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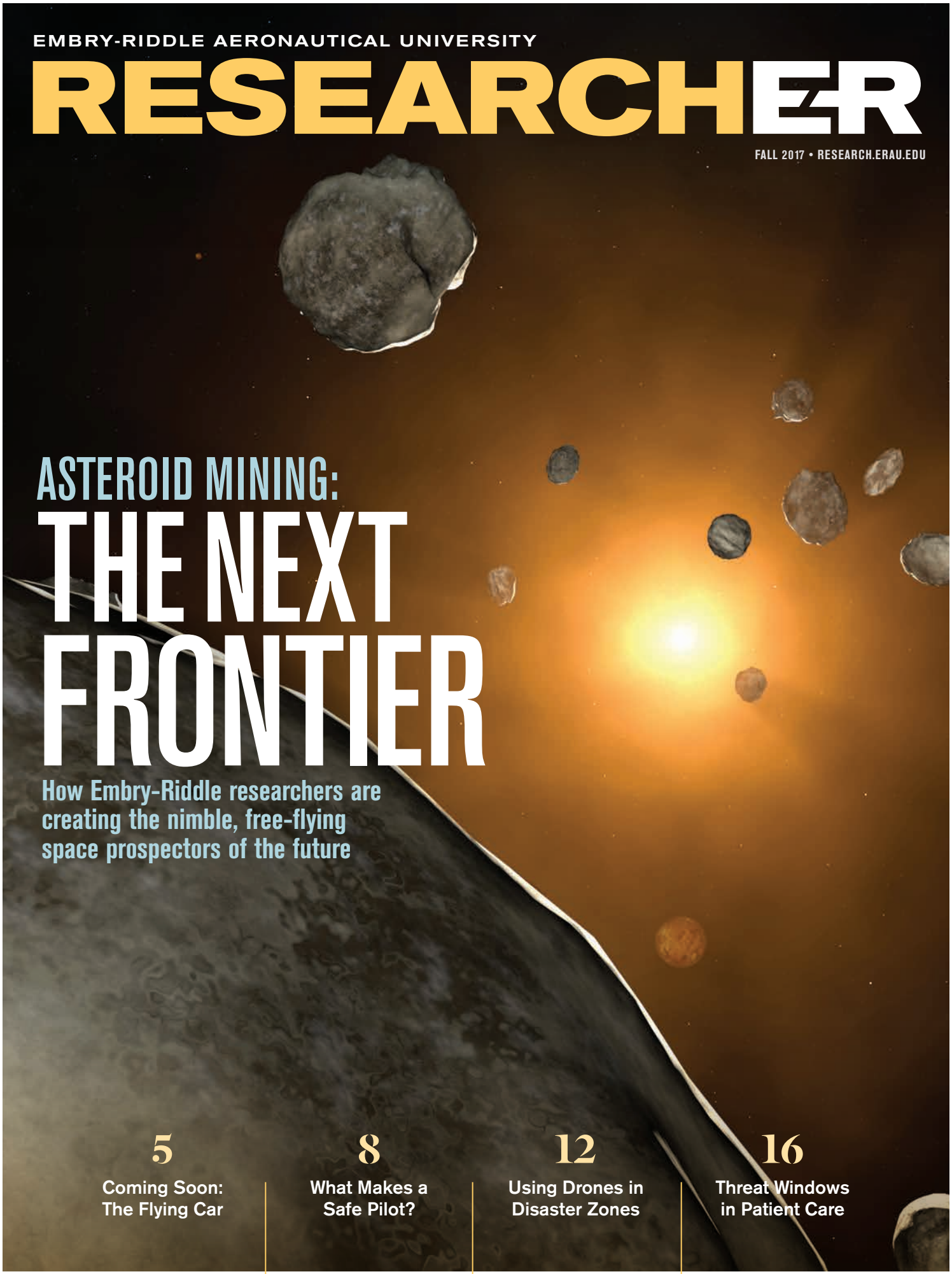

ASTEROID MINING:
THE NEXT FRONTIER

How Embry-Riddle researchers are creating the nimble, free-flying space prospectors of the future

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At the height of twister season, an Embry-Riddle team drove straight into Tornado Alley to conduct the first test of small drone-based augmented reality software.

FEATURES

Rob Ferguson and Putnam Reiter

Cover photo: iStock

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Clockwise from top right: Mario Merino, Thinkstock, Connor McShane

20 Space Prospectors

The next frontier for aerospace researchers? Developing spacecraft to explore asteroids for natural resources.

IN EVERY ISSUE

Dear Friends and Alumni,

Embry-Riddle Aeronautical University is in the midst of a significant transformation, manifested mainly through the accelerating growth of our research endeavors. Building on its 90-year legacy of excellence in aviation and aerospace, the university is now expanding its research footprint, even as we remain committed to the paradigm of "research that matters to industry."

This juxtaposition reminds me of the late Abraham Flexner of the Institute for Advanced Study in Princeton, N.J., and his famous 1939 essay, which had the thought-provoking title, "The Usefulness of Useless Knowledge." In it, Flexner warns against the exclusive pursuit of "applied research," where investigations target the solution to a specific problem, as opposed to new knowledge – the product of pure curiosity in pursuit of no particular end.

It is this latter type of inquiry, Flexner points out, which has resulted in some of the world's greatest discoveries. Indeed, Larry Page and Sergey Brin reportedly did not set out to develop the Google search engine and a global enterprise employing more than 60,000 people. Initially, they were simply curious to learn whether they could write a mathematical algorithm to rank webpages. Similarly, Larry Smarr's curiosity-driven research into the collisions of black holes eventually led to the development of web browsers.

Perhaps it can be argued that the line between basic and applied research has become far less stark today than it was in Flexner's time. Setting aside the overuse of words like "innovation" and "entrepreneurship," it is hard to separate pure curiosity-based research from curiosity that results from looking for solutions to some of the world's most complex problems – including many considered intractable in our recent past.

I invite you to read through the pages of this issue to learn about the wide spectrum of research projects being conducted at

David Massey

Embry-Riddle – from the design and development of a smart personal flying vehicle (Page 5), to understanding the science of atmospheric dynamics (Page 6), to the study of aviation psychology and its implications for safety (Page 8). You will further find several articles that outline our growing efforts in the fields of unmanned aerial systems (as described on Pages 12, 26 and 29), medical human factors (Page 16) and robotics (Page 20).

Thank you for supporting our efforts, and please do let us know how we can continue to improve both the conduct and communication of our research.

Sincerely,

Dr. Maj Mirmirani

INTERIM SENIOR VICE PRESIDENT FOR ACADEMIC AFFAIRS AND RESEARCH AND DEAN OF THE COLLEGE OF ENGINEERING, DAYTONA BEACH CAMPUS

VOLUME 1, NO. 2

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Sending T-Cells Into Space

EMBRY-RIDDLE PAYLOAD TO ASSESS MICROGRAVITY IMPACTS ON THE IMMUNE SYSTEM

When Blue Origin's New Shepard vehicle makes its next launch into space from West Texas, it will have a little bit of Embry-Riddle Aeronautical University on board: a payload designed by students in Pedro Llanos' Satellite and Spacecraft Systems class.

The Cell Research Experiment in Microgravity (CRExIM) suborbital payload will be the first of what he hopes will be many payloads to fly through Embry-Riddle.

"It's a multidisciplinary effort between various colleges at Embry-Riddle and other universities nationwide," Llanos says. "Spaceflight operations and aerospace/mechanical engineering students – along with Embry-Riddle's Department of Applied Aviation Sciences – are working together with a science team comprised of the University of Texas Health Science Center at San Antonio and the Medical University of South Carolina."

THE MISSION

The CRExIM payload, which contains T-cells isolated from mice and grown in the laboratory, will be exposed to microgravity for about three and a half minutes. These types of cells are the main warriors of our immune system, tracking down and defeating cells that are infected or have become cancerous. The idea behind the experiment is to get insights on how brief exposure to microgravity orchestrates the landscape of different types of immune cells, say Llanos and his colleague Kristina Andrijauskaite with the University of Texas Health Science Center.

Sathya Gangadharan, a mechanical engineering professor who helped advise on the design of the structure of the payload, says: "I'm very glad that Embry-Riddle is pioneering this new area of cancer cell research from a biomedical engineering perspective, utilizing its past experiences in microgravity to bring solutions to problems that are critical to the medical field."

GETTING IT OFF THE GROUND

The payload itself will be housed in a 3-D printed structure designed and printed at Embry-Riddle's Engineering Physics Propulsion Lab on the Daytona Beach Campus in Florida. It was tested to meet the different milestones set by Blue Origin's payload users guide for ensuring the safety and containment of biological agents.

To plan the mission, Llanos formed three teams to work on the suborbital payload: a flight operations team, a design and engineering team, and a science team.

"We went through various design iteration processes and worked closely to test the designs using computational analysis software," says Vijay Duraisamy, a mechanical engineering Ph.D. student who worked on the project along with a large team of Llanos' undergraduate students.

COLLABORATION IS KEY

Because of the nature of this multidisciplinary project, students had to build and expand their team dynamics by working with other teams at the university, as well as with industry experts.

Llanos says the project, which was awarded second place at the 2017 Embry-Riddle Discovery Day Awards, allowed the team to work on real-world opportunities while giving students the chance to collaborate with other groups and mature their problem-solving skills.

A second payload, which will measure conditions aboard Blue Origin's New Shepard rocket before the spacecraft's first manned flight, is in the works. /TOM IACUZIO

Pedro Llanos displays the CRExIM payload that was designed by Embry-Riddle students to study the effects of microgravity on T-cells.

Daryl LaBello

The Audacity of New Ideas

THESE FOUR MICAPLEX INCUBATORS ARE ADVANCING MEDICAL TECHNOLOGY AND MORE

1 SAFER SUCTIONING

Nurse-anesthetist Kristi Myers was suctioning blood and vomit from a patient 21 years ago when she looked at the medical device in her hand – the ubiquitous Yankauer suction instrument – and wondered where to stash it. "Everybody tries to use the package to contain the used Yankauer suction tip, but it falls off, so you stick it under the patient's pillow or mattress, or you leave it on a countertop," Myers explains.

Nearly 94 percent of all tonsil suction devices are teeming with bacteria, including antibiotic-resistant organisms, 24 hours after use, research shows. Myers realized, given the risk of healthcare-acquired infections, that the haphazard placement of used suction tips was a significant problem.

