NEXTGEN BIOREFINING

Pioneering low-cost and sustainable biorefineries catalyzed by biological engineering
America Converges Here

This past year Rutgers University celebrated a milestone birthday: 250 years old! It’s been a dynamic and engaging year looking back and looking forward. We enjoyed a Day of Revolutionary Thinking—a university-wide showcase of alumni expertise and knowledge (including five School of Engineering alumni)—along with lectures, performances, fireworks, and lots of cupcakes. The university also marked the anniversary with an historic commencement event on May 15, 2016 that featured keynote speaker President Barack Obama, the first sitting U.S. president to address a Rutgers graduating class.

Saying of Rutgers “America converges here,” President Obama superbly captured what makes the university so unique among U.S. colleges. Our diversity creates an “intellectual melting pot” where ideal flourishes through the benefit of global thinking. The president also recognized STEM (science, technology, engineering, and mathematics) programs. Our School of Engineering is conducting cutting-edge research in sustainable and bio-fuels along with harnessing big data for a world of good.

It’s an exciting time for Rutgers Engineering as we continue the traditions of the last 250 years in progressive and relevant ways.

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Rutgers welcomes aspiring engineers with four different summer programs to inspire and interest area students.

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Big data is getting bigger—and School of Engineering professors are coming up with new ideas to apply its power and improve existing processes.
Hiding Objects from Sound

Andrew Norris, a distinguished professor of mechanical and aerospace engineering, is leading one of nine engineering-led teams of interdisciplinary researchers—supported by $18 million in National Science Foundation (NSF) funding—that are altering the conventional ways in which electronic, photonic, and acoustic devices are designed and employed in order to create new functionalities.

Supported through NSF’s Emerging Frontiers in Research and Innovation, 37 researchers at 17 institutions will pursue transformative research in the area of new light and acoustic wave propagation, known as NewLAW, over the next four years. The Norris-led team will demonstrate novel methods for realizing non-reciprocal behavior through the design of heterogeneous acoustic, elastic, and electro-mechanical systems. Technology that violates these fundamental rules opens the possibility of changing the standard operating procedures for measuring and utilizing acoustic and elastic waves.

“Cloaking is an admittedly fantastic concept, well represented in popular culture using ingenious ‘technologies.’ The Cloaking Field Generator in Star Wars is an example of an active device requiring a power supply.” — Andrew Norris

Islands of Fibers

Future brain therapies for Parkinson’s and Alzheimer’s patients possible with stem cell bioengineering innovation

A new technology that converts adult tissue-derived stem cells into human neurons on three-dimensional “scaffolds,” or tiny islands, of fibers could someday help treat Parkinson’s disease and other devastating brain-related conditions. The scaffold, developed by scientists from Rutgers and Stanford universities, consists of tiny polymer fibers. Hundreds of neurons attach to the fibers and branch out, sending their signals. Scaffolds are about 100 micrometers wide, roughly the width of a human hair.

“We take a whole bunch of these islands and then we inject them into the brain of a mouse,” said Prabhas V. Moghe, a distinguished professor in the Departments of Biomedical Engineering and Chemical and Biomolecular Engineering at Rutgers. “The neurons transplanted into the brain survived miraculously well.”

The scaffold technology results in a 100-fold increase in cell survival over other methods. Neurons, or nerve cells, are critical for human functioning. The human brain has about 100 billion neurons, which transmit signals from the body to the brain, and vice versa.

Subsequent steps in the research will improve the scaffold biomaterials, allowing scientists to increase the number of implanted neurons. With progress, the researchers could eventually perform studies on people and, if successful, could lead to helping people with Parkinson’s disease, multiple sclerosis, amyotrophic lateral sclerosis (ALS), Alzheimer’s disease, spinal cord and traumatic-brain injuries, and concussions.

“We take a whole bunch of these islands, and inject them into the brain of a mouse. The neurons transplanted into the brain survived miraculously well.” — Prabhas V. Moghe
NextGen Graphene

Rutgers Engineers have found a simple method for producing high-quality graphene that can be used in the next generation of electronic and energy devices: heat the compound in a microwave oven. Graphene—which is 100 times stronger than steel—conducts electricity more effectively than copper, and it rapidly dissipates heat, making it useful for many applications such as printable electronics, electrodes for batteries, and catalysts for fuel cells. “This is a major advance in the graphene field,” says Manish Chhowalla, a professor in the associate chair of the Department of Materials Science and Engineering (MSE) and also the director of the Rutgers Institute for Advanced Materials, Devices, and Nanotechnology. “This simple microwave treatment leads to exceptionally high-quality graphene, having properties approaching those of pristine graphene.” Post-doctoral associates and undergraduate students made the discovery, and their findings were published in Science, says Chhowalla. Having undergraduates as coauthors of a paper worthy of Science may be rare but, he says, “MSE and SoE cultivate scientists and engineers who are ‘working for expanded inclusion for the next generation.’”

Vanity Fair Features Engineering’s Olabisi

Department of Biomedical Engineering assistant professor Ronke Olabisi was among eight “STEM luminaries” featured in the December 2016 issue of Vanity Fair. “Solving a New Guard of STEM Stars” was co-sponsored by IBM to celebrate the film Hidden Figures, which tells the story of the contributions African-American women made to the space race of the 1950s and 1960s, by highlighting today’s accomplished women scientists and engineers who are “working for expanded inclusion for the next generation.”

Gaming Security Systems

Hat if playing cops and robbers could help devise defensive strategies to thwart a real attack? That’s the thinking behind the GRIST (Game Research for Infrastructure Security) project under development at the Rutgers School of Engineering Department of Industrial and Systems Engineering. Researchers use game theory to build a game in which players either attack or defend different targets, simulating attacks by terrorists on location models that are derived from real-world sites. The data collected from these games can help law enforcement and public-service agencies predict, and prevent, attacks by learning how players behave when they pursue or protect virtual targets. The project was inspired by past terrorist attacks on populated locations.

“We know that some attackers pick crowded areas as their target, and you want to limit the effect of those attacks,” said Melike Baykal-Gursoy, associate professor of industrial and systems engineering and director of the Laboratory for Stochastic Systems and the lead researcher on the project.

