

# RESEARCH at RIT

The Rochester Institute of Technology Research Report

Spring/Summer 2015

SPOTLIGHT ON

## INSIDE THE TOOLKIT

### Cool Tools

A look at some of the capabilities and resources sparking research and innovation

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## RESEARCH at RIT

The Rochester Institute of Technology  
Research Report—Spring/Summer 2015

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## The Toolkit

It is often said a worker is only as good as the tools he or she uses. This issue showcases some of the research tools supporting the research goals that serve as cornerstones of our new strategic plan.



Growing our sponsored research awards to more than \$100 million each year, producing 20 new startup companies, and increasing graduate

enrollment to 30 percent of RIT's overall student body are just some of the goals we have set for ourselves. I welcome these challenges and recognize they will not be easily achieved, but I believe we are on our way to developing the necessary "toolkit." Whether it is accomplished faculty, outstanding corporate and community support, or some of the brightest students found anywhere, we have what it takes.

RIT has a heritage of developing the types of academic programs and research infrastructure not only to work at the cutting edge of technological development, but to help define it. Continuing this approach is what will allow us to accomplish our research goals. It is comforting to know that we do have the support and commitment of one of the largest and best contingents of corporate partners of any institution in the country. Nearly a quarter of our total sponsored research support last year came straight from industry, and this doesn't include what we receive in partnership with or via pass-through from these corporate partners on state and federal research awards.

Some of the new tools in our toolkit include a metal organic vapor phase epitaxy (MOVPE) reactor used to grow semiconductor materials for next-generation lasers, micro and optoelectronic devices and detectors, and solar cells. This new multimillion dollar capability in our region will serve as a catalyst for new programs in a number of fields

related to imaging, optics, and photonics. In a related story, you will read about the capabilities in our Center for Electronic Packaging and Assembly (CEMA) in which prototype devices are produced using the MOVPE and packaged into commercializable systems.

In addition, we recently had the ribbon cutting on our new Battery Prototyping Center. This facility was made possible with the support of NYSERDA, New York Empire State Development, and the New York Battery and Energy Storage Technology Consortium (NY-BEST). It serves as another important piece to the upstate energy storage ecosystem that has become a driver of economic development in our region. Another emerging capability on campus—which is leveraging our heritage in printing and driving a number of economic development activities—is that associated with additive manufacturing and 3D printing. Whether it is the printing of new prosthetic devices through the e-NABLE program, new battery or solar cell films in the AMPrint Center, or students making the next generation of innovative commercial products in The Construct makerspace, RIT is doing its best to ensure that Rochester remains the printing capital of the world.

I hope you enjoy reading about these and some of the other tools that have helped make RIT's toolkit a category of one.

Best regards,

Ryne Raffaele  
Vice President for Research  
and Associate Provost

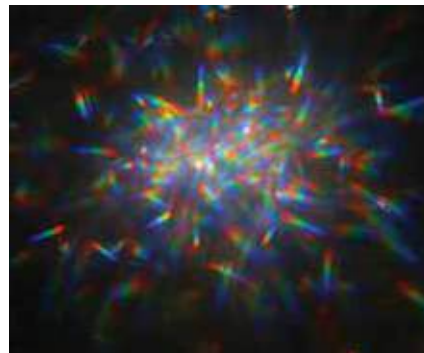


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## On the Cover



Inside view of the growth chamber of RIT's new MOVPE tool that will lead to the next generation of photovoltaic and optoelectronic research. Photo provided by AIXTRON SE.

# RIT in the News

RIT faculty and students are making headlines for their research. Below are samples of some of their newsmaking innovations, discoveries, and activities.



**Super Success:** The video game *Super Daryl Deluxe*, created by two RIT students, won the top prize at Microsoft's U.S. Imagine Cup Finals in the games category. Their game also took first place at the 2015 Intel University Games Showcase. The students (pictured below from left to right) are Gary Porter and Dan Plate.

## Student-Created Video Game Takes Top Prize at Two National Competitions

RIT students Dan Plate and Gary Porter, best friends since high school, are scoring national accolades and money with their co-created video game.

They took the top prize in Microsoft's U.S. Imagine Cup National Finals held in San Francisco in April. Their game, *Super Daryl Deluxe*, won in the games category. They were awarded \$4,000, and advance to represent the U.S. at the World Semifinals. This national recognition comes just two months after the students'

game won first place in the Visual Quality category of the 2015 Intel University Games Showcase at the Game Developers Conference (GDC).

Plate, an illustration major, created the game's visual elements, while Porter, a game design and development major, wrote the code. *Super Daryl Deluxe* is a 2D action role-playing game featuring a customizable combat system and visual style. RIT's MAGIC Spell Studios—the commercial, for-profit component of the Center for Media, Arts, Gaming, Interaction and Creativity—exhibited the game



in its booth at GDC. Plate and Porter expect the game to be released within a year. A free demo of *Super Daryl Deluxe* is available at [superdaryldeluxe.com](http://superdaryldeluxe.com).





Grover Swartzlander

### Could Glitter Help Solve the Cosmic Cost of NASA's Future Telescopes?

Telescope lenses might someday come in aerosol cans filled with glitter.

RIT scientists and the NASA Jet Propulsion Laboratory are exploring a new type of space telescope with an aperture made of smart dust released from a canister and controlled by a laser.

The cloud of glitter would be larger, cheaper, and lighter than apertures on conventional space-based imaging systems like NASA's Hubble and James

Webb space telescopes. The Webb space telescope is scheduled to launch in 2018 at a price tag of \$8 billion.

“Our motivation is to make a very large aperture telescope in space and that’s typically very expensive and difficult to do,” said Grover Swartzlander, associate professor of RIT’s Chester F. Carlson Center for Imaging Science and Fellow of the Optical Society of America. “You don’t have to have one continuous mass telescope in order to do astronomy—it can be distributed over a wide distance. Our proposed concept could be a very cheap, easy way to achieve larger coverage, something you couldn’t do with the James Webb-type of approach.”



**Smart Dust Technology:** This image shows white light reflected off of a glitter mirror onto a camera sensor. Researchers tested this as part of a low-cost solution for space telescope mirrors.

### Scholarship Program Supports Students Pursuing Cybersecurity Careers

A nearly \$4 million grant from the National Science Foundation is helping RIT establish a CyberCorps® Scholarship for Service Program. The grant allows the university to become part of this federal scholarship program established in 2000 in partnership with the Department of Homeland Security in response to threats to the nation’s information technology infrastructure. The program provides full tuition and a stipend in exchange for future government service.

RIT expects to grant six of these scholarships a year for a total of 21 students over the life of the grant.

“Being part of CyberCorps® is very exciting, a great recognition of the quality of our computing security program at RIT,” said Bo Yuan, chair of RIT’s computing security department. “Since our computing security department was established in 2012, our applications and enrollment have grown dramatically. This will help us continue that growth and add to the ranks of highly qualified RIT graduates now working in the field.”



**Secure and Defend:** Cybersecurity students take on industry pros in an information security competition. To help recruit top students to the computing security program, RIT has set up a federal scholarship program.



David Borkholder

### Tool for Detecting Brain Injuries to go on the Market

Blackbox Biometrics Inc., a company that grew out of RIT’s Venture Creations business incubator,

plans to commercially launch its wearable technology that measures whether an athlete may be at risk for a concussion. The Linx Impact Assessment System (IAS) uses a sensor about the size of a stick of gum that fits into a custom headband or skullcap. Using the companion mobile app, parents, coaches, and athletic trainers can monitor the force and frequency of impact to an athlete’s head.

According to a 2013 Institute of Medicine report, up to 3.8 million people per year are affected by a sports- or recreation-related brain injury.

Blackbox founder and RIT professor David Borkholder and his team debuted Linx IAS at the Consumer Electronics Show in Las Vegas in January, where it received three CES Innovation Honoree Awards. The system will be available for purchase later this year.

BlackBox Biometrics also manufactures the Blast Gauge System, a blast dosimetry system that captures exposure to explosive blasts. It’s used by military troops and police officers. Medical personnel on the battlefield can download the critical data to aid the triage and treatment of blast-related head injuries.



**Wearable Head Technology:** The Linx Impact Assessment System (IAS) uses a sensor that fits into a custom headband or skullcap. Using the companion mobile app, parents, coaches, and athletic trainers can monitor the force and frequency of impact to an athlete’s head.



**MOVPE Gas Cabinet:**

View inside the new MOVPE cabinet. This cabinet holds the group III and V source materials that are eventually delivered by the stainless steel pipes to the growth chamber for deposition and nanoscale semiconductor files.



# MOVPE Equipment Changes Everything in Semiconductor Processing

by Michelle Cometa

RIT has a newly acquired metal organic vapor-phase epitaxy system, also referred to as an MOVPE, which grows III-V thin-film crystals. The state-of-the-art tool gives researchers the ability to build high-performance optical and electronic devices and will be a key learning and training resource. This capability was once an outsourced commodity that has now become an in-house function available to RIT researchers as well as the regional Rochester photonics community.

## Impact on Technology and Science

The newly acquired AIXTRON SE metal organic vapor-phase epitaxy (MOVPE) system is a vital piece of semiconductor equipment that can produce crystalline III-V semiconductors, so named because they consist of elements from groups III and V of the periodic table of elements. Metal-organic and hydride molecules are broken down into the constituent elements that are then reorganized on the substrate surface as a thin crystalline film. These crystals have semiconducting properties, with a wide range of materials available from binary, ternary, or higher order combinations of the group III and V elements. The substrate can be other III-V materials, more conventional semiconductors like silicon, or other crystalline or noncrystalline materials, which gives a glimpse at the wide range of possible material combinations available using the MOVPE.

The MOVPE technique has led to many technological advancements in the last 25 years, due in part to its nanoscale control of semiconductor composition and thickness. Some of these advances include the lasers and photo-detectors that power the backbone of the Internet and other long-distance communication systems, many of the transistors used to send and receive signals in our mobile communication devices, high luminous efficiency LED light bulbs, high storage density optical systems such as Blu-ray and some of the highest power conversion efficiency solar cells used both terres-



**Solar Cells:** Seth Hubbard, associate professor in physics and microsystems engineering, holds a high-efficiency solar cell that was grown using an MOVPE tool.

trially and in satellites. The III-V area of research continues to be ripe for scientific discovery and advancement. Some of these areas include study of new material systems for optical and electronic devices, miniature devices based on quantum dots and nanowires, as well as integration of III-V materials with low-cost silicon for both integrated photonics and the next-generation high-speed transistors.

