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PARAMETERS

Cullen College of Engineering Magazine • Spring 2018

THE NEXT BIG THING

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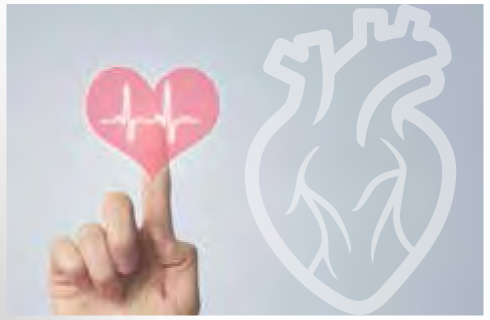
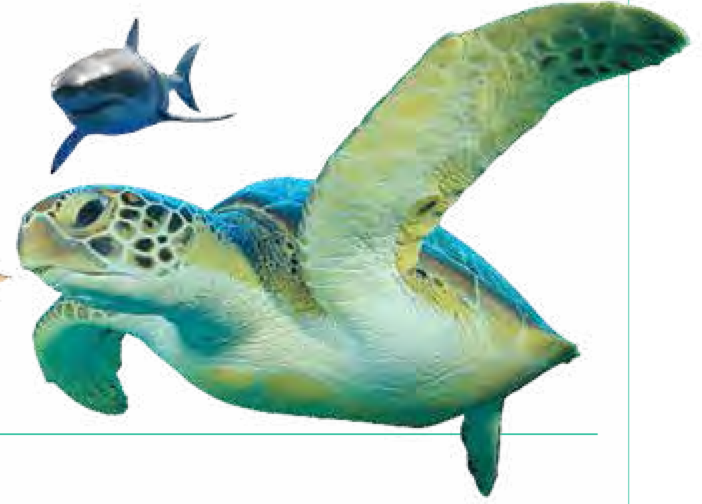
The Next BIG Thing



Talk to the Animals



IN EVERY ISSUE

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DEAN'S LETTER

It wasn't too long ago that my cell phone was just that – a cellular phone. Today, this 5-by-3-inch computer is my personal assistant, researcher, healthcare advisor, social planner, email manager, travel booker and real-time mapping and directions provider. Oh, right… and it makes phone calls.

This is just one small microcosm of a much larger technological revolution we are lucky enough to experience in our lifetimes.

Game-changing discoveries are right around the corner in a number of crucial fields. Self-driving cars and high-speed trains are changing the face of transportation; robots and smartphones are filling in as healthcare providers by administering medicines and diagnosing diseases; American space ambitions are reigniting as plans to colonize the Moon and Mars come into focus; and all the while endless streams of data collected through smart devices and sensors are opening up new avenues for invention and shaping our global economy in unexpected ways.

Behind each of these examples are brilliant engineering minds – creative problem-solvers who see science as a doorway to a better tomorrow. In this theater of innovation, engineers take both a front row seat and a leading role. They have never been more necessary, more crucial to the plot of our history, than they are today.

Their inventions and ingenuity continue to change our world in ways both big and small, in ways we can't even begin to grasp yet. New technologies and tools born of their efforts cause the global economy to shapeshift, creating gaps in workforce talent faster than we can fill them with skilled workers.

Standing at the center of this innovation super-wave are Houston's engineers, poised to usher in the world of tomorrow while educating the engineering students of today. Amplified by Houston's thriving and diverse medical, energy and aerospace industries, Cullen College professors and students are laying down the framework for the next generation of engineering talent, jobs and frontiers.

In this issue of *Parameters* we explore the latest trends and hottest fields in engineering and introduce you to the brilliant Houston engineers at the forefront of discovery and education.

Warm regards,

Joseph W. Tedesco, Ph.D., P.E.
Elizabeth D. Rockwell Dean and Professor

Engineers of Today and Tomorrow:

OUTLOOK THROUGH 2024

Life-changing innovations are right around the corner in a number of fields, from energy and transportation to medicine and robotics. Engineers will be inventors, problem-solvers and pioneers of our future, playing a key role in the discoveries that will change our daily lives for the better. But the engineers of today won't be the same as the engineers of tomorrow. At the UH Cullen College, the next generation of global engineers are trained to fill current and future skills gaps across all engineering professions. Read on to learn more about the future of the engineering workforce.

Engineering is one of the fastest growing occupations in the U.S.

65,000 new engineering jobs will be added through 2024

12% increase in engineering jobs through 2024

What will be the fastest growing engineering occupations in the future?

Biomedical	+ 25%
Environmental	+12.4%
Petroleum	+ 9.8%
Civil	+ 8.4%

More people are earning engineering degrees since 2007, but the supply of engineering talent isn't keeping up with the demand.

Science and engineering will need **2.4 million new workers** (between 2010 and 2020)

The U.S. will be short 1.1 million STEM workers overall

Engineers are among the highest paid workers in the U.S.

On average, STEM workers earn **29% higher wages** than their non-STEM counterparts

$134,730 average annual salary of engineering professionals in 2017

Highest paid engineering occupations:

Petroleum engineers	$128,230
Computer engineers	$115,080
Aerospace engineers	$109,650
Chemical engineers	$98,340
Electrical engineers	$96,270
Materials engineers	$93,310

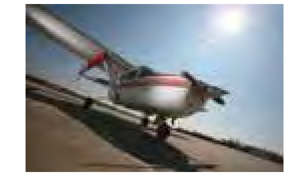
A 2013 U.S. Congressional Study found that science and engineering jobs are virtually "recession-proof."

Employment in **STEM** grew by **10.5%** **(or 817,260 jobs)** between 2009 and 2015

Science and engineering jobs **increased by .6%** during the recession.

SOURCES: 1) U.S. Bureau of Labor Statistics Occupational Data. 2) U.S. Science and Engineering Workforce: Recent, Current and Projected Employment, Wages and Unemployment, Congressional Research Service. 3) "The Native-Born STEM Shortage," American Action Forum, 2016 Report

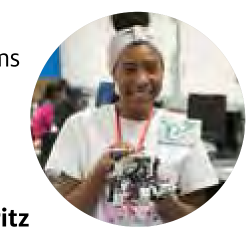
IN THE MEDIA SPOTLIGHT



A game-changing discovery made by researchers with the National Center for Airborne Laser Mapping (NCALM) has archaeologists and adventurers across the world buzzing with excitement. NCALM researchers provided 3-D maps generated by state-of-the-art LiDAR technology that uncovered a complex Maya settlement hidden for centuries amidst the jungles of Guatemala. Their findings were described in a recent documentary on the **National Geographic Channel**, as well as in articles published in the **New York Times, USA Today, BBC News, TIME Magazine, Daily Mail, NPR** and **Fox News.**

The New York Times · USA TODAY · BBC NEWS · TIME · npr · FOX NEWS · Daily Mail

HOUSTON CHRONICLE



A combination of outreach and student success programs is changing the face of engineering at the UH Cullen College, where 28 percent of the student population is female (compared to 20 percent nationwide). The Cullen College offers a variety of programs that have successfully increased the enrollment of women and minorities. **Fritz Claydon,** associate dean for undergraduate programs and student success, details these programs in the recent **Houston Chronicle** article "Gender, diversity gaps persist in STEM."

Clean energy research in the UH Cullen College of Engineering was the subject of a front page story in the **Houston Chronicle** titled "Is Houston missing the next energy wave?"

UH mechanical engineer **Daniel Araya** spoke with the Chronicle about his research on unconventional wind turbines, like the one he invented for use on urban rooftops to generate electricity from shifting winds and turbulence caused by tall buildings.

Despite the abundance of clean energy research at the University of Houston, the city of Houston has very few start-up companies incubating new, clean energy technologies. **Hanadi Rifai,** associate dean of research and facilities, shared some of the Cullen College's plans to help curb those trends, including a start-up pitch event where engineering entrepreneurs can showcase their business plans to potential investors.