Enter the Yankaddy®. A disposable holster for the Yankauer suction instrument, Myers' invention features an adjustable arm and a spring clamp that latches onto bedrails, counters and equipment. After Myers secured patent-pending status, Myers Devices LLC gained support from the John Mica Engineering and Aerospace Innovation Complex (MicaPlex) at Embry-Riddle Aeronautical University's Daytona Beach Campus in Florida, where she became an incubator tenant.

Other MicaPlex incubators are pursuing equally audacious ideas. By supporting entrepreneurs, Embry-Riddle hopes to "speed innovation and generate meaningful, high-paying jobs for Volusia County," says Rodney Cruise, senior vice president for administration and planning.

Kristi Myers, a MicaPlex incubator tenant, invented a disposable holster for the Yankauer suction instrument.

Scott Weintraub (left)

2 SATELLITE SERVICES THAT FLY HIGHER

Think of it as a kind of space Uber that picks up satellites and hauls them exactly where they need to go – without limits or the hassle of hitching a ride on the International Space Station. Now, imagine that this precision orbital placement service also offers space-based roadside assistance and recycles space trash.

Scott Weintraub, founder of Weintraus LLC, plans to launch his first spacecraft by 2020. A second spacecraft with robotic arms will offer a full range of satellite services, including refueling, debris mitigation and demolition, and assistance with asteroid mining. Ultimately, Weintraub envisions capturing, stripping and rebuilding dead satellites.

"I'm a dreamer," he says. "For a long time, my approach was to try and help one person at a time, but my true passion is aviation and aerospace, and I want to change the world somehow."

David Massey

3 DRONE SWARMS FOR GOOD, NOT EVIL

Cooperative swarms of drones may sound like science fiction, but Michael Campobasso and Shane Stebler have a noble, real-world plan for Embedded Control Designs LLC. They are building mechanical swarm agents, rigged with communication architecture and control algorithms, to help farmers monitor their crops.

The solution offers reliability since crop inspections completed by multiple drones offer redundancy. Campobasso says a swarm of mechanical flying inspectors could also cover a whole farm in less time and at a lower cost than a fleet of individually operated drones. The technology, which placed second in the university's recent Launch Your Venture competition, reflects the inventors' passion for innovation.

Campobasso, an Embry-Riddle master's degree student, says he and Stebler "want to be part of the movement to make the best drones in the world."

4 FOCUSED BEYOND THE LINE OF SIGHT

With the global population predicted to hit 9.6 billion by 2050, farmers need to increase crop yields and reduce losses caused by pests, plant disease and other challenges. While growing up in Illinois, Trevor Perrott regularly heard about farming hardships and came to understand that close, continuous crop inspections are essential to preventing losses. Inspections are critical for oil pipelines, too; in fact, federal law requires a complete assessment every 21 days.

Aerial inspections offer efficiency, but traditional unmanned aerial systems (UAS) called quadcopters can only fly relatively short distances at line of sight. Manned aircraft and satellites fly farther but cost more.

Perrott and two other former Embry-Riddle students, Payal Chaudhari and John Lobdell, launched Censys Technologies Corp. to develop long-range high-efficiency UAS. Specifically, they are developing drones that can fly beyond the operator's line of sight. They are also evaluating fuel-burning, hybrid and electric propulsion systems.

Censys Technologies Corp. and Weintraus LLC each accepted seed grants of $25,000 from the nonprofit FireSpring Fund. /GINGER PINHOLSTER

Mario Merino

A rendering of the Embry-Riddle personal air vehicle (PAV).

THE FLYING CAR BECOMES A REALITY

The promise of flying cars has been "right around the corner" since we watched George Jetson commute to work in his "aerocar" in the 1960s.

Finally, it looks like that promise may be kept, and it could be in the form of a personal air vehicle (PAV) designed by a team from Embry-Riddle Aeronautical University that will make high-flying commutes a quiet, safe, energy-efficient breeze.

Several nascent aviation companies with prototype flying cars or PAVs are in the initial stages of flight testing, but they face steep technological, safety and regulatory hurdles. That's where Embry-Riddle's Richard "Pat" Anderson, director of the Eagle Flight Research Center (EFRC), and his faculty and student teams boast a big head start. They have been working toward this goal since 2011, when the EFRC's EcoEagle, a hybrid electric prototype motorglider, took flight as one of four finalists in the Google-NASA Green Flight Challenge.

The EFRC team's progress toward creating a Jetson aerocar-like PAV has included the development of the battery-powered *eSpirit of St. Louis* — a lightweight, 70-foot wingspan, student-designed and modified Diamond HK-36 aircraft, which will demonstrate the promise of clean, quiet flight.

Concurrent research, design and flight of the EFRC's Heurobotics computer-controlled hybrid aircraft called the Mark II has been another technological breakthrough that will support the development of a personal flying vehicle. Featuring a mechanically simple 10-foot-wide airframe with two fully articulating rotor heads, the highly intelligent, stable and maneuverable Mark II lifts off vertically like a helicopter, leans to a 90-degree angle and flies horizontally like an airplane.

Federal Aviation Administration directives overhauling airworthiness standards for small aircraft are also fueling public and researcher interest in developing PAVs. The new provisions allow innovative aircraft design teams like the EFRC to take advantage of performance-based industry standards in place of "prescriptive" manufacturing methods that have long hindered the development of new designs and technologies.

Anderson's prototype personal flying vehicle design and build team, led by research engineer Borja Martos, is moving rapidly, having built and tested the proof-of-concept eight rotor "On-Demand Mobility" PAV this summer.

Martos' team has many aerospace giants to call upon for support. Embry-Riddle belongs to the Hybrid Electric Research Consortium, which includes Airbus, Boeing, GE Aviation, Hartzell, Argonne National Laboratory, Rolls-Royce and Textron Aviation. /JAMES RODDEY

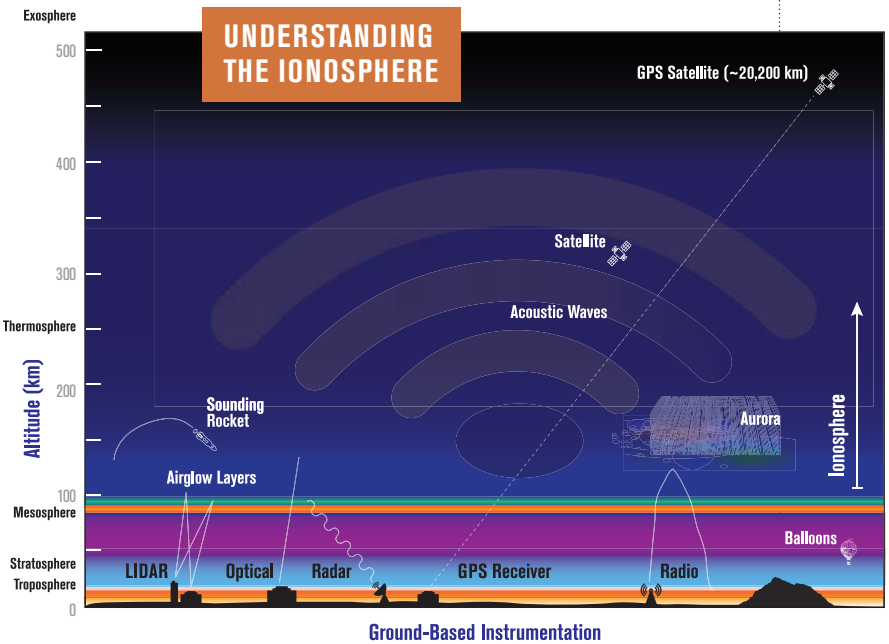
When the Earth Rings

RESEARCHERS DECODE THE ATMOSPHERIC SIGNATURES OF EARTHQUAKES AND UNDERGROUND NUCLEAR TESTS

A strong earthquake, volcanic eruption, rocket launch or underground nuclear test can send a train of acoustic shock waves high into the atmosphere. As they barrel upward, the sound waves steepen and intensify into shocks, crashing into space more and more intensely before the particles collapse back down in a signature pattern.

"These waves start as brief packets, but they form into focused narrow bands, indicating a natural resonance or ringing that's persistent," says Jonathan Snively of Embry-Riddle Aeronautical University. "This ringing can last for hours, and it's readily detectable."

In addition, the acoustic shock waves produced by undersea earthquakes trigger chemical changes that researchers can spot as telltale "holes" in space, says Snively's colleague Matt Zettergren. These anomalies, resulting from the depletion of electrons in the Earth's ionosphere – a highly conducting, ionized region of the atmosphere – could offer deeper insights into how earthquakes affect the upper atmosphere.



WHAT WE KNOW

The research, supported by NASA and published in the February 2017 edition of the *Journal of Geophysical Research,* remains fundamental; Snively and Zettergren emphasize that their work doesn't currently suggest a way to predict major earthquakes or the tsunamis that follow them.

Over the long term, however, the work may have important implications for remotely sensing earthquake impacts such as tsunamis. Moreover, understanding what happens in the atmosphere following an underground bomb blast could be critical to global security.

Spanning part of the atmosphere where auroras dance and satellites fly, the ionosphere continuously gains charged particles when energetic solar and cosmic radiation converts molecules into ions and electrons. This has important implications for communication. When lower-frequency radio waves hit the ionosphere, its particles act like ping-pong paddles, bouncing signals to receivers on the ground or in space. Signals from global positioning systems (GPS) can get scattered by the ionosphere, too.

As with earthquakes, the detonation of a nuclear weapon also leaves a mark on the ionosphere. Embry-Riddle researcher Michael Hickey, the university's dean of research and graduate studies, recently began looking at how North Korean weapons tests affected the atmosphere in 2006 and 2009. The new project, related to a U.S. Defense Threat Reduction Agency grant awarded in collaboration with James L. Garrison of Purdue University, will compare total electron content (TEC) data derived from satellite GPS with Hickey's computer model of waves pushed through the ionosphere by ground-based blasts.

SIGNATURE SONGS

Snively and Zettergren – both associate professors of engineering physics at Embry-Riddle's Daytona Beach Campus in Florida and recipients of National Science Foundation Early Career Development Awards – are meanwhile deciphering the exact sequence of events that take place whenever the Earth essentially gets its bell rung.