Her team is developing different projects that each relate to one specific aspect of the game. They range from optimizing the use and placement of defensive assets to learning what strategies emerge when the amount of information attackers and defenders have varies. The approaches will ultimately be combined to create the final game.

“We want to know: can you learn from the attackers?” she said. “We have already demonstrated the 2D game at the School of Engineering Open House and at Rutgers Day and collected data. We are now building a 3D game, which will be more informative.”

Interested in testing the game? Visit grist.rutgers.edu.
BRIANNA BINOWSKI discovered the sport of rowing when she came to Rutgers and is now among an accomplished and disciplined group of Scarlet Knight athletes studying engineering.

Designed to Be the Best

Combining Engineering and Athletics by Diane Reed
engineeering is among the worst majors for a student athlete to pursue, according to campusports.net. The intense workload, demanding course requirements, and inflexible scheduling obstacles don’t necessarily play well with team practice and travel schedules. But at the School of Engineering (SoE), a select group of students each year rise to the challenge and compete to win on both the playing and academic fields.

During the 2015/2016 academic year, 18 of the 650 student-athletes at Rutgers were from the engineering program. They represented each of the engineering departments and competed in eight sports: men’s soccer, lacrosse, and baseball, along with women’s rowing, soccer, tennis, track and field, and cross country. Although juggling the demands of sport and school isn’t always easy, SoE students are making it work with the support of faculty, coaches, teammates, and an outstanding ability that is important for all of them—time management.

Managing their time is one of the first things student-athletes learn as first-year students, said Randi Larson, assistant director of academic support services for Rutgers athletics. "Participating in a collegiate sport is a six-day-a-week commitment," said Larson. "There is a lot of sacrifice that studentathletes make, particularly engineering students who have a lot of coursework. They have to say no to certain activities and social events."

It Takes a Team

Larson and her colleagues work as liaisons between athletes and schools, consulting with SoE’s academic services unit, including Lydia Prendergast, assistant dean of undergraduate education, and her staff.

"We have to ask questions, help the students strategize a course schedule, or assist with a class conflict," Larson said. "We work with students and the schools to make sure students can complete the curriculum and compete."

According to John Paxton, Rutgers’ athletics academic advisor who supports men’s soccer, wrestling, and women’s swimming and diving, the fixed first- and second-year engineering course schedule is relatively easy to work around when accommodating class and practice schedules.

"Junior and senior years get tougher because there aren’t really options to the curriculum," he said. "Taking 16 to 18 credits alongside a demanding practice and competition schedule is challenging, to put it mildly."

Larson has worked most recently with the women’s soccer team, which includes Christine Monroy, a senior from Scotch Plains, New Jersey, who is majoring in chemical engineering. Monroy was recruited to play soccer for the University of Louisville, but left after one year because she didn’t feel the academic program was rigorous. A center midfielder, she helped the team last fall make it to the first NCAA Final Four women’s soccer championships in Rutgers’ history.

With two to three mandatory practices a week, coordinating schedules has been one of Monroy’s biggest challenges. “My coaches have been very understanding about the lack of flexibility with my class schedule, so it hasn’t restricted my ability to balance both school and sports,” she said. Alayna Famble from Cliniers, Georgia, was recruited by many schools and had her heart set on Georgia Tech—until she visited Rutgers, where she “felt like I was home.”

As a track and field star out and 400-meter sprinter, Famble—who is majoring in bioenvironmental engineering and completed an internship this summer at Trimont, a commercial real estate company in Atlanta—was most recently a member of the 4x400 and 4x100 relay teams at the NCAA East Regional competition and was part of the relay team that placed third in the Penn Relay 4x400.

“I’m so glad I’m at Rutgers,” she said. “It’s such a great school.”

Big Ten Scoreboard

S
ince joining the Big Ten Athletic Conference in 2014, the competition has provided new opportunities for Rutgers’ students.

It’s a “different ball game,” according to Paxton. “If you’re a student being recruited into the Big Ten, you are among the elite across the board,” he said. “These are very special young men and women, coming to us with great GPAs and helping to raise the bar and profile of Rutgers. The success of these students will filter into the greater university.”

Rutgers’ student-athletes, representing all majors, have a higher GPA than the university’s student body. According to Paxton, the most recent team GPA for men’s soccer was 3.28, thanks in part to engineering student-
endorphins, which are a huge stress-reliever, “she said.

Another advantage for student-athletes is that being a professional athlete: he’ll have a lighter course load, with more evening classes, and can “give 100 percent to the sport.” Kemmerer will also be around to help first-year students make the transition to college-level competition in the Big Ten conference.

“Managing your time is a big learning curve, and you won’t recognize the workload until you’re under it,” he said. “It’s a balancing act, for sure, but sports help you manage your time and don’t give you the opportunity to procrastinate.”

Sports also provide an opportunity to “express yourself in a different way,” according to Kemmerer, by carrying over a competitive nature into classwork.

“That’s been a big driving factor for me,” he said. “It’s a balancing act, for sure, but sports help you manage your time and don’t give you the opportunity to procrastinate.”

The hard physical work that she puts into rowing complements the motivation that she and her teammates have to do their best to win. And that motivation has helped her as a student. During the summer, Binowski completed an internship with the international engineering firm HDR, Inc., where she assisted the movable-bridge company with project-delivery, including engineering reports, engineering design plans, cost estimating, and review of engineering calculations.

“I’m proud of myself,” she said, regarding the challenges of being a student-athlete. “I love the sport of rowing, and it drives me to be the best I can be in everything I do.”

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Great Minds Win Alike

Why engineers make great rowers

When I first met Max Borghard, I expected him to be 6’6” and wearing high-tech athletic apparel. I was wrong. Borghard, who holds a degree in chemical engineering, returned to Rutgers as head coach of the women’s rowing team in 1983 and is the Bartels/Nicholas head crew coach, one of the few endowed university coaching positions.

Borghini and Wagner are also part of a rowing and engineering legacy at Rutgers that comprises Borghard’s father, Al Borghard ENG’54, Bruce Nicholas ENG’49, Richard N. Weeks ENG’56, and Fred Borchelt ENG’51, one of the few endowed university coaching positions.

