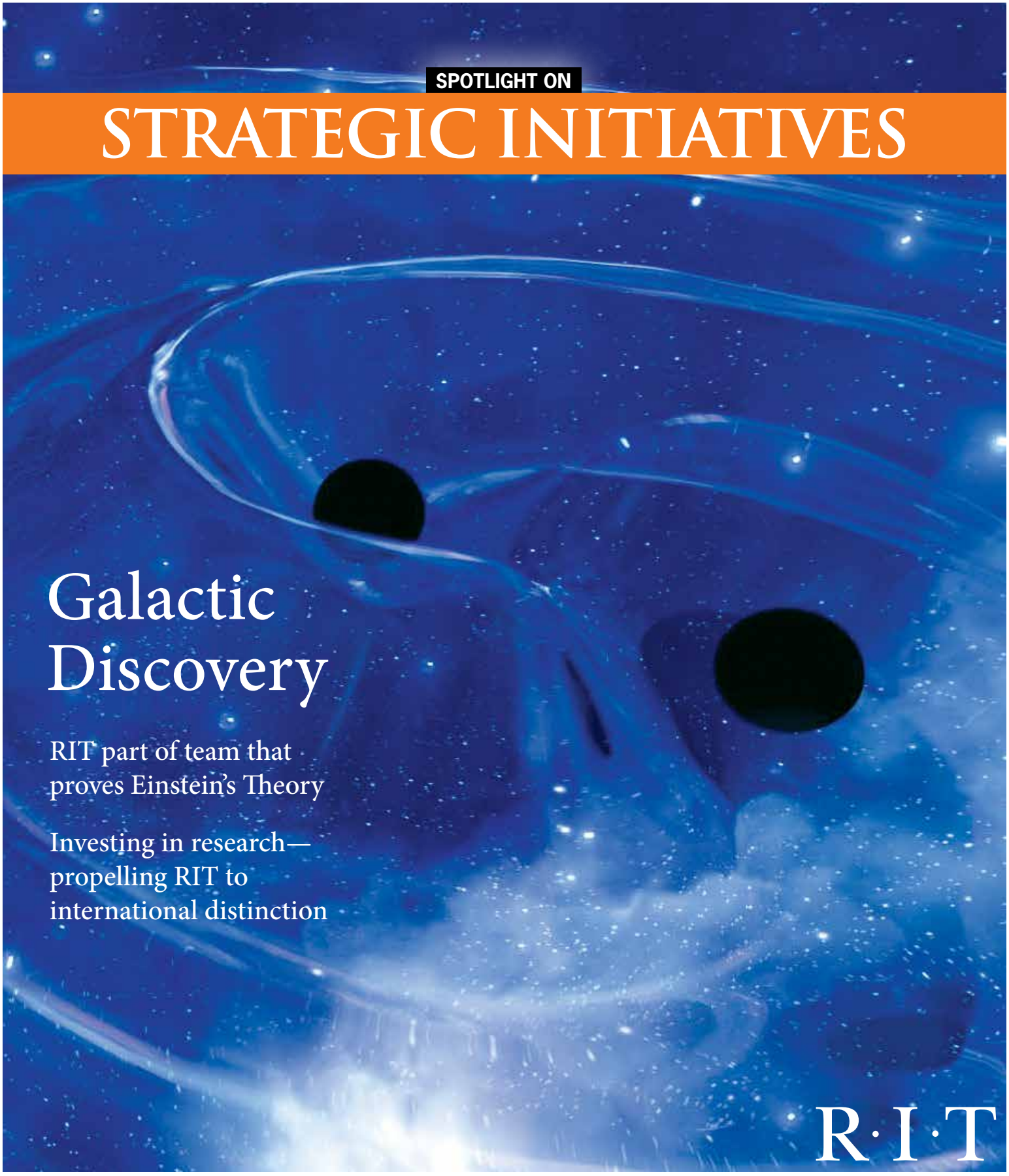
RESEARCH at RIT

The Rochester Institute of Technology Research Report

Spring/Summer 2016



SPOTLIGHT ON

STRATEGIC INITIATIVES

Galactic Discovery

RIT part of team that proves Einstein's Theory

Investing in research—propelling RIT to international distinction

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RESEARCH at RIT

The Rochester Institute of Technology
Research Report–Spring/Summer 2016

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Strategic Research Initiatives

RIT's research is changing at a remarkable rate. Our growth is reflected in our sponsored research funding and our recent change in national classification. This issue looks at some strategic initiatives the university is investing in as we build upon our reputation.

Last year was a record year for sponsored research and we have already eclipsed the $50M mark this year, and thus are well on our way to setting another milestone. Our growth in research is reflected in The Carnegie Classification of Institutions of Higher Education changing RIT's classification from "Masters Comprehensive" to "Doctoral University—Limited Research." This change means RIT will be ranked among the "National Universities" by *U.S. News & World Report*, rather than among the top "Regional Universities" as has been the case since the magazine began its annual rankings in 1983. The attention being paid to our research productivity has never been greater.

The importance of research to RIT's overall mission is reflected in our 2015-2025 strategic plan, "Greatness Through Difference," outlining that RIT will be internationally distinguished as a research university through its focus on and investment in specific inter- and trans-disciplinary research areas.

Last year, RIT initiated a process to identify areas for strategic investment. Proposing teams were asked how their area would build on current faculty strengths, RIT's reputation, and existing resources, how it was reflective of a growing significance in society, as demonstrated by relevance to funding agencies and industries, and how RIT in particular would be able to make unique and high-impact contributions.

The response from the RIT community was tremendous—26 proposals were submitted from interdisciplinary teams representing every college and institute. The proposals were judged not only on the above criteria but also on their potential for sponsored research funding, philanthropic giving, and corporate and government investment.

In this issue we highlight our new Signature Interdisciplinary Research Areas: **Sociotechnical Approaches to Cybersecurity, Personalized Health Care Technology, Remote Sensing with Unmanned Aerial Vehicles, Computational Relativity and Gravitation, and the Future Photon Initiative**. RIT will invest approximately $1 million in each of these areas over the next five years. This will be in addition to matching commitments from deans, department heads, center directors, and individual team members in support of these initiatives. In addition to our signature research initiatives, we've had some exciting activity surrounding several of our research centers—MAGIC (Media, Arts, Games, Interaction, and Creativity) Center and AMPrint Center. I hope you enjoy reading about all of these developments and initiatives that I believe will soon be recognized nationally and internationally as RIT research strengths, standing proudly alongside our other currently recognized areas.

Best regards,

Ryne Raffaelle
Vice President for Research
and Associate Provost

Inside this Issue

RIT News

Below are just some of the recent headlines coming from the university, including newsmaking appointments, new classifications, degrees, and other activities.

Rochester Draws In Entrepreneurship Centers: University of Rochester and RIT will co-host the 2016 Global Consortium of Entrepreneurship Centers (GCEC) from Sept. 29 through Oct. 1. The conference will feature plenary sessions, workshops, breakout discussions, and keynote speeches.

RIT/UR to Host Global Entrepreneurship Conference

University of Rochester and RIT will co-host the 2016 Global Consortium of Entrepreneurship Centers or GCEC this fall. More than 350 entrepreneurship experts from the around the world will be in Rochester, N.Y., to learn about the universities' entrepreneurial expertise and programming excellence.

The conference, to be held Sept. 29-Oct. 1, themed "Turning Over a New Leaf," features a variety of plenary sessions, workshops, breakout discussions, and keynote speeches from national and international entrepreneurship experts as well as UR and RIT faculty and staff.

The GCEC, the premier academic organization addressing the emerging topics of importance to the nation's university-based centers for entrepreneurship, allows universities to network, benchmark, and explore how to best promote entrepreneurship education and new venture creation. To learn more, go to GCEC2016.com.


Doreen Edwards

Doreen Edwards Appointed Dean of Kate Gleason College of Engineering

Doreen Edwards has been named dean of RIT's Kate Gleason College of Engineering. Edwards, who is currently dean of the Kazuo Inamori School of Engineering at Alfred University and acting vice president of Statutory Affairs for the university, will join RIT on July 1. She will be the first female dean of RIT's engineering college, which is the only engineering college in the United States that is named after a woman.

Edwards, who has published more than 60 papers and holds two patents, brings more than 20 years of experience in academia and industry as a researcher, educator, and administrator to the new position.

Edwards joined Alfred University in 1997 as an assistant professor of materials science and has received numerous faculty awards there, as well as the Chancellor's Award for Excellence in Teaching, one of the State University of New York's highest honors. She has served as the principal investigator on fundamental and applied research projects, focusing on oxide materials for fuel cells, batteries, thermoelectric devices, environmental remediation, and solar energy applications.

Edwards succeeds Harvey Palmer, who served as dean of the Gleason College for 15 years.


Anne Haake

Anne Haake Named Dean of Golisano College of Computing and Information Sciences

Anne Haake has been named dean of RIT's B. Thomas Golisano College of Computing and Information Sciences where she served as interim dean since July 2015. She becomes the first female dean of the Golisano College. Haake has a distinguished career in academia, including 16 years at RIT. She has served in interdisciplinary curriculum development and teaching roles for several programs, including bioinformatics, medical informatics, the Ph.D. in computing and information sciences, and the human-computer interaction master's degree program.

Haake has been a leader in interdisciplinary research, as principal investigator of the National Science Foundation and National Institutes of Health-funded research and as a mentor for undergraduate and graduate student research most recently in bioinformatics and user-centered design of medical information systems. In 2012, she was named RIT's first National Science Foundation Expert in the foundation's Division of Biological Infrastructure and served as a program director for the division. Haake also has experience as a technical adviser to industry, serving as a board member for Phoenix Bioinformatics in Redwood, California.

Father of 3D Printing Honored with RIT's Cary Award

Charles Hull, co-founder and chief technology officer of 3D Systems, who is widely considered the father of 3D printing, was honored with RIT's Melbert B. Cary Jr. Award in April. Hull is the inventor of the solid imaging process known as stereolithography, the first commercial 3D printing technology.

The Cary Award is presented to those who have distinguished themselves in the advancement of technology in graphic communications and related industries. It's named in honor of Melbert B. Cary Jr., whose lifelong love and support of the graphic arts inspired others.

Past award recipients include Frank D. Steenburgh, former senior vice president for business growth, Production Systems

Group at Xerox Corp.; Frank Romano, world-renowned printing expert and RIT professor emeritus; John Warnock and Charles Geschke, co-founders of Adobe Systems; and Robert Howard, founder of Centronics and Presstek and inventor of the dot matrix printer.

RIT to Offer New Ph.D. Program in Mathematical Modeling

In an effort to provide graduates with a solid foundation in the development and application of mathematical models of real-world problems, RIT will offer a new interdisciplinary Ph.D. program in mathematical modeling starting in fall 2017. This is RIT's eighth doctoral program. The degree program will be housed within the School of Mathematical Sciences and the College of Science. Mathematical modeling is a critical tool of research and spans such disciplines as applied mathematics, scientific computing, business, and the social, physical, and life sciences.


Charles Ruffing

Former Kodak Executive Heads Pollution Prevention Institute

Charles J. Ruffing, a recognized environmental leader and former vice president of Health, Safety, Environment and Sustainability at Eastman Kodak Co., is the new director of the New York State Pollution Prevention Institute (NYSP2I).

At Kodak, Ruffing was responsible for coordinating sustainability initiatives across the company's multinational locations, including environmental compliance support to operations and products worldwide.

As director, Ruffing leads NYSP2I under the sponsorship of the New York State Department of Environmental Conservation together with RIT and its partner universities: Rensselaer Polytechnic Institute, the State University of New York at Buffalo, and Clarkson University. NYSP2I, which is headquartered at RIT, also works with the state's 10 Regional Technology Development Centers to help disseminate data and strategy.

National Classification Changed to 'Doctoral University'

The growth in RIT's Ph.D. programs has resulted in a change in the university's classification from a master's university to a doctoral university. This is a recent change designated by the Carnegie Classification of Institutions of Higher Education. The change occurs when a university graduates more than 20 Ph.D. degrees per year, a figure RIT has exceeded in recent years. The university awarded 33 doctoral degrees in May 2015.

Cybersecurity from a Sociotechnical Approach: An interdisciplinary research team is looking at ways of minimizing human errors in the design, implementation, and monitoring of cybersecurity.

Cybersecurity: Where Humans Meet Computers

by Scott Bureau

To better defend against threats to the nation's cyber infrastructure, RIT is bringing together an interdisciplinary team of faculty and students to study and implement cybersecurity from a sociotechnical approach—one that uses insights into human behavior to create the next generation of secure computing systems. RIT's commitment to cybersecurity will help the university hire new experts in computing security and establish a new Center for Cybersecurity.

A Recognized Leader in Cybersecurity

Jared Stroud understands that cybersecurity begins and ends with humans. In his research project, called Fuzzball, the RIT computing security graduate student is looking for coding errors and security loopholes in web applications that were mistakenly put in place by developers.

Using a fuzzer—a tool that generates massive amounts of random data—Stroud tries to crash an application and find any vulnerabilities, such as buffer overflow.

"Ever since I got into computing, I wasn't so interested in making apps or building games—I wanted to break things," said Stroud. "I like the whole idea of testing a network in order to help improve a company's security."

With recent cyber breaches hitting the U.S. government and companies such as Target and Sony, the need for computing security experts like Stroud has skyrocketed.

By 2019, the United States will need 2.5 million cybersecurity professionals to protect its networks and computer systems, but more than a quarter of those jobs will go unfilled because there aren't enough qualified workers.

RIT is helping to close this gap as a leader in computing security education. Since the university created one of the first graduate and undergraduate degree programs in computing security and networking a decade ago, the number of students enrolled in the programs has jumped from fewer than 40 to more than 400 this past fall.

In-Demand Industry: Jared Stroud, an RIT computing security graduate student, is among the up-and-coming cybersecurity experts in demand. Graduates of RIT's computing security program land jobs with government agencies, and such companies as Google, Cisco, Raytheon, and FireEye.

In 2012, RIT broke the mold of traditional cybersecurity education by creating the first academic department devoted solely to computing security, a department that integrates faculty from other computing disciplines, including computer science, software engineering, information science and technology, and public policy.