With colleagues at NASA's Jet Propulsion Laboratory at the California Institute of Technology, Snively and Zettergren use a pair of unique computer models, and they confirm their simulations based on real-world measurements of events. Ionospheric holes (TEC depletion) may only accompany extremely large acoustic waves, they say, but ringing may occur and persist even for weaker waves. Going forward, they hope to "couple" their models, to run them together. / GINGER PINHOLSTER

Trish Kabus

Reamonn Soto's ceramic sensors precisely and wirelessly measure gas turbine temperatures, potentially saving operators thousands of dollars.

David Massey

Keeping Gas Turbines Healthy

EMBRY-RIDDLE WORLDWIDE STUDENT SCORES A WINNING INNOVATION

Inside big ships, jets, rockets, hospitals, factories, oil-drilling rigs and many other operations, a type of internal combustion engine called a gas turbine reliably generates power. But routine maintenance comes with a steep price tag. Over a typical 10-year life span, keeping a gas turbine healthy may run as much as $30 million, says Reamonn Soto, whose startup business, Sensatek Propulsion Technology, offers a way to reduce those costs significantly while also increasing the efficiency of power generation.

Soto, a U.S. Marine Corps veteran who is pursuing a master's degree in aeronautics at Embry-Riddle Aeronautical University's Worldwide Campus, has been piling up competitive awards for his business model. In addition to a $25,000 seed grant from the nonprofit FireSpring Fund, Soto has won: $10,000 and first place in this year's Launch Your Venture competition; the $50,000 grand prize in the U.S. Department of Energy's 2016 Megawatt Ventures contest; a $50,000 business travel budget from the National Science Foundation's Innovation Corps (iCore) program and more.

THE SECRET TO THE SENSORS' SUCCESS

From a technical perspective, all the fuss is warranted, says Mark Ricklick, an Embry-Riddle assistant professor of aerospace engineering who serves as an adviser to Soto's company. Sensatek licenses patented technology to manufacture ceramic sensors that precisely and wirelessly measure gas turbine temperatures. This allows operators to prevent failures and optimize engine performance by modifying temperatures, as needed.

Sensatek has positioned itself to address a critical business need. The efficiency of a gas turbine improves when combustion temperatures are higher – 500 to 800 degrees Celsius, above the safe operating temperatures for materials, Ricklick explains. Dialing down the heat too suddenly can also cause failures. To optimize performance without breaking anything, operators have to take the engine's temperature on a continuous basis. Yet, currently available sensors cannot be placed near the engine's hottest spot – the turbine inlet – so temperature readings are captured in cooler locations. Mathematical models are then used to estimate heat levels.

Soto's company is commercializing a different type of sensor, originally developed at the University of Central Florida, based on a polymer-derived ceramic material that is easy to fabricate and tolerates high temperatures well. The sensors can also be "tuned" with doping agents to send different frequency signals to a remotely located antenna. "The resonant frequency of these sensors changes in response to temperature," Ricklick explains. "They act as little passive antennae. The frequency of the sensors can be manipulated to correspond with a particular temperature."

$480,000

The estimated annual savings per engine for gas turbine operators that improve efficiency by just 1 percent.

Even with a 1 percent improvement in gas turbine efficiency, Soto says, operators could save $480,000 per engine every year. Optimizing performance can also extend the life of a gas turbine, he notes.

The Sensatek research team is currently investigating how to position the sensors on engines to get the best results for customers. Meanwhile, Soto continues to soldier on – networking, learning as much as he can about the technology and refining his business model based on customer feedback.

"We've been like a quiet storm for the past two years," he says. "We've been going out there, attending industry conferences, cold-calling business leaders and showing up where it's least expected to get the answers we need. We want to better understand how our research can have a positive impact on society and real economic consequences as well." / GINGER PINHOLSTER

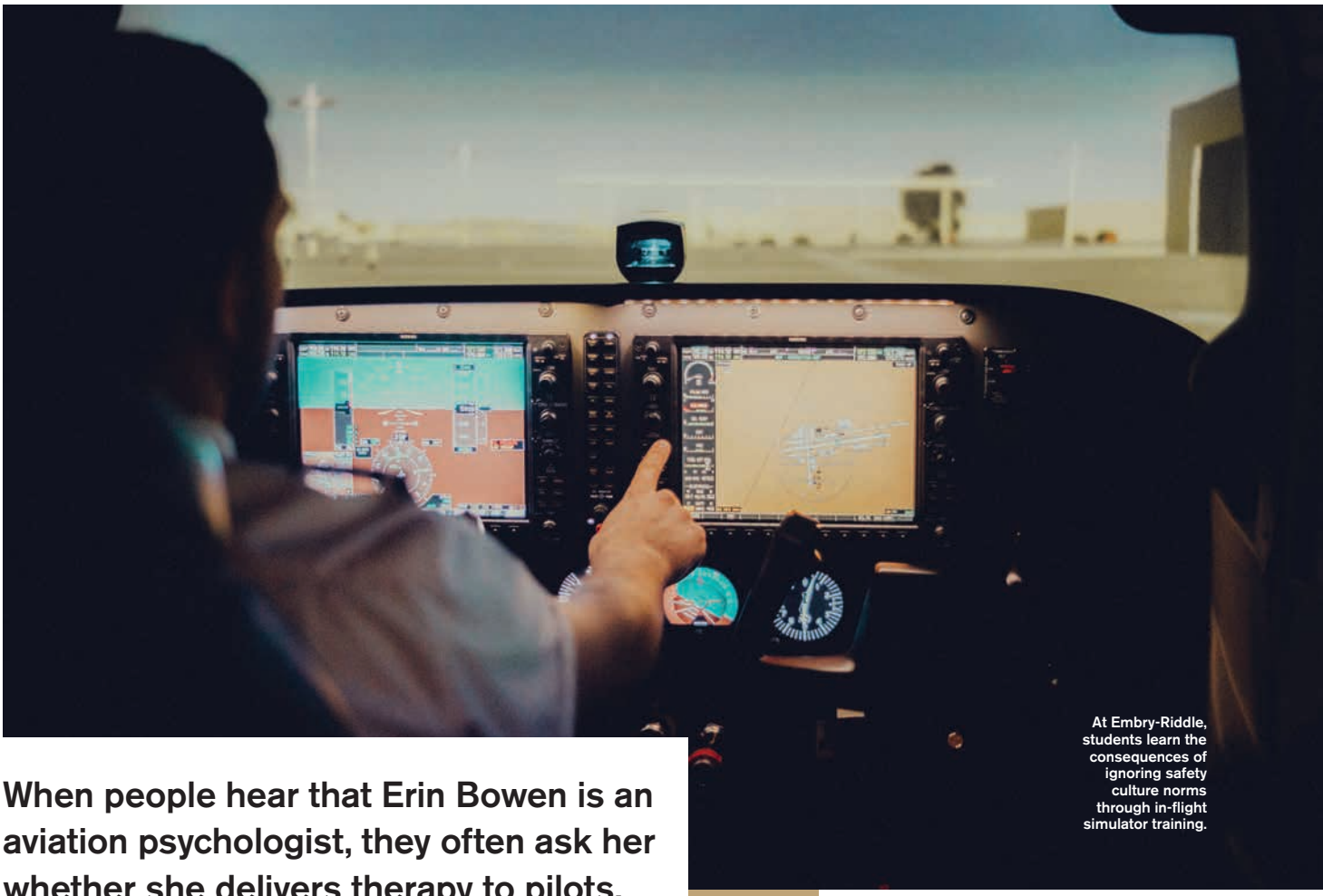
"One of the things I try to teach here is that with the extremely rare exception, 99.9 percent of pilots don't get into a plane thinking, 'I'm going to crash today,'" says aviation psychologist Erin Bowen.

Connor McShane

What Makes a Safe Pilot?

At the Robertson Safety Institute, Erin Bowen dives deep into "aviation culture" to track changes in group thinking over time

by Becky Ham



At Embry-Riddle, students learn the consequences of ignoring safety culture norms through in-flight simulator training.

Connor McShane

When people hear that Erin Bowen is an aviation psychologist, they often ask her whether she delivers therapy to pilots, or what she thinks about rare tragedies such as Germanwings Flight 9525 —

the flight crashed by its co-pilot in 2015. But she and her colleagues take a much more expansive view of flight safety, one that focuses less on the pilot and more on the surrounding aviation culture.

Indeed, aviation psychologists who work on ways to improve flight safety must look beyond pilot personalities and training to examine the entire "culture" at work every time a plane takes to the skies.

"When we look at what might make a safe pilot, it's more about how do we build the policies, the systems, the selection procedures, the regulations, the environment, the culture," says Bowen, an associate professor of behavioral and safety sciences at Embry-Riddle Aeronautical University's Prescott Campus in Arizona. "How do all those things play into the decision that the pilot makes when that moment comes, the moment when they have to make the critical choice?

"It's a lot easier to see if there is a safe system in place than it is to claim that a person is a safe pilot," she adds.

In May, Bowen and Brian Roggow, an aviation safety program manager at Embry-Riddle, presented new research at the International Symposium on Aviation Psychology looking at four years' worth of safety climate surveys from a collegiate aviation program where the participants ranged from flight instructors to dispatchers to office workers. Their study revealed several responses – particularly regarding safety communications between pilots and instructors – that showed significant change over time.

Their study is one of the few to look at how an aviation culture changes over the long run. Bowen says their results may in part reveal how high turnover among pilots and instructors – as a global pilot shortage continues – can impact safety. Without a stable workforce to communicate the cultural "norms" of an organization, she notes, "you're risking pervasive change to the safety culture."

When an organization can't agree on these norms, individuals may commit "small but ever growing violations of rules, procedures and policies," Bowen says. "They might justify it to themselves by saying, 'I got away with it once – in that nothing bad happened – even though I took a shortcut here or skipped this step.'"

At Embry-Riddle, Bowen says, students learn about the consequences of ignoring these norms, with the help of cautionary case studies, "most wanted" lists of errors from the Federal Aviation Administration (FAA) and in-flight

simulator training. Often it is learning communication "soft skills" – for instance, keeping a sterile cockpit with no non-flight-related talk during critical periods – that pose the most difficulties for students.

Too often, organizations may attempt to fix one safety problem – singling out pilots for violating the sterile cockpit, for example – without examining the rest of the safety culture. "And that absolutely is not going to work," Bowen says. "It's like you have 99 oars rowing one way, and here's one little stumpy oar rowing the other way."