Why engineers make great rowers

The careers and accomplishments of Max Borghard ENG’87 (above left) and Steve Wagner ENG’76 (above right) prove the hypothesis.

As head coach of Rutgers women’s rowing since 1983, Borghard knows how to balance a challenging academic curriculum—his degree is in mechanical engineering—and a commitment to competitive athletics. He captained the lightweight rowing team his junior and senior years and was selected to two consecutive U.S. national teams in 1985 and 1987.

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At the Department of Chemical and Biochemical Engineering, professors Nina Shapley and Shishir Chundawat are working to develop environmentally sustainable production processes that could have global implications.
Jane Palmer, a Los Angeles textile designer, has a passion for using natural and environmentally friendly dyes to color fabrics. During the last six years, she’s gained a loyal following among high-end boutique clothing and housewares designers. Her sights, however, are set much higher—to move mass-market fabric dyeing away from its polluting and energy consuming ways. One of Palmer’s first steps in the quest has been to work with a Rutgers engineering professor with no background or experience with dye chemistry.

Nina Shapley, an associate professor of chemical and biochemical engineering, had just started working with colleagues on a project to protect molecules sensitive to ultraviolet light damage. Their test molecule was beta carotene, a natural bright-orange substance used in food dyes.

“Jane saw one of our papers and she contacted us,” Shapley said. “She was looking for potential new technologies to take her natural dye work to the next level.”

Palmer values the colors that natural dyes bring to her fabrics—sometimes vibrant, other times subtle. But natural dyes have drawbacks that make them unsuitable for mass-market fabrics: they are expensive and they fade in sunlight or when washed. The major clothing labels have looked at natural dyes but have yet to embrace them.

Change is on the horizon, however. Clothing manufacturers use billions of gallons of boiling water to dye their fabrics, and it’s hard to remove dye residue from wastewater. A New York Times story in 2013 illustrated the harm of clothing manufacture in regulation-lax Bangladesh where a river glowed purple.

“It’s a health risk to the aquatic system, the environment, the general population,” Palmer said.

Just as the major labels have chosen, or have been forced, to address products made with sweatshop labor, they now need to drive environmentally sensitive and sustainable dyeing techniques. Palmer has discussed the issue with Patagonia, North Face, Nike, and others. Shapley and Palmer secured a $225,000 National Science Foundation (NSF) grant at the beginning of 2016 to move natural-dye technology toward commercial viability.

“It’s more like applied research,” Shapley said. “Other projects I’ve worked on are very fundamental. So it’s exciting to see something with a shorter time line.”

The investigators find that their different backgrounds—Palmer with a master’s degree in fine arts and Shapley with a doctorate in chemical engineering—are complementary.

“I love working with Nina because she’s really creative,” Palmer said. “She’s very open to ideas. We come from different approaches, but we’re open-minded about our ideas. So, it’s fun.”

“Jane already knew so much about dye chemistry and did so much literature-searching herself,” Shapley said. “So it’s easy for us to talk about these things. We’re both on the same wavelength. But this project is moving into a new area for both of us. We’re learning a lot of new things that we hadn’t explored.”

Their grant is from the NSF’s Small Business Innovation Research program.
Alternative Fuel Sources Driving CBE Research

Making fuel from plants has long been a goal of scientists and engineers hoping to limit wild swings in fuel prices and availability and to prepare for a time when finite supplies of petroleum dry up.

But the promise of obtaining abundant and sustainable supplies of liquid fuel from biomass, by and large agricultural crops, is a challenge that still vexes scientists and engineers after decades of research.

Rutgers School of Engineering assistant professor Shishir Chundawat, who joined the chemical and bioengineering faculty in 2015, is one of the experts taking up the challenge.

“One of the big drivers for the work I do—and it’s my personal philosophy also—is that it’s important to be sustainable,” he said. “Having sustainable ways to produce energy would allow society to deal with many of the issues we face.”

Before joining Rutgers, Chundawat pursued graduate and postdoctoral studies at two leading land-grant universities and the prestigious Great Lakes Bioenergy Research Center, which was funded by the U.S. Department of Energy.

Plant biomass is, theoretically, self-sustaining, he said. “It can essentially grow with just the availability of carbon dioxide, water, and sunlight.”

Yet, achieving this sustainability is not straightforward, a realization that came early in his undergraduate research on the chemical conversion of edible oils and later in his graduate research on the biological conversion of inedible plant biomass into fuels and chemicals. Ethanol, a popular additive that stretches gasoline supplies and cuts pollution, is made from corn grain, but its production requires a lot of energy—mainly for the fertilizer used to grow the corn. It also demands high-quality land that could be used for food crops.

“Once I started looking at inedible biomass and how one could convert that to value-added products,” Chundawat said. Grasses and woody plants such as switchgrass and poplar grow abundantly on land unsuitable for food crops and with little upfront energy demand input. They store a lot of energy as carbohydrates, but, unlike those found in cereal grains and seeds, the carbohydrates are not easy to “press out” and process into simple sugars, which are the building blocks for fuels and chemicals. Grass and wood carbohydrates are locked into plant structures such as plant cell walls as long-chain cross-linked polymers.

Of the nearly 16 billion gallons of ethanol produced annually in the United States, nearly all comes from corn grain. Only a few hundred million gallons come from inedible cellulosic biomass. The Department of Energy is targeting sufficient cellulosic biofuel production by 2022 to replace nearly 30 percent of the country’s current petroleum consumption.

“The growth in cellulosic biofuels seems to be slow and steady,” he said, “but there are both logistical and scientific issues that have to be sorted out.”

Chundawat and other scientists are attacking the problem biologically by searching for enzymes that break down this tightly bound biomass into simple sugars. By examining the synthesis and breakdown of sugar polymers at the cellular level, they are looking for enzymes suitable for large-scale industrial processes.

Chundawat says he’s in good company at Rutgers, citing colleagues in his department such as Fritz Cebik and George Tsilomelekis who are researching chemical catalysis to upgrade plant biomass to useful products, and Hanan Zhang who is engineering microbes to make fuels and chemicals. He also sees opportunities for collaboration in other Rutgers schools and centers.