That department graduated 59 students last academic year, and more than 96 percent were hired at places such as Google, Cisco, and the federal government. Graduates also get hired at security companies such as Raytheon, FireEye, and Dell SecureWorks.

"I really believe students studying computing security at RIT are very well prepared to address a lot of the needs in the industry," said Kirk Striebich '89 (economics), supervisory special agent in the FBI Cyber Division. "Cybersecurity students at RIT are well rounded and can think in terms of the whole business or whole government approach to the

Recognized Cybersecurity Leader: The National Science Foundation awarded RIT $4 million to join the federal CyberCorps® scholarship program, a partnership with the Department of Homeland Security. In exchange for government service following graduation, students receive full tuition and a stipend. Pictured above is CyberCorps® scholarship recipient Scott Vincent (left), a BS/MS student in the computing security program, and Brian Schanbacher, a second-year computing security student.

problem, which will enhance their value on any team approach to cybersecurity."

Nationally, RIT has become recognized as a leader in this arena—the National Security Agency and Department of Homeland Security designated RIT one of its National Centers for Academic Excellence in Cyber Defense and the National Science Foundation awarded RIT $4 million to join the federal CyberCorps® scholarship program. The program, a

CyberCorps®
Defending America's Cyberspace

partnership with the Department of Homeland Security, provides students full tuition and a stipend in exchange for future government service.

A Sociotechnical Approach

RIT will invest $1 million to study and implement sociotechnical approaches to cybersecurity. In addition, RIT's B. Thomas Golisano College of Computing and Information Sciences is committing $2 million toward the research effort.

Bo Yuan, chair of RIT's Department of Computing Security and associate professor, wants to see individuals and organizations consider cybersecurity before attacks and breaches ever happen. He also understands that defending against threats to a cyber infrastructure demands perspectives and efforts far beyond software and hardware technology.

"Basically, human factors have been identified as the weakest link in cybersecurity ecosystems," said Yuan. "If we can fully understand the human factors in cybersecurity, then we can help design applications, systems, and security measures that defend against attacks more efficiently."

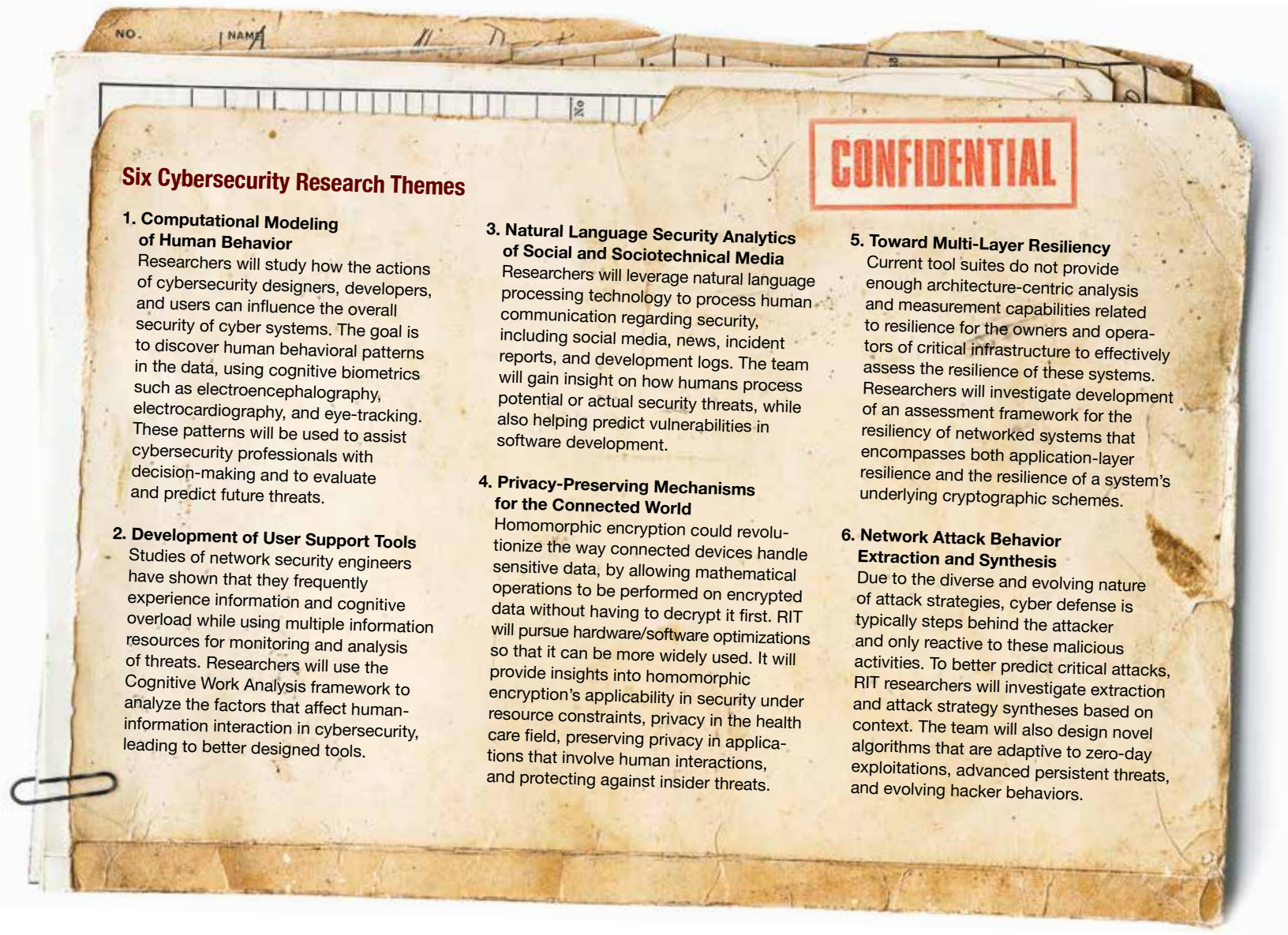
To address the main sociological and technological components of the cybersecurity ecosystem, RIT researchers from various disciplines will work together. Faculty from such areas as computing, engineering, psychology, mathematics, public policy, business, and English will use their expertise to gain insight into human behavior and tackle the challenges of cybersecurity.

Center for Cybersecurity

Faculty work will be the foundation for the opening of a new Center for Cybersecurity in fall 2016. The center will be led by Matthew Wright who comes to RIT from the University of Texas at Arlington where he was an associate professor in the Department of Computer Science and Engineering. Wright is an expert in internet security and privacy. He researches systems for providing internet privacy, usable security, and secure and reliable peer-to-peer and ubiquitous

Photo credit: Robert Crosby, UT Arlington

Matthew Wright



Six Cybersecurity Research Themes

1. Computational Modeling of Human Behavior
Researchers will study how the actions of cybersecurity designers, developers, and users can influence the overall security of cyber systems. The goal is to discover human behavioral patterns in the data, using cognitive biometrics such as electroencephalography, electrocardiography, and eye-tracking. These patterns will be used to assist cybersecurity professionals with decision-making and to evaluate and predict future threats.

2. Development of User Support Tools
Studies of network security engineers have shown that they frequently experience information and cognitive overload while using multiple information resources for monitoring and analysis of threats. Researchers will use the Cognitive Work Analysis framework to analyze the factors that affect human-information interaction in cybersecurity, leading to better designed tools.

3. Natural Language Security Analytics of Social and Sociotechnical Media
Researchers will leverage natural language processing technology to process human communication regarding security, including social media, news, incident reports, and development logs. The team will gain insight on how humans process potential or actual security threats, while also helping predict vulnerabilities in software development.

4. Privacy-Preserving Mechanisms for the Connected World
Homomorphic encryption could revolutionize the way connected devices handle sensitive data, by allowing mathematical operations to be performed on encrypted data without having to decrypt it first. RIT will pursue hardware/software optimizations so that it can be more widely used. It will provide insights into homomorphic encryption's applicability in security under resource constraints, privacy in the health care field, preserving privacy in applications that involve human interactions, and protecting against insider threats.

5. Toward Multi-Layer Resiliency
Current tool suites do not provide enough architecture-centric analysis and measurement capabilities related to resilience for the owners and operators of critical infrastructure to effectively assess the resilience of these systems. Researchers will investigate development of an assessment framework for the resiliency of networked systems that encompasses both application-layer resilience and the resilience of a system's underlying cryptographic schemes.

6. Network Attack Behavior Extraction and Synthesis
Due to the diverse and evolving nature of attack strategies, cyber defense is typically steps behind the attacker and only reactive to these malicious activities. To better predict critical attacks, RIT researchers will investigate extraction and attack strategy syntheses based on context. The team will also design novel algorithms that are adaptive to zero-day exploitations, advanced persistent threats, and evolving hacker behaviors.

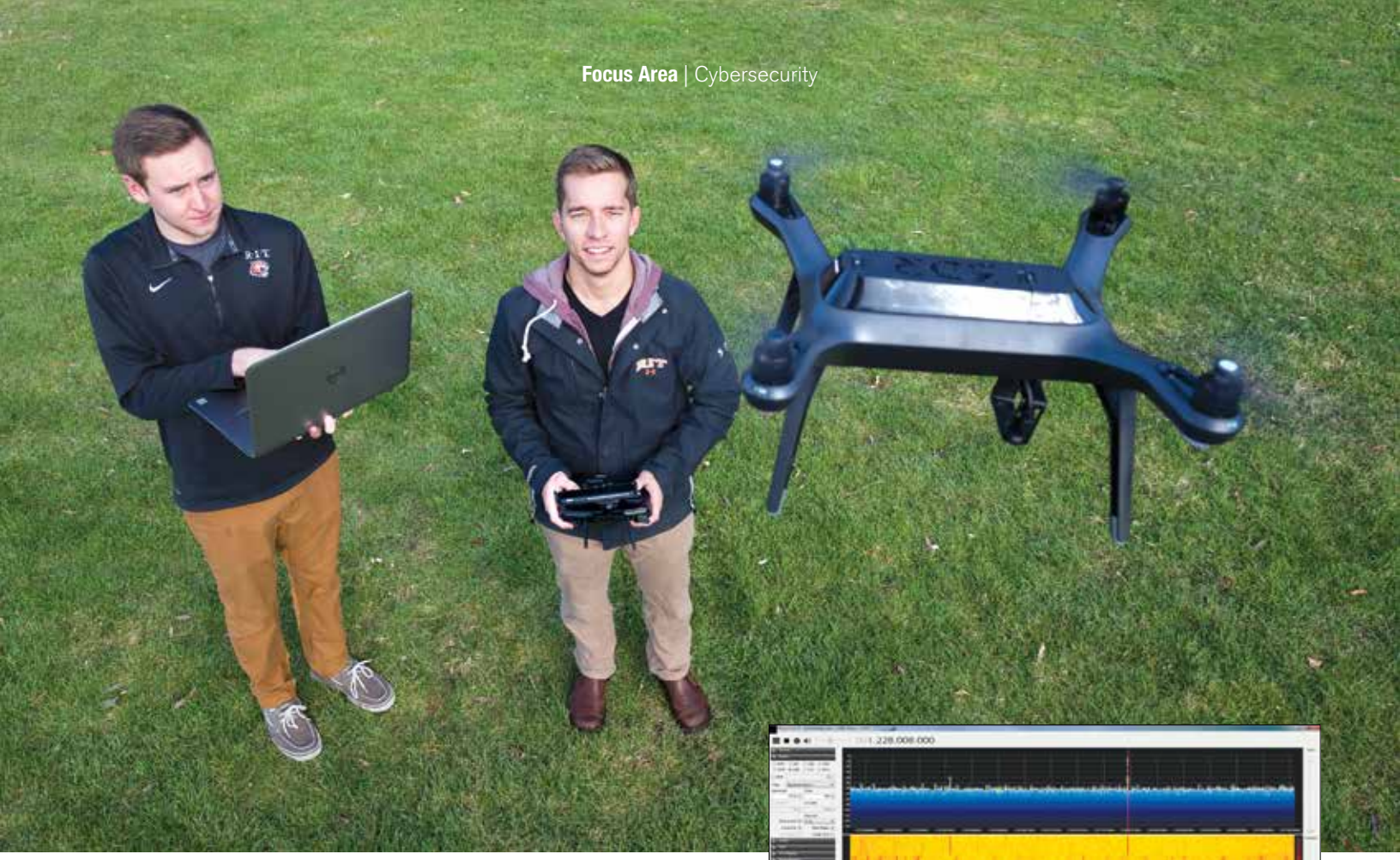
computing. The center will be located in the Center for Integrated Manufacturing Studies (CIMS) and provide a venue for collaboration of faculty and student researchers.

The initial cybersecurity team of 25 faculty researchers come from five different colleges at RIT (B. Thomas Golisano College of Computing and Information Sciences, Saunders College of Business, College of Liberal Arts, Kate Gleason College of Engineering and College of Science) and 11 departments. Four additional faculty, specializing in cybersecurity, will be hired in the Golisano College this summer. Collectively, team members have published more than 800 peer-reviewed journal and conference articles, received more than $20 million in external research funding.

"Interdisciplinary work is critical to addressing the range of social and human-centered issues involved in this area, and to provide multifaceted solutions for ensuring cybersecurity," said Cecilia Ovesdotter Alm, assistant professor of English in RIT's College of Liberal Arts who studies computational linguistics. "We are fortunate to have useful expertise spread across RIT, in addition to a strong track record of being successful at interdisciplinary collaborations that span multiple colleges."

The team's objectives include modeling human behaviors of legitimate users and adversaries within the context of cybersecurity problems, to explore vulnerabilities and defense mechanisms; investigations into human behavior-informed secure, resilient, and privacy-preserving cybersecurity ecosystems; and data collection, analysis, and refinement of real-world security scenarios. Six research themes have been identified to address these challenges (see above).