INSIDE THE MINDS OF PILOTS

Other Embry-Riddle researchers approach aviation safety at the level of the pilot. For instance, Bob Walton, a faculty member with Embry-Riddle Worldwide and executive director of campus operations, has studied accident differences between male and female pilots.

A 2016 study published by Walton concluded that at low levels of training and experience, female pilots have accidents that cause higher amounts of aircraft damage and personnel injury, compared to male pilots, but that female pilots go on to have significantly fewer accidents at higher levels of experience. Walton also found that pilot suicide, as in the Germanwings case, is very rare but more likely to be carried out by male pilots with depression.

In general, Bowen says, airlines are on their own in choosing what kind of psychological assessments to use with their pilots (or whether to use them at all). There is no preferred "pilot personality," she says, although some assessments will evaluate a pilot's conscientiousness, attention to detail, willingness to follow policy and procedures, and stress-response skills.

As the director of Embry-Riddle's Robertson Safety Institute, which contains the largest aircraft accident laboratory in the country, Bowen always keeps safety top of mind. "One of the things I try to teach here is that with the extremely rare exception, 99.9 percent of pilots don't get into a plane thinking, 'I'm going to crash today,'" she says. "So why do we have accidents? It's not equipment failures as much anymore. It's people and communication problems." ER

Strike Force: Navigating Wildlife

Geese, blackbirds, deer, salmon (yes, salmon — more on that below) are the culprits behind more than 7,500 wildlife strikes on aircraft in the United States each year. For 15 years, a database that was launched at Embry-Riddle has documented many of these damaging and sometimes deadly collisions.

The FAA's Wildlife Strike Database (wildlife.faa.gov) was first developed in 2000 under the guidance of Archie Dickey, a professor of biology at Embry-Riddle's Prescott Campus in Arizona. The database contains a wealth of strike reports, the best known of which may be the Canada goose strike that prompted Chesley "Sully" Sullenberger to land in the Hudson River in 2009.

The goal, Dickey says, is to know more about where, how and why these strikes take place so that wildlife biologists can work to reduce their number. "We've been very active in trying to educate people, airports, pilots, everyone connected with the aviation industry, that if they have the ability to report these strikes, they should report them," Dickey says.

Embry-Riddle offers the only undergraduate degree in wildlife science with an aviation focus in North America, and the wildlife biologists trained through this program learn how to make airports less inviting to animal neighbors. The FAA database helps these researchers look at trends for particular airports and regions, to see if recent habitat changes or events such as winter storms have altered the strike risk, Dickey notes.

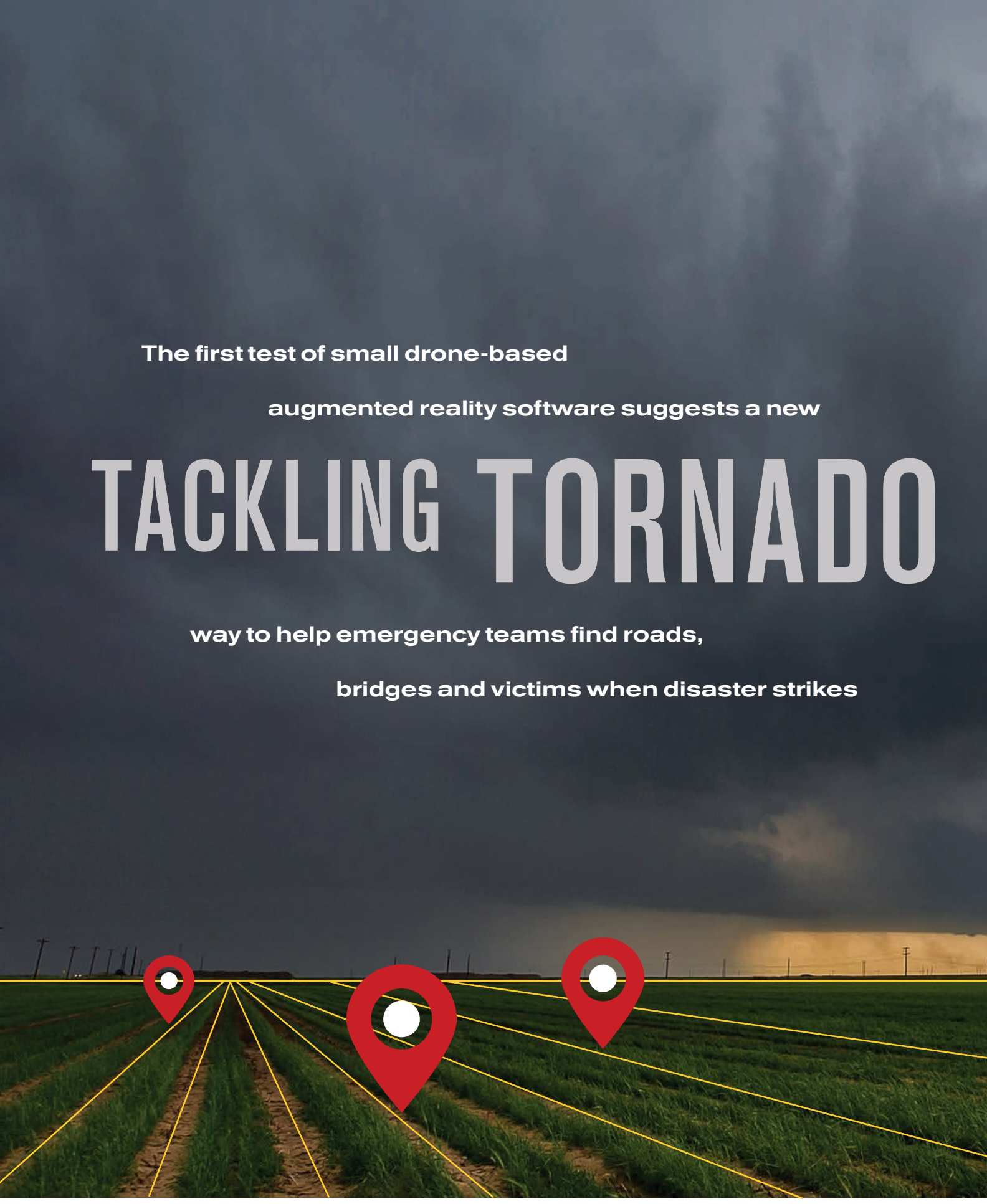
These biologists often focus on changing the habitat around airports using different mowing techniques or removing nearby trees or standing water to make an area less attractive to bird flocks, in particular. But noise cannons, trained falcons, netting and models of predators like wolves or dogs all play a part in creative strike deterrence, Dickey says.

This year, he and his students are exploring a technological fix to see whether a special sequence of flashing lights on planes could reduce strikes. But Dickey warns that birds are very adaptable. "If anyone ever calls you a birdbrain, you should shake their hand," he says. "Birds learn very fast, and what may work on them today may not work tomorrow."

And then there are the strikes that no planning can predict or prevent. The strangest incident in the database, Dickey says, is the tale of a bald eagle who plucked a salmon from a river northeast of Seattle. Startled by the takeoff of a small plane, the eagle dropped the fish, which made a crash landing through the cockpit window.

Wildlife biologists trained at Embry-Riddle learn how to make airports less inviting to animals, including using models of wolves and other predators to help decrease the number of wildlife strikes on aircraft.

Archie Dickey



The first test of small drone-based augmented reality software suggests a new way to help emergency teams find roads, bridges and victims when disaster strikes

TACKLING TORNADO

Rob Ferguson and Putnam Reiter

BY GINGER PINHOLSTER

On May 13, during the height

of twister season across America's notorious Tornado Alley, faculty members Joe Cerreta, Dan Macchiarella and Scott Burgess headed to Oklahoma, along with seven students. The National Oceanic and Atmospheric Administration's colorful online tornado-prediction map was showing a dark bull's-eye over central and western Oklahoma.

The Embry-Riddle Aeronautical University team drove straight into the danger zone.

The group had just set up operations in Alva, Oklahoma, when an EF2 tornado struck 100 miles to the south, in Elk City. Spinning winds as fast as 135 miles per hour, the storm caused damage to at least 150 homes and killed one person, according to Keli Cain, a public information officer with the Oklahoma Department of Emergency Management. Soon after the storm had passed, the Embry-Riddle team, working from a mobile command trailer, provided high-resolution damage assessments based on imagery captured by small unmanned aerial systems (UAS).

They also conducted what is believed to be the nation's first test of an emerging UAS technology to benefit first responders at disaster scenes. The team's demonstration of the technology was livestreamed by the National Weather Service – another first.

The Embry-Riddle group provided proof of an important new concept.

AUGMENTED REALITY IN ACTION

Augmented reality software, coupled with livestreaming video captured by small drones, can provide emergency management personnel with real-time aerial damage assessments, as well as critical assistance in navigating roads and bridges obliterated by fallen trees, flattened homes and floodwaters. The technology lets first responders communicate with UAS operators via smartphones, using either voice or text messages to quickly clarify coordinates or request close-ups of shadowy debris.

Combined with virtual "pins" indicating the Federal Emergency Management Agency's

four damage-assessment categories (affected, minor, major and destroyed), the augmented reality imagery may prove instrumental for getting communities the help they need when disasters happen, says Cerreta, an associate professor in the College of Aviation at the university's Daytona Beach Campus in Florida.

"To my knowledge, this was the first use of augmented reality for small drones in post-disaster relief operations in the United States," Cerreta says. "A version of the technology was developed for unmanned aircraft systems used by the U.S. Army, but it has not previously been used with small drones to benefit civilian first responders in this country."

Cerreta's assessment was confirmed by Michael Abernathy, director of technology for Rapid Imaging Software Inc., maker of the SmartCam3D View augmented reality software.

"Although our augmented reality technology has been used by the military as well as NASA for decades, it is not in broad use for civilian applications," Abernathy says. "This technology adds valuable information to video that improves decision-making. We foresee that in the near future it will be a must-have for large and small emergency response organizations, and it will save countless lives."

Putnam Reiter, project manager at the Oklahoma Department of Emergency Management, who helped spearhead the partnership with Embry-Riddle, reports that the technology demonstration went well. Reiter's colleague Zach Stanford, a special projects officer, agreed. "The team positioned themselves in such a way that they could assist wherever they were needed," Stanford says. "They assisted with providing an initial overview of the damage. There were several areas blocked by downed trees and power lines. They were able to get clear images from the air."