“This tool is the first of its kind at RIT and represents a major equipment acquisition for the university,” said Seth

Hubbard, the project lead and an RIT associate professor in physics and microsystems engineering. “It opens a lot of doors for my research and my colleagues at RIT who work in the areas of photonics, nanomaterials, and microsystems. This tool will allow RIT scientists to explore many new avenues of research that were not possible before.”

## Boost to Research and Economic Development

The equipment was acquired through



**Growth Process:** Michael Slocum, an RIT research scientist and recent graduate of the microsystems engineering Ph.D. program, prepares to load a new wafer in the MOVPE system.

funding from the National Science Foundation, New York State's Empire State Development, the Office of Naval Research, RIT's Kate Gleason College of Engineering, and RIT's Office of the Vice President for Research. The state-of-the-art tool, located in the engineering college's Semiconductor and Microsystems Fabrication Laboratory, represents a major upgrade to the RIT cleanroom user facility. The MOVPE will be used by numerous multidisciplinary research teams including Hubbard's team working in quantum dot structures and solar cells. Other teams will use this tool for integrating III-V materials with silicon for photonics; advancing tunneling

field effect transistors for the next generation of information processors; expanding infrared detector technology to longer wavelengths for astronomy and military applications; and combining carbon nanotubes and solar technology for lightweight space applications.

"We are all asking the question, 'What is next after silicon?' As we approach the limit of what silicon can do toward increasing our computing power, one of the possibilities is integrating III-V materials with silicon to harness the power of photons for optical information processing," said Hubbard.

"In fact, integration of III-V and silicon is a cross-cutting theme to many

of our faculty members' work. For example, in my research area, one of the biggest expenses with III-V solar cells is the substrate itself," Hubbard explained. "Over 50 percent of the solar cells cost is the substrate. By finding innovative methods for combining the III-V layers with alternative, low-cost substrates, we hope to effect a direct cost reduction in the solar cell, which is carried over into reduced cost of the electrical power generated."

#### **Access for Student-Researchers and Industry**

These new frontiers in material development and processes will benefit industrial research and development





**MOVPE Chamber:** The chamber is enclosed in a nitrogen-filled ultra-clean glovebox to prevent contamination. After growth of new materials, the wafers are removed from the glovebox using a specially designed load-lock system.



**Valuable Resource:** The National Science Foundation, New York State's Empire State Development, the Office of Naval Research, and the Kate Gleason College of Engineering provided funding for the MOVPE tool.

teams through more timely experiments, testing, and assessment as well as provide new educational avenues for RIT's student-researchers.

"Students have been actively involved here at the university with III-V device processing, modeling, and testing," said Hubbard. "However, due to our outsourcing of the materials growth, they were never able to deal directly with the MOVPE tool. We now have the ability to have students get involved at all levels of the device cycle, from the birth of the material in the MOVPE tool all the way to the packing of devices."

Added Michael Slocum, an RIT researcher and recent graduate of the microsystems engineering Ph.D. program,

"The MOVPE system will allow us to expand our research interests due to the increased process control capabilities of this reactor. As a recent graduate, I truly appreciate the hands-on exposure students will receive on the MOVPE, which will dramatically increase their ability to learn a technical and valuable skill set."

Regional universities and industry will also have access to RIT researchers and the facilities. The MOVPE process is quite expensive when it's outsourced, but its availability at RIT will allow other universities and small businesses to prototype device designs affordably in a research setting.

"Bringing together scientists and

engineers from industry with RIT faculty and student-researchers will lead to innovation in various industries related to imaging, optics, and photonics," said Ryne Raffaele, RIT vice president of research and associate provost. "It has long been a dream of mine to have this enabling technology at the university and it's gratifying to finally see this dream become reality."

#### On the Web

Semiconductor and  
Microsystems Fabrication Laboratory  
[www.smfl.rit.edu](http://www.smfl.rit.edu)

**Fuel Cell Technology:**

The Golisano Institute for Sustainability (GIS) conducts full-scale testing and has simulation capabilities for fuel cell systems. Mike Waller, Ph.D. candidate in RIT's sustainability program, works on a lab-scale fuel cell to understand its performance when operated on reformed propane.





# Testing Ground for Fuel Cells: From Ideas to Prototypes

by Suzette Norris

In the Fuel Cell Testbed at the Golisano Institute for Sustainability (GIS), doctoral candidate Mike Waller opens up a metal box containing graphite plates, the outer core of a fuel cell. This technology extracts hydrogen from propane and instigates a chemical reaction between the hydrogen and oxygen that exists in the air, generating electricity.

## Applications of Fuel Cell Technology

Using a research grant from the National Institute of Standards and Technology (NIST), Waller is exploring practical methods of applying fuel cell technology to everyday business challenges.

This type of research occurs at other universities across the world, but what gives Waller and other RIT researchers a leg up is the ability to take a project from a small-scale, experimental stage to full-scale testing of a system or even a vehicle—all in the same facility. This sets RIT apart from many other universities working on advanced energy technology.

The testbed attracts research funding from NIST, the U.S. Department of Defense, the Department of Energy, the Environmental Protection Agency, and a host of private companies—large and small—looking to advance the fuel cell market and meet the demand for reliable electric power.

Waller and other RIT researchers focus on practical applications of fuel cell technology. Take, for example, commercial lawn mowers. The majority of mowers use an internal combustion engine that is noisy, run on gasoline (contributing to air pollution), and can potentially leak oil and gas, damaging the grass. Waller wants to use fuel cell technology to convert small amounts of propane into electricity that will ultimately lead to a cleaner, quieter way to operate mowers or other types of vehicles. Applying fuel cells in this way would allow golf course maintenance crews to cut the grass with lower carbon dioxide emissions and without the threat of oil or gas damaging the grass. They'd

also be able to run the mowers early in the morning or at night without bothering the neighbors. Fuel cell systems can run for relatively long periods of time. Even a small, one-pound propane tank (the size people typically take camping) can run a lawn mower for several hours, much longer than existing internal combustion or battery-powered equipment. In the testbed, Waller is able to experiment with fuel cell technology and eventually test his ideas in full-scale prototypes.

## Dynamometers Can “Stress Test” Engines

The Fuel Cell Testbed also offers access to two dynamometers that are used to provide a mechanical version of a “stress test” on engines. Companies working on new engine or exhaust system components, sensors, or alternative fuel technologies can work with RIT to run tests on new fuels or vehicle designs to understand how they would perform on the road.

RIT obtained its first dynamometer through a program with the Department of Transportation that explored alternative fuels such as biodiesel, said Thomas Trabold, associate professor and director of the Center for Sustainable Mobility.

“Today we use it to help companies in New York state and in other regions that are working to improve efficiency and reduce emissions,” Trabold said. Local companies designing various components can run tests and help evaluate performance claims.

That testing capability expanded several months ago with the installation of a full chassis dynamometer, a sort of rolling road that can measure how



**Stress Test Engines:** Dynamometers are part of RIT's Vehicle Dynamics testbed. Companies work with RIT researchers to evaluate new fuels or vehicle technologies on engine and chassis dynos.

different components and fuels perform in an actual vehicle. The room, built in a corner of the GIS building, opens to the parking lot, where a car or other type of vehicle can be driven inside and onto the dynamometer rollers. The dynamometer accelerates the car and can simulate loads such as wind resistance or climbing up hills. Companies have used the tool to test sensors, for example. “We can put a bad part in the car and test to see if a sensor detects it,” Trabold said. “It’s pretty uncommon for a university to have this capability ... it’s much closer to a real application.”

The dynamometers also can be used to test the results of ongoing efforts to convert waste materials, including the university’s waste cooking oil and cafeteria scraps, into biodiesel, ethanol, butanol, and methane-rich biogas for use in RIT vehicles, heating equipment, and engine-generator sets for electricity production.

**Building Pouch Cells Layer by Layer:**  
The stacker machine in RIT's new Battery Prototyping Center builds pouch cell energy storage technologies including lithium ion batteries, supercapacitors, and battcaps.





# Powered Up: RIT Opens Battery Prototyping Center

by Kelly Sorensen

Whether it's consumer electronic devices such as cell phones or electric hybrid vehicles, people are dependent on batteries in their everyday lives. Analysts predict that the global market for batteries will reach \$87 billion by 2018. To help the industry bring the next generation of rechargeable batteries to market, RIT has opened a battery prototyping center.



**State-of-the-Art Equipment:** The semi-automated Z-Fold machine uses robotic arms to stack cathodes and anodes.

## Creating an Energy Storage Ecosystem

RIT's \$1.5 million Battery Prototyping Center officially opened for business in March. The center is another resource in New York state's growing energy storage hub and was made possible by support from New York State Energy and Research Development Authority (NYSERDA), Empire State Development (ESD), and the New York Battery and Energy Storage Technology Consortium (NY-BEST).

"We are excited to be a resource for academic researchers, startups, and established companies who believe they have a promising solution for battery materials," said Ryne Raffaele, RIT vice president

for research and associate provost. "The Battery Prototyping Center will be an important step for them as they test and validate their ideas that could ultimately lead to commercialization."

William Acker, executive director of NY-BEST said, "We are creating a strong energy storage ecosystem in New York state. From R&D to manufacturing, New York state has unique and valuable assets and resources to support the growth of the energy storage industry. This important industry is transforming two major sectors of our economy—transportation and electricity—into cleaner and more efficient industries. By providing

the expert resources needed to develop new advanced batteries, RIT's Battery Prototyping Center will play a pivotal part in that transformation."

The center will work with companies and universities in prototyping the next generation of batteries, including lithium ion batteries.

"We are that bridge for companies to help them move from the concept stage in a laboratory to a working prototype," said Christopher Schauerman, co-director of the center and RIT research scientist. "The goal is to avoid that valley of death in the commercialization stage and help them bring their next generation batteries to mass production."

Currently, the center can prototype pouch-cell-size batteries that resemble those found in cell phones. It's an open user facility that gives companies and researchers access to a dry room and laboratory space for a fee. Companies also have the option of providing their materials and assembly formula to center personnel who would build the battery based on the company's specifications.

"This is a fee-for-service laboratory that anyone can use," said Matthew Ganter, center co-director and RIT research scientist. "It's a great resource for startups and university researchers who can't afford to purchase this equipment or who would not otherwise have access to a facility like this."

There are only a handful of facilities in the country that offer similar prototyping capabilities, including Argonne National Laboratory outside of Chicago and the Battery Innovation Center in Indiana.



**Center Directors:** Research scientists Matt Ganter and Chris Schauerman (left to right), both graduates of RIT's doctoral program in sustainability, are the center's directors.

Even with the Battery Prototyping Center in its infancy stage, Ganter and Schauerman have already had interest from more than 50 companies and universities around the world, including Russia, the United Kingdom, and Canada.