Los Angeles Times

Prior to SpaceX's highly anticipated and ambitious demonstration launch of its Falcon Heavy Rocket, **LA Times** writer Samantha Masunaga spoke with space architecture director **Olga Bannova** for insights on the use of heavy-lift rockets. Bannova said such rockets are necessary if we want to complete bigger, more complex missions in outer space. "If we're talking about expanding exploration, it will be good to have more capabilities," Bannova said.

UH Chemical Engineering Grads Earn

HIGHEST STARTING SALARIES IN THE U.S.

In addition to being among the top-ranked chemical engineering programs in the country, alumni of the UH Cullen College's department of chemical and biomolecular engineering have yet another reason to be proud of their alma mater: new rankings released by *U.S. News and World Report* find that UH chemical engineering graduates earn the highest starting salaries in the nation.

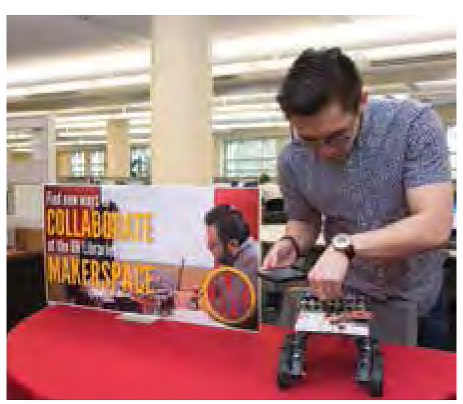
UH chemical and biomolecular engineering alumni earn a median starting salary of $70,658, while new chemical engineering grads nationwide earn starting salaries between $60,000 to $68,000 annually.

NEW UH MAKERSPACE

Encourages Student Testing, Tinkering and Invention

A new Makerspace at the University of Houston Libraries is now open, giving students across the campus a place to test out ideas, build prototypes and turn dreams into inventions.

The Makerspace was established through a collaboration between the Cullen College's department of electrical and computer engineering and the UH Libraries. Located on the first floor of the MD Anderson Library within the Learning Commons, the Makerspace is comprised of five work bays that are open to individuals or groups to use when engaged in maker activities. A sixth bay offers access to high-end measurement and testing equipment.



UH Launches

INSTITUTE FOR DATA SCIENCE

BY JEANNIE KEVER

The University of Houston has launched a new Institute for Data Science, naming **Andrea Prosperetti,** Distinguished Professor of mechanical engineering at the Cullen College and member of the National Academy of Engineering, to lead the venture.

"Houston is a natural location for a focus on data science, with its strengths in energy and healthcare and its substantial technology and software industries," said Prosperetti, who also serves as director of the UH Center for Advanced Computing and Data Systems.

The Institute's initial work will span four areas of application: cyber and physical security, drug development and discovery, sustainable communities and infrastructure, and accessible and personalized healthcare.

Data science continues to transform society, harnessed by companies including Uber, Amazon, Netflix and Facebook. Technologies developed by the Institute will have a transformative impact on the local, national and global economy – saving resources in the healthcare system by being able to accurately predict what treatments will work for specific patients, for example. But it also may yield broader benefits, helping to thwart a cyber attack or lessening the risk of an offshore oil accident.

The Institute will be housed within the Multidisciplinary Research and Engineering Building, which opened last year and contains core facilities including high-performance computing infrastructure, a nuclear magnetic resonance spectrometer lab and imaging equipment.

GULF COAST UNIVERSITIES TEAM UP

to Address Hurricane Resilience

BY JEANNIE KEVER

A new multi-institution research center led by the University of Houston will focus on helping the Gulf coast do better at preparing for and mitigating the damage and loss of lives from hurricanes and other severe storms.

At the Hurricane Resilience Research Institute (HuRRI), six participating universities will share their expertise, from flood mitigation and hurricane modeling to public policy.

The institute includes universities located in states spanning the Gulf of Mexico: the University of Houston, The University of Texas at Tyler, Texas Tech University, Louisiana State University, the University of Miami and the University of Florida.

Hanadi Rifai, John and Rebecca Moores Professor of civil and environmental engineering at UH, will serve as director. Her work includes an ongoing study of the chemical and microbiological contamination in Houston waterways after Harvey.

Each institution brings unique research capabilities – in engineering, science, policy, education and technology – and significant institutional support that will be supplemented with external grants and contracts and cooperative agreements to launch projects in hurricane resilience.

Rifai said the institute's work will focus on "anticipating and accommodating" the storms' impact, rather than the current model of waiting for a storm to pass and then devoting funding to repair and recovery. "It will take an enormous number of resources to influence a paradigm change and offer evergreen solutions for hurricane resilience for affected communities," she said.

Researchers from the six institutions will be eligible to apply for the initial round of internal funding, which will require collaboration with at least one faculty member from another member institution.

Rifai noted that each partner brings special expertise to the new institute. UH, for example, will use research capacities in its Center for Advanced Computing and Data Science, along with the Hobby Center for Public Policy and the Energy, Environment & Natural Resources Center.

UH Researchers Begin Carbon Capture Project with OIL INDIA

BY JEANNIE KEVER

Researchers from the University of Houston launched a $1.4 million project to demonstrate using carbon dioxide captured from nearby petrochemical plants to boost oil recovery in a field in the Indian state of Assam, a project which will help to reduce the country's carbon footprint.

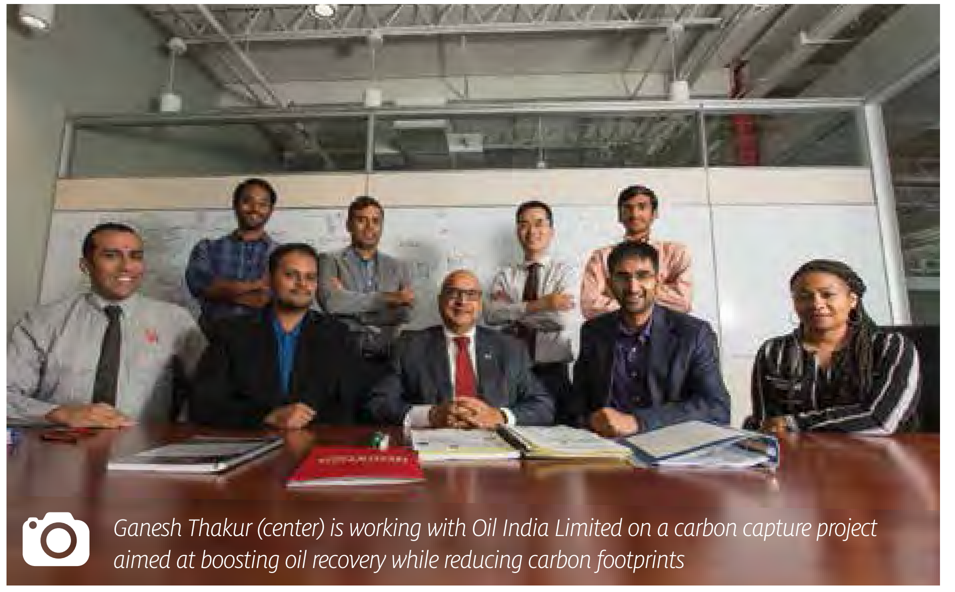
The project is part of an ongoing partnership launched between the University and Oil India Limited, the Asian nation's national oil company.

The initial phase, funded by $500,000 from Oil India, included the calculation by UH researchers that the company's oil reserves are substantially higher than previously thought, as well as recommendations that increased production by 21 percent at one well alone – a first-year revenue increase of $4 million.

"This ambitious partnership has offered clear benefits for both Oil India and for the University of Houston,"

said **UH President Renu Khator.** "Finding a way to safely meet the growing demand for energy in India and other parts of the world is a fundamental challenge, and we appreciate the opportunity for our faculty and students to play a vital role in solving such important real-world problems."