The SmartCam3D View software blends geographic information, such as road locations, boundaries and icons, with live UAS-captured video from the disaster area, essentially laying a map over obliterated office parks and submerged bridges. "Sometimes it's difficult or dangerous for emergency crews to get into areas that were damaged – for instance, if there are wildfires or floodwaters," Cain notes. "Anything that technology can do to make it less difficult for first responders would be a good thing."

"IN THE NEAR FUTURE [UAS TECHNOLOGY] WILL BE A MUST-HAVE FOR LARGE AND SMALL

LEARNING THROUGH REAL-LIFE EXPERIENCE

The Oklahoma project was part of a "study away" summer course – supervised by Cerreta; Macchiarella, a professor of aeronautical sciences at the university's Daytona Beach Campus; and Burgess, an associate professor of aeronautics with the Worldwide Campus – for students pursuing degrees in unmanned aircraft systems. (While they were in Oklahoma, meteorology students in another Embry-Riddle study away program, supervised by Assistant Professor of Applied Meteorology Shawn Milrad and Associate Professor of Meteorology Thomas Guinn, searched for tornadoes from Kansas to Texas.)

The goal of the UAS trip, says Rohit K. Gohil, a senior Embry-Riddle student studying unmanned aircraft systems science, was to "have aircraft in the sky within 15 minutes of finding a parking spot." Working quickly, the group deployed a variety of drones, including a tiny fixed-wing senseFly eBee, a quadcopter DJI Phantom 4 and two DJI Inspire I models equipped with a Zenmuse X3 12-megapixel camera or thermal night-vision Zenmuse XT FLIR camera.

The Elk City storm was bad, Gohil says, and he soon realized that strong organizational skills, along with clear, direct communication, were key. "The tornado was classified as an EF2, but it was strong enough that it threw part of a school bus a quarter of a mile, and it flipped a Greyhound bus on its side," he says. "It generated grapefruit-sized hail."

Top left: Rapid Imaging Software; Bottom left and opposite: Joseph Cerreta

The Oklahoma UAS study away program, led by faculty members Scott Burgess, Dan Macchiarella and Joe Cerreta (this page: far left, center and far right, respectively), leveraged the talents of students Michael Morgan, K'Andrew France-Beckford, Judy Dun, Andrew Hardy, Andrew Bieniek, Rohit Gohil and Max Dunphy. The group used UAS paired with augmented reality software to survey damage left behind by the Elk City storm (opposite page).

EMERGENCY RESPONSE ORGANIZATIONS, AND IT WILL SAVE COUNTLESS LIVES."

The team trimmed its operational tear-down time to eight minutes, flat. They also learned to "scout and jump" locations by sending a small advance reconnaissance team to set the stage for the rest of the group. "This made it possible to be very responsive and transition from the initial touchdown location all the way to the end of the tornado's path," Burgess explains.

At the request of an emergency management official in Johnston County, Oklahoma, where two tornadoes touched down, students located a herd of lost cattle. Cerreta, Macchiarella and Burgess stood back and let the students work. "Within three minutes," Cerreta reports, "the students independently found the 30-animal herd stranded on a vanishing island in the middle of a flooded area. They applied UAS fundamentals to safely, effectively perform a beneficial use of UAS technology. It was a proud moment."

Also during their trip, the group provided homeowners with UAS-captured images to be sent to an insurance company. Macchiarella documented the car where a man in Elk City tragically lost his life during the tornado.

The Embry-Riddle team further worked with industry partners Textron Systems and Aeryon Labs Inc. to provide community-engagement demonstrations at locations such as the Northwest Technology Center. They teamed up with Oklahoma State University partners as well as Oklahoma-based Embry-Riddle Worldwide faculty members, who provided access to private airspace.

When they weren't surveying tornado damage, students practiced capturing UAS-based multispectral imagery to assess the health of agricultural crops. "The multispectral imagery gets processed into false color maps," Cerreta explains. "The maps show healthy vegetation as green, while yellows, oranges or reds indicate some type of issue that a farmer may want to address."

Maxwell Dunphy, a junior at Embry-Riddle, says helping people was his top priority during the study away program. He wasn't disappointed.

"I was able to help out a lot of people on this trip, and that's one thing I was really looking forward to," he says. ER

Developing an Intelligent, Autonomous Flight Vehicle

BY JAMES RODDEY

Aerospace engineering researchers Richard Prazenica, Troy Henderson and Hever Moncayo at Embry-Riddle's Daytona Beach Campus and Creare LLC have received a Phase II $1 million grant from the U.S. Defense Advanced Research Projects Agency (DARPA).

Their research will focus on developing a highly sophisticated autonomous flight control system to navigate unmanned aerial vehicles (UAVs) in unknown dynamic environments, such as crowded urban locations, or in dangerous or hostile situations.

"Potential uses for this technology include search and rescue missions or remote surveillance and assessment of conditions too hazardous for humans," says Prazenica, an assistant professor of aerospace engineering and principal investigator. "This intelligent, autonomous UAV could explore unmapped or unsafe environments to locate someone injured in an earthquake, or assist and communicate with firefighters while gathering information as it moves through a smoke-filled building."

The College of Engineering research team, which includes graduate students, has also developed a high-fidelity simulation environment to model autonomous UAV flight in virtual urban environments. The simulator includes detailed six-degrees-of-freedom UAV models, sensor models and hardware-in-the-loop simulation capability.

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CLOSING THREAT WINDOWS

By Sara Withrow

Medical human factors research can be intense. Researcher Tara Cohen can attest to that. Last summer, she and her colleagues witnessed several traumatic injuries, including compound fractures, knife wounds, severe lacerations and traumatic brain injuries.

Along with seven other graduate students in her cohort, Cohen spent hundreds of hours in emergency and operating rooms over the past two years, observing doctors, nurses and other medical staff. The ultimate goal: To improve patient safety and quality of care by identifying workflow disruptions.

Cohen, who received her Ph.D. degree in human factors in May, says the key to accurately collecting data on workflow disruptions was to stay out of the sterile area but to keep a close eye on doctors, nurses and support staff.

Now a research scientist at Cedars-Sinai Medical Center, Cohen's work documents the

Embry-Riddle researchers help doctors optimize their performance by addressing the workflow disruptions that can affect patient care

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variety of distractions that can pull the attention of doctors and nurses away from their patients.

On average, trauma-care doctors or their staff members were disrupted once every two minutes, Cohen reports in her article, "Using Broken Windows Theory as the Backdrop for a Proactive Approach to Threat Identification in Health Care." The paper, published online in 2016 by the *Journal of Patient Safety,* was one of 10 research articles Cohen published during her time at Embry-Riddle.

"It's all about optimizing performance," says Professor and Human Factors and Systems Chair Scott Shappell. "We're talking about doctors with a minimum of nine years of post-baccalaureate education, so they're highly trained and very good at what they do. Other groups have looked at human and medical error. That's not our focus. Instead, we want to know what's keeping these talented people from performing at 100 percent all of the time?"

CHAOTIC ENVIRONMENTS INCREASE RISKS

Cohen and Albert J. Boquet, Embry-Riddle Human Factors professor and lead author on the paper with Cohen, borrowed "broken windows theory" from the criminology field to explain their research. The theory states that as minor crimes such as vandalism, litter and public drinking are allowed to continue unchecked in a neighborhood, it sets the stage for more serious crimes and general disorder. Ultimately, residents may begin to fear for their safety and stop investing in the area.

Though the theory is controversial in relation to decisions about policing tactics in different communities, Boquet says that from a social sciences standpoint, it provides a useful way to think about disorder in healthcare settings. "The analogy of a neighborhood fits nicely with the sociotechnical environment in healthcare," he says. "If there is a chaotic environment in a surgical unit, communication, coordination and other workflow disruptions can increase, order is degraded and patient care can be undermined."

PULLING THE RIPCHORD

Before the researchers could start identifying and counting the "broken windows" that disrupt workflow in healthcare settings, they needed an assessment tool. While he was in the military, Shappell teamed up with Doug Wiegmann, now a faculty member at the University of Wisconsin-Madison, to create the Human Factors Analysis and Classification System (HFACS) framework, a well-regarded tool for identifying human performance failures that contribute to aircraft accidents.

Turning his attention to medical research, Shappell collaborated with colleagues at the Medical University of South Carolina and at Clemson University to design a human

NEW AEROSPACE PHYSIOLOGY PROGRAM OFFERS PRE-MED PATHWAY

Individuals seeking careers in medical research, or those who want to improve the health and well-being of pilots, astronauts, flight crew members and air or space travelers, now have a degree program custom-made for them.

This fall, Embry-Riddle's Daytona Beach Campus in Florida launched a Bachelor of Science in Aerospace Physiology – believed to be the first undergraduate program of its kind in the nation.

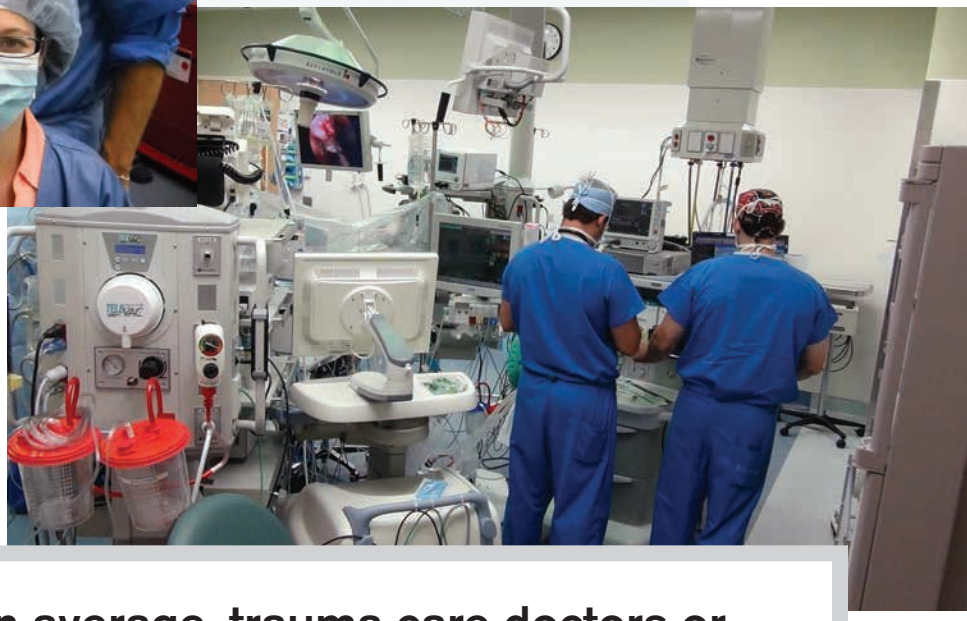
The program offers real-world experience in clinical settings, thanks to a partnership between the university and six local Florida Hospital branches. Florida Hospital helped design the curriculum, which exposes students to advanced patient-care techniques and clinical instrumentation. Additionally, the hospital will provide two practicum clinical courses.