The 2,000-square-foot facility is located on the fourth floor of RIT's Institute Hall and features a 1,000-square-foot state-of-the-art dry room. Keeping

moisture and humidity out is essential for battery performance so the relative humidity in the dry room is less than 0.5 percent. On one side of the dry room is the semi-automated prototyping equipment line.

"It's a pilot line production facility that can produce commercial quality cells," said Ganter. "The equipment can precisely stack dozens of layers of material.

This is much more efficient and reliable than someone working in a laboratory attempting to stack the layers by hand."

SoLith, an Italian company specializing in battery manufacturing testing equipment, manufactured most of the center's equipment.

Once the battery materials are stacked, they are then tested in one of two environmental chambers where their performance can be measured under extreme conditions.

"The chamber is a combination refrigerator and oven so it can do both heating and cooling to test the cell's performance at various temperatures from minus 45 degrees Celsius up to 190 degrees Celsius," said Schauerman.

The dry room is broken up into two areas with the other side set up as a laboratory space for those who want to test battery materials and chemistries in a moisture-free environment. The division of the dry room allows more than one company to use the space at one time and eases concerns about the security of the inventor's intellectual property.

The center is currently equipped





**Prototyping Capabilities:** Panoramic view of the prototyping portion of the dryroom, which is equipped with individual stations necessary to create a pouch cell.

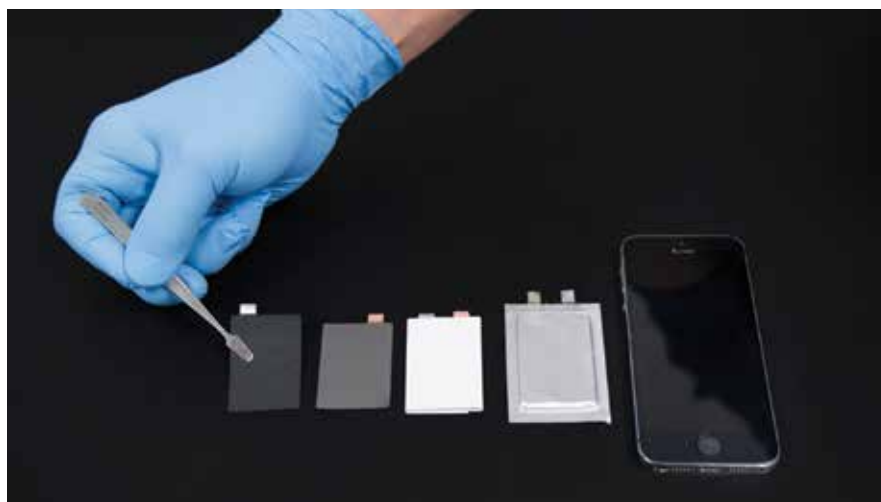
to produce cell-phone-size batteries, but future applications could include prototyping electric car batteries.

“We would like to bring in another line with larger form factors so we could assemble batteries that are similar to those in the Nissan Leaf or Chevy Volt,” said Schauerman.

After the prototypes are made at RIT, companies and researchers can take their technology to the nearby BEST Test and Commercialization Center in Eastman Business Park in Rochester to test the viability and performance of their batteries.

### Working Classroom for Students

RIT’s center will be used not only by companies, but by its own faculty and student researchers. Ganter and Schauerman both earned their doctoral degrees from RIT’s sustainability program. They continue to do their own research on battery innovations and plan to work side by side with students at the center who want hands-on experience in manufacturing batteries for this



**Inside a Lithium Ion Battery:** These different components form lithium ion batteries, which are found in most portable electronics, including cell phones.

emerging industry.

Added Ganter, “My Ph.D. dissertation focused on creating better and more sustainable battery technologies, so there is a direct link between my education here and the work we are currently doing at the Battery Prototyping Center.”

### On the Web

**Battery Prototyping Center**  
[www.rit.edu/batteries](http://www.rit.edu/batteries)

### Video

**Battery Prototyping Center**  
<http://bit.ly/RITBatteryCenter>



**Hands-On Training:** Companies have access to CEMA's production-scale equipment for product development, research, and training.

# Electronics Packaging

by Michelle Cometa

The Center for Electronics Manufacturing and Assembly is an academic research laboratory used by students and faculty for electronic packaging education, and design and assembly projects. The facility is also a research and corporate training resource for industry professionals.

## Electronics and Optoelectronics Research

There is a complex and multidimensional aspect to the lifecycle of electronics, starting with processing silicon for integrated circuits to the development of device prototypes to the final fabrication and packaging stages before a consumer product is brought to the marketplace, said Martin Anselm—and it is a natural progression

from silicon into RIT's Center for Electronic Manufacturing and Assembly (CEMA).

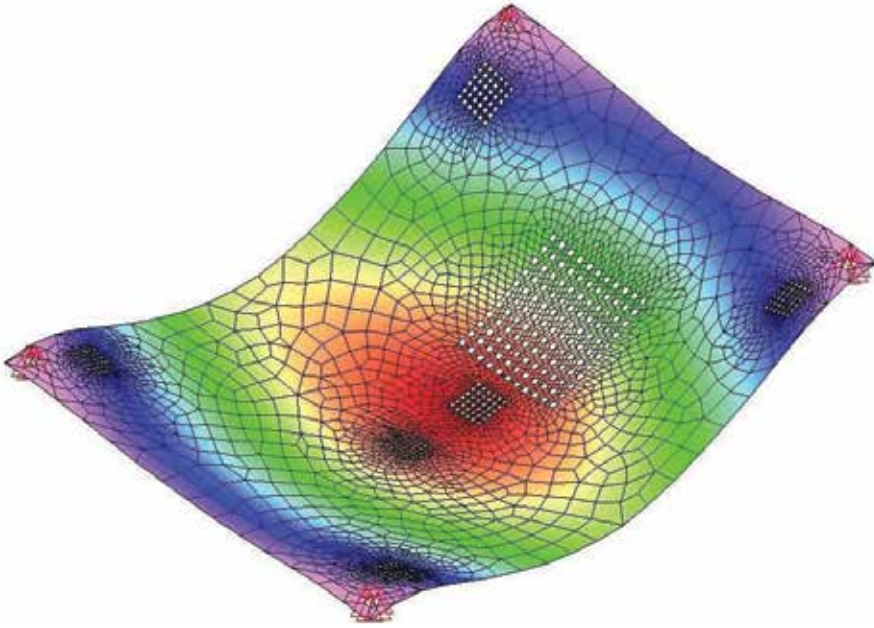
Anselm, assistant professor of manufacturing and mechanical engineering technology in the College of Applied Science and Technology, also serves as the associate director of CEMA.

CEMA is an academic research laboratory and manufacturing facility that is part of RIT's College of Applied

Science and Technology. It's a multi-purpose facility used by students and faculty for design projects, and by industry members for research, product development, and extensive corporate training.

CEMA's capabilities reside in two distinct areas—in developing state-of-the-art electronics assembly and manufacturing techniques using surface





**PCB Assembly Deflection:** Finite element model depicting a PCB assembly under deflection during drop test.

mount technologies, and in the analysis of electronics packaging reliability, production, and performance. The latter area is supported through several of CAST’s packaging science labs, located adjacent to the CEMA facility, for materials analysis, usability, ergonomics, and shock/vibrations testing.

Research into new circuit board technology and materials is coupled with testing facilities focused on strength of materials, predictions of the product’s lifecycle, and failure analysis, all areas important to next-generation manufacturers.

“CEMA is about getting from something that is so small that you can’t even see it to a device that is functional,” said Anselm, who was a process research engineer and manager of failure analysis service for Universal Instruments before joining RIT.

Current research in the lab includes improvements to package-on-package technology—the method used to 3D-stack components on printed circuit boards. Another area is in the transition from using lead-based alloys on circuit boards. Companies are eager

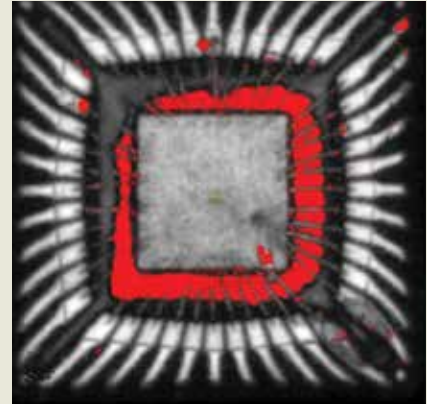
to explore the use of alternative materials to solder components on the boards, and are collaborating with CEMA to test which material fits their needs, Anselm said.

Package-on-package technology is more prominent, but due to restrictions in use of hazardous substances, researchers are testing both the reliability of the new technology and the learning, at the same time, the reliability of lead-free solder.

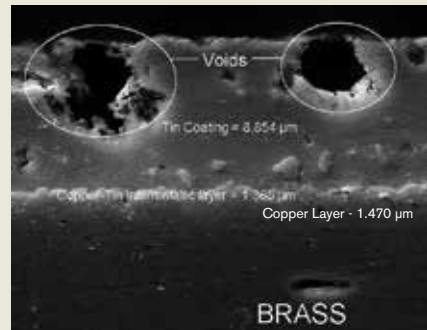
“Over the past decade, CEMA has established a strong presence in the electronics packaging industry for its workforce training and applied research prowess, which we are extremely proud of,” said Manian Ramkumar, director of CEMA, who added that the technology is advancing, and package-on-package arrays will become more prevalent in the manufacturing industry, and may be a means to its resurgence in the U.S.