The project is led by **Ganesh Thakur,** who was recruited by UH in 2016 as director of Energy Industrial Partnerships. A member of the National Academy of Engineering and a former executive at Chevron Corporation, Thakur also serves as Distinguished Professor of petroleum engineering.



Ganesh Thakur (center) is working with Oil India Limited on a carbon capture project aimed at boosting oil recovery while reducing carbon footprints

He has overseen both Phase 1 and 2 of the partnership, which focuses on demonstrating the effectiveness of flooding key oilfields in northeastern India with carbon dioxide, a technique that has been used to enhance oil recovery in the United States for 45 years.

Demand for energy is increasing in India, where the gross domestic product (GDP) is rising about 7 percent a year, Thakur said. The country now imports more than 80 percent of its oil consumption, making it important to increase what it can produce domestically. The UH team is composed of a dozen people, from faculty members and postdoctoral researchers to graduate students, in disciplines including petroleum and chemical engineering and the geosciences.

Moreover, Thakur said the partnership also offers advantages for UH.

"It provides a good field research lab for us," he said. "It allows us to take the challenges the oil industry is facing and provide an integrated solution."

The carbon capture project will also include technical training for Oil India personnel on advanced enhanced oil recovery techniques and project design, along with a seismic study of the Makum-North Hapjan Field.

The initial project was completed in June with several key accomplishments:

- UH research indicated the oil resources are about 20 percent higher in the key field of Oil India than previously thought.
- Research-based production recommendations led to a production increase of 220 barrels per day from just one well, a 21 percent increase worth $4 million a year.
- Fifty Oil India reservoirs were screened for enhanced oil recovery (EOR) opportunities; UH researchers also developed and patented a methodology to rank reservoirs and assess EOR potential. Researchers found the four top-ranked reservoirs have a potential for 17 million barrels of additional recovery.
- UH field research discovered that drilling at a potential site would be uneconomic. The result was a savings of $4 million in drilling costs.

REMOVING THE ROADBLOCKS to a More Efficient Car Engine

BY JEANNIE KEVER

Almost 160 years after the invention of the internal combustion engine, a new type of engine – operating at low-temperature, allowing it to consume less fuel – offers promise for the transportation industry as it plans for the future.

But the next-generation engine requires a next-generation catalytic converter to reduce harmful emissions of pollutants including nitrogen oxide, carbon monoxide and volatile organic compounds. So far, that has remained elusive.

A chemical engineer from the University of Houston will lead a $2.1 million project to find new catalytic materials that work at low exhaust temperatures, allowing automakers to build vehicles that operate more efficiently while retaining the ability to clean emissions before they leave the tailpipe.

Michael Harold, chairman of the department of chemical and biomolecular engineering at UH, will serve as principal investigator on the grant, funded by the U.S. Department of Energy National Energy Technology Laboratory (DOE NETL). The project also includes researchers from the University of Virginia (UVA), Oak Ridge National Laboratory (ORNL) and Southwest Research Institute (SwRI). Engineers from Fiat-Chrysler Automobiles Inc. and Johnson Matthey Inc. also will be involved in the project.

Catalytic converters clean vehicle exhaust into nitrogen, water and carbon dioxide. While carbon dioxide contributes to global warming, it is considered less damaging to health than raw automotive emissions. Current catalytic converters use precious metals, including platinum and palladium, to eliminate the main pollutants emitted by internal combustion engines.

"These expensive precious metals may work, but it's important to find less expensive materials that have enough activity at the low exhaust temperatures," Harold said. "Not only that, we have to come up with operating strategies so the new catalysts work over the wide range of conditions encountered during driving."

The new engines, based on a lean burn, compression ignition technology, can't be commercialized without a way to ensure they run cleanly to meet emission rules. Although the conventional three-way catalytic converter doesn't work for the new engines, Harold said the new converters might be transferrable to current vehicles.

Harold, a catalytic reaction engineer, and Lars Grabow, associate professor of chemical and biomolecular engineering at UH who works in fundamental catalysis, will work to discover and determine the effectiveness of new catalytic materials, working both with a class of known materials and developing new ones. Researchers at UVA will conduct high throughput materials synthesis and screening, ORNL researchers will contribute in materials synthesis and characterization and SwRI will provide evaluation of fuels. Fiat-Crysler and Johnson Matthey will bring their industrial expertise in vehicles and catalysts, respectively.

MICHAEL HAROLD WILL LEAD A **$2.1 MILLION PROJECT** TO FIND NEW CATALYTIC MATERIALS THAT WORK AT LOW EXHAUST TEMPERATURES

DESIGNING MICROORGANISMS

to Convert Natural Gas Liquids into Useful Products

BY AUDREY GRAYSON

Patrick Cirino is converting small hydrocarbons into metabolic intermediates that can be used as building blocks for the biosynthesis of new chemicals

A team of researchers led by a UH chemical and biomolecular engineer will design microorganisms that can convert natural gas liquids (NGLs) into useful products more efficiently than current technologies.

The National Science Foundation awarded Associate Professor **Patrick Cirino** more than $300,000 to study and engineer microorganisms that can metabolize hydrocarbons, including NGLs. Once the activities of the enzymes responsible for metabolizing NGLs are uncovered, Cirino and his collaborators – Ramon Gonzalez, a metabolic engineer at Rice University, and Squire Booker, a biochemist at Penn State University – will create metabolically engineered microorganisms capable of converting NGLs into a variety of valuable products.

Patrick Cirino is finding better ways to turn natural gas liquids into useful products and chemicals

What are NGLs?

The production of natural gas in the U.S. has reached record highs with the use of new extraction methods such as hydraulic fracturing and horizontal well drilling. Natural gas reserves also contain compounds called natural gas liquids, or NGLs, which are hydrocarbons that are harvested along with the natural gas. Ethane, propane, butane and isobutane are all examples of NGLs.

NGLs are useful chemicals that span almost all sectors of the economy, but current methods of purifying these low-value hydrocarbons are energy intensive, and their conversion to higher value products is inefficient. With the increased production of natural gas comes increased production of NGLs in the U.S., and that has led to some concerns over processing and distribution constraints in coming years.

A better way

Cirino believes there's a better way to turn NGLs and longer hydrocarbons into other products, and he's looking to nature for the answers.

One approach that microorganisms use to metabolize hydrocarbons is to activate these compounds by the addition of a metabolite called fumarate, which plays an essential role in the metabolic process. The resulting fumarate adducts are broken down into smaller molecules that can then be used as building blocks for the biosynthesis of new chemicals. This metabolic conversion of hydrocarbons into new chemicals doesn't generate waste or require large amounts of energy, but isn't well understood.

"We have a good handle on which genes are at play in the natural systems. We can clone those genes, but getting the enzymes to work in a repurposed context is tricky. We will have to engineer them to do specific tasks," Cirino said.

Ultimately, Cirino hopes to metabolically engineer microorganisms that can convert NGLs into a variety of desirable biochemicals like butanol, a biofuel.

If successful, Cirino said the project will not only provide fundamental insights into how certain microorganisms metabolize hydrocarbons; "It will also provide a novel engineering platform for activating hydrocarbons and using them as feedstocks in bioprocesses."

TOMORROW'S BATTERIES TODAY:

Yan Yao Charges Up Battery Research

BY AUDREY GRAYSON

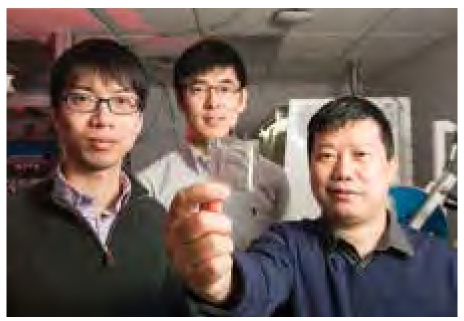
Batteries capable of powering the electric vehicles of tomorrow may be available sooner than we think, thanks to more than $5.7 million in seed funding provided through the Department of Energy's Battery500 consortium. **Yan Yao,** associate professor of electrical and computer engineering at the Cullen College, is among 15 principal investigators funded through the consortium, which is led by DOE's Pacific Northwest National Laboratory and includes multiple partner universities and national labs.