But beyond merely looking for enzymes that can do the job, Chundawat is looking to engineer and characterize new enzymes that are more effective. He is currently a principal investigator on two related NSF awards to understand and engineer enzymes to reduce non-productive enzyme binding biomass during biofuel production. He recently also won the 2016 Ralph E. Powe Junior Faculty Enhancement Award from the Oak Ridge Associated Universities to develop low-cost pretreatments and biological processes for converting waste cellulosic biomass into fermentable sugars.

“The problem is that enzymes get stuck on biomass,” he said. “We are essentially trying to understand how to overcome that barrier.” He believes using protein engineering to make novel enzyme mutants and characterizing their activity with new single-molecule analytical tools will shed light on the problem.
The Academy at Rutgers for Girls in Engineering and Technology introduces middle and high school girls to career opportunities in engineering.

Summer-time is STEM
Science
Technology
Engineering
Math
TIME

Rutgers School of Engineering’s summer programs introduce students of all backgrounds to the world of engineering.

By Amy Wagner and Diane Reed
Photographs by Bill Cardoni
An engineering education is more than just science, physics, and problem-solving, evidently. On a July day this past summer, a group of engineering-minded students gathered in Schohar Recital Hall to hear a concert given by pianist Kenneth Grigg who demonstrated how applying the aesthetics and etiquette of concert performance can improve personal presentation.

The daylong event was part of “How to Go to a Concert,” a program offered to students taking part in New Jersey Governor’s School of Engineering and Technology (GSET), an engaging and participatory learning experience. They also had the opportunity to work with Google engineers who were building Rube Goldberg machines. GSET—a unique residential program for high-achieving New Jersey high school students entering their senior year—was one of four SoE summer programs that brought the excitement of engineering to life for precollege students from an array of backgrounds.

The campus also hosted The Academy at Rutgers for Girls in Engineering and Technology (TARGET), a program that introduces middle and high school girls to career opportunities in engineering; Student Learning and Achievement Aerospace and Mechanical Engineering Summer Academy (SLAAM), a department-specific pilot program for academically talented and motivated high school students; and a five-week residential program for incoming first-year Educational Opportunity Fund (EOF) and Educational Opportunity Program (EOP) students.

The benefits of the on-campus School of Engineering summer programs extend well past the summer. “All of our summer programs give students an understanding of what engineering is,” says Ilene Rosen, associate dean for student services at the School of Engineering. “We are educating not only students, but also their families and their teachers about the exciting possibilities of engineering.”

The programs are an important outreach for the campus as well. "How to Go to a Concert," a program offered to students taking part in GSET, was one of four SoE summer programs that brought the excitement of engineering to life for precollege students from an array of backgrounds.

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The Best and the Brightest

Since 2001, the GSET program has provided talented students from all over New Jersey with the opportunity to gain experience in engineering during a free four-week program. During the summer, 87 students, representing nearly 80 high schools and nearly every county in the state, lived on campus while participating in the program, according to Jean Patrick Antoine, the assistant dean for enrichment programs at the School of Engineering. Although students must take core courses in robotics and modern physics, they also explore their own interests through electives, ranging from bioengineering to android programming. They collaborate on team research projects, which they present to guests at a final symposium. This summer, they attended 10 lectures given by a diverse group of guest speakers, including the founder of Hacker League, Mike Swift, and Rutgers professors Wise Young and Thomas Papathomas, who discussed cell biology, neuroscience, and the cognitive science of human and machine vision.

Life-skills workshops, visits to local corporations such as Boeing, Lockheed Martin, and Bristol Myers Squibb, and events like the Grigg musical performance rounded out the program. “Students get to learn in a vigorous and rigorous environment beside other students who share a passion for STEM learning,” says Antoine.

The program is a success. Most GSET alumni choose STEM majors at universities that they attend, among them Rutgers, Princeton, Cornell, and MIT.

Big Number: TARGET Participants

This past summer, the School of Engineering offered six-week long programs for 149 girls who participated in the TARGET program. Each session sought to increase awareness of career opportunities in engineering for women. Students took part in exciting hands-on engineering activities, including designing Rube Goldberg contraptions, exploring 3D printing, and using drones for aerial photography.

Girls Aspiring to Be Engineers

This year, 149 girls in grades six through 11 took part in six TARGET programs. Each weeklong session sought to increase awareness of career opportunities in engineering for women. They took part in exciting hands-on engineering activities, including designing Rube Goldberg contraptions, exploring 3D printing, and using drones for aerial photography.

“One of the biggest benefits of TARGET is that middle and high school students are mentored by our undergraduate and graduate female engineers,” says Candiece White, assistant dean for women in engineering at the School of Engineering. “We want to encourage young women to consider engineering and then empower them.”

TARGET, in its 19th year, has become a pathway for girls wishing to explore engineering. Many girls return year after year, and many of the program’s alumnae go on to participate in GSET, study engineering at SoE or other engineering schools, or pursue another STEM discipline in college.

“I’ve been coming to this program since sixth grade; it’s fun and cool. All of the projects are great; I still have the water-gun project in my garage from my first year.”

Ipsika Kumar, TARGET Participant
rigorous summer program that gives them the tools to match the success of the general engineering population. The EOF program at the School of Engineering, funded primarily by the state of New Jersey’s EOF office, began contributing supplemental funding in 2014, leading to the expansion of the program (EOF) and giving additional students the opportunity to participate in what its graduates consider a life changing experience. “All in all, this has been a great experience,” says Shahroz Khalil, of Jersey City, New Jersey, who found the program challenging during his first week but now feels more prepared. “My study techniques have improved tremendously, and I’ve learned how to keep better track of time.”

The students’ intensive time together also works to form a community, one that the students can rely on for emotional and academic support once they return to campus in the fall. “I feel like I’m part of this now,” Shahroz Khalil, of Jersey City, New Jersey, who found the program challenging during his first week but now feels more prepared. “My study techniques have improved tremendously, and I’ve learned how to keep better track of time.”