**On the Web**  
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**Manufacturing and Assembly**  
[www.rit.edu/cema](http://www.rit.edu/cema)

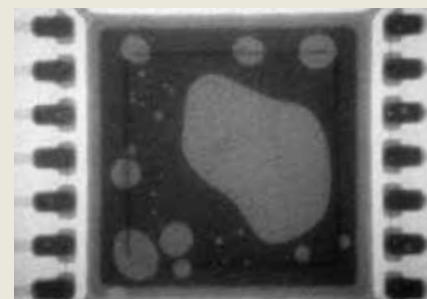
**Some of CEMA’s Methods for Electronics Packaging Failure Analysis**



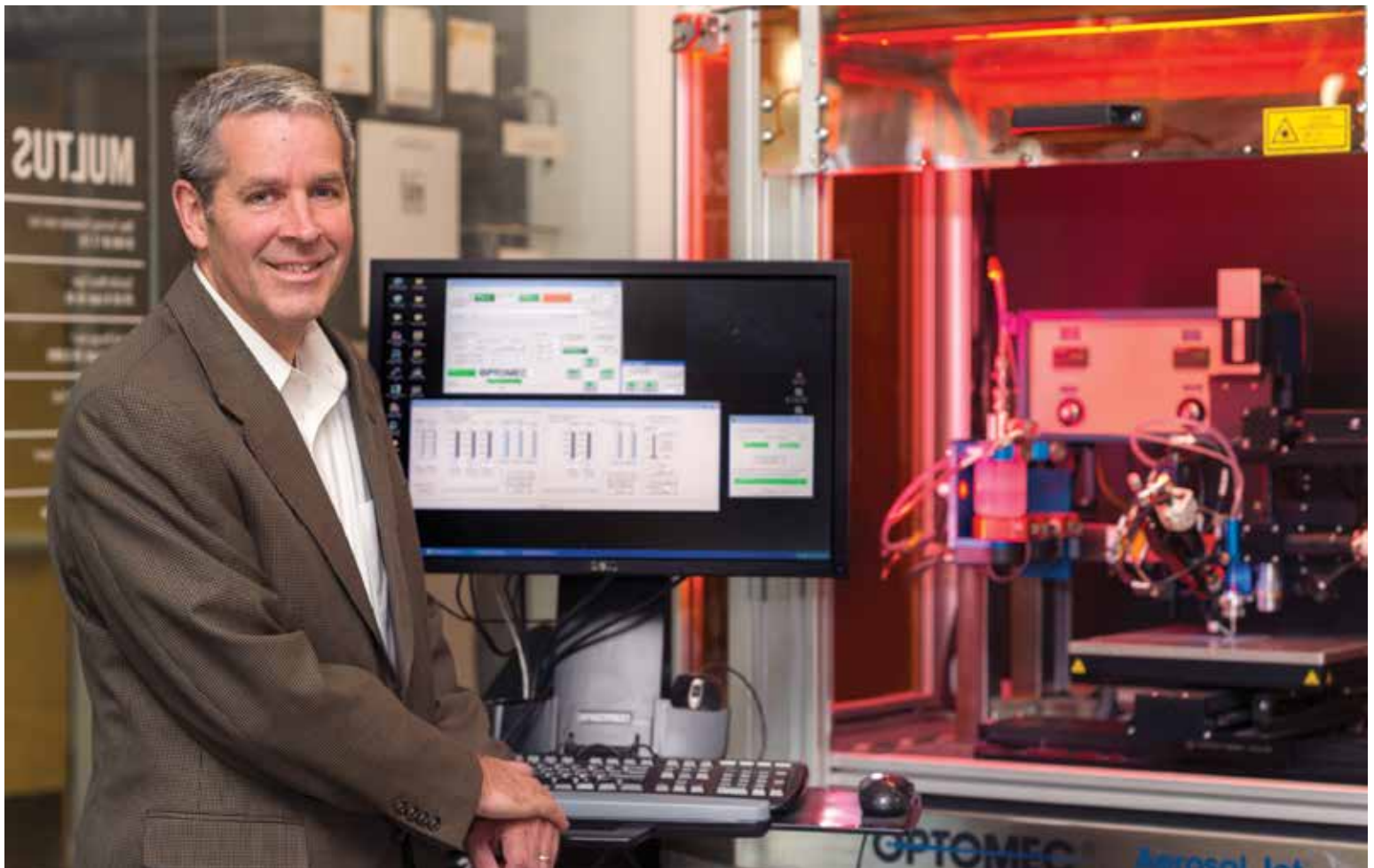
**C-SAM Analysis:** Ultrasonic imaging to analyze the internal defects within components. Analysis reveals die attach adhesive delamination.



**SEM-Analysis:** Scanning electron microscopy analysis revealing plating voids on a pin surface, resulting in surface oxidation and non-wetting.



**X-Ray Analysis:** Solder voids under a QFN thermal pad. The presence of voids affects the thermal performance of these components.



**Multifunctional Printing Capabilities:** Denis Cormier, the Brinkman Professor in RIT's Industrial and Systems Engineering Department, directs the university's efforts in 3D printing, additive manufacturing, and printed electronics.

## RIT is Central to Multifunctional 3D-Printing Ecosystem

by Michelle Cometa

Denis Cormier calls Upstate New York a functional 3D printing ecosystem. He likens it to Silicon Valley because of its collection of high-tech innovators—companies, universities, and people—necessary to make a lasting impression on the rapidly expanding consumer electronics industry and advanced manufacturing processes using 3D printing.

### **Additive Manufacturing and Multifunctional Printing**

In 2012, Cormier, the Earl W. Brinkman Professor in RIT's industrial and systems engineering department, was awarded nearly \$600,000 by the National Science Foundation for a project entitled "Partnership for Innovation in Printed

Devices and Materials." It brought together RIT and Rochester-based company Intrinsic Materials, located in the Eastman Business Park, as well as NovaCentrix and Optomec, national companies that manufacture equipment for print/deposition, nano-inks, and print applications. The university-corporate

partnership collaborates to further develop ink chemistries suited to aerosol jet printing and photonic sintering. The partnerships also target development of multi-material printing techniques to enable the synthesis of devices such as micropumps for drug delivery, organic solar cells, among other new applications.



These focus areas are the key in the market growth in functional 3D printing—improvements to print equipment, new nano-ink materials development, and applications for products built using functional 3D-print technologies. RIT has made significant inroads into training both its students and industry professionals in using functional 3D-printing technologies. The lab partnerships also have expanded to include capabilities in chemical processing, new materials development, and expanded prototyping work for startup companies.

Growth has been so significant since the initial grant and collaborations that Cormier will soon oversee the installation of a new lab at RIT, the Additive Manufacturing and Multifunctional Printing (AMPrint) Center.

Companies make printable nano-inks. Other companies build devices using the nano-inks, but in between it is necessary to fuse the inks into solid form through thermal processing that makes the materials and devices operational. RIT's unique pulsed photonic curing system from NovaCentrix has been an incredible magnet to the lab, said Cormier, because it is the unifying factor for enabling the lab to print devices that blend together multiple materials in ways never before possible.

The NovaCentrix can thermally process and fuse high-temperature metals and ceramics onto low-temperature paper or plastic. These are the foundational materials being used for flexible electronics, considered a targeted growth market for New York state, and specifically for companies in the Eastman Business Park.

“And for that reason, that NovaCentrix system we have is a huge draw for a lot of local companies, both large and small, that bring samples here to test the process,” said Cormier.

Testing processes and products have included faculty from RIT as well as company R & D personnel. RIT chemistry professor Chris Collison has been working with Cormier on developing water-based organic photovoltaic materials that are ink-jet printable. Engineering professor

David Borkholder has utilized the lab capabilities to build nano-structures for a micro-pump, inner ear drug delivery system. Outside of RIT, the lab has had visitors from across the U.S., including startup company Liquid X, a Pittsburgh-based company that makes conductive silver ink.

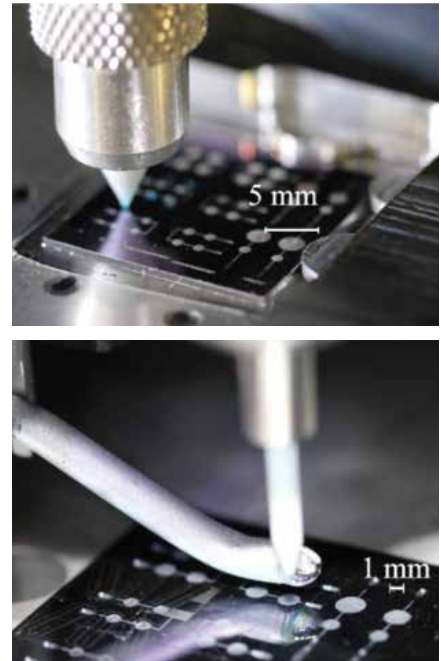
“Initially the company was looking more into photonic curing, and as the project started to evolve, we were having some printing issues,” Cormier explained. A possible solution was modifying the ink chemistry, and to explore this, Cormier engaged Scott Williams, a College of Science chemistry professor with expertise in ink chemistry. The group has since extended the project scope.

Another collaboration is part of a NYSEERDA grant with an LED light bulb manufacturing company in the Albany area. Although LED bulbs are an energy-efficient technology, they are expensive to produce. The company has refined a low-cost manufacturing process, but needs to be able to print the electronics onto molded plastic parts. Cormier will be able to guide them through the process and possibly the use of new materials for developing an even more efficient light bulb.

This integrated use of 3D-printing technologies for mechanical, electrical, chemical, and optical capabilities is an example of the broader focus the group will take through the new AMPrint Center.

For example, printed organic photovoltaic inks can be used to create cost-effective and flexible thin film solar cells that turn sunlight into energy. Printed touch sensors require conductive inks that can be used to make the necessary electrical contacts. Multifunctional printing can be used to print sensors such as medical diagnostic test strips or food spoilage indicators. It's even possible to print material that can be used in thermal applications such as heating and cooling elements for automotive windows like rear window defrosters.

“These are different types of functions, and they are all produced by different materials. All of those materials are



**Functional printing technologies** were used to print a micro-pump, inner ear drug delivery system.

printable, which is the basis of the AMPrint Center,” said Cormier. “We hope to define where 3D printing is going to be five years from now. Rather than just making mechanical parts, 3D-printing processes will soon be able to blend together materials that serve multiple functions to enhance product performance in ways we never thought possible. We believe that is the next big thing, and we believe that RIT will play a large role in making that transformation happen.

“We also believe that Rochester is uniquely positioned to drive the evolution of 3D printing because this region arguably has the largest concentration of print industry expertise in the world. Between the area's universities, companies, and state/federal support, Rochester could very well become the Silicon Valley of multifunctional 3D printing.”

#### On the Web

**Brinkman Lab**  
[www.rit.edu/kgcoe/ise](http://www.rit.edu/kgcoe/ise)

**Passionate Volunteers:**  
e-NABLE is made up of more than 5,100 volunteers from around the world. Jeff Erenstone, a full-time prosthetist and e-NABLE volunteer based in Lake Placid, N.Y., fits 8-year-old Lusie Santangelo with her second 3D-printed arm that gives her more range of motion.





# RIT Scientist Launches Global Network for 3D-Printed Prostheses

by Scott Bureau

Using 3D printers, open-source designs, and a little bit of ingenuity, a group of students and a research scientist at RIT are helping to advance the quality of prosthetic devices and make them available to everyone.

## Printing Affordable Prosthetic Devices

In the past four years, the emergence of affordable 3D printers and the do-it-yourself Maker movement have sparked a revolution in prosthetic devices. Just as a painter uses layers of paint and specific brush strokes to create art, a 3D printer uses specific digital instructions to lay down layer upon layer of plastic to create a finger or palm.

The customized parts are then assembled using string, nuts, bolts, and Velcro from an everyday hardware store. The total cost is less than \$50, nowhere near the thousands of dollars people pay for traditional prosthetic devices.