"Each of these themes leverages existing faculty and student research strengths and can potentially lead to high-impact research outcomes through external funding," Yuan said. "More importantly, incorporation of research outcomes into our curricula will culminate in the production of hundreds of graduates, erudite in contemporary



Security Vulnerabilities: Bryan Quinn, a first-year software engineering student (left), and Kyle Murbach, a computing security graduate student, are among a team of students conducting research as part of a CyberCorps® project on drone security. The screen shows the GPS information the drone is receiving. The students are able to manipulate the data to make the drone think it's moving when it's not. Their goal is to highlight the current security vulnerabilities with drones so they can be fixed.

security and privacy issues and equipped to tackle adversarial situations."

Student Researchers That Can Hack It

Kyle Murbach is flying a drone at a local park, but it's hurtling in the wrong direction. Using a cybersecurity attack known as GPS spoofing, he has the ability to tell the drone that it is somewhere it's not.

The computing security graduate student is one of dozens of RIT students conducting research in order to tackle security and privacy issues that people face every day.

Working with Ben Short, a fifth-year computer science student, and Derek Leung, a fourth-year software engineering student, Murbach is researching vulnerabilities in the popular 3D Robotics and DJI drones. The team is conducting the research as part of a requirement for the CyberCorps® Scholarship for Service program.

"We are looking at known vulnerabilities, including ways for people to connect wirelessly to drones that are not secured correctly," said Murbach, who will begin working with the Department of Defense after graduation. "We're also going through the firmware and essentially reverse engineering it to see how developers created the software."

For students like Murbach, the Center for Cybersecurity will provide a space to bounce ideas off and collaborate with faculty and other student researchers that they wouldn't normally meet. It will also promote partnerships with industry and help with outreach to high schools and middle schools, to create awareness of computing security as a career.

In addition, the center will include a Pentesting Laboratory, where businesses can penetration test software and hardware vulnerabilities with student pentesters.

"We imagine providing pentesting services for medium and small companies that would not typically be able to afford large contracts to do a pentest," said Yuan. "This would help companies verify the security of their networks, systems, and software services, while giving our students real-world experience."

On the Web

B. Thomas Golisano College of Computing and Information Sciences—Computing Security Department
www.rit.edu/gccis/computingsecurity

RIT One of Three Digital Gaming Hubs in New York State

by Kelly Sorensen

Workinman is capitalizing on the talent and expertise of RIT graduates looking to make a mark in the gaming industry. Workinman, a game design and development company located in downtown Rochester, N.Y., hires RIT graduates and co-ops from majors including new media design, illustration, game design and development, and computer science. Of its 43 employees, 85 percent are RIT graduates.

Growing the Gaming Industry

"We value RIT as a partner," said Jason Arena, CEO of Workinman. "Many of our employees are RIT graduates and have turned into full- time employees after their one or two semester co-op with us—it's such a great program for both RIT and Workinman."

In an effort to spur new companies and games like Workinman, New York state's Empire State Development has designated RIT as one of three digital Gaming Hubs. The other hubs are Rensselaer Polytechnic Institute and New York University. Each will receive $150,000 a year over a three-year period. The hubs' goal is to provide resources and mentoring to encourage students and entrepreneurs to enter the growing gaming industry.

Andrew Phelps, director of RIT's Center for Media, Arts, Games, Interaction and Creativity (MAGIC), will lead RIT's management of its gaming hub with the goal of promoting multi-disciplinary, entrepreneurial research and development activities at RIT and through its network of partners and affiliates. RIT's MAGIC Center is a nonprofit, university-wide research and development laboratory and a for-profit production studio.

"RIT's MAGIC Center has established a network of dozens of companies, university resources, and partners—including regional community colleges and K-12 institutions—to continue to spur regional economic development and keep our talent within New York state," said Phelps.

In addition to Workinman, local companies such as Second Avenue and Darkwind Media leverage RIT talent. Nationally, companies and games studios such as Disney, Nickelodeon, Microsoft, and Electronic Arts hire RIT alumni.

Leveraging RIT Talent: Game design and development companies like Workinman are recruiting RIT graduates. Nearly 85 percent of its employees are RIT alumni. New York state has designated RIT a Digital Gaming Hub in hopes of spurring new companies like Workinman.

"The relationship between RIT and gaming companies is invaluable," said Arena. "It's a perfect storm for creating game developers and great game development companies who are able to compete at the highest level in an incredibly competitive industry."

And it was a perfect storm when three games with ties to RIT, Workinman, and Darkwind Media were exhibited at PAX East 2016 in Boston at the highly competitive Indie MEGABOOTH. The games were "Deathstate" created by Workinman, "Wulverblade" produced by Darkwind Media, and "Super Daryl Deluxe" created by Dan and Gary Games LLC. Dan Plate, fourth-year illustration major, and Gary Porter '15 (game design and development) are the creators of "Super Daryl Deluxe." Their game, which will be released later this year, has already won several awards including the top prize in Microsoft's U.S. Imagine Cup National Finals in 2015. Steam, the world's largest online game distribution service, has already released "Deathstate," and "Wulverblade" is expected to be released later this year on Xbox One and Steam. Each of the teams that created these games includes RIT alumni from a variety of majors.

On the Web
MAGIC Center
magic.rit.edu

Future Photon Initiative: FPI will combine the science and technology efforts of more than a dozen research groups, in addition to expertise from RIT business and branding entities. Here are some of the key players in the FPI:

1. Ben Zwickl, assistant professor of physics
2. Richard DeMartino, director of RIT's Simone Center for Student Innovation and Entrepreneurship
3. Bruce Smith, director of RIT's microsystems engineering Ph.D. program
4. R. Roger Remington, Vignelli Distinguished Professor of Design
5. Ed Hach, assistant professor of physics
6. Mishkat Bhattacharya, assistant professor of physics
7. Drew Maywar, associate professor of electrical, computer, and telecommunications engineering technology
8. Zhaolin Lu, associate professor of microsystems engineering Ph.D. program
9. Seth Hubbard, director of RIT's NanoPower Research Laboratories
10. Parsian Mohseni, assistant professor of microsystems engineering Ph.D. program
11. Raj Murthy, associate professor of marketing
12. Stefan Preble, director of RIT's Integrated Photonics Group
13. Michael Zemcov, assistant professor of physics
14. Jing Zhang, assistant professor of electrical and microelectronic engineering
15. Don Figer, director of Future Photon Initiative, director of Center for Detectors

Future Photon Initiative
Developing Advanced Photonics

by Jane E. Sutter

Are we alone in the universe? How does the human brain develop? Can we extend the lives of breast cancer survivors? Can we "see in the dark" and through obstructions to ensure national security? Partners in the Future Photon Initiative hope to develop new photonic devices to pursue the answers.

Solving Pressing Problems

Photonics is the field of technology that uses photons to process information or energy. Around the RIT campus, significant photonics research already takes place. The Center for Detectors develops next-generation detectors in a facility that rivals that of major space agencies. The NanoPower Research Laboratory designs and fabricates advanced photovoltaic devices. The Integrated Photonics Group is leading the design, fabrication, and characterization of photonic chips. And that's but three examples.

The Future Photon Initiative (FPI) will leverage RIT's unique assets to develop advanced photonics, which represents the cutting edge of the field of photonics, with the ultimate goal of becoming one of the most effective applied photon research and development centers in the world.

Don Figer, director of the Center for Detectors, will lead the Initiative. "We've always had the idea to bring together the researchers to address the bigger problems" the world faces related to U.S. competitiveness and national security, he said. Initially, FPI will develop devices for advanced manufacturing, communications and information technology, defense and national security, energy, and health and medicine.

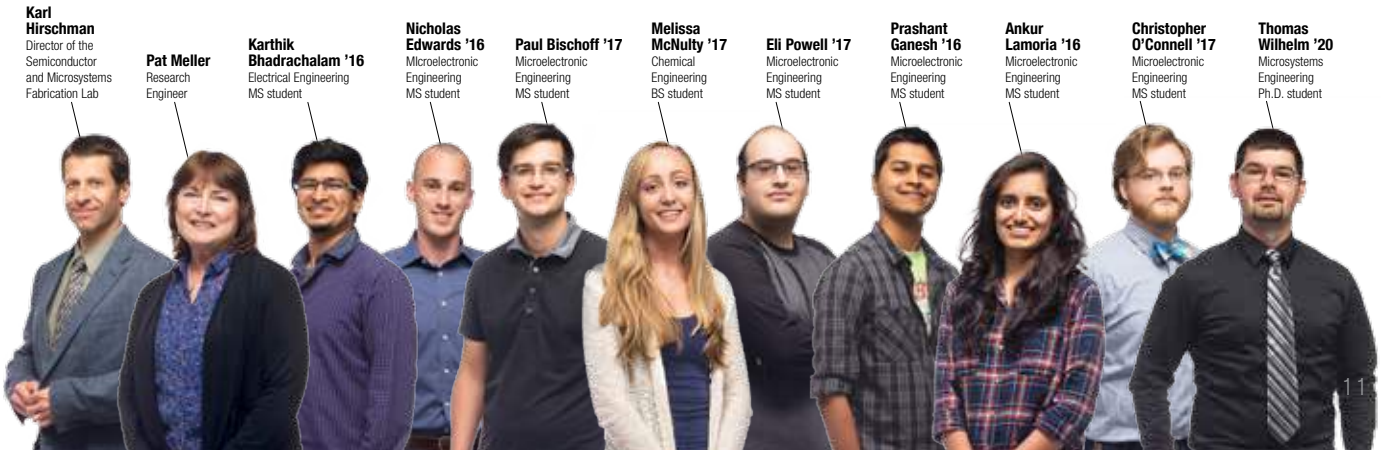
Some of those big questions Figer cites: "Are we alone in the universe? What is dark energy and dark matter?" and others listed at the beginning of this article. "The odd thing about these questions is they don't seem to be related but they all overlap in the technology that's needed to address them," according to Figer.

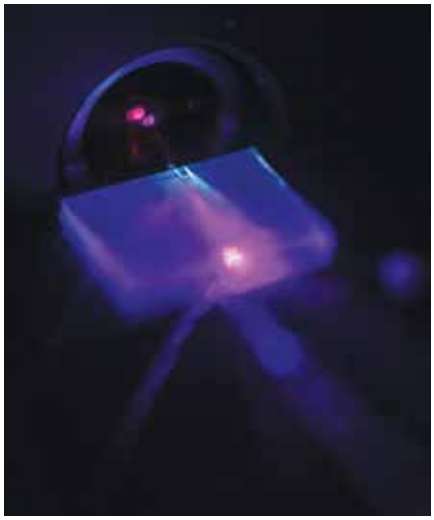
FPI will apply and commercialize the efforts of existing RIT groups that develop technology for the generation, transmission, manipulation, absorption, and detection of photons.

Future Photon Initiative: FPI spans the entire field of photonics from advanced optical systems down to photonic devices of the scale of nanometers. In this photo red laser light is directed into a chip (bottom right) with nanoscale photonic devices. Photo credit: Michael Fanto

Collaborative Effort

Faculty, staff, and students from across the university are working on this interdisciplinary signature Future Photon Initiative. Below are some of the collaborators.





Photonic Chip Operating at Ultraviolet Wavelengths that is being used to realize memories in future quantum computers and communication systems. Photo credit: Michael Fanto

Semiconductor Laser Integrated on a Silicon Chip to power internet communications of the future. Photo credit: Zihao Wang

Leveraging Success

Being awarded $1 million in funding from RIT will provide the resources needed to take the individual research groups and transform them into an internationally recognized Initiative, Figer said.

Key to that is analyzing the areas of expertise that RIT currently has on its research faculty and identifying gaps that exist. Also important is analyzing a list of potential customers (ranging from Fortune 500 companies to the Department of Defense) in order to target opportunities for funding and possible expansion, Figer said.

An assistant director will be hired to be the liaison between researchers and the industry, federal agencies, New York state, and nonprofit organizations. "We think we could significantly increase funding for research," Figer noted. The most important long-term goal is to obtain funding to create a national photon device center. The total external funding goal for the Future Photon Initiative is $100 million within five years.

This RIT research initiative will be able to capitalize on opportunities, including funding, related to the American Institute for Manufacturing of Photonics (AIM Photonics), a public-private partnership announced in 2015 in which RIT is a Tier 1 academic partner.

Impressive Support

"One of the measures of our emergence as international leaders is the strength of the letters of support in our proposal" to RIT for funding the Future Photon Initiative, Figer said. Organizations and businesses such as NASA, the U.S. Army and Air Force, Raytheon, Nikon, Intel, and Harris enthusiastically endorsed the proposal, and in some cases, cited the opportunity to work with or continue to work with RIT.

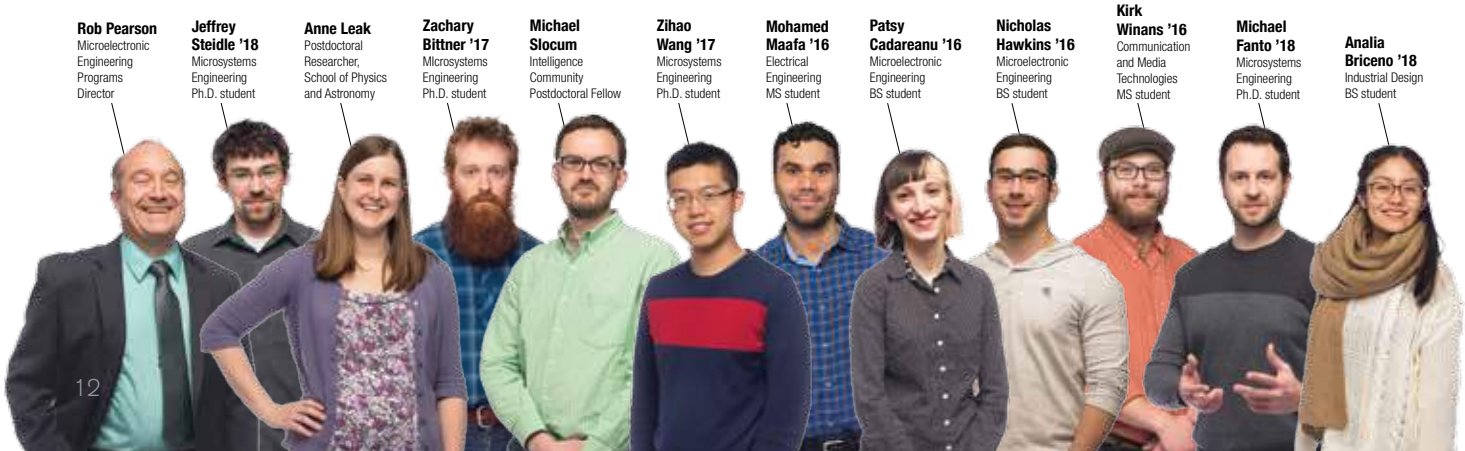
"A number of our research groups are already working with NASA," including in the field of infrared detectors, Figer noted. "But NASA has many interests … We can become an entity that could be a think tank for NASA." The NASA letter of support specifically mentions the potential collaboration on areas such as high-speed lasers and optoelectronics.