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HARNESSING THE POWER OF Big data

RUTGERS ENGINEERS ARE PUSHING THE BOUNDS OF LARGE DATA SETS, PIONEERING BIG DATA-ENABLED PROCESSES AND TECHNOLOGIES. By CARL BLESCH

ILLUSTRATION: JAMES STEINBERG
Big data,” though widely discussed, means different things to different people. The term may convey the idea of working with massive amounts of information circulating on the internet. Or it could be running computer models to pinpoint a hurricane’s landfall or perhaps to describe how galaxies evolve. Or big data could describe the hardware that handles enormous amounts of information, from the seemingly quaint 1970s’ Cray supercomputers to today’s massive arrays of servers spread around the world.

Rutgers engineers are working with big data, harnessing its power to make complex industrial processes flow smoothly and to manage issues related to health care. They are also shaping computing tools and software that allow high-energy physicists to discover the secrets of subatomic particles.

Susan Albin, professor of industrial and systems engineering, is an expert in quality and reliability. She has witnessed the evolution of big data in her own field, noting that modern manufacturing processes are equipped with sensors from start to finish.

“In the beginning of quality control, somebody with a caliper and a clipboard measured things and wrote down a few pieces of data,” she says. “But the kind of data that comes in now is just gigantic. Making decisions about how much of that data is useful and how much can help you are major issues.”

The School of Engineering is pioneering an industrial process that is pushing the bounds of big data in chemical engineering: the “continuous manufacturing” of pharmaceutical tablets. Pill-making is currently a “batch process” because, until now, it has been the only way to meet the need for strict monitoring and quality control. But batch processes are slow and expensive.

“Time to market is very important,” says Rohit Ramachandran, associate professor in chemical and biochemical engineering. “The faster you produce something of good quality, the more money you will save.”

Continuous manufacturing allows for “personalized medicine” or “precision medicine,” customizing drugs for individuals or small populations with unique needs. Ramachandran is one of many engineers involved in developing continuous manufacturing of powder-based pharmaceuticals and related items such as foods and agricultural products. Rutgers began its work in 2006 through major support from a multi-year National Science Foundation (NSF) Engineering Research Center grant. Ongoing development...
Ramachandran manages the large amounts of data that sensors will generate throughout the process—data that will need to be analyzed and acted upon to quickly address deviations. It starts with models, which are mathematical descriptions of how the actual process should run. 

“A model is a lot cheaper to optimize and test parameters,” says Ramachandran. “You use a model to mimic the process. You build your strategies and optimizations, find the best conditions, and then implement them in the plant. Your model and the plant are not going to be perfect. So you use data from the plant to reconcile the model with the actual process.”

Although chemical engineers have been developing processes this way for years, continuous manufacturing of pharmaceuticals poses new challenges.

Ramachandran and colleagues Marianthi Ierapetritou and Shantenu Jha received a two-year NSF grant last year to use big-data approaches to efficiently solve models using data from a pilot manufacturing plant housed on the Busch Campus at Rutgers-New Brunswick.

The Rutgers development team is collaborating with Janssen Pharmaceuticals, a unit of Johnson & Johnson, to implement continuous manufacturing in a commercial production facility in Puerto Rico. This adds another challenge to Ramachandran’s management of big data.

“You’ll have companies with sites across different geographic regions,” he says. “We will need cloud-computing strategies to quickly send large amounts of data between multiple sites around the world.”

To deal with the challenges of big data, Ramachandran tapped the expertise of colleague Shantenu Jha, an associate professor in electrical and computer engineering. Jha is helping Ramachandran integrate his applications with advanced resources such as supercomputers and cloud computing.

“In just a year’s time, we’ve been able to get Rohit’s team to start using the world’s fastest and most powerful supercomputers,” Jha says.

Jha heads a team of cyberinfrastructure experts called RADICAL—Rutgers Advanced Distributed Cyberinfrastructure and Applications Laboratory. He describes it as “a producer of technologies for big-data-enabled science.”

Supercomputers, Jha points out, have traditionally been used to model and simulate physical processes, such as colliding black holes or galaxy formation. “However, instead of just running simulations that produce data from equations and governing principles, there is a reverse need: to process large volumes of data and derive governing principles,” he says. “The RADICAL team makes middleware for the largest NSF project that is tasked with doing this.”

Jha also works on processing data from the ATLAS subatomic particle detector at the Large Hadron Collider in Geneva, Switzerland, possibly the first project ever to have processed one exabyte, or a billion gigabytes, of data in a year.

“The process of particles colliding is a technology tour de force,” Jha says. “From our point of view, it’s a massive source of data generation. By some accounts, it’s the world’s most data-intensive academic project.”

He is part of a project team that recently received $2 million in funding from the U.S. Department of Energy to help design the next generation of supercomputing resources that will help process all that data.

Jha’s colleague in electrical and computer engineering is assistant professor Anand Sarwate, who also sees the need
Emina Soljanin

If you have big data, someone has to store it. Someone has to make it accessible and also secure. That’s where Professor Soljanin comes in.

**Q:** How is your background in communications research related to information storage?

**A:** My technical areas are coding and information theory. Coding theory is behind both error correction and data compression. Applying error correction to the signal coming off a magnetic disk enabled disks to grow in capacity and shrink in size. Today we use it to protect data stored in the cloud, and we hope to reduce the size of data centers. There is data compression and de-duplication—lossless reduction of acquired and generated data so that it doesn’t take up as much storage space and can be distributed securely. Coding theory is also used to make data incomprehensible to adversaries.

**Q:** What is involved in retrieving data?

**A:** We have to retrieve data quickly. If there is a delay of more than a tenth of a second, people aren’t going to wait. For Google, a one second delay means that page views drop 11 percent. That’s money lost because of lost advertising revenue.

Data stored in the cloud may reside in several physical locations. I compare it to grocery shopping. One person in a family can get all of the groceries, or you can split up the shopping list and send every member of the family into the store. Then you choose the shortest cashier line. These are all mathematical queuing problems: how to allocate data so delay is minimized.