“This is an inexpensive process that can be completed by almost anyone, especially now that many schools and libraries have 3D printers for people to use,” said Jon Schull, a research scientist in RIT’s Center for Media, Arts, Games, Interaction and Creativity (MAGIC).

In 2013, Schull created the online community e-NABLE, a group that is advancing the development of these affordable devices by connecting 3D-printing hobbyists and professionals with people in need of prostheses. Today, the popularity of e-NABLE has exploded with more than 5,100 volunteers helping at least 500 people around the world.

At RIT, more than a dozen students, alumni, and volunteers have joined Schull. Using their design and biomedical engineering skills, they hope in the future to take these assistive devices beyond children with birth abnormalities to help people who have lost limbs due to war and violence, natural disasters, or disease.

In May 2014, RIT students developed a prototype and design for e-NABLE’s first 3D-printed mechanical forearm (the “RIT



**Hand for Lucas:** Lucas LeMay, 10, at home with his dog. Lucas was born without fingers on his right hand. RIT students made him a 3D-printed mechanical hand.

arm”), which they donated to two recipients in Buffalo. The team is now working to create exoskeleton devices and more effective arms and hands to augment or replace muscles. They also are collaborating with a Johns Hopkins University research lab.

“I think that the technologies and practices that Jon and the students at RIT are helping to create could significantly improve millions of lives worldwide,” said Dr. Albert Chi, a trauma surgeon at Johns Hopkins Hospital and world-renowned researcher on state-of-the-art prostheses. “Now is the time to bring e-NABLE’s collaborative approach to design and democratization of 3D-printed prostheses into mainstream medicine.”

## Putting e-NABLE on the Map

Born in Shanxi, China, a mining area about 300 miles southwest of Beijing, Lucas LeMay would wake up every morning to streets covered with inches of coal dust. He was living in a province that saw a rate of birth defects six times higher than the national average.

But in 2008, everything changed. Jim and Kim LeMay traveled to the city in search of a son. They fell in love with the shy, clever 4-year-old boy and decided to adopt him. Lucas was still adjusting to life with a big sister, Lindy, and his dog, Chance, in Walworth, N.Y., when the first 3D-printed hand was created in 2011.

As the story of that first hand goes, after a South African carpenter named Richard Van As sawed off most of the



**e-NABLE at Work:** e-NABLE founder Jon Schull and professional studies graduate student Jade Myers hold a plaster cast of Lucas' hand and measure where Lucas' wrist will bend.



**Pace of Innovation:** A computer-aided design program helps e-NABLE volunteers create and scale a 3D-printed hand (top). In-progress parts of a 3D-printed hand (bottom).

fingers on one hand in an accident, he became determined to get back to work. Because he couldn't afford a prosthetic device, he turned to the Internet to learn how to make one.

He connected with Ivan Owen, an American prop maker who had created a mechanical puppet hand, and together the pair from halfway around the world designed and produced a working hand for the carpenter. By flexing his wrist, Van As was able to control the fingers, which were attached to cable "tendons" that would tighten and relax the hand's grip.

They also created a hand for a 5-year-old in South Africa, who, like Lucas, was born without fingers on his right hand due to a congenital condition called Amniotic Band Syndrome. ABS is the result of fibrous bands that wrap around a hand or a foot in utero and cut off circulation. About one in 1,200 children born every year has underdeveloped fingers and limbs as a result of the condition.

Although the first hand was designed with aluminum, Owen decided that using plastic parts created by a 3D printer would save time and money. Calling it

the Robohand, they posted a crude 3D-printable design and an instructional how-to video online for anyone to use.

"When I came across that video, I immediately got excited," said Schull. "Comments on YouTube videos are rarely inspirational, so what I saw amazed me," said Schull. "People were saying, 'This is cool, I have a 3D printer and I'd do this.'"

Schull then had the idea to create a custom Google map and linked it to a comment of his own. He simply said, "If you're willing to receive inquiries from people who need an assistive device, put yourself on this map. Crowd source the distribution network."

Within six weeks, there were 70 pins on the Google map—e-NABLE was created.

### **Making a Difference**

For the LeMays, there was never an urgency to purchase a commercial prosthetic hand. Lucas had visited a doctor when he first came to the United States, but it would have cost thousands of dollars. And he didn't need one.

"He's very clever," said Kim LeMay. "He's figured out his own way to play the Xbox and he's even learning how

to play the guitar."

However, when a friend posted a link to e-NABLE on Kim LeMay's Facebook wall, she was intrigued.

As Lucas got older, he did encounter a few activities where more grip would be useful. A second hand could put more power behind his baseball swing and steady his basketball shot.

At this point, the e-NABLE community had grown to almost 1,000 members worldwide, and Schull and RIT students were playing a crucial role in its success.

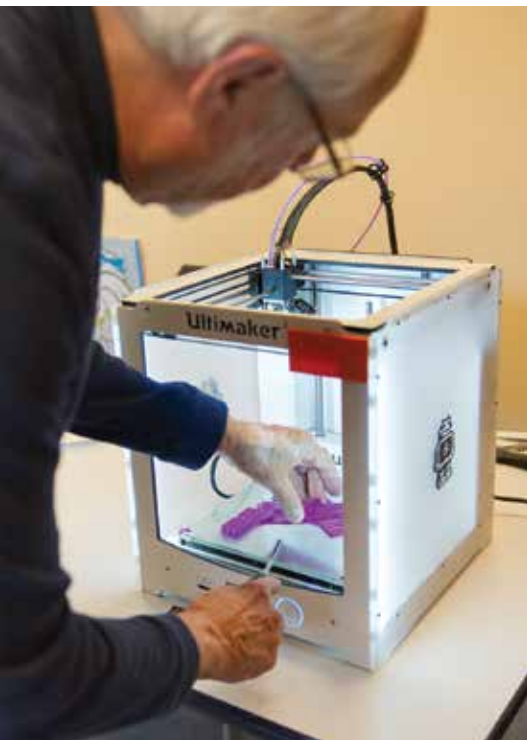
When 10-year-old Lucas visited RIT for the first time in June 2014, the local group had already created two arms and three hands.

Jade Myers, a graduate student in RIT's professional studies program, designed and built Lucas's new hand. It was a natural fit, even though it was the first 3D-printed hand she had ever built.

Having always had an interest in prosthetic devices, she came to RIT with plans to tailor her major toward prosthetic design, robotics, and cybernetics.

"I happen to know a lot of veterans who have waited years to get a prosthetic device, and that's just not right," said





**Printing of 3D Arm:** Skip Meetze, a full-time volunteer on RIT's e-NABLE team, oversees the printing of Lusie's new arm.



**Assembly Required:** After the prosthetic device is printed, Meetze assembles Lusie's arm with a natural grip posture.



**Testing It Out:** Lusie picks up an object on the table in the e-NABLE lab. More adjustments need to be made to the fit of her new arm and the size of the fingertips.

Myers. “If we have the ability to build people an affordable alternative that can help, then we really need to be doing it.”

While building Lucas' hand, Myers encountered a few complications. They learned that they needed to make the shell level thicker because the plastic was splitting.

“There is certainly a learning curve for building these devices, and there are always more improvements to make on your design,” she said.

The family of 8-year-old Lusie Santangelo of Greece, N.Y., has also learned that with these printable prosthetics comes room for improvement.

Lusie, who was adopted as a baby from Armenia, was born without most of her forearm, also due to Amniotic Band Syndrome. Like Lucas, Lusie had reached an age where a prosthetic arm would help her be more active, said her mother, Kathy Santangelo. Lusie wants to swing on the monkey bars at recess, ride her bike down her driveway, and ring the bell in her bell choir. In the fall of 2014, the RIT team fitted Lusie with an arm, but it provided limited functionality because the elbow-activated string tensioner on her arm did

not allow for full arm movement.

Schull and Skip Meetze, a full-time volunteer on RIT's team and a retired Xerox engineer, connected with prosthetist Jeff Erenstone, an e-NABLE volunteer based in Lake Placid, N.Y., whose full-time job is making orthotics and prosthetics for amputees out of carbon fiber and titanium. Erenstone got involved with e-NABLE because of the impact he believes it will have on people in developing countries. He developed a design—called the Monette—that utilizes a shoulder harness and a custom-fitted socket that is molded using heat. In April 2015, the Santangelo family returned to RIT to meet with Erenstone, and he fitted Lusie with a new printable arm using the Monette socket design.

“A custom socket is crucial to the proper fit of a prosthesis for a transradial patient,” said Erenstone. “And this was the first time this design has ever been fitted on someone. To be able to print and fit Lusie with a new 3D-printed arm in just a few hours is something that would take me weeks to do at my prosthetist practice,” said Erenstone.

Erenstone will travel to India soon

to fit a little boy with an arm like Lusie's. It's volunteers like Erenstone that Schull believes will help e-NABLE grow in both numbers and impact.

“I see the community working together to create a variety of assistive technologies,” Schull said. “e-NABLE really only works because we have so many professionals, volunteers, and recipients who are willing to collaborate and help each other.”

Erenstone agrees and says volunteering for the e-NABLE community is addictive.

“It's the engineering and seeing these designs progress and understanding where the potential is that makes it exciting for me. I really like working with these incredible designers around the world. This is a solution for a big world problem and to be part of that feels pretty good.”

#### On the Web

e-NABLE  
<http://enablingthefuture.org>

#### Video

e-NABLE  
<http://bit.ly/RITeNABLE>



**Digital Reproduction:** Using a 3D laser scanner, Mike Bradley, a materials lab technician at RIT, creates a digital reproduction of a hand-carved pillar from St. Patrick's Cathedral in New York City.

## Lab Helps Companies, Government Apply Digital Technology to the Real World by Suzette Norris

The convergence of new technologies such as advanced software, new materials, and three-dimensional printing (to name a few) is changing the face of manufacturing, and creating massive business opportunities.

### **Digital Manufacturing and Product Realization Lab**

To explore how technology can make business more competitive, companies in and outside of New York state are looking to RIT's 3,300-square-foot, \$3 million Digital Manufacturing and Product Realization Lab on the fourth floor of the Golisano Institute for Sustainability (GIS),

which opened last year.

The lab contains software and equipment used to design and simulate electromechanical devices, build prototypes, and conduct product testing and inspection. Woerner Industries, a 100-year-old manufacturer in Rochester, found that the equipment and expertise of GIS staff provided them with a compet-

itive edge. Woerner, which manufactures woodwork, furniture, and other items for church interiors, wanted to bid on a high-profile renovation project at St. Patrick's Cathedral in New York City, but needed to find a cost-effective way of replicating the original hand-carved decorative woodwork required for the job.