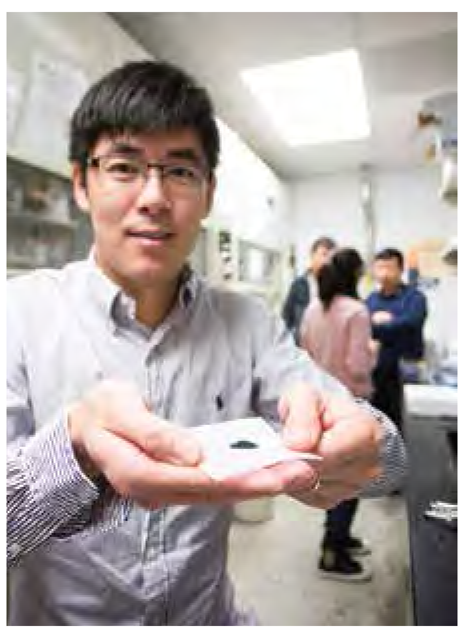
The seedling projects were announced in July as part of a larger unveiling of a total of $19.4 million in new DOE funding for vehicle technologies research. The latest phase of funding focuses on high risk, high reward, proof-of-concept research that could potentially identify major energy storage solutions.

After 18 months, the most promising of the projects will be selected to move forward to phase two with additional funding.

Battery500's goal is to develop lithium-metal batteries that can pack more than twice the amount of energy in the same size battery cell. Doubling the specific energy of batteries will allow electric vehicles (EVs) to drive farther distances on a single charge while reducing the cost and weight of the vehicles.

Yao's project focuses on using organic materials to increase the amount of energy that solid-state lithium batteries can store and discharge.





Yan Yao (top right) and postdoctoral researchers Yanliang Liang (top left) and Xiaowei Chi hold the future of batteries in their hands

Tomorrow's batteries today

After releasing its latest EV battery in 2016, Tesla CEO Elon Musk admitted current lithium-ion battery design and chemistry prevent them from packing more power into the battery packs.

"This is quite close to the theoretical limit," he said, likening the quest to stuff more power into the battery packs to "stuffing 11 pounds into a 10-pound bag."

Musk's lamentation underlies the importance of developing new battery technologies using different materials and chemistry, said Yao. The most powerful Tesla battery has an energy density of about 300 watt-hours per kilogram, with most standard EVs maxing out at about 170-200 watts per kilogram.

The Battery500 consortium, by comparison, aims to build a battery cell with a specific energy of 500 watt-hours per kilogram.

"If we want to go much further we need to consider different ways of storing energy," said Yao. "We need to increase our fundamental understanding of existing battery technologies."

"I'd like to partner with industry to see our new batteries make it to the consumer market.

Our ultimate goal is to not only improve battery technologies, but also to improve people's lives."

- YAN YAO

One such existing technology is solid-state batteries, which show promise in beating out their lithium-ion counterparts in terms of both energy density and safety. Current lithium-ion batteries use a flammable liquid electrolyte to transport positive lithium ions between the cathode and anode. Solid-state batteries use solid electrolytes, potentially enabling the use of a lithium metal anode.

But solid-state batteries come with their own set of drawbacks. For starters, solids don't conduct electricity as efficiently as liquids, which means the time it takes to charge the batteries might be longer while the battery life itself is much shorter than lithium-ion batteries.

Takeshi Uchiyamada, Toyota chairman and the engineer who led the development of the first Prius hybrid, is hoping to gain ground in the race to develop next-generation electric cars by trying to overcome some of the inherent drawbacks with solid-state batteries.

So far the automaker hasn't succeeded in extending the life of the batteries. Uchiyamada noted that he doesn't expect consumers will buy electric cars if they need to replace the battery packs every three years.

It isn't just electric vehicle manufacturers who will benefit from the arrival of tomorrow's batteries, Yao said. "We need this for alternative energy to take off – wind and solar, for example. We need to be able to store large amounts of energy off the grid. It's a big challenge."

The energy of Yao

The challenge of creating better, safer batteries energizes Yao's research group. His team specializes in the creation of next-generation batteries that use earth-abundant, organic materials such as magnesium to increase energy density and overall safety.

A paper published in *Nature Materials* in June outlines Yao's discovery of a new class of inexpensive organic materials called quinones, which give aqueous batteries a longer life, more chemical stability and the ability to function across a range of temperatures. The discovery could benefit several industries including renewable energy, transportation and personal electronics.

"We are looking at new organic battery chemistries that can rival the existing ones," Yao said, adding that he hopes to explore the use of quinones for solid-state batteries, coupling the material with lithium metal. "Ideally we want to combine the safety of aqueous batteries with the high energy density of lithium-ion batteries."

Using a mixture of computational analyses and experiments, Yao is charged with proving to the Battery500 consortium that greater energy density and battery life can be achieved by using new, organic materials for solid-state lithium-ion batteries. If proof-of-concept is achieved, Yao will focus on the manufacturability of his novel batteries.

"I'd like to partner with industry to see our new batteries make it to the consumer market," Yao said. "Our ultimate goal is to not only improve battery technologies, but also to improve people's lives."

LEAD NEWS

ENERGY

Researchers Study DEEPWATER GAS FORMATION to Prevent Accidents

BY JEANNIE KEVER

A team of researchers from the University of Houston is working with the oil industry to develop new ways to predict when an offshore drilling rig is at risk for a potentially catastrophic accident.

Ramanan Krishnamoorti, chief energy officer at the University of Houston, will lead the project, drawing expertise from data scientists, petroleum engineers and geoscientists at the University. The work is funded by a $1.2 million grant from the National Academies of Sciences, Engineering and Medicine.

The project is one of six announced in December by the Gulf Research Program of the National Academies to develop new technologies, processes or procedures to improve the understanding and management of systemic risk in offshore oil and gas operations.

The Deepwater Horizon explosion in 2010, which left 11 crew members dead and spilled more than 3 million barrels of oil into the Gulf of Mexico, involved the uncontrolled buildup and release of gas, sparking efforts to better understand the movement of hydrocarbons in offshore drilling.

> "We want to bring in expertise from industry to be complemented by data science and other academic disciplines to address a complex problem."
>
> - RAMANAN KRISHNAMOORTI

Gas, water and even drilling fluid can flow up the drilling pipe alongside the desired oil, Krishnamoorti said. The gas can release in a burst or explosion upon reaching the surface, potentially causing a serious accident.

Current industry standards don't address the issue, and the work at UH is aimed at developing new ways to monitor the flow of gas and other hydrocarbons in order to predict when it is necessary to evacuate the drilling platform or shut down production.

"We are trying to apply fundamental science and engineering processes to predict when a catastrophic event might occur and to develop new methodologies to monitor the process," Krishnamoorti said.

In addition to Krishnamoorti, other UH researchers involved with the project include Andrea Prosperetti, director of the University's Data Science Institute and the Center for Advanced Computing and Data Systems, George Wong and Konstantinos Kosterellos, associate professors of petroleum engineering.

They will work with Mulberry Well Systems LLC and other industry representatives on the project, which he described as a true partnership between industry and academia. "We want to bring in expertise from industry to be complemented by data science and other academic disciplines to address a complex problem," he said.

The project grew out of discussions between the International Association of Drilling Contractors and the Subsea Systems Institute, a research center led by UH, with partners Rice University and NASA Johnson Space Center. Krishnamoorti, a chemical engineer, also serves as director of the Institute.

The work will involve modeling using advanced computing to better understand what happens, and under what conditions, as gas moves up a drilling pipe, allowing researchers to determine how to predict when the gas poses a danger.