"An undergraduate degree in aerospace physiology from Embry-Riddle will put students on track to enter medical school, or to pursue careers in the military and civilian sectors," says Karen Gaines, dean of the university's College of Arts and Sciences. "Studying cellular function in space can help advance scientific research, human healthcare and life on Earth."

The program is supported both by a letter of commitment from Florida Hospital and a substantial gift from Florida-based philanthropist Helen M. Wessel, a longtime champion of higher education. Through her generosity, Embry-Riddle will establish a pivotal faculty position titled the Dr. Robert H. Wessel and Dr. Helen M. Wessel Endowed Chair for Aerospace Physiology.

The new program greatly expands the university's opportunities for research and development funding, including potential partnerships with Kennedy Space Center, NASA and others, Gaines says.

Over the past two years, human factors graduate students spent hundreds of hours in emergency and operating rooms, logging disruptions to patient care, including issues with communication, equipment and more.



factors framework specific to healthcare. The result was a system for classifying workflow disruptions: RIPCHORD (Realizing Improved Patient Care through Human-Centered Operating Room Design).

With guidance from Shappell and Boquet, Cohen took the RIPCHORD tool and expanded it to encompass Threat Windows Analysis (RIPCHORD-TWA).

> **"On average, trauma care doctors or their staff members were disrupted once every two minutes."**
>
> TARA COHEN, PH.D., HUMAN FACTORS, EMBRY-RIDDLE

EMBEDDED IN THE TRAUMA CENTER

With this new framework in hand, Cohen and other human factors graduate students acted as "on-call" members of the emergency room team for her *Journal of Patient Safety* study. "If we got a page, we would jump up and race to the hospital," Cohen says.

They logged their observations in real time on Windows-based tablets using a modified computer platform created in the Embry-Riddle Medical Human Factors lab. Thorough training helped ensure the accuracy of each researcher's results.

Together, the researchers observed and assessed 34 trauma cases for the study. They collected data from the time a patient arrived in the resuscitation bay, all the way through imaging, if required. "Anything that was a hindrance, a holdup or a hang-up for the medical provider was noted," Cohen says.

A total of 576 disruptions were identified, or an average of 17 disruptions per case. The disruptions included communication (or lack thereof); interruptions from people, devices or accidental spilling/dropping incidents; environmental and equipment challenges; personnel coordination; and usability.

The physicians, circulating nurses and others in the room usually don't notice these breaks in the workflow, or "threat windows," says Boquet, yet all medical professionals face them on a daily basis.

"We think of threat windows as the normalization of deviance. The more disruptions you have to work around, the more that becomes normal," he explains.

ELIMINATING THE ERROR SPACE

Boquet calls the time it takes to resolve each disruption and refocus on the task at hand the "error space" – the time when mistakes are most likely to occur. "It represents the cognitive disengagement between the practitioner and the patient," he says.

He hopes Embry-Riddle research will help hospital administrators identify problems that create and expand the error space, so workflow disruptions can be mitigated or eliminated.

Cohen agrees. "It's all about making a difference," she says. "We want to help identify human factors issues in healthcare that may lead to catastrophe in the future. We want to approach patient safety in a proactive way – much like preventive medicine." ER

Medical Human Factors Lab

SPACE PROSPECT

THE NEXT FRONTIER FOR AEROSPACE RESEARCHERS? DEVELOPING SPACECRAFT TO

SOMEDAY – 10, 20, 50 YEARS FROM NOW – a powerful rocket will lift off from the Kennedy Space Center, bound for a rendezvous with an asteroid millions of miles from Earth.

When it catches up to the asteroid – hurtling through space at more than 60,000 miles per hour – it will release a cadre of small robotic prospectors that will descend to just a few feet from the surface and scour it for minerals, landing when they find something to sample. Eventually, they will return to the mother ship to deposit their samples and head back out.

Hever Moncayo and Richard Prazenica, both assistant professors of aerospace engineering at Embry-Riddle Aeronautical University, hope the technologies they and their students are developing on the Daytona Beach Campus in Florida today will help those robots perform their missions.

For the past five years, Moncayo and Prazenica have been conducting several NASA-funded projects to develop hardware and software that will enable the robotic prospectors to do almost all of their jobs autonomously, so they won't have to rely on orders from operators millions of miles away on Earth.

BY JOSEPH M. KAYS

Moncayo is focusing on guidance and intelligent autonomous flight control systems, while Prazenica works on navigation and mapping using artificial vision systems. Embry-Riddle's research partner, Honeybee Robotics in California, is meanwhile developing sampling systems that will collect and analyze asteroid samples. The project, managed through NASA's Swamp Works initiative at the Kennedy Space Center, also includes Embry-Riddle graduate student Michael DuPuis.

ORS

EXPLORE ASTEROIDS FOR NATURAL RESOURCES

Swamp Works' goal is to establish rapid, innovative and cost-effective missions by leveraging collaborative partnerships across NASA, industry and academia.

NASA is counting on the collaborators to produce the critical components of early asteroid prospectors that will help identify the raw materials that comprise celestial bodies. Space mission planners believe large ships for interplanetary colonization must be built and powered by raw materials found in space because lifting terrestrial materials to orbit is simply too expensive.

To date, most deep-space missions to Mars, comets and asteroids have relied on a single piece of hardware, but Moncayo says there are significant risks to such a strategy. One well-publicized example is the $165 million Mars Polar Lander, which is believed to have crashed on the planet in 1999 when its descent engines shut down prematurely.

"The problem with sending just one piece of equipment to explore is that if something fails you risk losing the whole mission," Moncayo says. "If one of the low-cost minispacecraft we're developing fails, there will be others to continue the mission."

From left to right: Angelica Betancur, Nicodemus Myhre and Andres Chavez assemble a Nano Drill system, developed by HoneyBee Robotics, on a SkyJib quadcopter.

FAST, NIMBLE AND FREE-FLYING

The Curiosity rover has been an unparalleled scientific success during its almost five years on Mars, but the vehicle has only traveled about 10 kilometers and covered an area smaller than the island of Manhattan during that time.

Prazenica says the free-flying vehicles the Embry-Riddle team is developing will be able to move much faster and get into much tighter spaces.

"The ability to fly into a crater or lava tube and get into areas that are very hard to access with a rover, those are the kinds of capabilities we're trying to provide," he says.

But a fast-moving spacecraft won't be able to wait minutes or hours for instructions from Earth like Curiosity, so Prazenica's team is developing artificial vision-based technologies to help the vehicle navigate in an environment with no magnetic poles or GPS-equipped satellites.

They are leveraging a combination of cameras, LIDAR (a remote-sensing method that uses light to measure ranges) and sensor processing algorithms to "see" an asteroid's terrain and navigate through it.

"One approach is to look for specific things you know are going to be in the scene based on preliminary flyovers," Prazenica says. "If you don't know anything about the site, the spacecraft can analyze the scene and track landmarks as it's moving through it."

ASTEROID-MINING &

EVEN AS SCIENTISTS DEVELOP THE space-mining technology of the future, policymakers are thinking about the rights and responsibilities that will govern the search for new resources.

Diane Howard, an assistant professor of Commercial Space Operations, participates in policy discussion and development intended to facilitate space commercialization, both domestically and internationally.

She says the 50th anniversary of the Outer Space Treaty in 2017 is "the perfect time to be evaluating these issues, before the technology reaches critical mass."

Although the Outer Space Treaty of 1967 said that "outer space, including the moon and other celestial bodies, shall be free for exploration and use by all states," Howard says "there is a big

The researchers have already tested their technologies using a large quadcopter in a simulated extraterrestrial landscape at the end of the space shuttle runway at the Kennedy Space Center.

BIOMIMETIC CONTROL

Moncayo is turning to biological systems for inspiration into how to train the spacecraft to respond autonomously when it encounters a problem.

"We have been working with a new concept over the last five years to mimic the way our immune system works to identify intruders like viruses and bacteria," Moncayo says.

Specifically, his team has been focusing on the way the thymus evaluates useful antibodies in mammals.

"As the thymus generates candidate antibodies, it compares them against what it knows is normal," Moncayo says. "If they don't match with something that is normal, there's a high probability they will match with something that isn't normal."

In much the same way, the Embry-Riddle team is teaching the spacecraft's computer what is normal, then injecting problems into the system and teaching it to recognize and react to those problems.

"We have developed mathematical equations to mimic these biological mechanisms. We collect data when the spacecraft is nominal, then we throw in something that's

This page: Daryl LaBello; Previous: iStock

SPACE LAW

difference between being able to use something and being able to own something."

As an example, she cites the United Nations' International Telecommunication Union, which allocates global radio spectrum and satellite orbits to ensure networks and technologies operate with minimum harmful interference. Whether it's a government or a private company, they may own and have control over a satellite, but they don't own the actual location where the satellite is in orbit.

Howard says there is currently much discussion in the legal community about building a framework for future space commercialization. "Congress is reaching out to the space law community and really taking the time to get educated and ask really smart questions and think about the ramifications of things, not just the immediate benefits but the long-term challenges," Howard says.

not nominal and see what happens," Moncayo says. "It's like giving the spacecraft a vaccine."

Moncayo and former doctoral student Andres Perez illustrate the process in a video from the NASA Swamp Works Research Lab at the Kennedy Space Center, where a prototype spacecraft about 3 feet in diameter and arrayed with circuit boards and small gas thrusters is mounted in a three-axis gimbal that allows it to maneuver in all directions, as it would in space. The researchers purposely knock the spacecraft off its axis, but the system quickly returns it to normal flight.

"We have immunized the spacecraft," Moncayo says. "Once we collect the nominal data, then we inject small failures so the spacecraft can react and generate antibodies. In future encounters, the system remembers what to do."