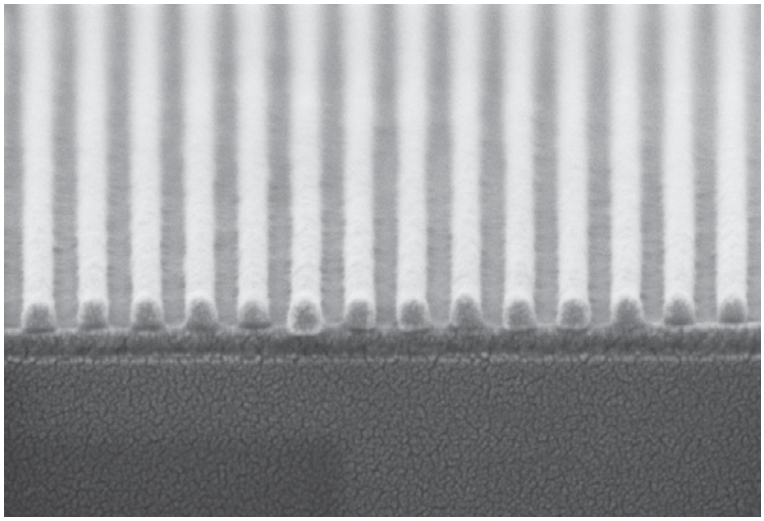
Specific R&D

FPI will focus on four specific areas for research and development.

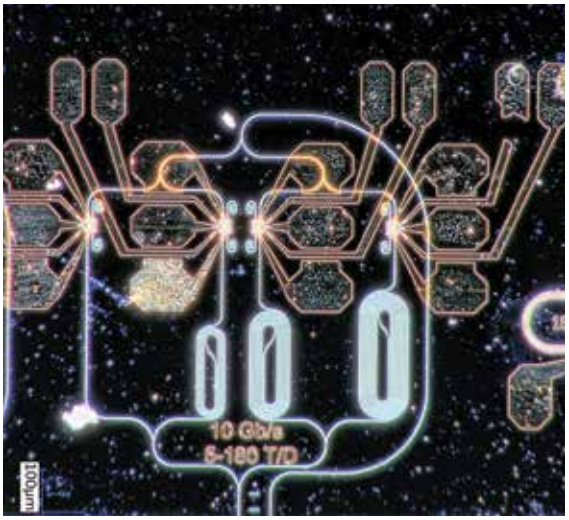
Integrated Photonics

Stefan Preble, director of the RIT Integrated Photonics Group, is leading work that integrates photons onto microchips, which will address the key computing, energy, communication, and sensing challenges of the future. Through the FPI, Preble





Scanning Electron Micrograph (SEM): Nano-patterning of semiconductor device structures smaller than 25 nanometers is enabled through the advances in deep-UV (DUV) and extreme-UV (EUV) lithography at RIT.



Photonics Circuit on a Silicon Chip that will be used to replace the power draining, slow, electrical wires we use today. Photo credit: Michael Fanto/Stefan Preble

believes revolutionary advances in photon science and technology can be made.

"The goal is to be able to process every photon. Light is made up of photons and it's very important you don't lose any of those. You want to get all the information you can from these photons. That's difficult to do at this point," Preble said.

A key theme will be the exploitation of the quantum properties of photons and matter to eliminate tradeoffs in speed, efficiency, and noise. "By moving to a quantum-limited regime in the laser, the waveguide, the detector, essentially you're able to have much higher performance than is possible in classical technology," Preble said. "As a result that shift helps us to answer those big questions."

Scaled Electronics

Bruce Smith, director of RIT's microsystems engineering doctoral program, leads this area, which focuses on microelectronics, "making devices very small, well beyond the wavelength of light itself. We're talking about building structures in electronic devices that approach the single nanometer scale. That requires huge challenges going beyond the traditional predictive scaling laws," Smith said.

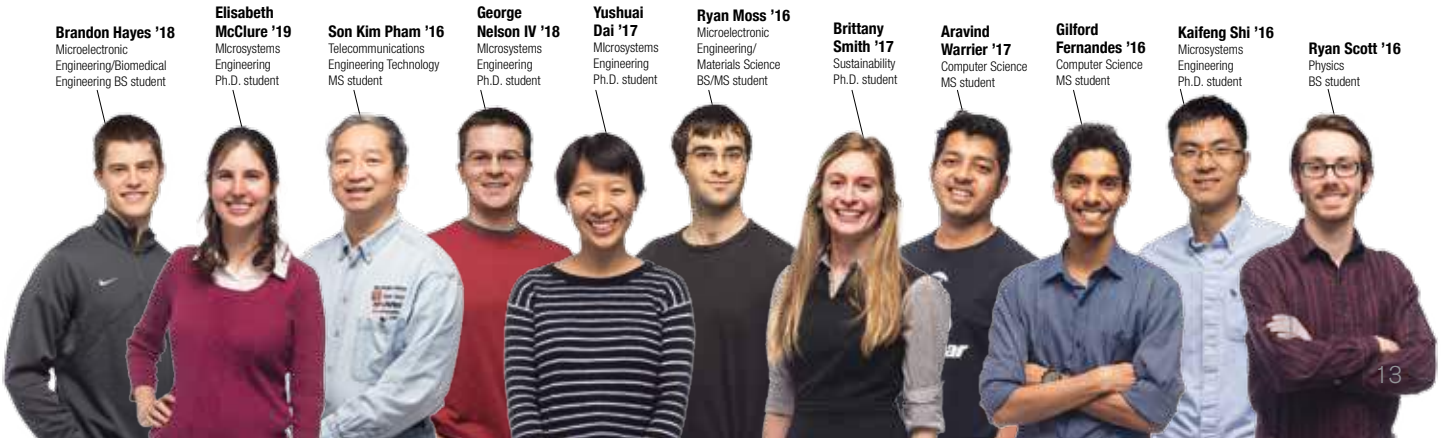
Having the Initiative build partnerships with businesses, consortia, and other academic institutions is key. "More than ever, there are challenges that require thinking about nano-scale devices and process technology in nonconventional ways. Collaborating with groups that are involved with the latest advances is extremely important as we move to new opportunities to communicate with, connect to, and control the world around us." Smith said. "The current challenges aren't anything that can be resolved with one single discipline; the goal is to create opportunities to work together."

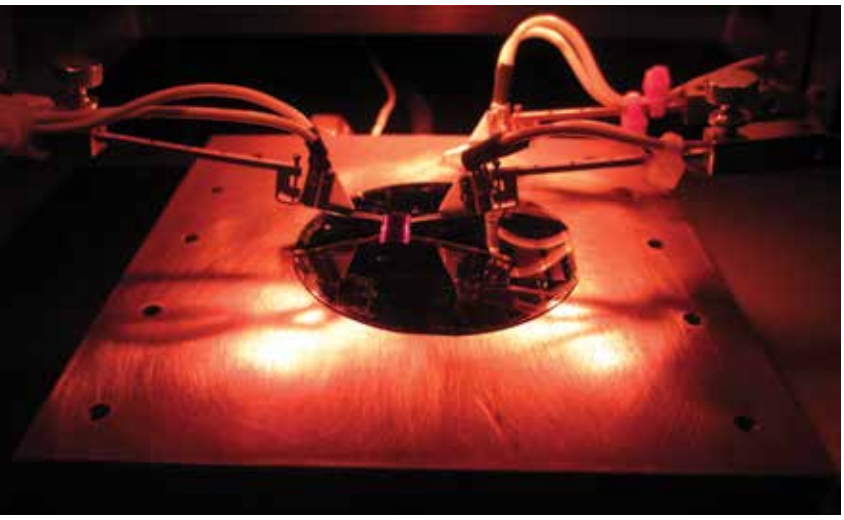
Photovoltaics

Seth Hubbard, director of RIT's NanoPower Research Laboratories, has overall responsibility for the energy area of the FPI. The United States and other countries have identified sustaining the energy supply as a high priority, according to Hubbard. His research focuses on photovoltaics, specifically improving the efficiency at which photovoltaics converts sunlight into electricity.

Hubbard, Preble, and Figer already have been collaborating for a number of years, and plans call for a multidisciplinary team of scientists and engineers to develop breakthroughs to advance the state of the art in device efficiency.

While Hubbard has already developed collaborative relationships with a number





Wide Band Gap III-V Solar Cell ($InGaP_2$) grown on RIT's metal organic vapor-phase epitaxy system for next-generation space power systems.

Imaging Detector Testbeds: These high-performance imaging detector testbeds in RIT's Center for Detectors give the FPI unique abilities to develop imaging devices for use in NASA missions.

of businesses over the years as a result of joint government funding, he believes the Future Photon Initiative will give the name recognition to be able to expand that.

Detectors

Two of the most exciting application areas for detectors are astrophysics and biophotonics, according to Figer, who oversees this area in his role as head of the Center for Detectors. The Center, which is one of the most well-funded astronomical detector programs in the world, is currently leading development programs for both single photon counting detectors and also large format infrared detectors. The FPI will leverage these developments for future astrophysics missions.

In the field of biophotonics, fast low-noise detectors are crucial for the development of next-generation biophotonic instruments. Ultimately, these instruments can help answer big questions such as how to extend the lives of breast cancer survivors and how to study brain hematomas in infants, Figer said. The Initiative plans to hire a principal investigator faculty member for this area.

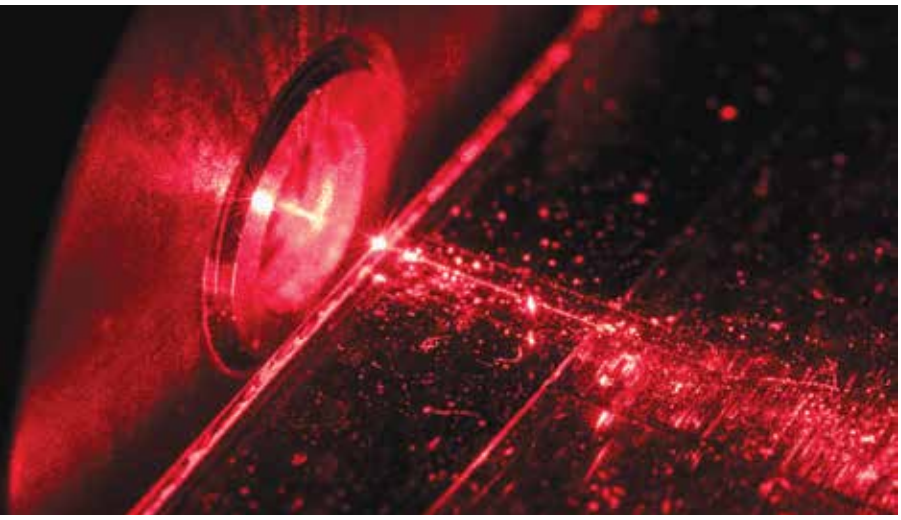
Commercializing Research

Taking the outcomes of research and turning them into viable patents and products is a key goal of the Initiative. Richard DeMartino, director of the Simone Center for Student Innovation and Entrepreneurship, believes the commercialization of research coming out of RIT can be magnified to a much greater extent. "I think we have just scratched the surface of what we can do when it comes to taking photonic technology and building a business around it," he said. As a former board member of the Rochester Regional Photonics Cluster and the author of several journal articles on commercializing photonics, DeMartino is well aware of the opportunities.

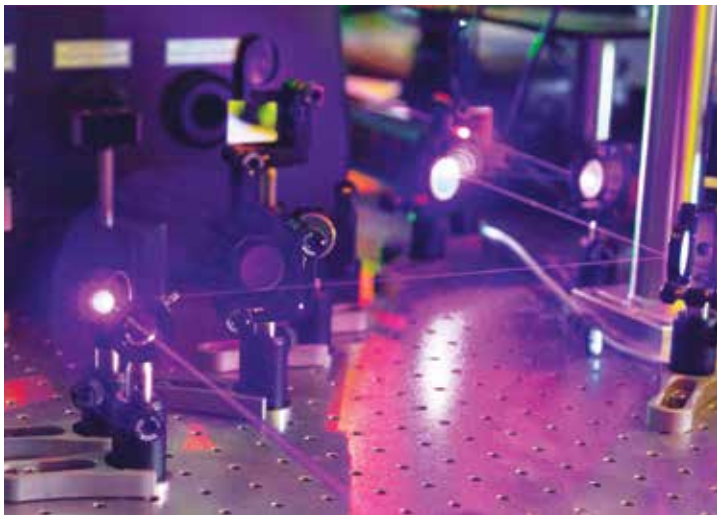
While several companies, most notably Pictometry, have been spun out from imaging science and photonic research at RIT, DeMartino noted that often in academia this process of exploring commercialization opportunities isn't built in systemically. That won't be the case for the Initiative.

Researchers will take advantage of the fact that RIT is an Innovation Corps (I-Corps) site designated by the National Science Foundation. I-Corps is a public-private partnership program that teaches grantees to identify valuable product opportunities that can emerge from academic research, and it offers entrepreneurship training to participants.

"This is a process that is specifically developed for science and technology



Polymer Waveguides: RIT microelectronic engineering senior design project that has demonstrated flexible polymer waveguide connections for use in printed circuit boards and computer chips. Photo credit: Ryan Moss/Michael Fanto



Advanced Photonics: FPI has state-of-the-art labs that will allow FPI to explore the future of photon technologies. Photo credit: Michael Fanto

where they work with scientists and coaches to help them understand the commercial value and push forward commercial opportunities," DeMartino said.