ENVIRONMENT

WHAT'S IN THE WATER?

Hanadi Rifai Studies Houston's Post-Harvey Waterway Pollutants

BY JEANNIE KEVER

A University of Houston engineer has joined the effort by the National Science Foundation (NSF) to better understand how disasters such as Hurricane Harvey happen and how best to respond.

Hanadi Rifai, professor of civil and environmental engineering and director of the environmental engineering graduate program at the UH Cullen College of Engineering, will characterize the chemical and microbiological contamination in Houston waterways after Harvey.

> "NSF-funded scientists have a long history of advancing our understanding of large-scale disasters and their aftermath."
>
> - NSF DIRECTOR FRANCE CÓRDOVA

The work is part of a $5.3 million effort by the NSF to rapidly fund 59 projects, most of them related to hurricanes Harvey and Irma. The NSF also plans to support work related to Hurricane Maria.

"NSF-funded scientists have a long history of advancing our understanding of large-scale disasters and their aftermath," NSF Director France Córdova said. "These researchers have increased our ability to predict the paths of tropical cyclones, found ways of improving flood water decontamination and enhanced our understanding of the mechanisms that may cause levee failures. NSF's new awards will result in similar advances critically needed in the face of such disasters."

Rifai's work looks at potential widespread contamination of water, soil and sediment following the unprecedented flooding from Harvey, which dumped more than 50 inches of rain over some parts of the Houston metro area.

It has been difficult to assess how a severe storm might affect water quality, both because the storms are relatively rare and because it's difficult to collect and evaluate enough information using traditional methods. Rifai's proposal, funded with an $181,801 grant, calls for using advanced metagenomics techniques to determine the microbiological condition of Houston's waterways after Harvey.

Four waterways – Brays, Buffalo and Greens bayous and Peach Creek – will be studied.

"These assessment techniques will allow us to conduct a detailed investigation of the health hazards to area communities after Harvey," Rifai said. "What we learn will guide decision-making to increase resilience within the urban water infrastructure during and after extreme weather events."

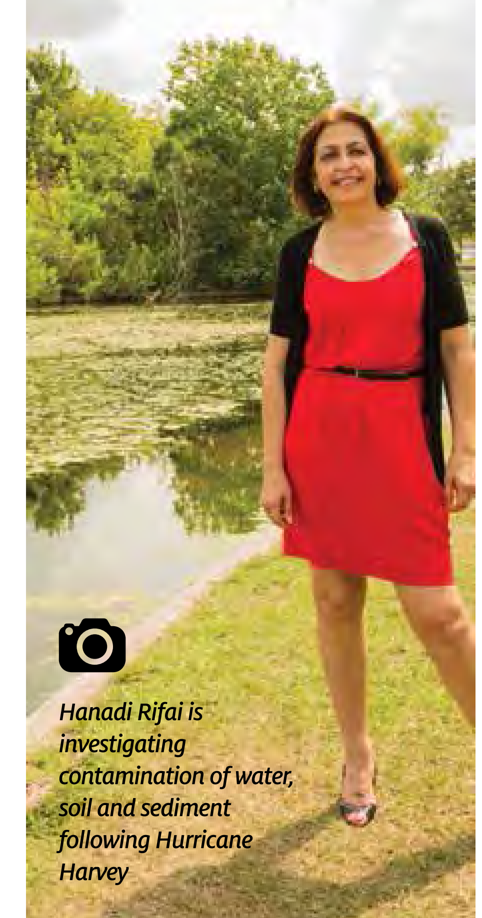
Rifai will study the potential contamination of

Brays Bayou

Buffalo Bayou

Greens Bayou

Peach Creek



Hanadi Rifai is investigating contamination of water, soil and sediment following Hurricane Harvey

UH Engineers

SHEDDING LIGHT on Water Pollutants

BY LAURIE FICKMAN

It's no secret that the water supply is constantly inundated with all sorts of waste and chemicals. Some are filtered out, others are not. Think about old, expired medicine you casually toss away. Pharmaceuticals don't degrade.

"For specific compounds, like low concentrations of pharmaceuticals or hormones, that's where our regular wastewater systems are not quite effective," said **Stacey Louie,** assistant professor of civil and environmental engineering.

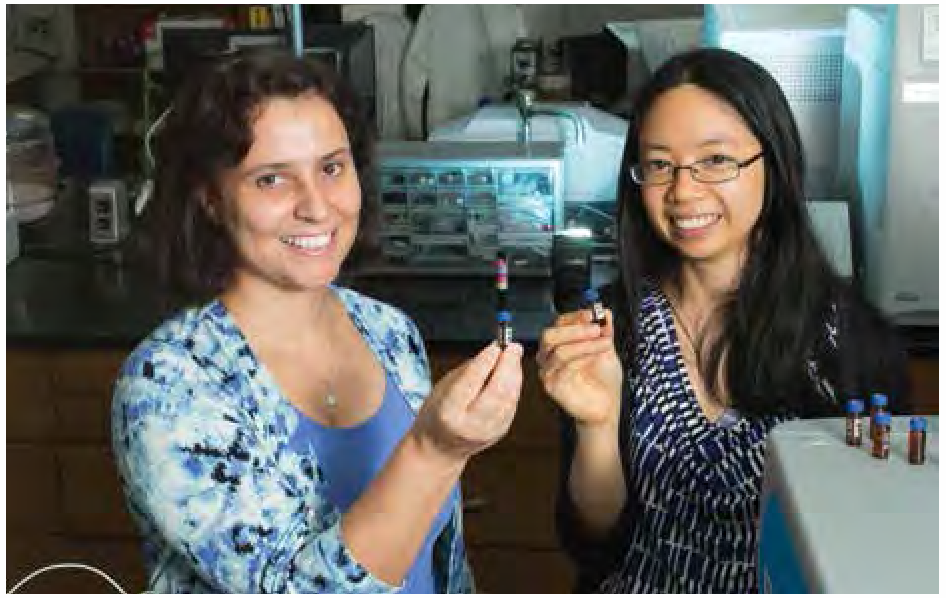
Follow the trail closely and you'll see that the pills you toss end up on a trash heap, which disintegrates and leaches into the water system where it eventually faces the water filtration system. It's a good system, but Louie thinks it can be better, especially in the field of light-reactive nanoparticles, which have been proposed to remove trace chemicals from drinking water. Louie said there are some drawbacks to the process.

"One of the current limitations is that the nanoparticles now in use to break down pollutants only work under UV light, which consumes a lot of energy, so we're trying to find new materials that work under sunlight," said Louie.

Another problem is that the nanoparticles can quickly become coated with foulants (any substance that dirties or grimes the surface) in the water treatment process. "We're investigating how these foulants change the effectiveness of the nanoparticles," said Louie. The National Science Foundation has given Louie and **Debora Rodrigues,** associate professor of civil and environmental engineering, $300,000 to do both for their project, "Effects of surface-adsorbed biomolecules and geomolecules on the photoreactivity of metal oxide nanomaterials."

Small particles, large impact

At water treatment plants, UV lamps activate nanoparticles, but Rodrigues and Louie are intent on modifying nanoparticles so the process will work under sunlight because, as Rodrigues says, "it's cheaper."



Debora Rodrigues (left) and Stacey Louie are finding better ways to remove trace chemicals from drinking water

"You won't have to plug in electricity and use a bulb or UV lamp," said Rodrigues. But first they have to change the nanoparticles to activate and degrade the chemicals when exposed to sunlight. Rodrigues already pointed a research spotlight on this subject.

THE NATIONAL SCIENCE FOUNDATION AWARDED RODRIGUES AND LOUIE

$300,000

TO RESEARCH NEW METHODS OF REMOVING TRACE CHEMICALS FROM DRINKING WATER

In her previous work Rodrigues identified and developed new nanomaterials that can degrade organic pollutants under sunlight irradiation. "This unique photoreactivity makes them attractive for applications in diverse water treatment technologies," said Rodrigues.