Today, master's degree student Angelica Betancur is continuing the work of Perez and other students who preceded her, advancing the design and assembly of a new spacecraft. "My thirst for knowledge on space exploration started when I was very young," Betancur says.

When she began looking for a place to conduct her graduate research, she focused on institutions that would provide the best mix of research experience, quality of education and networking opportunities. "I was attracted to Embry-Riddle's holistic educational approach – strengthening our professional development, providing the tools to solve real-world problems, and enhancing the student experience through partnerships with industry and government agencies," she says.

So far, all of the research has been conducted using the quadcopter or in the fixed gimbal, but Moncayo and Prazenica are looking forward to conducting more realistic experiments at the new John Mica Engineering and Aerospace Innovation Complex, or MicaPlex, the cornerstone building of the Embry-Riddle Research Park under construction just southeast of the Daytona Beach Campus.

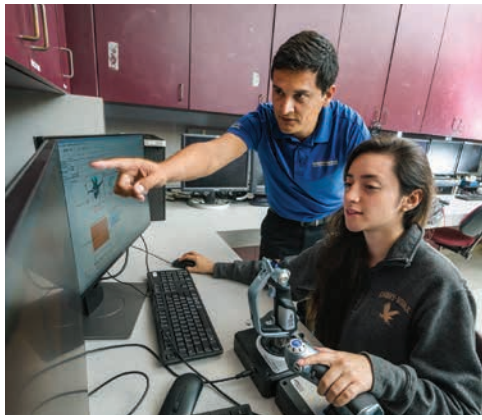
"At the MicaPlex, we are building a facility to enhance the testing of the spacecraft," Prazenica says. "We are assembling a huge crane so we can hang the spacecraft from a cable and simulate partial gravity."

Moncayo says this project has been important for building a strong research relationship with NASA. "This is an important project in our efforts to establish a long-term partnership with NASA Centers," he says. "Aerospace engineering students working together with faculty are pushing the boundaries of applied research toward innovative, low-cost technologies for the exploration of extreme environments, not only for space missions, but also for terrestrial applications."

FUEL RESEARCH STEAMS FORWARD

Another raw material essential to future space travel? Water, which is needed to make steam to propel spacecraft. Fuel is one of the heaviest, and therefore most expensive, parts of interplanetary missions, so researchers are developing steam-powered engines that could refuel using water mined in space.

Embry-Riddle Engineering Physics Professor Sergey Drakunov, along with Patrick Currier, an associate professor of mechanical engineering, and Moncayo and Prazenica, are collaborating with colleagues at the University of Central Florida and Honeybee Robotics on a NASA project called WINE, or the World Is Not Enough, that is studying ways to extract water from regolith, the loose soil that covers the moon, Mars and many other celestial bodies.



Angelica Betancur (seated) and Dr. Hever Moncayo evaluate the performance of a space mission using a special Embry-Riddle spacecraft simulation environment.

"In my Engineering Physics Propulsion Lab we are building a spacecraft prototype which will serve as a test bed for a steam propulsion system," says Drakunov, also associate dean for research in the College of Arts and Sciences.

Among the technical challenges Drakunov's team is addressing are maintaining the high temperatures and pressures needed for steam propulsion in the vacuum of space, optimizing the nozzle size and shape, and designing propulsion control to produce maximum thrust. The research, which also involves graduate student Samuel Kitchen-McKinley, has been supported by Jay D'Amico, head of the Louisiana Steam Equipment Co. ER

Daryl LaBello

Karen Gaines recently launched Embry-Riddle's Aerospace Physiology Bachelor of Science degree, the first of its kind.

WRESTLING WITH THE ELEMENTS

Irradiated wildlife on Earth could help researchers like Karen Gaines understand the effects of radiation in space

BY KELLY PRATT

Early on in her career, Karen Gaines worked in the field trapping alligators, examining deer kills and netting birds from the bow of an airboat to test them for radiation. Now using computer modeling to study and map environmental toxins, her research for the Department of Energy (DOE) continues to predict where and how much nuclear waste may affect wildlife and the humans interacting with it.

Gaines' ongoing study for the DOE uses a data set that originated in 1965 when the federal agency first began monitoring white-tailed deer radiation in a hunting program at the Savannah River Site in South Carolina. Built in the early 1950s to produce the basic materials used in the fabrication of nuclear weapons, the decommissioned site operated five reactors and several facilities for chemical separation, nuclear fuel fabrication and waste management, among others.

Gaines, a radioecologist and environmental toxicologist, studies how the nuclear waste product radiocesium (^{137}Cs) affects wildlife and humans through food chains. With 22 years of experience researching

This page: Daryl LaBello; Opposite: ThinkStock

contaminants, Gaines, whose current career focus is building and running academic programs, says the studies are important for understanding exposure threats on Earth and also for giving scientists a glimpse into what happens to humans at the cellular level in space.

Faculty and students at Embry-Riddle Aeronautical University will be expanding on this area of research through the new Aerospace Physiology Bachelor of Science degree – the first undergraduate program of its kind in the world – which Gaines launched in 2017 during her first year as dean of the College of Arts and Sciences at the Daytona Beach Campus. (Learn more on Page 18.) Thanks to her leadership, human factors Ph.D. students are also going to be adding to the body of research on radioactive exposures with applications to aerospace physiology.

"I'm excited to have students enhance the knowledge base that my colleagues and I developed through the DOE's 52-year study and apply that to exposures in space," she says. "By bringing together human factors, engineering and cellular physiology research, we can reduce the risk of radiation for our astronauts and pilots."

Exposure to radiation at low levels in unpredictable pulses is similar to what humans are exposed to at the International Space Station (ISS), she says. This can change the rate of DNA methylation, the reversible chemical change in DNA that can affect gene expression and essentially alter the rate at which cells replenish, or age.

Preliminary results from the NASA Twins Study have begun to examine these effects. Released in early 2017, the NASA study shows variability in the methylation patterns in identical twin astronauts Scott and Mark Kelly, which may indicate that genes are sensitive to a changing environment. The twin who remained on the ground experienced increased methylation levels and then returned to normal. Meanwhile, the twin brother living on the ISS for one year experienced decreased methylation and a higher variability while in flight, and then returned to baseline levels when he returned to Earth. Gaines says the experiment provides insight to new possible biologically relevant endpoints for both life on Earth and to better understand radiation exposure in space.

FIELD DAYS ON THE WATER

Gaines earned her master's degree from Purdue University, where she focused on both wildlife science and GPS and mapping technologies. The DOE then hired her to map nuclear waste sites and assess environmental risks to wildlife across the 300-square-mile Savannah River Site.

"I assessed whether wildlife could move nuclear waste off-site. That animal might also be fish or game, which means they could be hunted or consumed by the public, so a big focus of what I did involved making recommendations for public health exposures for the DOE," she says.

She became well-versed in evaluating the body burden of radioactivity and learned to measure the amount of atoms with excess nuclear energy (radionuclides) in various media, such as water, plants and animals, and the risk to people who eat fish and game as well as grow their own food.

Gaines worked with a crew out of an airboat moving across nuclear reservoirs to catch alligators and other wildlife to attach radio tracking devices and test their radiation levels. A typical day involved trapping alligators, bringing them on board and creating a makeshift laboratory over the animals' tails. Reptiles are tough animals – known for their ability to handle high amounts of radiation – but require delicate handling to measure gamma rays emitting from the same vertebrae previously checked to determine changes in radiation exposure.

"You would have to get the alligator out of the water and do it very quickly to ensure the animal didn't overheat," she says. "You didn't want to stress it out, but you didn't want to get bitten either."

Gaines never knew what a day might bring: getting caught in an electrical storm at night with a broken carburetor or careening into a forest to catch a bird while stretching a net from the bow of the boat. "Sometimes I wonder how I'm still alive," she says, laughing.

> "By bringing together human factors, engineering and cellular physiology research, we can reduce the risk of radiation for our astronauts and pilots."
>
> KAREN GAINES, DEAN OF THE COLLEGE OF ARTS AND SCIENCES AT EMBRY-RIDDLE'S DAYTONA BEACH CAMPUS

MOVING INTO ACADEMIC LEADERSHIP

Gaines earned a Ph.D. in public health from the University of South Carolina in environmental toxicology, where her work with human exposure risk was honored with a Doctoral Achievement Award. Eventually, she went on to serve as chair of the department of biological sciences at Eastern Illinois University.

As the new Embry-Riddle aerospace physiology program begins to gain traction, she foresees students sending experiments to the ISS that may shed new light on radiation effects at the cellular level. Working in concert with the College of Engineering, Gaines envisions students designing payloads to hold such experiments.

Karen Gaines' early research included trapping wildlife, such as alligators, to test them for radiation.

Brent Terwilliger's work helps to build a safer, more secure UAS operating environment.

David Massey

THE SKY'S NO LIMIT

Meet Brent Terwilliger, whose expertise will help define best practices for the safe, responsible operation of future unmanned aerial systems

BY MELANIE HANNS

As unmanned technology develops at lightning speed and news feeds increasingly feature reports of drones encroaching on U.S. airspace and sometimes even commercial aircraft, airports across the country urgently need guidance, tools and a road map to provide users and customers with a safe, secure operating environment.

Brent Terwilliger is developing solutions.

Terwilliger – an Embry-Riddle Aeronautical University Worldwide assistant professor of aeronautics and program chair for the Master

of Science in Unmanned Systems degree in the College of Aeronautics – investigates outreach and engagement efforts between airports and the unmanned aerial systems (UAS) operational communities.

"Understanding the environments where this technology presents some of the most significant technological and safety challenges, while establishing a clear path to disseminate research findings and recommendations, will be essential to realizing success," he says. "By working with a well-rounded, connected and experientially diverse team at Embry-Riddle, we are able to bring unique perspectives and possible solutions to the table."

His work is part of the 2017 Airport Cooperative Research Program UAS and Airports research project – a 10-month initiative approved in February 2017 and supported by $1 million in funding. Booz Allen Hamilton, a strategy, technology and engineering management consulting firm, serves as the project lead, with Embry-Riddle providing key support as a subcontractor. Richard Stansbury, an associate professor and unmanned and autonomous systems engineering master's program coordinator at Embry-Riddle's Daytona Beach Campus in Florida, serves as the university's primary investigator on the project, while Terwilliger leads stakeholder engagement efforts and more.