Teams that have developed a photonic-related output will participate in the I-Corps program. Through seminars and meetings with coaches, Future Photon Initiative researchers and students will "explore if there are real customers for what they have and see if there's a business that can be developed from that," DeMartino said.

Growing RIT's Reputation

The Vignelli Center for Design Studies is collaborating with the Initiative to create an effective communications strategy.

"We have expertise that can help this initiative in terms of establishing a coordinated, integrated, visual communications program," said R. Roger Remington, Vignelli Distinguished Professor of Design.

Remington will work with Figer and the FPI colleagues. "The first phase we'll be involved with will be a phase of analysis and fact finding, and that will lead us to the place of trying to develop some specific strategies for the Initiative's terms of communicating to its audiences and having a new face to use for internal and external publics. And then once we have a consensus on a direction with this, we will begin to work with them in terms of specific applications such as websites and promotional literature."

Powerful Synergy

A team of 16 researchers and professors currently make up the FPI, and the excitement is palpable.

"Each of us has been trying to grow our reputation for the last 10 years," Hubbard said. "You get hired to the faculty and you start growing your reputation nationally and internationally in a very specific field. Now that we can bring all of us together, I feel that the whole is better than the sum of the parts. So we can have a very strong Initiative that's recognized in many different fields such as solar energy to detectors to integrated photonics to bio-device industries. It's a huge swath. We can get increased name recognition with this Initiative."

On the Web

Center for Detectors
ridl.cfd.rit.edu

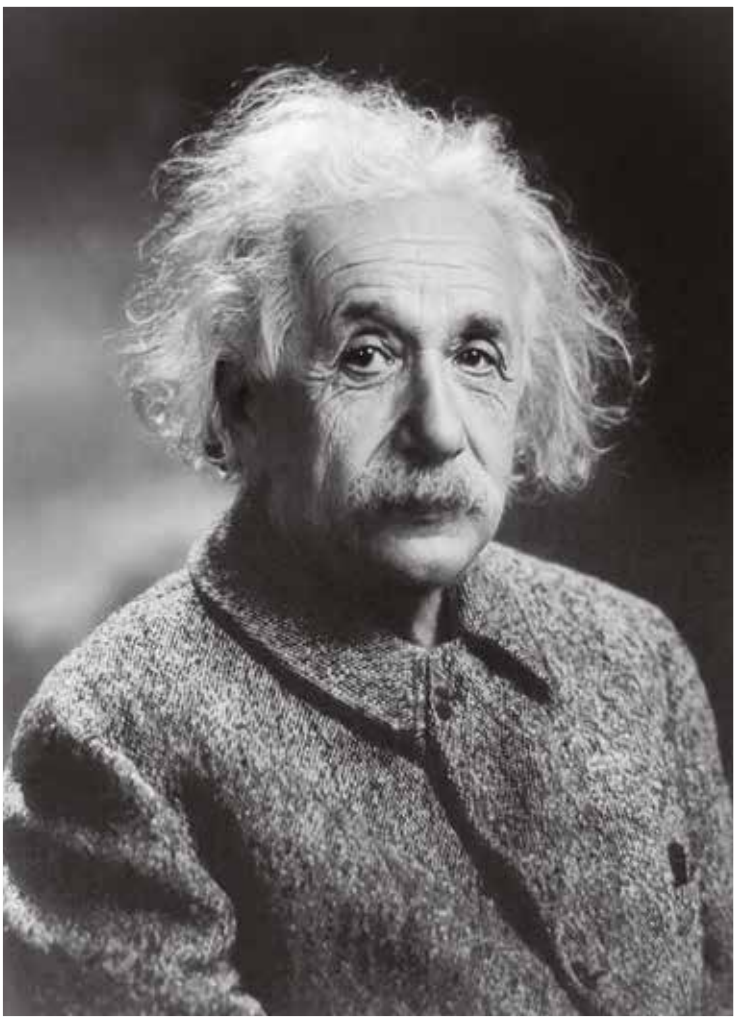
RIT Integrated Photonics Group
www.rit.edu/kgcoe/nanophotonics

NanoPower Research Laboratories
www.rit.edu/gis/research-centers/nanopower

Future Photon Initiative
fpi.rit.edu

Galactic Discovery:
RIT researchers played a key role in findings that confirm the existence of gravitational waves predicted in Albert Einstein's general theory of relativity.

Gravitational forces draw two black holes into a cataclysmic tango. The dance ends in a massive collision, sending gravitational waves rippling through space at the speed of light. Rendering by University of Florida/S. Barke.



Albert Einstein

Cosmic Coup—RIT Part of Team that Proves Einstein's General Theory of Relativity

by Susan Gawlowicz

RIT scientists made fundamental contributions to the breakthrough detection of gravitational waves—ripples in the fabric of space time—from black holes that collided 1.3 billion years ago. The Laser Interferometer Gravitational-Wave Observatory (LIGO) announced the discovery earlier this year.

Landmark Discovery

Researchers in RIT's Center for Computational Relativity and Gravitation have helped launch the era of gravitational wave astronomy and introduced a new branch of physics with their colleagues in the LIGO Scientific Collaboration. Their astrophysical simulations, data analyses, and big-data searches in support of the National Science Foundation-funded LIGO experiment validated the existence of gravitational waves and the black holes that produced them.

News of the landmark discovery, made public on Feb. 11, confirmed rumors that LIGO had detected the first gravitational waveform predicted by Albert Einstein's 100-year-old general theory of relativity.

RIT's Significant Contribution: Researchers at RIT's Center for Computational Relativity and Gravitation (CCRG) contributed to the first direct detection of a gravitational wave signal reported by the LIGO and Virgo scientific collaborations.

Aerial view of LIGO Hanford Observatory in Hanford, Wash.

Center for Computational Relativity and Gravitation Members: From left to right in the front row, Jam Sadiq, John Whelan, Jason Nordhaus, Monica Rizzo, Carlos Lousto, and Manuela Campanelli, director; in the second row, Joshua Faber, Brennan Ireland, and Naixin (Chris) Kang; in the third row, Yosef Zlochower, Yuanhao (Harry) Zhang, and Richard O'Shaughnessy; in the fourth row, Dennis Bowen and Jake Lange; and in the fifth row, Zachary Silberman, Hans-Peter Bischof, and James Healy.

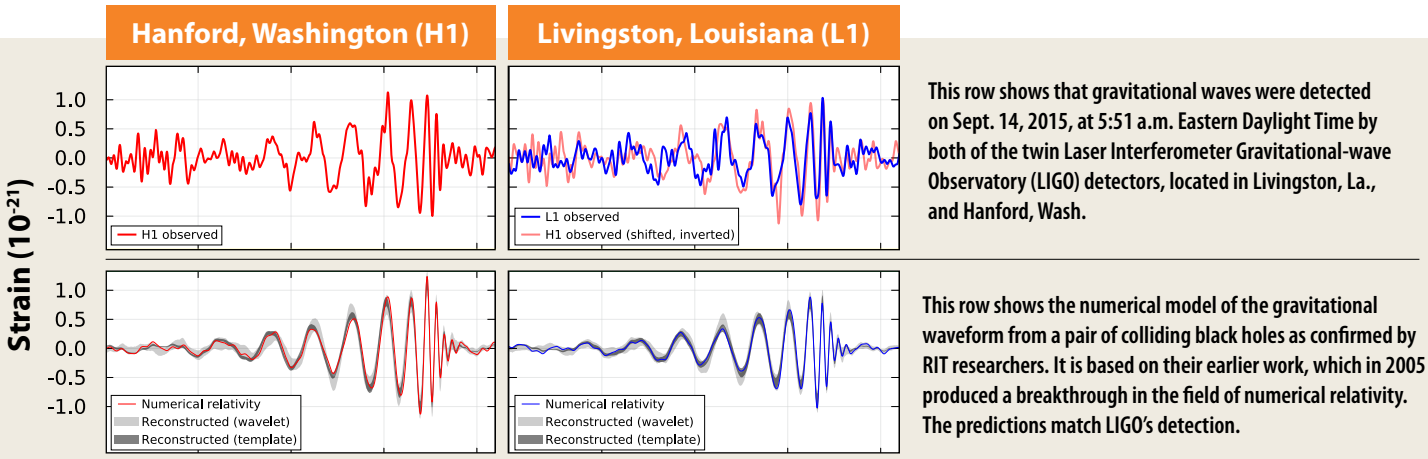
Following a five-year hiatus and a major upgrade, Advanced LIGO detected the first signal on Sept. 14, just before the start of the scheduled scientific run. The twin observatories in Livingston, La., and Hanford, Wash., detected tiny disturbances to space and time the moment gravitational waves passed through the Earth.

The L-shaped observatories, operated by Caltech and Massachusetts Institute of Technology, measure 2.5 miles long and contain precisely positioned mirrors at the end of the tunnels. Laser light travels back and forth down the length of the arms and measures the distance between the mirrors. Scientists estimate that the signal LIGO detected resulted from the impact of black holes weighing 29 and 36 times the mass of the sun.

Publication of the collaboration's findings in *Physical Review Letters*, a journal of the American Physical Society, coincided with the international announcement, and included six RIT co-authors. They are James Healy, post-doctoral research fellow; Jacob Lange, graduate student in RIT's astrophysical sciences and technology program; Carlos Lousto, professor in the School of Mathematical Sciences and an American Physical Society Fellow; Richard O'Shaughnessy, assistant professor in the School of Mathematical Sciences; John Whelan, associate professor in the School of Mathematical Sciences and principal investigator of RIT's group in the LIGO Scientific Collaboration; and Yuanhao Zhang, graduate student in RIT's astrophysical sciences and technology program. Center director Manuela Campanelli, professor in the School of Mathematical Sciences and an American Physical Society Fellow, Hans-Peter Bischof, professor of computer science, and RIT students Jackson Henry, Ryan Hesse, Marc McClure, Monica Rizzo, and Jam Sadiq, are also members of the RIT LIGO group.

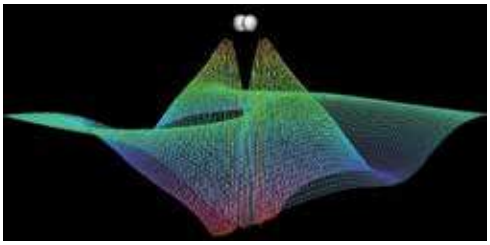
The Numerical Relativity Contribution

LIGO's landmark paper prominently cites Campanelli's team as one of three groups that advanced modeling of black-hole mergers on supercomputers and accurately predicted gravitational



Gravitational Waves Detected: The signal detected by LIGO (top row) matches the numerical model of the waveform (bottom row) confirmed by RIT researchers and predicted in their 2005 breakthrough science. Figure adapted from Abbott et al, *Physical Review Letters* 116, 061102 (2016).

Commemorating CCRG: U.S. Rep Louise Slaughter visited RIT in March to celebrate RIT's historic scientific contribution. Slaughter presented CCRG researchers with individual copies of her Congressional Record statement, commending their role in the discovery. In turn, Manuela Campanelli, right, director of the center, presented Slaughter with an RIT poster that appeared in the *Chronicle of Higher Education* celebrating the RIT team, and a signed copy of the landmark discovery paper published in *Physical Review Letters* on Feb. 11.



Supercomputer Simulation: Image of a supercomputer simulation of the merger of two black holes performed at the CCRG. It shows a powerful gravitational wave being produced by the fast-moving black holes. Credit: Campanelli et al. Image: Hans-Peter Bischof.

waveforms. Campanelli's 2005 breakthrough method, known as the moving puncture approach, played an integral role in enabling and interpreting the LIGO discovery. Lousto, a member of the original team, and Healy used the method to inde—pendently calculate the gravitational waves observed by Advanced LIGO by modeling the merger of simulated black holes. The observed waveform matched their prediction.

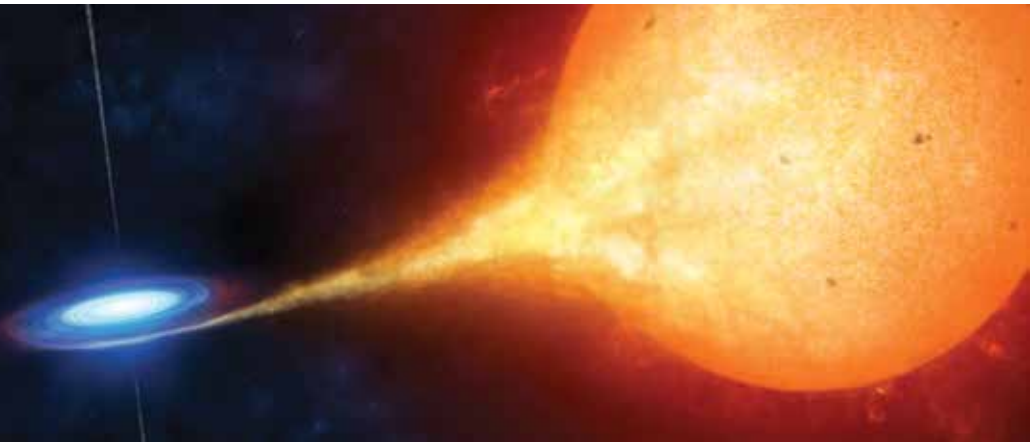
"The inclusion of our results made the paper a much stronger case for relativity because it's a double confirmation," Lousto said. "It is not that we have only detected gravitational waves and statistically it makes sense, but they happened to be exactly what we predicted for the collision of black holes. It ties it together very well."

Campanelli describes the detection of the black-hole merger as "an amazing confirmation of our theoretical calculations."

"To me, the fascination is you have these mathematical equations that describe natural phenomena—such as how binary black holes coalescence should happen—and finally you see it in nature," she said. "It was mind blowing."

Predicted but never confirmed until now, black holes are massive stars that have collapsed into compact objects with gravity too strong for light to escape. Einstein's general theory of relativity predicted that massive bodies undergoing the cataclysmic event of merging, spinning, or exploding could produce gravitational waves. As the sensitivity of Advanced LIGO increases during subsequent scientific runs, scientists expect to see more black-hole mergers and other sources of gravitational waves at different frequencies, such as black hole-neutron stars or binary neutron star collisions, highly spinning neutron stars—known as pulsars—supernovas, and the Big Bang.