In this research they will compare titanium dioxide, which is activated by ultraviolet light, to molybdenum oxide, a visible light-active nanomaterial that could show improved viability for water treatment applications. Louie and Rodrigues will further change the makeup of the materials by adding a coating to them to represent realistic water treatment scenarios. Along the way they will develop a model capable of predicting the effects of surface coatings on photoreactivity across a variety of materials.

"They are non-toxic," said Rodrigues, who added that the team would ultimately like to shine on several beams: Advancing the science of nanomaterials while at the same time finding alternative treatments that will be energy efficient and safe for humans.

That sounds like a ray of sunshine in the dark world of pollutants.

BREATHE EASY:

Megan Robertson is Making it Easier to Recycle Plastics

BY JEANNIE KEVER

Most of the 150 million tons of plastics produced around the world every year end up in landfills, the oceans and elsewhere. Less than 9 percent of plastics are recycled in the United States, rising to about 30 percent in Europe.

That's a $176 billion problem, the potential energy savings scientists say could be achieved from recycling all global plastic solid waste. But new approaches can increase the amount of plastic waste that can be successfully recycled, researchers from the University of Houston and IBM report in a perspective published recently in *Science*.

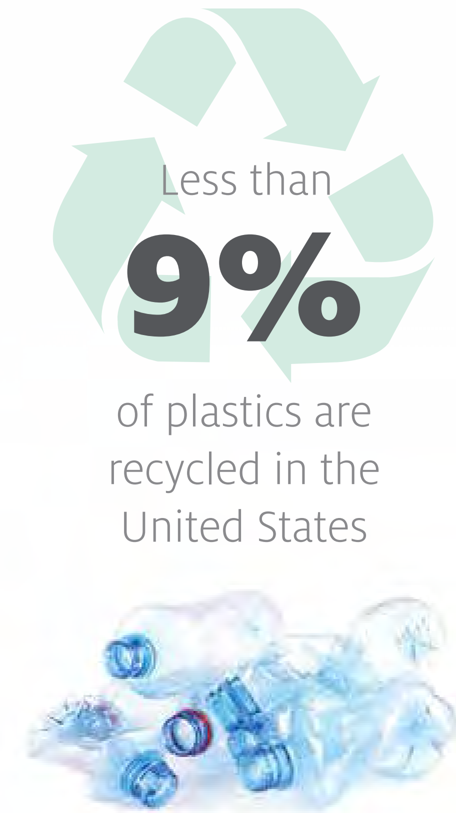
That means developing new plastics that are more easily recycled, along with finding ways to more efficiently recycle existing plastics. These approaches can range from methods to recycle different types of plastics together in one waste stream, avoiding a costly and time-consuming sorting process, as well as methods to break down plastics in a more energy-efficient manner.

"Recent research points the way toward chemical recycling methods with lower energy requirements, compatibilization of mixed plastic wastes to avoid the need for sorting, and expanding recycling technologies to traditionally nonrecyclable polymers," wrote the article authors, **Megan Robertson,** associate professor of chemical and biomolecular engineering at the UH Cullen College, and Jeannette M. Garcia, a polymer chemist at the IBM Almaden Research Center.

Improving methods to recycle existing plastic materials is a key priority. "New materials enter the market slowly, and thus the biggest impact is in developing more efficient methods to recycle the plastics that are produced in large quantities today," said Robertson. "On the other hand, research advances can pave the way for more easily recyclable materials for the future." One example is the category of polymers known as thermosets, which can't be melted down for repurposing, preventing their recycling with traditional methods.

Robertson's lab develops biorenewable components for thermosets, replacing hydrocarbon-based polymers with those made from vegetable oils or other plant-based materials. That could lead to new end-of-life options such as composting or chemical recycling for these materials – a huge leap forward.

The perspective is part of a series published by *Science* to explore issues related to the environmental impact of polymers, including their source (petroleum versus biosources), advances in recycling and biodegradable polymers.



Robertson and Garcia note three key issues:

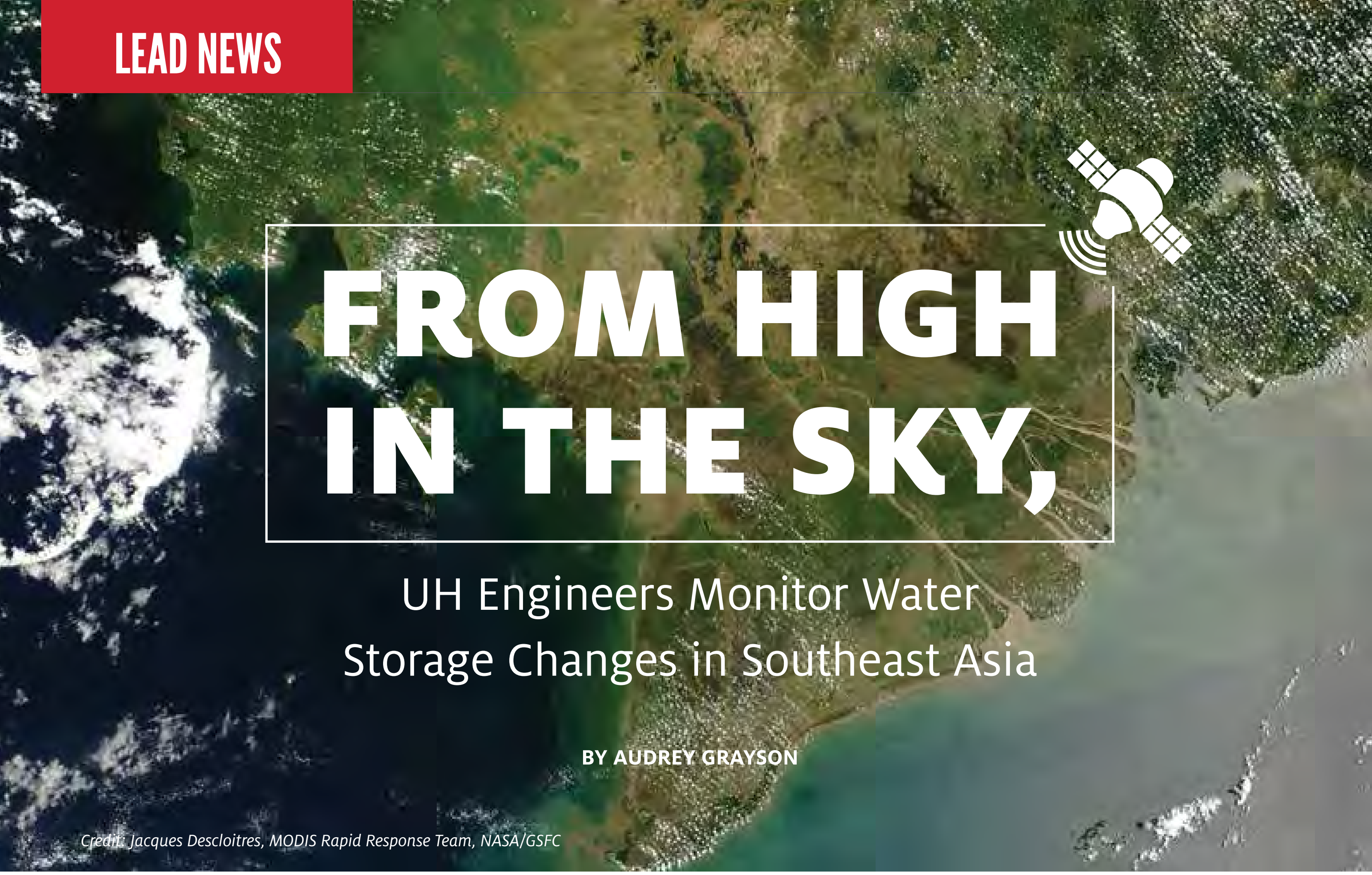
- Plastics must be sorted for recycling, which adds effort and expense. Plastics, or polymers, are comprised of large molecules, so most don't mix when heated, similar to the interaction between oil and water. Research is focused on finding substances that can facilitate the mixing of different types of plastics, known as compatibilizers, allowing them to be recycled together. Finding a compatibilizer that works for all polymers would be ideal, but Robertson said current technology requires a tailored approach for each plastic mixture.
- Chemical recycling involves using a catalyst to break down plastics to produce lower-molecular-weight products, a process the researchers say has been hindered by high energy costs. Work to develop more efficient catalysts is underway.
- The majority of plastics currently recycled are composed of polyethylene terephthalate (PET), which is the component used in most water bottles, and polyethylene, the most highly produced plastic. Expanding recycling technologies to other plastics beyond PET and polyethylene is an ongoing area of research. Even more challenging is developing methods for recycling polymers that can't be processed through melting at elevated temperatures, such as thermosets and elastomers (rubber materials).

