmed and configured dynamically. Its transceiver is designed to use the best wireless channels in its vicinity. Such a radio automatically detects available channels in the wireless spectra, then accordingly changes its transmission or reception parameters to allow more concurrent wireless communications in a given spectrum band at one location.

So, while this is her work today, in the future Mu wants to conduct in-depth research in wireless communications, focusing on two more aspects.

"First, I would like to further investigate communication theories to push the fundamental limits of the communication network. Second, I would like to give more attention to some practical implementation concerns to bridge the gap between wireless communication theory and practical implementations."

As she continues to publish, exposing her algorithms to the world of the cellular network designer, a mobile technology provider such as a Qualcomm or Broadcom, for example, would use her theoretical research in their new systems.

Mu looks forward to the day when her algorithms can be implemented. "When you design something that works better than what anyone else has designed," she says, "that is really exciting."

Karen Rhine

"In the long run, I'm focusing on the fundamental theories in wireless communication. These can be applied to build a more efficient, secure and reliable high-speed wireless network to support the ever-increasing demand from various wireless services."

Hua Mu

Testing a UAV are professors Luis Otero and Paul Cosentino, left and right, and students Luz C. Ortega and Nick Gagliardo.

UAVs Offer Bird's-eye View to Make Bridges Safer

In the American Civil War, when both sides loaded balloons with explosives, set them aloft and hoped for the best—or worst—unmanned aerial vehicles (UAVs) in the United States first took flight. Today, UAVs are not just weapons, but are found in logistics operations, the civil and commercial sectors, and research and development.

At Florida Tech, L. Daniel Otero, assistant professor, department of engineering systems, understands their potential. He's working with UAVs to help the Florida Department of Transportation (FDOT) develop more efficient methods to inspect bridges and high mast luminaires, or lights (HML).

Every two years, the FDOT inspects approximately 7,000 bridges and 4,300 HMLs. Bridge inspections are typically time-consuming and often involve costly traffic delays. The FDOT relies upon the inspectors to make important decisions that have significant economic and public safety implications.

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“The research team will design experiments and analyze data to investigate the system’s capabilities to detect structural defects such as corrosion and concrete cracking.”

L. Daniel Otero, assistant professor, Department of Engineering Systems

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As the principal investigator (PI) of a $250,000-plus, 24-month research study funded by the FDOT Research Center, Otero leads the effort to develop and implement a UAV system to provide real-time remote access to bridge and HML inspection data and evaluate the system’s capabilities through experimentation. He and co-PI Professor Paul Cosentino expect the system to be cost-effective and improve safety and accuracy.

“The research team will design experiments and analyze data to investigate the system’s capabilities to detect structural defects such as corrosion and concrete cracking,” says Otero. “Field and wind tunnel test data will be analyzed to identify maximum wind speeds and light conditions for proper system operation.”

Otero’s main research area is transportation systems engineering with a focus on structural inspections. He is director of the Transportation Systems Engineering Research (TSER) laboratory at Florida Tech, putting forth proposals that involve underwater and surface structural inspections of railroad bridges using various sensors.