"At RIT, we're working on a wide range of gravitational wave astrophysics," Campanelli said. "We're one of a handful of groups worldwide developing the tools and performing the simulations needed to interpret phenomena dominated by strong-field physics in Einstein's theory of gravity."



Scorpius X-1: Gravitational-wave signals from X-ray sources such as those from Sco X-1 might be detected in the future as Advanced LIGO and Advanced Virgo collect even more sensitive data. Credit: Fahad Sulehria, www.novacelestia.com.

Impact on Astrophysics

Research in complementary areas at the center focuses on analyzing and interpreting gravitational waveforms in the LIGO data and creating scientific visualizations. Several members of the RIT LIGO team were listed on the 12 companion papers that followed the initial discovery, including "Astrophysical Implications of the Binary Black-hole Merger GW150914," published in *The Astrophysical Journal Letters*.

O'Shaughnessy and Whelan specialize in developing methods for detecting and interpreting gravitational wave signals. O'Shaughnessy's research connects the gravitational-wave signatures observed by LIGO to the astrophysical sources that produced them. He estimates both the nature of these sources—in this case, a binary black hole—and how they formed. LIGO's discovery is consistent with the specific method O'Shaughnessy and his collaborators use to predict how massive stars evolve into black holes and form merging pairs.

"The discovery of a black-hole merger is only the tip of the iceberg," O'Shaughnessy said. "We're on the cusp of a revolution in our understanding of how massive stars evolve."

Monica Rizzo, a second-year student in the School of Physics and Astronomy, is part of the LIGO Scientific Collaboration. She works with O'Shaughnessy on models that simulate gravitational wave signals for colliding neutron stars. These stellar remnants have collapsed under their own weight but lack the mass to form into black holes. Although Rizzo did not contribute directly to the initial discovery, her research has helped advance techniques for interpreting future data.

"My work over the past few semesters has led to the development of new techniques we can use to analyze gravitational waves from binary neutron stars and has helped me become more knowledgeable as a researcher," Rizzo said.

Neutron Stars

The scope of gravitational wave astronomy will widen as the international network of detectors becomes fully operational. Scientific runs at increasing levels of sensitivity are planned for the U.S.-based LIGO detectors and the Italian counterpart, Advanced Virgo, Whelan noted.

"We're looking not just for binary mergers, but for a range of signals from unexplained bursts to a background 'hum' from many weak signals from the distant universe or even the Big Bang," said Whelan, graduate program coordinator of RIT's astrophysical sciences and technology program. "Closer by, our own galaxy is also full of potential strong sources such as rapidly spinning neutron stars."

Merging pairs of neutron stars produce a fainter signal than binary black holes, but are expected to be more common in nearby galaxies. Whelan predicts that these mergers will be detected as the network's sensitivity improves.

"One of the strengths of the center is that we now play a major role in both the simulation of gravitational waves and the scientific analysis of the LIGO data itself," Whelan said.

Center's Future Goals

The recent gravitational wave discovery is only the beginning. With financial support through RIT's strategic research initiative, the center will build a wide-spanning and integrated program around the new science of gravitational wave astronomy and multimessenger astrophysics. CCRG researchers also plan to play a leadership role in the science of the upcoming "third-generation" gravitational-wave detectors (the current LIGO detectors are second-generation instruments), and future space-base detectors such as the Evolved Laser Interferometer Space Antenna (eLISA). Sources such as coalescing compact binary systems, neutron stars in low-mass X-ray binaries, stellar collapses and pulsars, massive black hole binaries are all possible candidates for future observatories. With these future observations, researchers will be able to map the geometry of the universe, and in the long run improve our understanding of cosmology.

Campanelli says CCRG is already contributing to many aspects of research involving supermassive binary black holes.

"On the technology side, there will be opportunities to include advancements developed for LIGO into other domains," said Campanelli. "These include highly stable optics, squeezed light, extremely sophisticated suspension systems, and new materials. We foresee many opportunities for synergistic collaborations between theorists and engineers at RIT."

On the Web

Center for Computational Relativity and Gravitation
ccrg.rit.edu

Investing in Future of 3D Printing with New Research Facility

by Michelle Cometa

Construction will begin later this year on RIT's AMPrint Center for Advanced Technology, a research and teaching facility dedicated to developing next-generation 3D printers, 3D printer materials, and their applications. A recent $500,000 grant from New York state's Higher Education Capital (HECAP) Matching Grant program will be used toward construction of the center, which will be located on the fourth floor of RIT's Institute Hall.

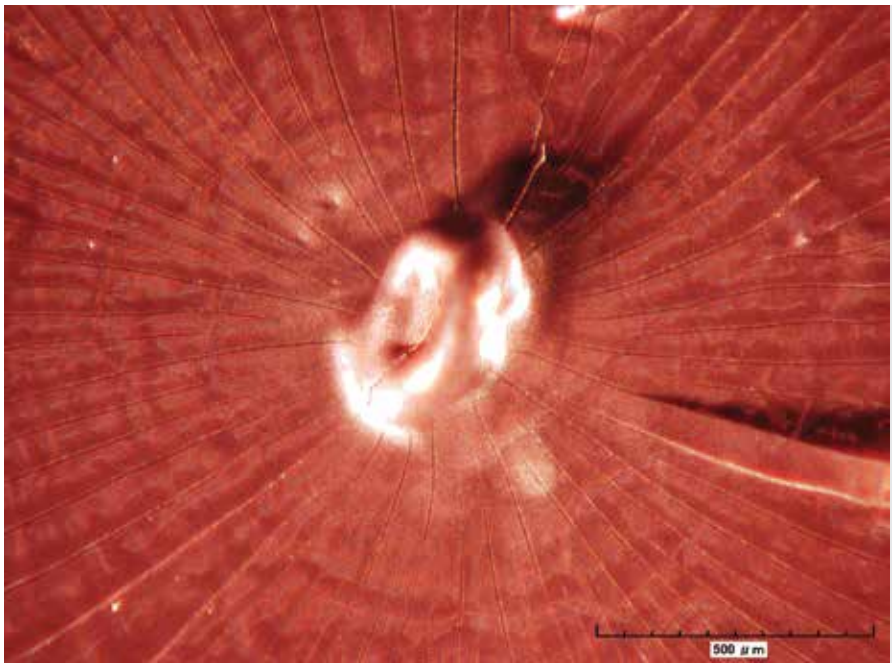
AMPrint Center

The 3,200-square-foot facility will serve as a resource for RIT students and the university's corporate partners. Researchers will have access to functional 3D printing and fusing equipment, direct-write printing equipment, analog printing, and surface metrology technologies. Also included will be wet-chemistry infrastructure necessary to synthesize printable nano-materials.

Denis Cormier, an expert in 3D printing technologies, is director of RIT's AMPrint Center and the Earl W. Brinkman Professor in RIT's Kate Gleason College of Engineering. A professor of industrial and systems engineering, his research focus is in functional 3D printing, which includes the synthesis of printable nano-inks, the development or enhancement of 3D printing processes, and the design of novel printed electronic devices.

"This region is world renowned for its print technology expertise," said Cormier. "However, the same technologies used to print documents and images are directly applicable to 3D printing as well. The AMPrint Center's mission is to help transform this region from the document and image printing capital of the world to the 3D printing capital of the world."

The $500,000 grant toward construction of the AMPrint Center facility was among 29 grants totaling $35.3 million statewide announced in February by Gov. Andrew M. Cuomo. The program, administered by the Dormitory Authority, funds renovation or construction of critical academic facilities and high-tech projects at universities across the state.

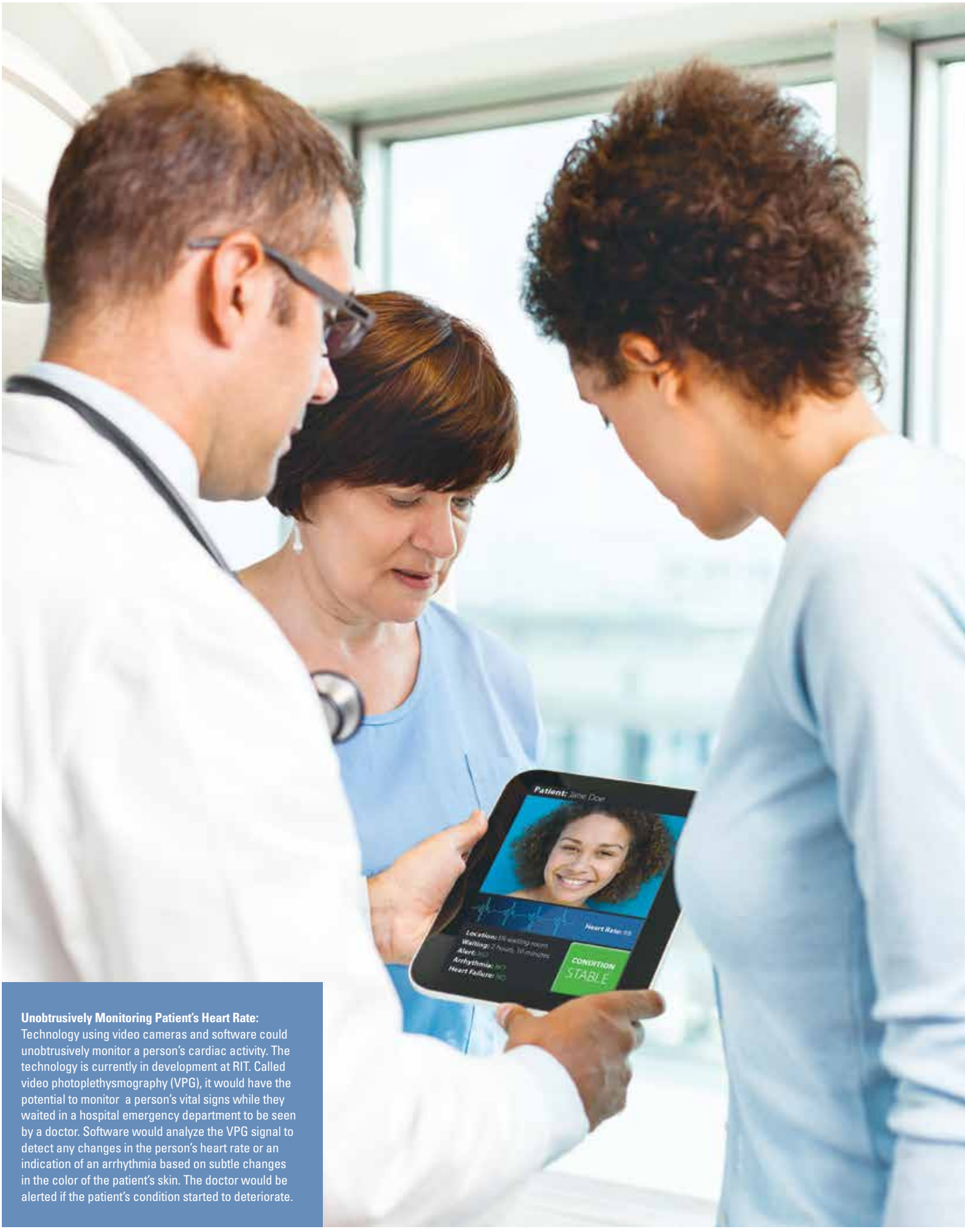


Functional Inks: Image of an inkjet printed copper nanoink. Developing and printing new functional inks is one of the unique aspects of the AMPrint Center that differentiate the 3D printing center from other centers around the country.

The AMPrint Center is one of 15 Centers for Advanced Technology funded by Empire State Development to support academic-corporate-government partnerships in growth industries such as 3D printing. Cormier was the original principal investigator for the center and brought together university partners from Clarkson University and SUNY New Paltz with corporate partners that include Xerox, GE Research, Corning, and Eastman Kodak to design novel devices and develop next-generation polymer, metal, and composite technologies.

On the Web

Brinkman Lab
www.rit.edu/kgcoe/ise/brinkman



Unobtrusively Monitoring Patient's Heart Rate: Technology using video cameras and software could unobtrusively monitor a person's cardiac activity. The technology is currently in development at RIT. Called video photoplethysmography (VPG), it would have the potential to monitor a person's vital signs while they waited in a hospital emergency department to be seen by a doctor. Software would analyze the VPG signal to detect any changes in the person's heart rate or an indication of an arrhythmia based on subtle changes in the color of the patient's skin. The doctor would be alerted if the patient's condition started to deteriorate.

Using Technology to Track Trends in Your Health

by Kelly Sorensen

Fitness trackers and smart watches are just two examples of wearable products on the market that are helping people better monitor their daily activity and providing data such as their heart rate. RIT plans to leverage its strengths in new media design and behavioral, social, and data sciences to enhance personalized health care and access through various intelligent, mobile, and wearable technologies.

Waiting Room Camera: An example of an unobtrusive video camera in a hospital waiting room.

Personalized Health Care Technology

Providing evidence that mobile and wearable technologies could predict trends in people's health and prevent disease is a priority for the National Institutes of Health as part of its strategic plan. The NIH's goal closely aligns with one of RIT's signature research initiatives in personalized health care technology. RIT will invest $1 million in this area over the next five years.

RIT plans to leverage its resources and expertise from a wide number of research centers and faculty researchers to facilitate further innovation in health care and build upon its history in applying science and technology to support individuals with a wide range of challenges. For example, in health care delivery, communication between doctors and their patients can often be a huge hurdle especially for certain populations like the deaf and hard of hearing, the elderly, and people with varying physical and cognitive abilities.

"Directly monitoring someone greatly facilitates assessing their health status," said Dan Phillips, Faculty Associate and Lead of RIT's Partnership for Access Technology Research and Development. "If you connect a measurement device to somebody, objective data will be collected that can be directly provided to a clinical professional for evaluation, regardless of the individuals ability to communicate. This is incredibly important for individuals in which communication abilities are limited or non-existent."

Gill Tsouri, RIT associate professor of electrical and microelectronic engineering, is working on developing technology to unobtrusively monitor a person's cardiac activity. It's called video photoplethysmography (VPG) and it monitors vital signs using a video camera and signal processing algorithms.