The firm brought a sample of a hand-





**Digital Manufacturing:** A view of the GIS' Digital Manufacturing and Product Realization Lab. The \$3 million facility, which supports design, prototyping, and testing of new products, opened in fall 2014.

carved pillar to the Digital Manufacturing and Product Realization Lab. The lab's 3D laser scanners created a digital reproduction of the pillar using special design software. The data was then converted into a computer-aided design (CAD) model that could be used on Woerner's own computer-controlled machine tools. The CAD model was so precise that it accurately captured the complex contours of the carvings. Working in the lab alongside its staff enabled Woerner to submit a competitive bid and explore additional business opportunities.

GIS is a member of the Digital Manufacturing and Design Innovation Institute (DMDII) led by UI Labs in Chicago, and is working with companies and universities from across the United States. DMDII is focused on research to

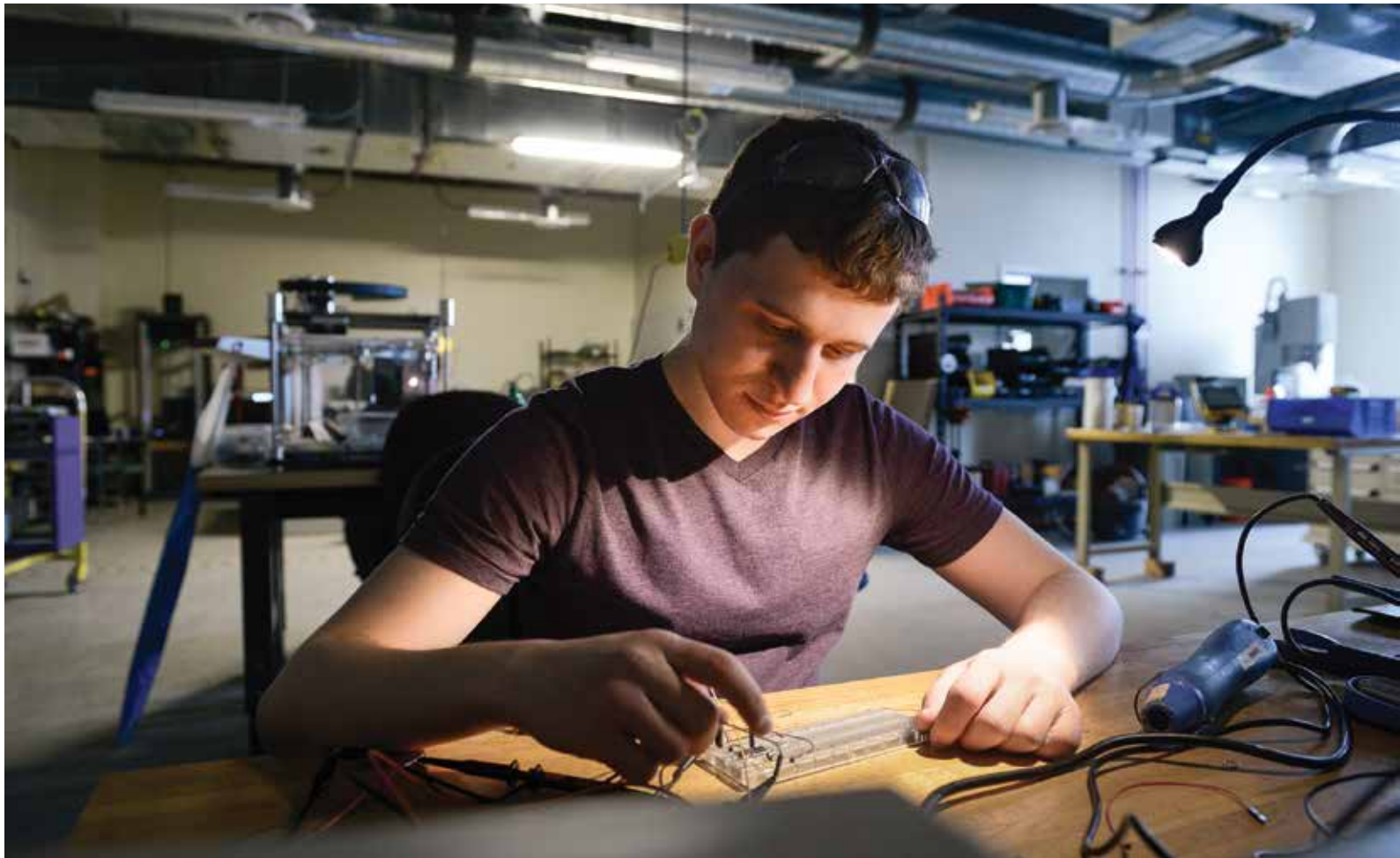
expand the utilization of digital data in integrated design and manufacturing, said Michael Thurston, RIT research professor and director of the New York State Center of Excellence in Sustainable Manufacturing. "It is good to see the investments that are being made in manufacturing research," said Thurston. "The companies involved and the Department of Defense see digital manufacturing as a key to reducing development time and cost, and improving U.S. competitiveness."

### **3D Printers Cut Prototype Time and Cost**

The lab also provides access to 3D-printing technologies in plastic and metal, including the unique Optomec LENS technology—a high-power laser used to fuse powdered metals into fully dense, three-dimensional

structures. "We work with companies of all sizes to generate and evaluate ideas on how these new technologies apply to their products," Thurston said. "Our goal is to help New York state-based companies look at how they can apply these technologies to become more competitive."

For example, traditional tooling processes often can take several weeks to produce prototype parts. The wait time can lead to increased costs and development time, especially if multiple design modifications are required. With simulation-based design, it improves the likelihood that designs are right the first time. Rapid prototyping (including 3D printing) allows designs and design modifications to be fabricated and tested much more quickly, accelerating product development cycles and cutting costs, Thurston said.



**Makerspace:** Roy Cohen, a computer engineering student, prototypes some electronics in RIT's new makerspace called The Construct. The facility opened in October 2014.

## Dream Big: You Can 'Make It' at The Construct

by Marcia Morphy

The Construct Labcam says it all: Nerds in their natural habitat. Do not feed.

The atmosphere at RIT's communal makerspace is a bit like an episode of "The Big Bang Theory." There is unabashed geeking-out on science and technology, but there is also an enthusiasm for just making something that is truly infectious for all sorts of students.

### **Tinkering Welcome**

Under the helm of the Simone Center for Student Innovation and Entrepreneurship, The Construct relocated to its permanent home on the fourth floor of Institute Hall in October 2014. Turning right from the elevator, students gain entry to a 3,000-foot, brightly lit, loft-like hive of

innovation where they can gather together to build or take things apart.

"The Construct is a university-wide resource available to all students at RIT," said Richard DeMartino, director of the Simone Center. "It was developed in large part through student leadership and the assistance of many faculty from the

colleges who recognized the importance of creating a safe place for students to create their own innovations."

Tinkerers at The Construct have access to a variety of high-tech and low-tech equipment: CNC router and mill, laser cutters, 3D printers, drills, saws, soldering irons, electronic circuitry, and





**Precision Machinery:** A CNC mill used to cut metal is just one of the pieces of machinery in the lab. The Construct is a communal space for all students.



**Promoting Ingenuity:** Matthew Glazer, an electrical engineering student, tinkers with his electric long board that he revamped in the makerspace.

woodworking and metalworking supplies.

Open to all disciplines and skill levels, the communal space can be used for self-directed projects, entrepreneurial ventures, and even tasks as seemingly mundane as fixing high-tech gadgets when they break.

Take it from three Kate Gleason College of Engineering students who have found the workspace invaluable.

Roy Cohen, who hails from Tenafly, N.J., claims it was the labs and the co-op program that led him to RIT. Now he is fulfilling part of his dream at The Construct, where he also works as a part-time lab manager. “The Construct is the perfect place for our club, the RIT Launch Initiative, to build a high-powered amateur rocket engine because everything is under one roof—3D printers, laser cutters, soldering equipment, and high-precision machinery like the CNC mill to cut metal. If you want to build something, these are the kinds of tools you don’t have in your garage or dorm room.”

Matthew Glazer, a senior from Long Beach, N.Y., agrees. He’s been using the lab to revamp his electric long board that enables him to reach speeds of 15-20 miles per hour. “I’ve always wanted to tinker around and so after I bought my Enraged Panda Board as a freshman, I’ve installed LED lights on the sides and a power box with rechargeable batteries. I can’t say enough about the lab because it’s a place where you can get help and advice while working on your project.”

And then there’s Samuel Feine from Houston, who said he started building things as a child—from little cities made out of recycled materials to a bedroom door lock with radio-frequency identification. He believes the sense of like-mindedness is the connecting thread of students who come to The Construct.

“It’s a different education model where we learn through doing and can help one another and meet people who share the same interest.”

All agree that the best part of the lab is “the cool tools that are available when you have a shared resource.”

But above all, it’s safety-first for lab manager Michael Buffalin, who constantly monitors student progress at work stations with help from trained student lab assistants who are experienced in handling the equipment.

“The Construct caters to the inventor mentality, the entrepreneur who wants to take that extra step while here at college and who doesn’t have access to other labs,” said Buffalin. “It could be a business student who wants to make a sign, a design student who wants to make housewares. Anything and everything is possible here.

“The Construct is a lab for anyone who has an idea or a dream.”

**On the Web**  
The Construct  
[hack.rit.edu](http://hack.rit.edu)



**Antennae Galaxies:**

Captured by the NASA/ESA Hubble Space Telescope, this image shows two galaxies—NGC 4038 and NGC 4039—and their supermassive black holes in the process of colliding into each other. Credit: ESA/Hubble & NASA.



# Wonders of the Universe Draw Multidisciplinary Researchers

by Susan Gawlowicz

Scientists at Rochester Institute of Technology's Center for Computational Relativity and Gravitation simulate extreme astronomical phenomena in the universe on supercomputers. Their work explores the inspiral and mergers of binary black holes and neutron stars, the implosion and explosion of core-collapse supernovae, and the accretion of matter in disks encircling and feeding black holes.

## Computational Relativity and Gravitation

Research conducted at the center is tied to Einstein's Theory of General Relativity, first published in 1915. His ideas redefined gravity and foresaw contemporary astrophysics. Einstein envisioned gravity as the geometry of space-time—the fabric of the universe—instead of as the Newtonian concept of force.

Center Director Manuela Campanelli and her colleagues are celebrating the centennial year of Einstein's famous theory with invited talks and a conference and workshop at RIT in May, among other activities.