With any potential solution, the researchers say it is critical that a material's performance isn't impacted in order to make it easier to recycle. Subjecting plastics to many use and recycling cycles without loss of performance is an open challenge for researchers.

"Enhancing plastics recycling beyond the current level has many potential societal advantages, such as reducing greenhouse gas emissions, avoiding waste buildup in the environment, decreasing the dependence on finite petroleum resources for its production, and recovering the economic value of plastic solid waste," the researchers wrote.

That has begun, they say, pointing to start-up companies that have scaled up chemical recycling methods for polystyrene waste or developed sorting processes to separate materials into pure feedstocks.

That and other research, they wrote, "raise hope that, before long, recycling rates for plastics will be much higher than today."

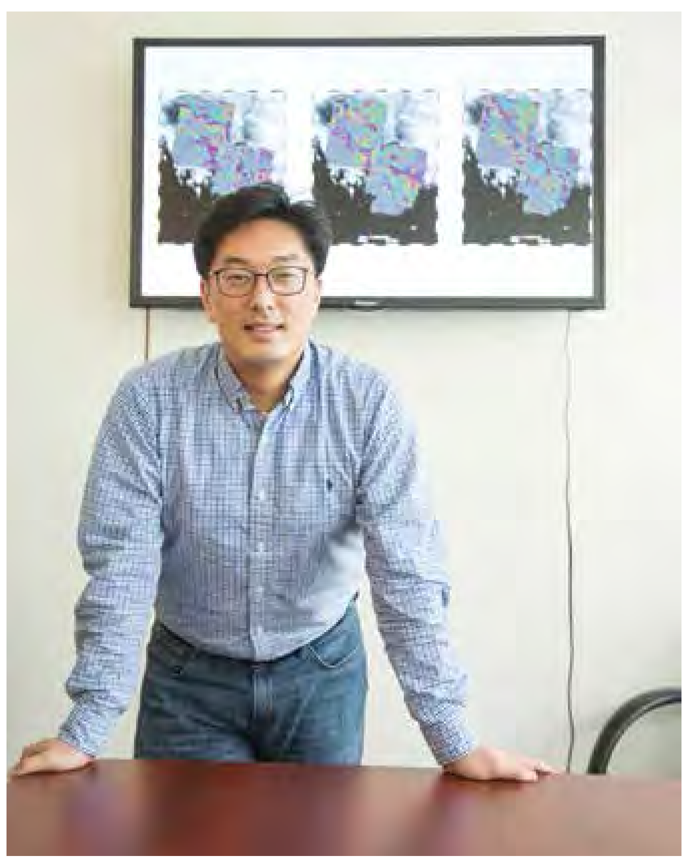


FROM HIGH IN THE SKY,

UH Engineers Monitor Water Storage Changes in Southeast Asia

BY AUDREY GRAYSON

Credit: Jacques Descloitres, MODIS Rapid Response Team, NASA/GSFC



One of the biggest challenges faced here on Earth – how to manage water resources for an ever-growing global population – may soon be solved more than 20,000 miles above our heads.

Principal investigator **Hyongki Lee,** associate professor of civil and environmental engineering, along with co-investigator and postdoctoral researcher **Ning Cao** received more than $320,000 in funding from NASA to help build a sustainable system for water management in the lower Mekong region of Southeast Asia, where several countries share a single water source.

The project is one of 32 funded by NASA in support of the Group on Earth Observations (GEO) Work Programme, an initiative that uses data obtained by Earth-observing technologies (such as satellites) to help inform decision-making on Earth, such as how to manage natural resources and maintain the health of our environment.

Lee and Cao were selected to help guide the future of effective global water management through the GEO Global Water Sustainability (GEOGLOWS) initiative.

As above, so below

The Mekong River in Southeast Asia stretches from China in the north to Cambodia in the south, crossing through Myanmar, Vietnam, Laos and Thailand along the way. The livelihoods of millions of people throughout the region depend on the Mekong's waters for farming and fishing – the primary source of nutrition in the lower basin.

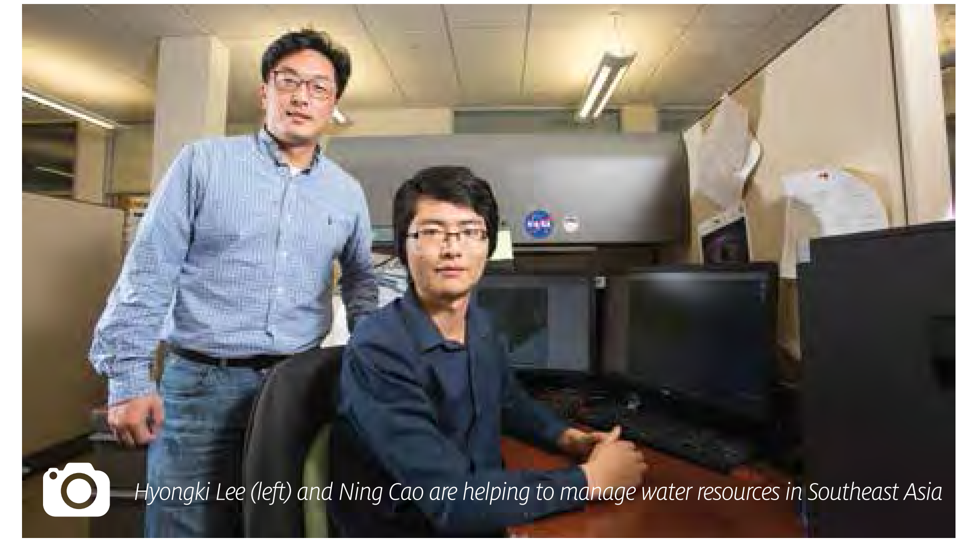
Although water is plentiful in the region, it is not evenly distributed among the countries according to needs, Lee said. In the lower Mekong especially, where several countries share this water source, the need for sustainable water management tools is dire.

In 2016 Lee was selected by the NASA SERVIR program to lead a project managing water resources in Indochina by gathering data from satellite observations of the region and building a user-friendly software tool to allow government officials to view information on water levels in real time.

"We take the raw data, then we analyze and process it to end up with a final product, which could be river level changes and groundwater storage changes, and even forecasting of these changes. We use the satellite data to solve scientific problems," said Lee.

As it turns out, there's a lot you can see from up above that isn't so apparent down below. "If a country upstream builds a dam, it can have catastrophic impacts on fishing and agricultural activities downstream," Lee said. The availability of near real-time satellite data takes the guesswork out of water management policies, providing complementary hydrologic variables with unprecedented accuracy.

With this latest grant, Lee and Cao are taking the work a few steps further. Integrating several forms of satellite data and images, the UH engineers have created a software suite that allows users to view water levels across the Mekong region on a 3-D map. The software toolbox can quantify and visualize changes in water storage over time, warning decision-makers when levels are dangerously high or low and even making valuable predictions on future changes.