**Q:** How do you tie your earlier work in electrical engineering and computer engineering to your research in storage?

**A:** Data centers are energy hogs. They consume two to three percent of the power we generate, and that consumption is growing at a rate of 20 percent per year. If I can minimize storage, I can cut energy consumption. Distributing data in a way is similar to electricity generation, where we had to constantly balance our sources of power and try to maximize our use of the cheapest source.

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**Q:** How is your work important in the era of big data?

**A:** It’s not just big data. Anyone who engages in data collection needs to ensure that data is protected and stored securely. That’s what my research is about. I design coding algorithms to efficiently store data so that it can be retrieved quickly and securely. This is critical for the era of big data.

Cloud computing drives dynamic underwater robotic collaboration

Rutgers engineers are advancing underwater robotic capabilities through mobile cloud sensor networks and expanding opportunities for oceanographic data collection, environmental and pollution monitoring, offshore exploration, and tactical surveillance. Dario Pompli, an associate professor of electrical and computer engineering, and doctoral student Parsil Pandey, teamed up with Jingang Yi, associate professor of mechanical and aerospace engineering, and won the 2016 Google Transactions on Automation Science and Engineering Best Applications Paper Award for their research.

New Faculty

**From the Ocean Floor to the Cloud**

Cloud computing drives dynamic underwater robotic collaboration

**Rutgers School of Engineering welcomes new faculty members:**

**Philip Brown**
Assistant Teaching Professor
Undergraduate Education

**Edmund DeMauro**
Assistant Professor
Mechanical and Aerospace Engineering

**Adam Gormley**
Assistant Professor
Biomedical Engineering

**Riju Parekkadan**
Associate Professor
Biomedical Engineering

**Amalina Scacchioli**
Assistant Teaching Professor
Mechanical and Aerospace Engineering

**Maria Striki**
Teaching Instructor
Electrical and Computer Engineering

**New Jersey Inventor of the Year**

**Fernando J. Muzzio,** distinguished professor of chemical and biochemical engineering, was honored for developing advanced manufacturing processes for pharmaceutical, chemical, and petrochemical industries. Muzzio is the director of the Center for Structured Organic Particulate Systems, which receives support from the National Science Foundation, Janssen Supply Chain, and the U.S. Food and Drug Administration.
Collagen Breakthrough Pays Off
Licensed technology yields scientific and financial rewards

What started as a simple transaction—buying collagen for soft-tissue engineering research—now has a commercially viable license for Rutgers and the School of Engineering. Since 2011, biomedical engineering doctoral candidate, Kathryn Drzewiecki, under the guidance of Professor David Shreiber, has been researching and developing collagen modifications to expand its use in medicine. Collagen scaffolds were one of the first FDA-approved biomaterials for use in wound care. However, the properties of collagen scaffolds are very difficult to control, limiting its medical use. The Shreiber group developed a method to couple methacrylic acid to collagen, yielding collagen methacrylamide, or CMA. CMA can be “crosslinked” using light and yielding control over the biological and mechanical properties of the collagen-based material.

Producing CMA is a difficult, weeklong process. According to Drzewiecki, if CMA were mass produced, more labs could use the material to conduct beneficial research—assuming that gave her the idea of approaching Advanced Biomatrix, one of the companies from which she purchased collagen, to license the process developed by Rutgers.

“Our goals are very similar, so we should work together,” she thought. The company agreed, and they began selling quality-controlled CMA, now called Photocol, last year.

According to Shreiber, commercially licensing this manufacturing process benefits Rutgers financially and contributes to further research and scientific advancements.

Bridges to Prosperity
Developing infrastructure for third-world communities

During the summer of 2016, two Rutgers students from the campus group Bridges to Prosperity traveled to Bolivia with students from the University of Colorado to help design and build a footbridge for the community of Chuoro Alwa, where children had to traverse a gorge en route to school. They often slipped down the sides of the gorge or were unable to cross during the rainy season when the gorge flooded.

“The main purpose of the bridge was to allow elementary school kids to get to school safely,” said Richard Lorper, a senior studying civil and environmental engineering who was part of the team.

The project took several weeks to build, and the students worked with the Chuoro Alto community.

“We were welcomed by the community,” Lorper said. “They were passionate about working together to build the bridge.”

Students arrived at the worksite each morning at 8:00 a.m. to mix concrete, carry materials, or start building the bridge’s deck. Working at an altitude of 12,000 feet above sea level meant very cold mornings.

“There were days where we were all layered up, two hoodies, jackets, and double socks,” said Cynthia Arellano, a member of the team and a Rutgers civil and environmental engineering student. The greatest impact for the students, however, was getting to know the community. Arellano became friends with 12-year-old Daniella, whom she met while they worked building the bridge. “She told me that I was the first female she had met who went to a university.”

“She told me that I was the first female she had met who went to a university. She thought only boys could be engineers.”

CYNTHIA ARELLANO WITH DANIELLA

“Arellano and Daniella made sure to be the greatest, kindest, happiest, most hardworking people I have met. They find happiness in every aspect of life. The trip was life changing.”

Sarah Abdelaziz
The Institute of Industrial and Systems Engineers awarded the Dwight D. Ginter Scholarship to Abdelaziz (ISE undergraduate).

David Alston, Michael Hildreth, and Justin Larczan
The Society of Hispanic Professional Engineers Student Excellence in Leadership Award was awarded to three HAC undergraduate students.

Seoul A Bare
Bare (ISE graduate student) was named a National Science Foundation Graduate Research Fellow in support of her doctoral research deciphering the somatic immune-metabolism interactions in colitis.

Charles Cao
Cao (ISE), a graduate student in Ashby-Goetz’s research group, earned second place in the 2016 Innovations in Fuel Cycle Research Awards sponsored by the U.S. Department of Energy.

Steven Cheng
Cheng (ISE undergraduate) received the 2016 U.S. Department of Energy Integrated University Scholarship for research in the field of nuclear waste management.

Parnreet Kaur
Kaur (ISE graduate student), who is exploring computer vision applications in dermatology and telemedicine, received the prestigious Google Anita Borg Memorial Scholarship of $30,000 and attended the Google Scholars’ Retreat at Google headquarters.