The Center for Computational Relativity and Gravitation (CCRG)—a research hub and an RIT Research Center of Excellence in the College of Science—has won nearly \$7 million in federal grants since it formed in 2007. The center consists of 26 members, including 10 faculty, administrative staff, postdoctoral researchers, and Ph.D. students. Last year, assistant professors Richard O'Shaughnessy and Jason Nordhaus joined the team.

Faculty members affiliated with the center hold positions in three different colleges at RIT: the School of Mathematical Sciences and the School of Physics and Astronomy in the College of Science; the Department of Computer Science in the Golisano College of Computing and Information Sciences; and the Department of Science and Mathematics in the National Technical Institute for the Deaf.

Likewise, the center is affiliated with

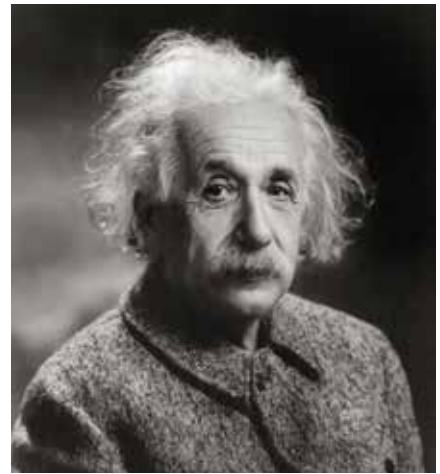
the astrophysical sciences and technology Ph.D. program and MS graduate programs—applied and computational mathematics, computer science, and data science. Future affiliations will draw upon two programs pending approval, a Ph.D. in mathematical modeling and an MS in physics.

“When it was created it was one of only a few centers of its kind,” said Campanelli, professor of mathematics and program faculty in astrophysical sciences and technology. “It's a model that has been repeated at other universities. The CCRG is now one of the largest and most renowned research groups in gravitational physics in the world.”

## A New Era for Astrophysics

Einstein's prediction of gravitational waves and the black holes that produce them still impacts and inspires new fields of research, Campanelli said.

General relativity led to numerical relativity, a specialized field of study that involves solving Einstein's equations with sophisticated mathematics and supercomputers, and further offshoots like computational relativistic astrophysics, gravitational wave astrophysics and observations, and galactic and stellar dynamics. Solving Einstein's equations draws upon mathematics, astrophysics, and computer programming, requiring expertise in mathematical modeling, high-performance advanced computation, data analysis and statistics in connection with big data and scientific visualization.



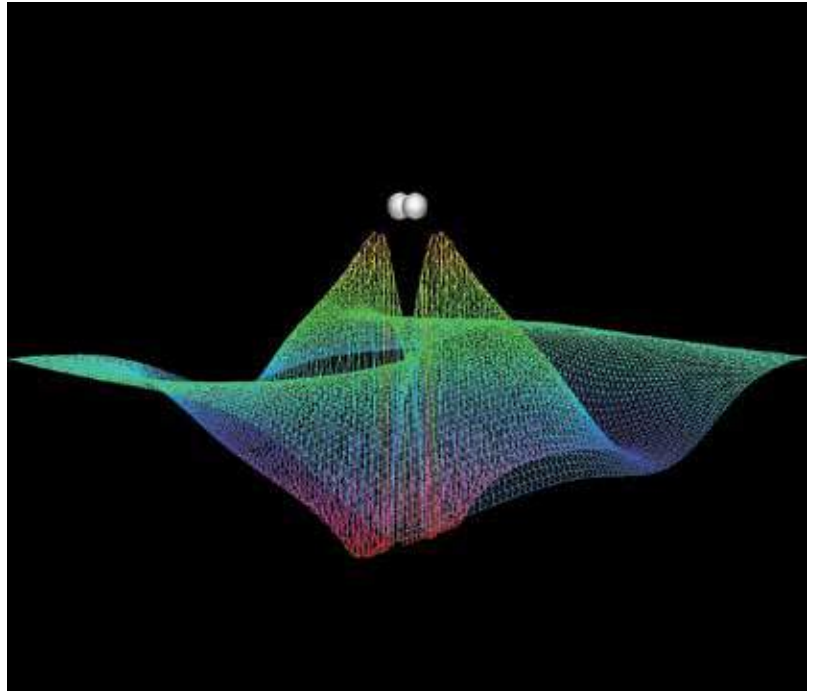
**Einstein's Theory:** The Center for Computational Relativity and Gravitation uses massive supercomputers to study Einstein's general relativity equations connecting matter, space, and time. The year 2015 marks the centennial of Einstein's Theory of General Relativity.

Contributions from Campanelli and professors Carlos Lousto and Yosef Zlochower have advanced numerical relativity over the last decade. In 2005, while at the University of Texas at Brownsville, the team, led by Campanelli, made a scientific breakthrough that computationally solved Einstein's strong field equations to describe the merger of two black holes and the resulting gravitational waves.

Simulations of gravitational waves are the blueprints other scientists will use to observe actual gravitational waves at observatories in Hanford, Wash., and Livingston, La., and other advanced detectors in the world. Campanelli,



**Gravitational Waves:** The LIGO Hanford Observatory is part of a network of ground-based detectors working to detect and measure the form of gravitational waves. RIT is among the nearly 80 institutions that compose the LIGO Scientific Collaboration.



**Supercomputer Simulation:** An 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.

Lousto, O’Shaughnessy, and professors John Whelan and Hans-Peter Bischof belong to the international LIGO Scientific Collaboration, along with several Ph.D. students and postdoctoral researchers. Hundreds of scientists analyze data taken by the Laser Interferometer Gravitational Wave Observatory (LIGO) and other detectors searching for gravity waves emitted by the violent collisions of massive astrophysical systems. Contributions of LIGO scientists have advanced gravitational physics with the anticipation of direct observations of gravitational waves by the end of the decade. The CCRG’s gravitational wave data analysis group, led by Whelan and O’Shaughnessy, works within the LIGO Scientific Collaboration to develop and implement methods to detect and interpret gravitational wave signals in the advanced detector data.

“So far, in astronomy, we’re looking at

the universe with electromagnetic waves, signals that come to us from the stars traveling at the speed of light,” Campanelli said. “Gravitational waves, which also travel at the speed of light, are a completely new form of radiation. It’s not the same spectrum. The shape of the gravitational waves—the way the energy is distributed—will tell us what the source was. They can even help us probe the universe fractions of a second after the Big Bang.”

The center’s signature projects simulate the inspiral and merger of binary black holes using various permutations of mass and spin. Campanelli, Lousto, and Zlochower are authors of numerous papers that have led to the famous discovery of large gravitational-radiation recoils (up to 5000 km/s) from merging spinning supermassive black holes, the study of spin dynamics effects, such as spin-flips, precession and hang-up orbits, and extreme mass-ratio binaries.

More recently, a focus on extreme pairs of spinning binaries of black holes, led by Lousto and postdoctoral researcher James Healy, revealed a new discovery, dubbed the “spin flip-flop” effect. The work, which was recently accepted by *Physical Review Letters*, demonstrates that a pair of spinning black holes under certain conditions can completely reverse their spins in just a few hundreds of orbits, possibly producing shocks and electromagnetic signatures in their surrounding accretion disks.

In a departure from her gravitational-wave studies, Campanelli is exploring electromagnetic emissions resulting from black holes and their accretion disks at the centers of quasars—the cores of primitive galaxies—and the surrounding magnetized gas. She and her Ph.D. students, Dennis Bowen and Brennan Ireland, are collaborating with a large team of scientists both at RIT and at other universities such as Johns Hopkins



University, the University of Tulsa, and the University of Kyoto.

In a related project, professors Nordhaus and Joshua Faber are working to solve the equations of magneto-hydrodynamics to learn what happens when stars are tidally disrupted by supermassive black holes residing at the center of galaxies.

### Black Hole Lab

At the heart of the center is the Black Hole Lab and its advanced computer clusters NewHorizons and BlueSky. The facility showcases the center's research and its commitment to green computing. Opticool Technologies, an in-rack green cooling solution installed in 2012, has a 60-ton cooling capacity. It is more efficient than traditional HVAC solutions and safer than water-based solutions that could develop faulty cooling lines, Campanelli noted.

BlueSky Linux is a 1040 processor cluster with more than four terabytes of onboard DDR3 RAM and 200 terabytes of high-speed Lustre-based storage interconnected with a QDR InfiniBand network. NewHorizons is a 736 processor Linux cluster with 3 TB of onboard RAM and over 100 TB of storage.

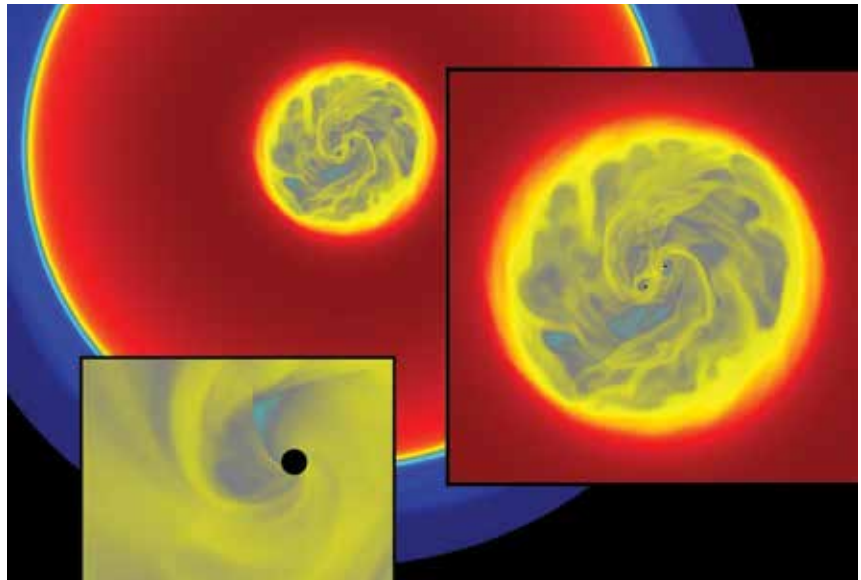
Scientists at the center supplement the Black Hole Lab with supercomputing resources at the National Center for Supercomputer Applications. Some of their largest simulations are done at the peta-scale Blue Waters system at the Illinois' National Center for Supercomputer Applications (NCSA) and XSEDE resources. "This is one of the most powerful supercomputers in the world available for open scientific research," said Campanelli. "Our resources, combined with CCRG's key experts in the field, are why we are one of the main contributors to the rapid growth of gravitational physics."

#### On the Web

Center for Computational Relativity and Gravitation  
[ccrg.rit.edu](http://ccrg.rit.edu)

#### Video

Center for Computational Relativity and Gravitation  
<http://bit.ly/RITCCRG>



**Orbiting Black Holes:** A simulation of hot magnetized gas accreting onto a pair of orbiting black holes performed by CCRG researchers at the National Center for Supercomputer Applications.