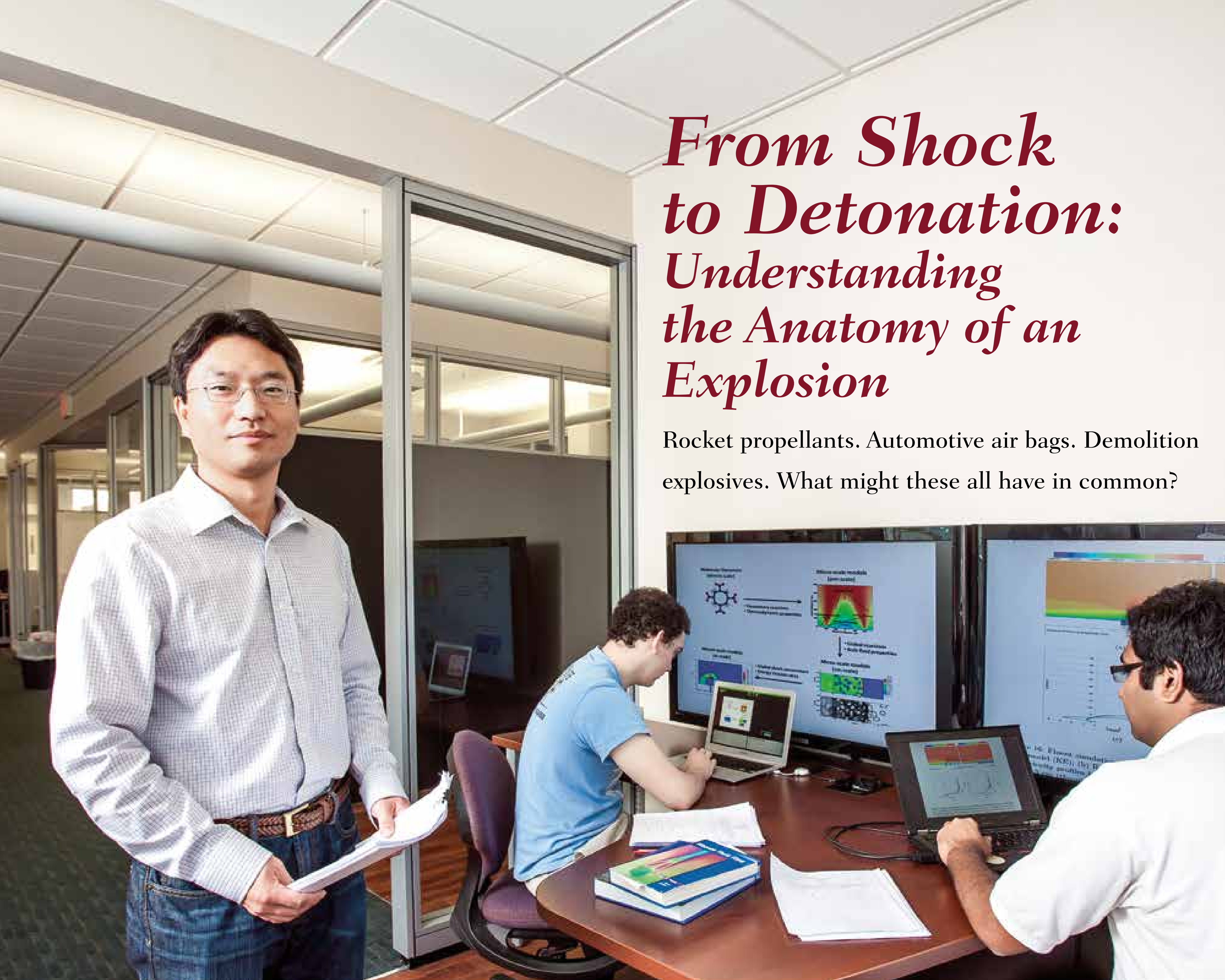
Otero’s research remains consistent with his department’s research goals in systems engineering. “In the past few years, our department has developed a unique identity for interdisciplinary research applications that involve the use of UAVs,” he said.

A native of Bayamon, Puerto Rico, Otero knew early on that he would pursue a career path in engineering. “I remember taking a physics class in high school about forces that influence structures. It got me thinking about how amazing it was that engineers could design long span bridges over water,” recalls Otero. “That day I wanted to major in engineering.”

Otero earned his Ph.D. in industrial and management systems engineering at the University of South Florida in 2009. He joined Florida Tech as a faculty member that same year. Just recently, his brother Carlos, a Florida Tech alumnus, joined him as assistant professor in computer engineering.

“I feel extremely blessed to be part of the Florida Tech family in the College of Engineering. Working with graduate students on research that can positively impact society has been very rewarding. Key to this positive experience has been the leadership of our department head, Muzaffar Shaikh, whose style sets the tone for productive and creative thinking.”

Maya Oluseyi



From Shock to Detonation:

Understanding the Anatomy of an Explosion

Rocket propellants. Automotive air bags. Demolition explosives. What might these all have in common?

Safety concerns for one thing—all contain energetic materials with issues for storage, handling and transportation. But more specifically, at the core of maintaining their safety is knowing the threshold for the energetic matter to detonate or be triggered. The security of the materials in these devices depends on understanding and reliably predicting their behavior in accident scenarios.

Ju Zhang, assistant professor of aerospace engineering, is charged with creating computer simulations to make these determinations. To that end, he is currently engaged in a three-year project under a Defense Threat Reduction Agency (DTRA) award for $450,000.

With one scientist, Thomas L. Jackson from the University of Illinois at Urbana-Champaign, and Matthew Gross from the Naval Air Weapons Station in China Lake, Calif., Zhang is a co-principal investigator on an effort that employs multiscale coupling strategies of several simulation tools used to numerically simulate chemical reactions and fluid dynamics. The overall numerical framework links calculations at the molecular level all the way up to those at macro-scale.