Maria Qudri
Qudri (ISE graduate student) was awarded the Executive Women of New Jersey’s Graduate Mentoring Award providing scholarship assistance to non-traditional graduate school students.
IN JANUARY 2016, five members of the Rutgers chapter of Engineers Without Borders went to Kolunje, Kenya, to finish installing rainwater catchment systems, which provide clean water for schools in the village of 7,000. Members returned in January 2017, to install a well system. Bechtel, Boeing, and Lockheed Martin sponsored the project. Left to right, Jared Lai, Tristen Wallace, and Sriram Gidugu pictured with children from Kolunje.

A big challenge for engineering is that most school children don’t take engineering courses, according to Jonathan Singer, assistant professor of mechanical and aerospace engineering. The 2016 USA Science and Engineering Festival Grand Finale Expo—a national grassroots effort to advance STEM (science, technology, engineering, and mathematics) education—was an important opportunity to show young students what they could do as mechanical engineers. Rutgers students and participants from more than 1,000 leading STEM organizations offered hands-on science and engineering activities to more than 50,000 science students. Students from the School of Engineering built and displayed an interactive robotic Venus flytrap. The Rutgers robot had to meet specifications to ensure that it would mimic a real Venus flytrap. These included sensitive hair-like triggers on the inside of the leaves that detect when a fly or foreign object has landed. The robot needed an internal “timer” that closes both leaves when two hairs have been touched within 20 seconds. It also required a switch to pump the leaves open and an interactive feature demonstrating that more energy is required to open the leaves than to close them. And the flytrap had to be safe for anyone to operate, including children. The flytrap has been donated to the United States Botanic Garden.

INGENUITY: The student-led Venus flytrap project, below, was created using 3-D computer-aided design software, PlastiDip paint, silicon rubber, and molds made from plastic syringe tips. Pictured from top: Jonathan Singer, mechanical and aerospace engineering assistant professor, and students Valeria Saro-Cortes and Adam Burrous.

Engineers Without Borders

PHOTOGRAPH: TRISTEN WALLACE

THE MOLES, an organization of heavy construction workers and engineers, invited civil engineering students to tour last spring by boat the construction site for the Tappan Zee Bridge, which spans the Hudson River.

Engineers Out in Field

SCHOOL OF ENGINEERING alumni enjoyed department-sponsored networking events held throughout the year and attended by graduates, faculty, and staff. Additional events are planned for 2017.

ALUMNI HONORED AT MEDAL OF EXCELLENCE DINNER

The school’s annual Medal of Excellence and Distinguished Alumni dinner in October recognized alumni achievement and raised scholarship funds. The 2016 honorees include, pictured left to right: Andrew J. Foden, Ph.D., senior bridge evaluation and technology manager, WPS | Parsons Brinckerhoff; John M. Allen, mathematician, Point Pleasant Borough High School; Jackelynne Silva-Martinez, aerospace engineer, NASA Johnson Space Center; and Dorin I. Comaniciu, Ph.D., VFI research and development, Exxon Mobil Research and Engineering Company; Marvin Shlager, chairman, UGI Corporation and UGI Utilities; and John McAllen, mathematics teacher, Point Pleasant Borough High School.
Paying It Forward
Erwin Hardenburg bequest to fund scholarships for future engineers

Erwin Hardenburg, a self-taught engineer, entrepreneur, and businessman, has always rejected his lack of a college education. “To provide students with the educational opportunities he never had, he has established a $750,000 trust that upon his death will fund engineering scholarships,” Hardenburg’s cousin and Rutgers alumnus to Rutgers goes back to its founding. He is a descendant of Jacob Rutgers Hardenbergh, the first president of Queen’s College, which became Rutgers University, as well as of Henry Janeway Hardenbergh, the celebrated architect who designed Rutgers’ Kirkpatrick Chapel and Geology Hall. In the wake of the Great Depression, Hardenburg’s parents were unable to pay for college. He ultimately built a successful career as a machinist and a businessman. His company, Precise Components and Tool Company, designed and built a prototype parts and fixtures which became the basis of many patents among wafers. There is likely a problem such as uneven temperatures, or chemical repeating among wafers, there is likely a problem such as uneven temperatures, or chemical photo-mask misalignment, or chemical misalignments where privacy isn’t necessarily protected. “Whether it’s to learn from the known cases to ascertain how likely they are to be incoming planes or early indications of cancer. But in a specific area Sarwate is studying, there are no clear or obvious patterns. Sarwate is working with, says Albin. “That’s the part that makes it engineering.”

Big Data
CONTINUED FROM PAGE 31

Santo Sarwate and his team are designing methods to derive patterns and principles from massive amounts of data. “Given a pile of data, can I see what patterns are in there without making too many presumptions about how that data was generated?” he asks.

Early forms of pattern recognition started with a known pattern, he explains, such as what a radar blip looks like when a plane is approaching or which genes are highly expressed in cancerous tissue. A computer then compares future blips from unknown sources or gene patterns from unaliquoted tissues with the known cases to ascertain how likely they are to be incoming planes or early indications of cancer.

But in a specific area Sarwate is studying, there are no clear or obvious patterns to start with. He is collaborating with researchers who are studying mental health disorders such as schizophrenia by using magnetic resonance imaging (MRI) and other scanning methods. The hope is to allow researchers in different groups to find such patterns by sharing data from their studies. However, it’s difficult legally and ethically to share this kind of data,” he says. “A researcher can’t just e-mail you the MRIs of all the subjects in a study. “If defective chips are scattered in the wafer, we presume the manufacturing process is okay,” he said.

“Therefore, if defective chips are clustered on a wafer or if we see defect patterns repeating among wafers, there is likely a problem such as uneven temperatures, photo-mask misalignment, or chemical misalignments. Sarwate is working with, says Albin. “That’s the part that makes it engineering.”