**Black Hole Lab:** The NewHorizons and BlueSky computer clusters in the Black Hole Lab.



**Multidisciplinary Researchers:** RIT faculty, postdoctoral researchers, and students of various disciplines compose the Center for Computational Relativity and Gravitation.



**Center-Based Research Model:** The Deaf Studies Lab (DSL) is one of five research centers housed in Rosica Hall. Each of the centers focuses on one of NTID's core research themes, such as teaching and learning, communication, access technology, and employment success.

## Sandbox for Research

by Kelly Sorensen

The opening of Rosica Hall gives form to the National Technical Institute for the Deaf's (NTID) new approach to research. In 2010, NTID began to disband its Department of Research that focused on individual research initiatives and adopted a center-based research model to foster cross-disciplinary collaboration.

### Rosica Hall

"It's a tremendous advantage for us to have a dedicated space in which faculty and students who are interested in research can come together to brainstorm ideas," said Gary Long, NTID interim associate dean of research. "We've created this engaging environment, a sandbox for research if you will, that wasn't here before."

The 23,000-square-foot facility serves as a hub for cross-disciplinary learning and promotes teachers/scholars working collaboratively on research projects with

students and colleagues from NTID, other colleges, and universities. The five centers housed in Rosica Hall focus on NTID's core research themes, including teaching and learning, communication, access technology, and employment success. To date, federal agencies have awarded Rosica's centers over \$6.7 million in funding for collaborative initiatives.

- **The Deaf Studies Laboratory (DSL)** studies the effect of sign language learning and audism on deaf

individuals' cognition, education, and health. The DSL also operates the NIH-funded Rochester Bridges to the Doctorate Program, a program of mentoring and support for deaf and hard-of-hearing graduate students as they prepare to enter a doctoral program in behavioral or biomedical research. The current Bridges scholars are enrolled in environmental science, applied statistics, and experimental psychology. DSL has also received more than \$5 million in funding from the NSF.





**State-of-the-Art Facility:** Rosica Hall opened in the fall of 2013 and serves as a research hub for NTID. The facility incorporates the maximum amount of natural light, open line-of-sight paths, and wide hallways to facilitate interaction.

- **Technological Education Center for Deaf and Hard-of-Hearing Students (DeafTEC)**

is an NSF-funded Center of Excellence that supports high schools, community colleges, and employers with deaf or hard-of-hearing constituents across the country. DeafTEC’s goal is to increase the number of deaf and hard-of-hearing students entering into science, technology, engineering, and mathematics (STEM) related careers. DeafTEC offers training and educational programming used by educational institutions and employers in Florida, Texas, and California.

- **Research on Employment and Adapting to Change (REACH) Center for Studies on Career Success**

conducts collaborative research on the career outcomes of deaf college graduates. The University of Rochester is currently collaborating with the REACH Center on a project that investigates stereotype threat effects on deaf and hard-of-hearing students’ performance on mathematics tests.

- **The Research Center for Teaching and Learning (RCfTL)**

is founded upon NTID’s commitment to bring faculty together from different disciplines to enhance deaf education. It’s currently collaborating with RIT’s College of Science on an NSF-funded initiative to develop online tools and strategies that present complex statistic concepts to deaf and hard-of-hearing students. The center has also participated in research projects about teaching deaf and hard-of-hearing students that are led by colleagues across the university.

- **The Collaboratory on Economic, Demographic, and Policy Studies**

collects demographic, economic, and occupational data on NTID alumni to determine the impact of a postsecondary education on people who are deaf or hard of hearing. One of the agencies the collaboratory partners with is the Social Security Administration.

From its conception, Rosica Hall has been a collaborative space. Deaf and hard-of-hearing faculty, staff, students, and alumni were invited to contribute to the building’s design plans, and an NTID alumnus was one of the architects. Throughout the two-story building there are technology-rich workspaces, including writable walls and mobile white boards that make it easy for students and faculty to display ideas and solve problems together.

Added Long, “The building’s features and amenities are just part of our overall strategy to grow our research funding and engage undergraduates and master’s level students in the research process.”

**On the Web**

**National Technical Institute for the Deaf**  
[www.ntid.rit.edu](http://www.ntid.rit.edu)

# Faculty and Student Achievements



Mishkat Bhattacharya

## CAREER Award Recognizes Promising Research of Three Professors

Three RIT professors have received the prestigious National Science Foundation's Faculty Early Career Development (CAREER) Award. The recipients are Mishkat Bhattacharya, assistant professor of physics in the College of Science; Casey Miller, associate professor of materials science in the College of Science; and Gabrielle Gaustad, RIT assistant professor in Golisano's Institute for Sustainability.



Casey Miller

Bhattacharya will use his \$450,000 grant to examine the continuing demand for better optical sensing of mechanical rotation devices used in fields such as nanoscience, precision measurement, remote sensing, and quantum computing.



Gabrielle Gaustad

"The study of rotation is very important—since rotation is what makes the world go 'round," said Bhattacharya. "In fact, society today relies critically on technologies that sense mechanical rotation. The proposed research is designed to investigate situations where these rotation-sensing technologies come up against limits posed by quantum physics. Such studies are expected to yield strategies for overcoming these limits and thus improving our ability to measure mechanical rotation."

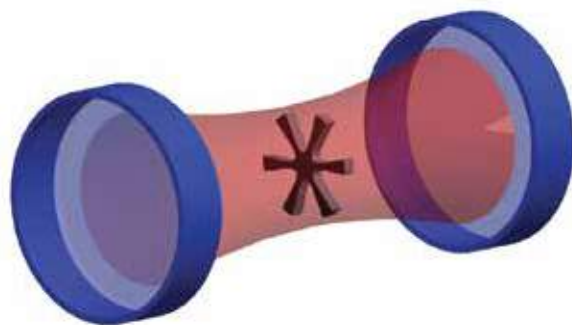
Casey Miller, director of RIT's materials science and engineering master's degree program, transferred his CAREER Award to RIT after joining the faculty last fall from the University of South Florida. His initial award for \$586,000 focuses on the magnetocaloric effect in metallic nanostructures.

"We are exploring advanced functional materials that change temperature with applied magnetic fields," said Miller. "This could result in highly efficient refrigeration technologies."

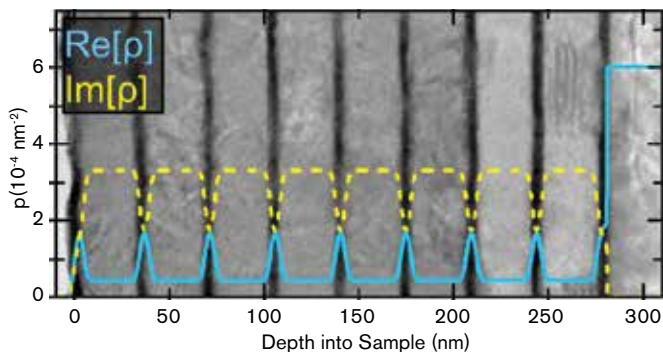
Gaustad will use the nearly \$510,000 award over the next five years to support research aimed at fully comprehending supply-chain risks for new clean energy technologies when it comes to material scarcity and criticality.

"The criticality of these materials is an important national issue right now—especially when it comes to the supply chain risks," said Gaustad. "Rare earth metals could be a major area of concern. The United States and other developed nations are mining fewer materials, so supply chains are getting less diversified."

The CAREER program is an NSF-wide activity that supports junior faculty who exemplify the role of teacher-scholars through outstanding research, excellent education, and the integration of education and research within the context of their organization.



**Rotation Sensor:** Bhattacharya's group recently proposed a windmill-shaped nanoparticle levitated by an optical beam confined between two mirrors. One of the mirrors transmits a part of the beam containing information about the windmill's rotation.



**Magnetocaloric Multilayer:** A transmission electron microscope image shows a magnetocaloric multilayer composed of gadolinium (light gray) and tungsten (dark gray) overlaid by the composition profile determined by magnetic depth profiling with polarized neutron reflectometry. Miller's research is in the area of magnetic nanostructures.



**Clean Energy Technologies:** Wind turbines, solar panels, and electric vehicles all contain the materials that are the focus of Gaustad's research.





**Clinical Health Sciences Center:** An artist's rendering of the new Clinical Health Sciences Center scheduled to open in fall 2015. It will be home to a primary care clinic and the Wegmans School of Health and Nutrition.



Barbara Lohse

**Community Nutrition Researcher to Head Wegmans School**

Barbara Lohse, a research professor and senior instructor at the Pennsylvania State University

Department of Nutritional Sciences, will head Wegmans School of Health

and Nutrition. She begins her new role at the school, part of RIT's College of Health Sciences and Technology, on July 1.

Lohse's leadership will provide the school with a research agenda that addresses critical health issues like obesity and promotes healthy lifestyles. Lohse has been engaged in research that focuses on eating competence,

or attitudes and behaviors pertaining to food, community nutrition, and nutrition education for low-income populations. She directed the Pennsylvania state SNAP-Ed program, a nutrition and public-health education resource.

A new campus facility, set to open in fall 2015, will house the Wegmans School and a primary care clinic to be run by Rochester General Hospital.



Dave Principe

**Theses Work Honors**

RIT's Office of Graduate Studies has honored two recent graduates for their outstanding theses. They each received a \$1,000 award.

Dave Principe, who earned his Ph.D. in astrophysical sciences and technology last August, is the 2015 recipient of the RIT Doctoral Dissertation Award. Principe's thesis work looked at multiwavelength observations of young stars and their planet-forming, circumstellar disks. His dissertation focused on analysis

of data obtained by three satellite observatories: NASA's Spitzer Space Telescope and Chandra X-ray Observatory, and the European Space Agency's XMM-Newton X-ray Observatory. Principe is currently a postdoctoral fellow with the Millennial ALMA Disks (MAD) group at the Universidad Diego Portales in Santiago, Chile.

Brendan Gordon, a 2014 graduate of the industrial design program in RIT's School of Design, won the MFA thesis award. Gordon's research looked at the stigma and outpatient treatment of adult urinary incontinence (UI). After researching UI history, social stigma, product history, market trends, and user needs, Gordon proposed



Brendan Gordon

developing a system-based design that would incorporate a reusable garment. An aspiring entrepreneur, Gordon was also part of an award-winning RIT student team that created Imagine

Soap. The venture tackles preventable disease by empowering entrepreneurs in the developing world to use local waste resources to produce and sell hygiene products at affordable prices. He currently works as a designer at the Coastal Sustainability Studio at Louisiana 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* 2015 edition of *The Best 379 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](http://www.rit.edu/research).

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