Embry-Riddle's contributions will help describe best practices for the safe, responsible management of UAS operations near an airport, and how best to engage stakeholders and incorporate UAS into airport infrastructure and planning. Researchers will also look at the potential use of UAS by airport operators and update existing UAS research materials.

Being able to explore the space beyond what is known drives Terwilliger's passion for his research, which has included extensive work in UAS development, teleoperation, situational awareness, human-machine interfaces, simulation and other unmanned disciplines.

"I have an inquisitive mind, and I am most happy when pondering challenges, technology and potential solutions," he says. "Research provides a structured and focused outlet to explore ideas, concepts, problems and possible effects."

> "I have an inquisitive mind, and I am most happy when pondering challenges, technology and potential solutions. Research provides a structured and focused outlet to explore ideas, concepts, problems and possible effects."
>
> BRENT TERWILLIGER, ASSISTANT PROFESSOR OF AERONAUTICS AT EMBRY-RIDDLE'S WORLDWIDE CAMPUS

NO STRANGER TO AVIATION

The son of a U.S. Air Force recruiter, Terwilliger was introduced at a young age to recreational radio-controlled (RC) aircraft, air shows, aviation museums and aviation-themed and RC modeling books. His passion for unmanned technology emerged while he was an Embry-Riddle undergraduate and graduate student. After graduation, he worked for more than 10 years in aviation and aerospace – leading integration testing, simulation and training development – and he developed documentation as a software/test engineer at Rockwell Collins Simulation and Training Solutions and ENSCO Inc.

Named Embry-Riddle Worldwide Campus Faculty Member of the Year (2013-2014), Terwilliger served as the lead for the Real World Design Challenge Development Team (2013-2015). He currently chairs the UAS subcommittee for the National Business Aviation Association's Business Aviation Management Committee, and he sits on the editorial board for the *Journal of Unmanned Aerial Systems*.

Terwilliger leads or supports nearly a half-dozen other technology and UAS-centric projects for Embry-Riddle Worldwide. As one of the world's first distance-learning academic platforms, with more than 125 campus locations in the United States, Europe, Asia and the Middle East and numerous award-winning online degree programs, Embry-Riddle Worldwide is leading the way in innovative solutions that embrace and incorporate research, Terwilliger notes.

Worldwide successfully collaborates on unmanned technology and research with faculty and students from Embry-Riddle's residential campuses in Daytona Beach and Prescott, Arizona. Recently, for example, faculty members collaborated to establish a Federal Aviation Administration UAS Center of Excellence at Embry-Riddle called ASSURE (the Alliance of System Safety for UAS through Research Excellence). Terwilliger also published an influential book, "Small Unmanned Aircraft Systems Guide," with colleagues John Robbins of the Daytona Beach Campus and David Ison and Dennis Vincenzi of the Worldwide Campus.

While his day job in the unmanned systems realm keeps him focused on U.S.-based airspace, the self-described "super nerd" indulges in global travel to Europe, Mexico and the Caribbean. His intergalactic adventures have included dressing in costume for the 2017 Star Wars Celebration held in Orlando, Florida, with wife Mary, 4-year-old son Everett and 17-year-old daughter Rose (who plans to attend Embry-Riddle to study mechanical engineering).

He also stays connected to his fellow alumni, including his brothers in the Embry-Riddle chapter of the Delta Chi fraternity, who are completing construction of a new $2 million-plus house on the Daytona Beach Campus (Chanute Complex).

As Terwilliger looks to future research opportunities, he says the sky has no limits.

Jon C. Haass

SAFETY NET

The Hacker Lab offers Embry-Riddle students hands-on experience fighting cyberattacks

In the wake of increasing computer breaches, the need for cybersecurity professionals is likely to increase 18 percent by 2024, says the U.S. Bureau of Labor Statistics. At Embry-Riddle Aeronautical University's Prescott Campus's College of Security and Intelligence, Department Chair and founding faculty member Jon C. Haass leverages decades of experience as a leading expert in digital security to arm students with the real-life skills to fill that demand. We recently spoke to Haass, who joined Embry-Riddle in 2013, about the Cybersecurity Lab and the importance of research to combat hacking concerns.

BY MELANIE HANNS

Q: The Cybersecurity Lab, also known as the Hacker Lab, is where students get hands-on experience analyzing and finding solutions to real-world cybersecurity issues and threats. Why is that so important?

A: Employers are looking for employees to help solve problems, and this requires critical and creative thinking. Understanding the theory is important and applying this theory to perform work for a client in government or industry is like an internship while still in school. As we grow the number of partnerships, students gain a broad view of the 31 different areas of cybersecurity as outlined by the National Initiative for Cybersecurity Careers and Studies (NICCS). Our cyber adversaries are talented, well-funded and constantly probing, so our students must be spending time in the lab to keep up.

Q: How important is research in the cyber world?

A: Research is critical, and it comes in many different flavors. Some spend time analyzing the latest malware because thousands of new variants are discovered each day. Others research vulnerabilities in new products or systems. For instance, what are the cybersecurity issues related to the introduction of unmanned aerial systems (UAS) into our airspace? Are the communications secure? Too often, developers rush to get product to market with cybersecurity relegated to version 3.0 or until something goes terribly wrong. In this field where we are still playing catch-up, research and the real world overlap daily. Some effort also has to look ahead and imagine what might be possible a few years from now.

Q: What research projects have you been involved in recently?

A: I co-authored a guidebook on best practices for airport security as part of an Airport Cooperative Research Program led by the Transportation Research Board (TRB), and I recently presented a paper, "Cyber Security: Research Opportunities," to the 96th annual TRB convention in Washington, D.C. My current activities include working with agencies and companies to better understand cyber threat intelligence sharing. Since we are faced with not just individual cyberattackers but also organized groups with financial and intellectual resources, countering that requires a network of defenders. The research is exploring value based on response times, improved detection of threats and the potential for rapid machine-to-machine threat sharing. Many threats are not discovered within a network for 45 days or more. Threat sharing holds the potential to reduce this dramatically, saving lost data, intellectual property and financial loss.

Q: Describe your role as both department chair and associate professor in the nation's first College of Security and Intelligence?

A: In the classroom and lab, my favorite part is introducing students to the exciting questions and challenges facing industry, government and academia under the broad umbrella of cybersecurity. As chair, a critical aspect of my job is being an ambassador of the program and introducing our college to industry and government. I am still finding too many groups and individuals surprised to find out about our excellent cyber intelligence program. We do more than aeronautics!

Connor McShane

CENTERED ON SAFETY

Embry-Riddle's ASSURE drives research to advance the safety of unmanned aircraft systems

As principal investigator for a major Federal Aviation Administration (FAA) Center of Excellence, Embry-Riddle Aeronautical University serves as the technical lead for research focused on air traffic integration with unmanned aircraft systems (UAS). The university also co-leads efforts to improve UAS pilot and crew training under a research center called ASSURE – the Alliance of System Safety for UAS through Research Excellence.

ASSURE, supported by $20 million overall since 2015, is currently modeling scenarios such as the impact of a UAS crash over a populated area. "That work is determining the level of human injury and damage to property that might occur," explains Richard Stansbury, Embry-Riddle's ASSURE director, who is an associate professor and unmanned and autonomous systems engineering master's program coordinator on the Daytona Beach Campus in Florida.

Embry-Riddle ASSURE researchers are collaborating with peers at other universities to investigate an array of safety-related issues, from test standards for UAS pilot certification to human factors and UAS surveillance technologies.

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Additional Embry-Riddle research centers and institutes include:

Eagle Flight Research Center (EFRC)
Established in 1998, the EFRC is helping to shape the future of human mobility, including clean, quiet flight, through research focused on four key areas: propulsion, unmanned autonomous vehicles (UAVs), manned flight control and the certification of new technologies.
→*Read about a current EFRC project on Page 5.*

FAA Center of Excellence for Technical Training and Human Performance (SOAR)
This consortium of 25 universities and nearly 40 industry partners is helping the FAA revolutionize technical training practices and human performance for its workforce. Led by Embry-Riddle and the University of Oklahoma, SOAR promotes training innovation and works with the FAA to develop solutions that lead to stronger personnel.

Robertson Safety Institute
As a professional development, outreach and consulting organization, the Robertson Safety Institute offers opportunities for advanced professional training, consulting on safety projects with corporate partners and applied research activities.
→*Learn more about the institute's research on Page 8.*

Center for Space and Atmospheric Research (CSAR)
CSAR investigates the terrestrial upper atmosphere and near-space environment. Its members conduct federally funded research to better understand the neutral and ionized atmosphere, as well as the plasma environment. The research leverages both modeling and advanced instrumentation.

Cybersecurity and Assured Systems Engineering Center (CyBASE)
Integrating the policy, intelligence and technical aspects of cybersecurity, CyBASE serves as a go-to source for cybersecurity solutions for aerospace, aviation and other enterprises utilizing embedded systems, particularly control systems.

Center for Wildlife and Aviation
This center combines Embry-Riddle's resources with those of other institutions, including the FAA, the U.S. Department of Agriculture (Wildlife Services), the Department of Defense (Air Force and Navy) and the Bird Strike International Committee. It collects, maintains and disseminates relevant bird strike data and bird strike research; promotes wildlife mitigation training, policies and plans; and bridges the gap between the scientific community and stakeholders.
→*Read about a current project on Page 11.*

Next Generation Air Transportation System Facility (NextGen)
NextGen is an FAA initiative in which government, industry and academia work together to transform and modernize the nation's national airspace, shifting from ground-based radar to satellite-based technology. The FAA has contracted Embry-Riddle to conduct national and international airspace research and operate its Florida NextGen Test Bed facility in Daytona Beach, Florida.

Southeast Association for Research in Astronomy (SARA)
This 14-university consortium, led by Embry-Riddle, operates 1-meter class telescopes for astronomical research and education at Kitt Peak National Observatory in Arizona, Cerro Tololo Inter-American Observatory in Chile and the Roche de los Muchachos Observatory in the Canary Islands. SARA telescopes are accessible over the internet in real time by authorized faculty and students.
→*Visit saraobservatory.org.*

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Open for business in 2017, the John Mica Engineering and Aerospace Innovation Complex (MicaPlex) is the cornerstone building of the Embry-Riddle Research Park. This unique 50,000-square-foot, cutting edge innovation hub is designed to support partner companies and organizations with research in aviation, space, engineering, unmanned systems and the environment.

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