Steve and Kerry Bray Scholarship
Stephen Bray earned his bach- elor’s and master’s degrees in industrial and systems engineering from the School of Engineer- ing. “I can’t overstate how much of my Rutgers education,” says Bray. With a $25,000 gift, he re- cently established the Steve and Kerry Bray Scholarship. Bray is a founding partner and presi- dent of chief operating officer of KMB Design Group, an engineer- ing firm based in Wall, New Jersey. The company offers services in School of Engineering alumni and offers internships for students. The Department of Industrial and Systems Engineering will select recipients of the scholarship on the basis of need and merit. Bray, a founding partner and president of KMB Design Group, is a serial entrepreneur who recently established the Steve and Kerry Bray Scholarship. "Bray is a founding partner and president of KMB Design Group, an engineering firm based in Wall, New Jersey. The company offers services in School of Engineering alumni and offers internships for students."

…”Steve and Kerry Bray Scholarship Scholarship…"

Alumni Around the Globe

A road trip to Fort Worth for SoS’s Tim Farris and Spencer Masloff included a visit with Ali Lawrey at ENTEC and SoS alumni working at Lockheed Martin. Left to right: Privacy Mohla, Kiwi Ella Paschal Masloff, Lawrey, Farris, Tommy Paschal, Jaclyn Lazo, Bill Saathoff, and Jordan Smart.

Big Data
CONTINUED FROM PAGE 31

Santo Sarwate and his team are designing algorithms and tools that can learn from this data while ensuring privacy for the subjects. His work is also relevant for collabora- tions where privacy isn’t necessarily an issue, but where large volumes of data make sharing everything impractical. “You have to communicate in a way that is efficient in how much you send back forth to learn from the data,” he says.

Myong K. Jeong, associate professor of industrial and systems engineering, is also developing big data techniques to extract useful information such as pro- cess conditions and yield-rate predictions from multiple data sources in complex processes. He has been working with semiconductor industry giant Samsung to better ascertain the functionality of memory chips used in computers and other electronic devices. In the semiconductor manufactur- ing process, hundreds of chips are fabricated on large silicon wafers called wafers. A final step is to test all of the chips on a wafer to determine if any are defective. Jeong’s research group wants to automate the whole procedure to iden- tify defective dynamic random access memory (DRAM) chips. It is one of the semiconductor industry’s key challenges.

There will always be defective chips in a normal process, he notes. But spatial defect patterns of chips on the wafer provide useful information about manufactur- ing conditions that can help engineers understand the ongoing processes. “If defective chips are scattered randomly on the wafer, we presume the manufacturing process is okay,” he said. “However, if defective chips are clustered on a wafer or if we see defect patterns repeating among wafers, there is likely a problem such as uneven temperatures, photo-mask misalignment, or chemical misalignments. Sarwate is working with, says Albin. “That’s the part that makes it engineering.”

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Brian Reilly

Brian Reilly ENG’80, a senior vice president at Bechtel, began working at the company in 1980 following his graduation from Rutgers with a degree in civil engineering. He is the project director for the construction of a $6.5 billion uranium process facility in Oak Ridge, Tennessee.

BRIAN REILLY ALWAYS KNEW HE wanted to build things, but he just wasn’t sure how. At the School of Engineering, he took a course in construction management that changed his life and helped him realize his dream. “Professor Bob Kreith asked me if I’d ever heard of Bechtel,” Reilly says. “He suggested I look them up because they were coming to campus to conduct interviews. I was hooked.”

As an engaged alumus, Reilly arranged to be interviewed, and he got a job. Kreith is one of many mentors who have made a difference throughout Reilly’s career. “Without mentors to turn to when it was time to make decisions, I don’t know if I’d be where I am,” Reilly says.

Leadership, he contends, is a form of mentoring. “I like to surround myself with really smart people who don’t necessarily agree with me and bring them into the decision-making process,” Reilly says. “With their input and perspectives, I can make a better decision.”

He mentors interns and colleagues at Bechtel, many of whom are SoE students and alumni. “The best part of my job is when younger people come to me and ask for time to talk,” he says.

Six years ago, after not being back on campus for 30 years, Reilly was ready to get involved. Bechtel was no longer recruiting Rutgers students, which didn’t make sense to him as the company had successfully hired graduates in the past.

He met with newly appointed dean Tom Farris, who gave him a tour and introduced him to students involved in Engineers without Borders. “The school and students sold themselves,” he says. “I was hooked.”

To read the complete interview with Reilly, visit soe.rutgers.edu/reilly.

Rutgers Engineering Marvels

An investigative research project during the Rutgers 250 anniversary uncovered an impressive trove of innovative feats attributed to Rutgers engineers. For an expanded list of alumni innovators, visit soe.rutgers.edu/marvels.

NATHAN NEWMARK ENG’50, “the father of earthquake engineering,” revolutionized geotechnical engineering.

LAURENCE LEDDES ENG’54, a leading expert in the technology of high-energy propagation of electrical waves through space, participated in the introduction of television on a mass scale and the use of radar during World War II.

LEONOR LOREE ENG 1869, president of the Baltimore & Ohio Railroad, developed the standard railway semaphore, or traffic light system, in use for 50 years.

HARLAND BARTHOLOMEW ENG 1911, one of the nation’s first city planners, designed more than 120 different American cities, including Newark, St. Louis, Washington, D.C., and Memphis.

ROBERT ZWOLINSKI ENG’57 co-developed a machine that provided lines to electric cables, making it easier to mass-produce tricker cables.

WILLIAM MOOG ENG’38 invented a valve that revolutionized aircraft and missile flight control systems. Moog, Inc. manufactures parts on several aircraft, including the Boeing 737.

HARLAND BARTHOLOMEW ENG 1911

ROBERT ZWOLINSKI ENG’57

NATHAN NEWMARK ENG’50

LAURENCE LEDDES ENG’54

LEONOR LOREE ENG 1869
Snowy Owl Restored and on Display

The Snowy Owl, masterfully crafted by renowned sculptor Edward Marshall Boehme, has a place of honor in the School of Engineering's Center for Ceramics Research. Three sculptures had been commissioned to commemorate the historic 1987 summit between President Ronald Reagan and Mikhail Gorbachev, the leader of the former Soviet Union. One was presented to Nancy Reagan and another to Raisa Gorbachev. The third sculpture was donated to the Department of Materials Science and Engineering following Boehme's death.