For someone waiting to be treated in a hospital emergency department, their status can be monitored using videos cameras and software that would immediately alert staff if the patient's condition starts to deteriorate. This technology could also be used in a home setting. Software analyzes the video signals to detect arrhythmias and heart rates. The technology is currently being tested in clinical trials in collaboration with J.P. Couderc of the Heart Research Follow-Up Program at the University of Rochester Medical Center.

Here's how the technology works: Light reflecting off the skin exhibits subtle changes in color as the heart delivers blood to and from the face. Tracking color variations over time provides a signal comparable to one obtained using a photoplethysmography skin sensor.

Another example of technology that ties in with personalized health care for heart patients is an industry-funded sensor system integrated into a toilet seat. Currently under development, it could revolutionize the way in which people are monitored and treated after being hospitalized for heart failure. The technology is the brainchild of David Borkholder, Bausch and Lomb Professor of Microsystems at RIT; Nick Conn, RIT Ph.D. candidate in the microsystems engineering program; and Dr. Karl Schwarz, director of the Echocardiography Laboratory at the University of Rochester. The seat measures a patient's vital signs such as heart rate, heart rhythm, blood pressure, arterial oxygen saturation, and weight.

Borkholder says that by the patient just sitting on the toilet seat doctors are able to obtain reliable measurements that require skin contact, such as the electrocardiogram.

"You get skin contact from the person without them doing anything out of the ordinary," says Borkholder. "You can obtain the patient's data at the same time every day, for example, when they first get up in the morning to use the bathroom. The person at this point hasn't had any food or caffeine. So all of the issues that confound the data when a person goes to the doctor's office are no longer part of the equation. You are collecting data

Predicting Health Trends for Heart Failure Patients: A toilet seat embedded with sensors is currently under development by David Borkholder, Bausch and Lomb Professor of Microsystems at RIT, and Dr. Karl Schwarz, director of UR's Echocardiography Laboratory. The seat (above left), designed for patients who have suffered from heart failure, can produce a patient's vital signs from skin contact with the seat. The patient's data could then be displayed on a user interface for both the doctor and patient to review (above right). User interface design credit: RIT Visiting Assistant Professor Hye-Jin Nae

Facilitating Better Communication: A collaborative student team project (Team Mendo) created by RIT new media developers and new media designers explored how mobile, handheld apps and large touchscreens could facilitate better communication between doctors and patients.

at the same time on a regular basis which is critical for trend analysis."

Borkholder and Schwarz are currently working with hospitalized patients at the UR and are also conducting a six-month, in-home trial with heart failure patients. The consistent data collection over time can show if there are trends that could predict deteriorating health conditions. This would allow doctors to intervene early enough so that the patient does not have to be readmitted to the hospital.

From Data Collection to Design Thinking

Once the data is collected from these various technology applications, the challenge then becomes how to effectively present all of this information to the user. This is where RIT's new media design program, led by Adam Smith, will take the technology and customize a digital interface for the client to view the data. The interface could be viewed on someone's phone, a tablet, or a touch screen at the doctor's office.

"We bring to the table the design approaches and philosophies that focus on the user through visual language," says Smith. "You always have to be thinking about the needs and wants of the consumer. We figure out what that data needs to look like for the both the patient and the doctor and can solve the information problem so that the data is usable."

The program is built on engaging multidisciplinary teams of undergraduate students, made up of new media interactive development majors and new media design majors. Each year, teams complete a senior capstone project for an industry partner. Past clients have included Adobe, Xerox, Rock and Roll Hall of Fame, and the UR's HIV Trials Unit. Last year, a student team created a digital touchscreen to display a patient's prescriptions, diet, and exercise recommendations to be reviewed with the doctor in the office. The interface could also be viewed on the patient's mobile devices.

Digital Therapies Impacting Positive Behavioral Health

RIT is also using medical interactive technologies like cell phone apps, virtual

Digital Behavioral Health Coach: Al-Virt® is a digital behavioral health coach developed at RIT to teach healthy communication and conflict resolution skills to offenders undergoing treatment for substance abuse and aggressive behavior.

tools, and avatars to change people's behaviors to be more positive and healthy. Caroline Easton, an RIT professor of forensic clinical psychology, specializes in working with people who have issues with substance dependency and family conflict. Easton and Richard Doolittl, vice dean of RIT's College of Health Sciences and Technology, lead a multidisciplinary team of faculty and students developing interactive digital therapies.

Al-Virt® is an avatar who engages clients in virtual-role playing exercises and model-conflict skills in between their therapy sessions. Initially designed four years ago by Alan Gesek, '11, '14 (illustration, medical illustration), Al-Virt® recently underwent a makeover after clients provided feedback about his appearance and emotions. Clayton Scavone, an RIT game design student, created a more realistic looking avatar.

"The avatar helps the clients apply their coping skills," says Easton. "For example, the offenders may yell and swear and become agitated with their partner and other people in their environment. Through our digital therapies, we teach them healthier ways to be assertive in their communication skills as opposed to using aggressive behaviors."

Al-Virt® rewards the clients for trying to take a step in the right direction regarding improving their own behaviorial health. Easton says that research shows that practicing a changed healthier behavior leads to better treatment outcomes such as a reduction in substance abuse and aggression.

Data-Driven Decision Making

Collecting data of people's use of language and social cues on social media platforms such as Twitter, Facebook, and Instagram is giving RIT researchers a glimpse at their behavior and health risks. RIT computer science professor Christopher Homan studies computational social network analysis. Homan says that due to the vast amount of information that people post from their personal mobile devices in any given day, researchers can see how people's behavior on social media could impact their health.

"Does the person's language on social media suggest they are happy, sad, or depressed?" asked Homan. "If someone is unhappy, they may develop unhealthy behaviors like eating unhealthy foods, failing to exercise, or taking drugs," said Homan. "By understanding behavior, you understand the personalized health risks that certain people have and also what kinds of treatments they are amenable to."

Homan is working with psychiatrists at the University of Rochester to analyze large amounts of social media data.

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College of Health Sciences and Technology
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B. Thomas Golisano College of Computing and Information Sciences
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College of Imaging Arts and Sciences
cias.rit.edu

Planning Unmanned Aerial Systems Flight: RIT Professor Carl Salvaggio (far left) and RIT student Elizabeth Bondi, 4th-year imaging science student, plan a UAS flight to collect data for precision agriculture studies. RIT researchers have an opportunity to assist local growers using image data they have not had access to before. Jeff Ring (right), a UAS flight consultant, works with RIT researcher Aaron Gerace (wearing blue shirt) to provide technical guidance and FAA compliant flight assistance.

Aerial Viewpoint: Remote Sensing with UAVs

by Suzette Norris

The technology research firm Gartner says that, barring regulatory hurdles, the United States unmanned aerial vehicles (UAV) business could be worth $7 billion in a decade. What's driving the growth? The Internet of Things—the idea of making physical things "smart enough" to provide intelligence reliably and cost-effectively.

Remote Sensing with Unmanned Aerial Vehicles

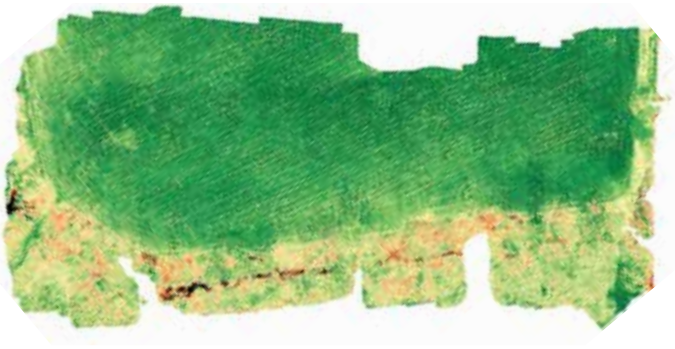
Commercial industries around the world are starting to understand the power of this concept, and are looking to UAVs as one way of getting there. RIT, long known for its expertise in both aerial and satellite imaging, is also one of the world's leading centers for research on UAVs.

As these two areas align, a new disruptive commercial model emerges. Low-cost UAVs collect information in new ways, and deliver it to software platforms capable of analyzing images and video reliably and in real time. The result produces insights that will dramatically change farming, insurance inspection, defense, law enforcement, disaster recovery, and many other industries.

But before that vision becomes reality, there are many technical and practical hurdles to overcome, including imaging science, engineering, and public policy, said David Messinger, director of RIT's Chester F. Carlson Center for Imaging Science. That's the reason RIT chose remote sensing with unmanned aerial vehicles as one of five strategic initiatives to receive $1 million for research. The interdisciplinary team, including imaging science, engineering, public policy, and computer engineering technology, will research ways to refine and integrate technology in ways that serve many different commercial and government needs.

When UAVs collect data, for example, there needs to be consistency in how the camera takes a picture, Messinger said. "Current instruments are not always stable, so we're looking to build a system that uses inexpensive cameras to collect data in a precise way."

Precision is critical, he said. Especially since many applications require "change detection." Today, humans are paid to watch hours of surveillance video looking for meaningful change between one image and another. Programming a computer to do this is a difficult problem to solve. Farmers practicing precision agriculture, for example, want to collect real-time data and use predictive analytics to make smarter decisions.



Turf Health: A vegetation stress orthomosaic formed from over 300 individual images collected over a turf field in Pittsford, N.Y. Dark green colors represent healthy turf with yellow areas indicating vegetation exhibiting stressed conditions.

Resolution Not Seen Before: True color orthomosaic of more than 400 images of a test plot in Macedon, N.Y., illustrating RIT's ability to collect remote sensing data with sub-centimeter resolution.

"But they don't want to stare at video to determine where a leak in their irrigation system is," Messinger said. "They want reliable usable information every day."

From Bug Infestation to Hail Storms

Today, large-scale farms look to three types of aerial imagery for precision farming. Satellite imagery, used since the 1970s, is relatively inexpensive but provides a resolution of only five to 20 meters. Aircraft pictures, a much more costly approach, capture images from 5 to 10 cm in resolution. Both of these options are limited in how often data sets are collected, and many farm management decisions require information on a daily or weekly basis. Other limitations also exist; for example, satellites can't see through clouds.

UAVs, on the other hand, can capture data from images with a 2.5 cm resolution, providing a level of detail that is vastly different from the other two options. But to work, "the science behind it needs to be rethought—and that's not always happening," said Carl Salvaggio, a professor at RIT in the Chester F. Carlson Center of Imaging Science and member of the Digital Imaging and Remote Sensing (DIRS) Laboratory. "A lot of people are claiming these camera systems can do things that they can't."

Rethinking the science, according to Salvaggio, is what his students are working on in their research. Take, for example, shadows. Detecting them is difficult for a computer program to sort out. But it's important if the farmer is going to get accurate crop information. Unlike using satellite imagery or aircraft pictures, an image taken from a closer point of view includes shadows, and these can be confused with signs of disease or infestation.

PrecisionHawk, a terrestrial data acquisition and analysis company, is collaborating with RIT to share technology improvements and test remote sensing applications using PrecisionHawk unmanned aerial vehicles. Data generated from applications such as precision agriculture will be shared between PrecisionHawk and RIT for future development. PrecisionHawk recently provided RIT researchers with its Lancaster UAV platform. This fixed-wing aircraft with a five-foot wingspan is capable of accepting interchangeable, modular imaging systems weighing up

PrecisionHawk Lancaster: PrecisionHawk of Toronto, Ontario, has provided RIT with its Lancaster fixed-wing aircraft capable of lifting imaging sensors to altitudes up to 400 feet for up to 45 minutes.

Pegasus Environmental: RIT's partner provides its DJI S900 n-copter to collect multispectral image data for water quality analysis research.

to 2.2 lbs. that collect hyperspectral, light detection and ranging, and high-resolution color imagery. This system can stay aloft for 45 minutes at altitudes up to 400 feet, flying at speeds up to 25 mph, providing large coverage to the RIT team.

Another ongoing research project relates to assessing water quality, Salvaggio said. A UAV equipped with the appropriate spectral sensing camera can be used to detect and map harmful algal blooms in lakes.

This new, finer point of view has endless business applications, including damage assessment for insurance companies. Instead of sending assessors onto a rooftop, these companies are looking to send up a UAV with camera systems that can reliably determine whether a roof was damaged by hail.

"Damage from hail has small characteristics that are different from other types of damage," Messinger said. "Looking for those small imperfections and separating them out is a hard problem that we are working on."

RIT has become the first academic technology member of the Property Drone Consortium, a group of major property insurance industry members and affiliated companies exploring technological improvements for their industry. RIT hopes to leverage its expertise in remote sensing with new opportunities and applications assisting consortium members Allstate, American Family Insurance, Erie Insurance, Auto-Owners Insurance, EagleView Technologies, Pilot Catastrophe Services Inc., Insurance Institute for Business and Home Safety, and National Roofing Contractors Association to explore use of UAVs and remote sensing technology for faster, more cost-effective property damage detection and claim adjustments. The goal is to provide new data, never before achievable in an automated fashion, to settle claims rapidly and accurately in post-disaster scenarios.

Working Together to Expand Research

Professor Daniel Kaputa with RIT's College of Applied Science and Technology is an expert in controlling how things fly. He says another key hurdle to advancing the aerial imagery research at RIT is creating a custom low-cost drone development platform. With a price point of around $200, the platform will be used to test out algorithms such as real-time

video processing and collision avoidance. "These platforms would have their own sensors, motors, and cameras that are tailored to our research," he said. "We can prove out our algorithms at a low cost, and then scale up." It would also open up many opportunities to explore indoor applications.

When drones fly outside, they have access to GPS navigation, which provides information within a couple of feet of the UAV's location. But inside, that navigation needs to be accurate to within an inch. "Imagine you own a retail store and want to do an inventory of books," he said. "You could use a drone to fly up and down every row and take images of what is in stock."

Creating a prototype system that's inexpensive will allow us to "attack any problem we want to," Salvaggio said. "Drones are just a beautiful way to get us where we want to go."

But along with progress comes considerable public policy challenges related to safety and privacy, said Josephine Wolff, assistant professor in RIT's public policy department and a member of the extended faculty of the computing security department. "Answering the technical questions well requires that we have some idea of how we want to answer the social and regulatory questions and, similarly, making policy recommendations requires that we have some knowledge of the technical capabilities and implications, so it's crucial to address questions like these as part of an inter-disciplinary team."