"This is a very challenging task to fulfill. It is complicated in simulations involving a vast disparity of scales," said Zhang. "We are trying to find the threshold for transition from shock to detonation so we can help the designers know what will happen. With our work, there will be less need to do expensive, difficult experiments."

Zhang's earlier postdoctoral work was in astrophysics and supernovae at the University of Chicago. In this period he recalls being in awe of the fascinating phenomenon he saw in the sky and wanted to simulate what he saw.

He continues today, keenly interested in combustion modeling. His work has potential for spin-off applications. "Next will come chip power generation and shockwave generation for medical imaging," he says. "An understanding of the material's initiation and explosion threshold is vital for safety. We need the capability of predicting their behavior."

Zhang, who earned a doctoral degree in aerospace engineering at the University of Texas at Austin and conducted postdoctoral work at the University of Illinois at Urbana-Champaign, teaches classes such as viscous flows and fluid mechanics. He has published extensively on the topic of combustion simulation since 2003 and enjoys working on theoretical projects, like numerical simulation.

Also a person who favors pen and ink, he says, "A computational flow field is fascinating and can be as beautiful as what we see in art."

Karen Rhine

Ju Zhang reviews computer simulation data with two graduate students, Antoine Jost from Spain and Yethiraj Chamarthi from India.

The students of Kunal Mitra share a common interest leading to a promising partnership. "NASA is always an attraction for our students," said Mitra, interim head of Florida Tech's biomedical engineering department. "So I was interested in finding an interface between biomedical engineering and space applications."

Mitra made that connection through collaboration with a longtime associate at NASA, Dr. Daniel Woodard. They are studying bone loss in microgravity through nanoscale finite element analysis of load-bearing structures in bone.

"I have known Dr. Woodard for a while and we thought this project would be an excellent fit," explained Mitra, who is also a professor in Florida Tech's mechanical and aerospace engineering department and directs the Laser, Optics and Instrumentation Laboratory.

"We received very good reviews from the funding agency (NASA's Florida Space Research Program) and the proposal received funding."

The loss of bone mass is a major medical concern of NASA's for long-duration, manned space flights but disuse-induced bone loss is a longstanding issue for the layperson as well. Astronauts, of course, are a very specific focus group, but Mitra explained how the practical application of the study hopes to reach a far wider audience.

"The number of ordinary Americans, including many citizens of Florida, who suffer from disuse-induced bone loss exceeds the number of astronauts by about three orders of magnitude," said Mitra.

This type of bone loss is seen in victims of spinal cord injuries, postpolio syndrome and other medical conditions, and it limits the ability of the muscles to apply loads to the bones. Mitra's study aims to develop a geometric dataset to describe the osteon, a common structural component of bone, based on atomic force microscopy images.

"A predictive theory of the load-bearing behavior of bone based on finite element analysis will benefit health and medicine by making it possible to predict how bone will respond to time-varying loads in ambulation, exercise, injury and disuse," he said.

"This will make it possible to optimize therapeutic regimens for bone disease, such as osteoporosis and fracture healing and to optimize the design of biomedical bone implants and prostheses."

While it may not sound as such to the average person, conducting this research in these varying gravitational profiles is far more practical than attempting to do so on the ground.

"It is not feasible to perform ground-based simulation of all of these profiles that would be needed to optimize these countermeasures by a trial and error approach."

By testing the response of bone during prolonged exposure to microgravity, Mitra and his team hope to develop optimal countermeasures more readily than through traditional experiments. The partnership with NASA seems a perfect match.

"It is well known that bones respond to stress," Mitra said, "But the mechanisms by which it occurs is very difficult to understand. [NASA's] wide range of missions is contemplated with different gravitational loading profiles (the moon, Mars, etc.), which will help in developing predictive tools."

Jon Jordan

Scientists Analyze Bone Mass Loss in Microgravity

From left, Mohit Ganguly; Dr. Daniel Woodard, NASA physician; and Kunal Mitra.

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At the 2013 Northrop Grumman Student Design Showcase the President's Cup award for College of Engineering went to the Building a Better Home team.

The team's advisor was Ralph Locurcio, director of the Construction Management program.

ENGINEERING SIGNATURE RESEARCH AREAS

Sustainability of the Environment • Intelligent Systems • Assured Information and Cyber Security • New Space Systems and Commercialization of Space • Communication Systems and Signal Processing • Biomedical Systems

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