Some of those questions include how UAVs can be incorporated into airspace without posing serious risks to the safety of other aircraft. And what kinds of privacy-preserving algorithms and technologies can be used to shield individuals from unintended surveillance?

"It's somewhat unusual to see the policy piece being addressed in tandem with—and by the same team as—the technical challenges since engineers tend to be wary of lawyers and policy-makers (and vice-versa)," Wolff said.

Rooftop Damage: RIT researchers are looking to automatically quantify the amount of damage to rooftops caused by hail (top) and wind (bottom) to help property casualty insurance inspectors carry out their inspections in a faster and more accurate fashion to settle claims for their clients.

"To have a research initiative like this one, that incorporates policy into a larger technical UAV research agenda, you really need scientists and engineers who are willing to acknowledge the importance of getting the policy landscape right and who aren't just writing off the regulatory piece as an unavoidable nuisance."

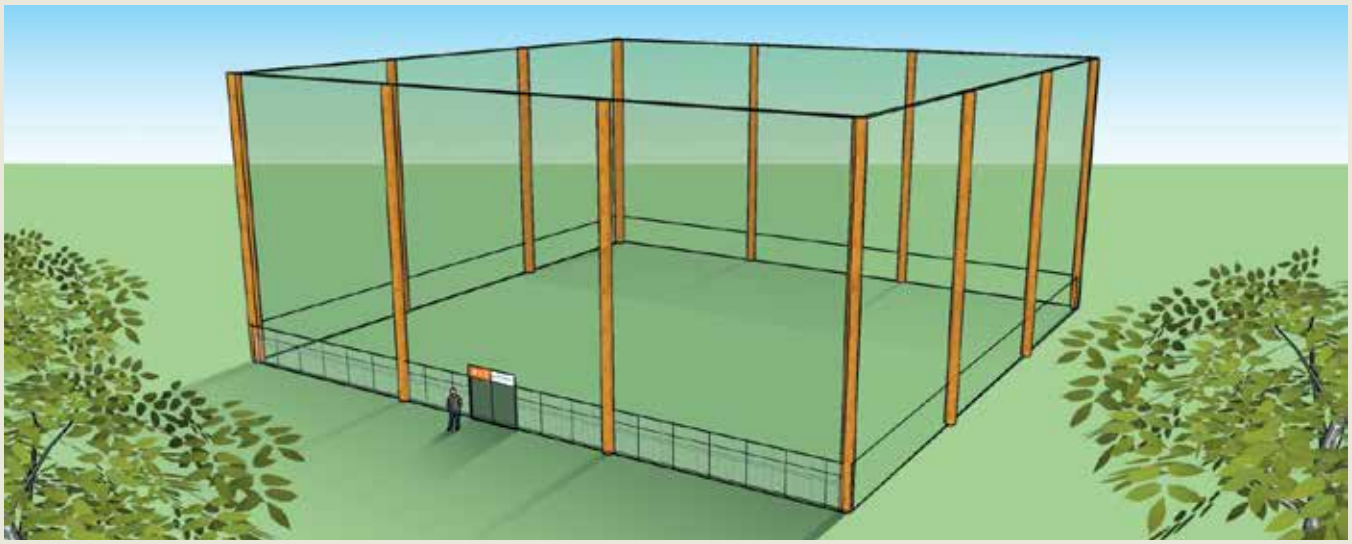
On the Web

Carlson Center for Imaging Science
www.cis.rit.edu

Kate Gleason College of Engineering
www.rit.edu/kgcoe

College of Applied Science and Technology
www.rit.edu/cast

RIT's Department of Public Policy
www.rit.edu/cla/publicpolicy



Flying Enclosure: While the FAA regulations for UAS flights are being established, RIT researchers will be able to test their platforms in a new flight enclosure. The enclosure, part of a partnership with EagleView Technologies Inc., allows for legal UAS flights within a five-mile radius of the Greater Rochester International Airport. Image courtesy of Pictometry, an EagleView company

Pictometry Partnership Will Expand Drone Research and Establish a UAS Outdoor Netted Enclosure Lab

by Michelle Cometa

RIT is partnering with Pictometry to build an Outdoor Netted Enclosure Lab for research and academic course work related to UAVs.

The enclosure, one of the first installed at a Northeast university, is part of an expanded research partnership between the university and the Rochester-based imaging company to advance development and testing of unmanned aircraft system technologies.

"This lab will allow students and researchers alike to build systems and fly and test them without the burden of researching regulations and safety issues related to open, outdoor drone flights," said Frank Giuffrida, executive vice president of engineering at EagleView Technologies Inc. Pictometry is a wholly owned subsidiary of EagleView. "The netted enclosure lab is an ideal test environment that allows full access to GPS signals that are essential for drone operation.

"In addition to advancing our research efforts, the lab also provides a great opportunity for RIT students to learn more about UAS technology and the science behind it, such as imaging capture, flight control, and sense and avoidance."

The outdoor, 100-by-100-by-50-foot enclosure will be located adjacent to the RIT campus and open year-round. Researchers could incorporate important test variables such as the impact of weather conditions on signal processing, for example, into research projects. The new enclosure would also meet Federal Aviation Administration requirements stating unmanned aircraft cannot fly within five miles of an airport. (RIT's campus is located within this vicinity; just under five miles from the Greater Rochester International Airport.) Regulations currently do not permit commercial, unmanned aircraft above 400 feet without certification, and these allowances are given primarily to law enforcement or the military.

"You can fly the drones indoors, but much of the research relies on how the global positioning system is used on board, and you don't get the weather elements. Both can be very useful in regard to designs for specific applications," said Agamemnon Crassidis, associate professor of mechanical engineering in RIT's Kate Gleason College of Engineering. He will manage the structure and much of the research and testing expected to take place at the outdoor facility. "With this type of enclosure, it's like flying indoors, so you won't need any special certifications from the FAA."

Some of the imagery captured by Pictometry is enabled by unmanned aircraft systems, and the company has been involved in advancing that technology capacity through projects with the NUAIR Alliance and RIT.

NUAIR, the Northeast UAS Airspace Integration Research Alliance, is a group of more than 40 companies and universities in New York and Massachusetts selected in December 2013 as one of six FAA test sites in the U.S. The alliance conducts research to improve unmanned aircraft technology and will recommend safe integration of unmanned aircraft in the national airspace system. Seventeen universities are involved with RIT and Massachusetts Institute of Technology as regional academic leaders.

"We'll have this facility at RIT, so if there are customers that come through NUAIR who want to fly right away, we'll have this facility available," said Crassidis, who is RIT's representative on NUAIR. He specializes in aircraft control systems and has worked for aerospace companies such as Calspan, an affiliate of the Flight Research Facility in Buffalo, N.Y., specifically part of the team that designed flight simulation systems for jet fighter pilots.

Faculty, Staff, and Student Achievements

RIT values the research contributions of its faculty, staff, and students. Below are some members of the RIT community who have received recent international, national, and university recognition.

CAREER Award Recognizes Promising Datacenter Research

Amlan Ganguly, RIT assistant professor of computer engineering, has received the prestigious National Science Foundation's Faculty Early Career Award Development (CAREER) Award. Ganguly will use his $596,000 award to look at creating energy-efficient datacenters with wireless interconnection networks. Currently, data centers all over the world consume huge amounts of energy due to the data communication between processing engines and memory accesses. Ganguly hopes to establish direct wireless links between components within a multichip system such as a server and also between servers of a data center to make the communication energy efficient. This would eliminate cables between servers and the expensive maintenance costs.

Pagano Named Outstanding Undergraduate Science Educator

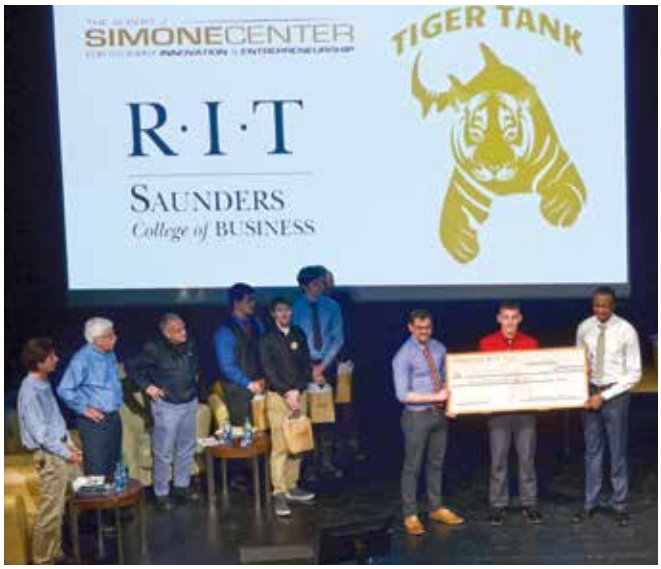
Todd Pagano, founding director of the laboratory science technology (LST) program at RIT's National Technical Institute for the Deaf, has been named the recipient of the 2016 Outstanding Undergraduate Science Teacher Award by the Society for College Science Teachers. He received the award at the National Science Teachers Association national conference in April in Nashville, Tenn. The award is co-sponsored by Springer publishing. Pagano was recognized for his American Chemical Society-approved program to prepare deaf and hard-of-hearing undergraduate students for technological careers in chemistry. More than 60 students are enrolled in the LST program at any one time, with about 80 percent of those students completing the program and 98 percent of those who graduate securing jobs or continuing their learning through additional education and advanced training. Both of these metrics exceed the success rates of their hearing peers. Pagano was named the United States Professor of the Year for 2012-2013 by the Council for Advancement and Support of Education/Carnegie Foundation for the Advancement of Teaching.

Zhang Wins Award from Office of Naval Research for Work on Semiconductor Lasers

The Office of Naval Research has honored Jing Zhang, assistant professor of electrical and microelectronic engineering, with a $390,000 award. Zhang's research focuses on developing solutions on nanostructured quantum wells based on III-Nitride materials for high-efficiency ultraviolet (UV) emitters and fabrication approach of high-density GaN-based UV laser arrays. The compact, efficient, and robust semiconductor lasers and emitters would have promising naval applications in sensing and communication.

Interdisciplinary Student Team Wins Innovation Award at SpaceX Hyperloop Competition

A team of RIT undergraduates won the Special Innovation Award in the Other Subsystem category at the SpaceX Hyperloop Pod Design Competition at Texas A&M University in January. The students received the award in the subsystem category for their novel approach to tube diagnostics and optical communication for the proposed futuristic high-speed rail system. RIT's winning team was made up of majors ranging from imaging science to motion picture science to physics to mechanical engineering. Two undergraduate teams from RIT participated in the design weekend. SpaceX and Tesla employees judged the projects.



Fatigue Detection and Alert System Wins Tiger Tank

Student entrepreneurs pitched early-stage products and services to a panel of judges at the annual Tiger Tank competition in April. The winning team was AWARE, a fatigue detection and alert system designed to combat drowsy driving. The system uses video-based monitoring of a user's head position, eye movement, and blink rate to detect physiological signs of fatigue. AWARE team members are mechanical engineering students Teryn Rynone and Claiborne Grosshans; electrical engineering students Zach Moxley and Emmanuel Dodoo; and Amanda Murray, a biomedical engineering student.

Hirschman Wins NSF's Major Research Instrumentation Award

Karl Hirschman, director of RIT's Semiconductor and Microsystems Fabrication Laboratory, has received the Major Research Instrumentation Award from the National Science Foundation. RIT has won the award the last 10 out of 11 years. The funds from the $345,000 award supported the purchase of a direct-write laser (DWL) system to enable innovations in electronic and photonic device design. The system is used on a variety of research applications including nanoelectronics, thin-film electronics, nanophotonics, and micro-optics. It's also a resource for microelectronic engineering undergraduates and graduate students in the university's Ph.D. programs in microsystems engineering and imaging science.

Multimillion Dollar Grants to Help Prepare Youth for College

Dianne Spang, director of RIT's Office of K-12 Programs, has been awarded a grant from the New York State Higher Education Services Corporation (HESC) for $3.9 million. The incremental funding, which spans the next five years, will expand RIT's Gaining Early Awareness and Readiness of Undergraduate Programs (GEAR UP). The grant, combined with funding awarded to the Urban League of Rochester, will provide cohort-based services to every eighth grader in the Rochester City School District as they prepare to enter and succeed in postsecondary education. The HESC award is just the latest in a series of grants won by the Office of K-12 Programs to support college readiness services for students traditionally underrepresented in higher education. The New York State Department of Education has awarded Spang and her team over $4 million throughout the next five years to help more than 650 students in grades seven through 12 at school districts around Monroe County.

RIT Dean Among IDSA's 50 Most Notable Members of Last Half-Century

Lorraine Justice, dean of RIT's College of Imaging Arts and Sciences, is among the 50 most notable members of the Industrial Designers Society of America (IDSA) during the last half-century. Justice received the recognition from IDSA members in the organization's flagship *Innovation* magazine. She is an IDSA Fellow who has worked in higher education for nearly 25 years. The "Notable 50" honor marks the latest recognition Justice has received from IDSA. In 2008, the organization honored her with its National Educator Award. Prior to her arrival at RIT in 2011, Justice served as director of the School of Design at The Hong Kong Polytechnic University (PolyU) for six years. She also headed the industrial design program at Georgia Tech and served for several years as a professor of visual communication at Ohio State University.

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Rochester Institute of Technology is internationally recognized for academic leadership in computing, engineering, imaging technology, sustainability, and fine and applied arts, in addition to unparalleled support services for deaf and hard-of-hearing students.

For two decades, *U.S. News & World Report* has ranked RIT among the nation's leading comprehensive universities. RIT is featured in *The Princeton Review*'s 2016 edition of *The Best 380 Colleges* as well as its 2015 *Guide to 353 Green Colleges. The Fiske Guide to Colleges 2014* describes RIT as "strong in anything related to computing, art and design, and engineering."

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To learn more about research opportunities on campus, contact us directly or through the RIT research website at **www.rit.edu/research**.

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