Hyongki Lee (left) and Ning Cao are helping to manage water resources in Southeast Asia

Bridge over troubled waters

The low-lying deltas of the Mekong are especially vulnerable to water availability due to an increasing population, extensive irrigation and unchecked industrial development farther upstream. For many years locals relied on groundwater as the go-to water source, leading to land subsidence and increased risk of flood. Couple that with climate change and an inability to quantify changes in water storage levels across the region, and you've got some troubled (and unequally distributed) waters.

Thankfully Lee's reputation for building bridges over troubled waters preceded him, and government officials in Vietnam and Cambodia soon came calling for his assistance. A lack of groundwater resources in the lower Mekong means the ability to measure and predict surface water storage changes is critical. Lee and Cao's software offers just that.

"This software suite can help stakeholders in those countries better understand and monitor surface water to improve water resource management across the entire transboundary basin," Cao said.

Lee and Cao will travel to Vietnam and Cambodia to train government officials in those countries on how to use the software in their decision-making on water policies.

Looking back, Lee said he wouldn't be starting this latest NASA project without the help of a UH GEAR grant in 2016 that gave him the seed funding to build his software suite.

"I had great support getting to this point by working with Ning," Lee said, adding that Cao's exemplary work has impressed him for more than four years. Cao began working with Lee as a Ph.D. student and has developed innovative spaceborne and airborne interferometric synthetic aperture radar (InSAR) techniques. "The fact that our proposal with Ning onboard as co-investigator has been selected highlights the importance and innovativeness of his past and current research."

Cao said he's excited by the opportunity to continue working side-by-side with Lee for the duration of this three-year project.

"After that I'm not sure what's next, but my experience with Dr. Lee has made me want to be a faculty member," Cao said.

From left: Jeremy Palmer, Jeff Rimer and Peter Vekilov are finding better ways to grow crystals

THE CRYSTAL CLEAR FUTURE of Pharmaceuticals:

UH Engineers Grow Better Crystals

BY LAURIE FICKMAN

The National Science Foundation has awarded $510,000 to **Peter Vekilov,** John and Rebecca Moores Professor of chemical and biomolecular engineering and chemistry, to conduct the first fundamental work on how the nature of solvents impact the crystallization process.

"This will be very cool because it will be the beginning of a new field of study," said Vekilov, one of the world's leading experts in crystallization and pioneer of two-step nucleation, a revolutionary method of controlling the production of crystallization of proteins, which could lead to effective treatments for some diseases such as sickle cell anemia.

"Very cool" to him may just end up being groundbreaking to the rest of us.

While much is known about how organic crystals form in water-based solvents, not so with organic solvents.

"The level of understanding of the fundamental processes of crystal growth from organic solvents is severely limited," said Vekilov. He calls it "the main obstacle to a rational approach to the optimization and control of crystallization in organic and mixed organic-aqueous media."

It's important

The biggest market for crystals is pharmaceuticals. If you've ever taken ibuprofen or acetaminophen then you've swallowed little crystals. It's a field in which Vekilov is expert.

He recently published an article shedding new light on how some of the most effective malaria drugs – those from the quinoline class – prevent the growth of hematin crystals, a key piece of the infection process, from taking place. The paper was co-authored by **Jeffrey Rimer,** Ernest J. and Barbara M. Henley Associate Professor of chemical and biomolecular engineering. Rimer joins Vekilov on this new work along with assistant professor **Jeremy Palmer**.

In this grant for the work titled "Solvent-structuring at the interface between crystals and mixed organic-aqueous solvents," the team will attempt to kill two birds with one stone, said Vekilov. One will be to understand the crystallization of organic solvents, and the other to understand the crystallization of hematin.

"The rate at which crystals grow depends on how fast bonds can form and the formation of the bonds is mediated by the solvent," said Vekilov. "So we want to understand how the bonds form and how the solvents affect them so we can grow better organic crystals faster."

Team work

The project takes the form of experimental and computational work. Vekilov and Rimer will conduct the experiments using atomic force microscopes. Palmer will conduct the computer work.

The group will study around 20 molecules. They will modify the hematin to see which parts of the molecule are important for crystallization and which are not. Through the process they will better understand how the malaria parasite deals with the toxic hematin.

"You can design the drugs by knowing how – that's crucial. Without knowing how you cannot design drugs," said Vekilov.

He's already working on the drug and treatment component with other support from the National Institutes of Health.

UNEXPECTED DISCOVERY

Leads to New Theory of Liquid Streaming

BY JEANNIE KEVER

Researchers at the University of Houston were studying the nonlinear transmission of light through an aqueous suspension of gold nanoparticles when they noticed something unexpected. A pulse laser appeared to have forced the movement of a stream of liquid in a glass laboratory cuvette (a type of test tube).

As they investigated, they realized something more complex was at work than a transfer of momentum from the laser photons to the liquid. Their observation led to a new optofluidics principle, explained in a paper published recently in the journal *Science Advances.*

"It was not so simple," said **Jiming Bao,** associate professor of electrical and computer engineering at the Cullen College and lead author of the paper. "The momentum from a laser isn't strong enough to activate the movement."

Light usually passes straight through water without any absorption and scattering, so Bao said even strong momentum from the photons wouldn't generate a liquid stream. The gold nanoparticles turned out to be key – researchers found that the nanoparticles were initially needed to create the stream because they reacted to focused laser pulsing to create a plasmonic-acoustic cavity, a structure Bao described as a "bowl" that formed on the inner wall of the cuvette.

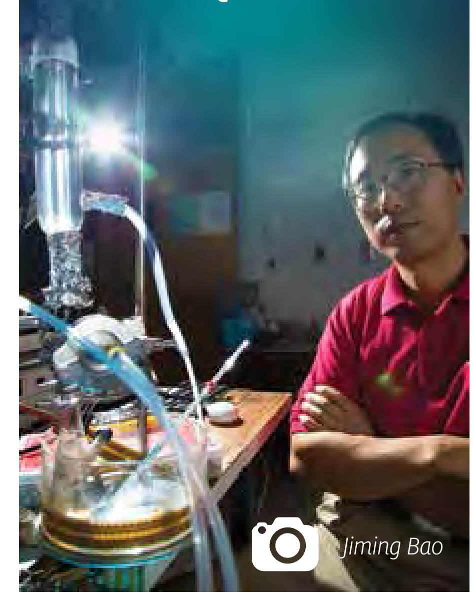
The moving stream of liquid is triggered by ultrasound waves generated by the expansion and contraction of the nanoparticles, which occurs when nanoparticles on the cavity surface heat up and cool down with each laser pulse. The stream was captured on video.

Once a cavity is created, the nanoparticles can be removed. Bao said streaming can be induced in any fluid.

The discovery has the potential to significantly improve work in a number of fields, including lab-on-a-chip experiments involving moving liquids, such as a droplet of blood, at a microscopic scale.

The driving of flow by acoustic wave is called acoustic streaming and was discovered by British scientist Michael Faraday in 1831; it is now widely used in microfluidics. The generation of ultrasound by gold nanoparticles, called photoacoustics, is also well known and is used in biomedical imaging.

THE DISCOVERY HAS THE POTENTIAL TO SIGNIFICANTLY IMPROVE WORK IN A NUMBER OF FIELDS, INCLUDING LAB-ON-A-CHIP EXPERIMENTS INVOLVING MOVING LIQUIDS



Jiming Bao

This new optofluidics principle couples photoacoustics with acoustic streaming. "It can be used to generate high-speed flows inside any liquids without any chemical additives and apparent visible moving mechanical parts," the researchers wrote. "The speed, direction and size of the flow can be controlled by the laser."

In addition to Bao, researchers involved in the project include co-first authors Yanan Wang and Qiuhui Zhang as well as co-authors Zhuan Zhu, Feng Lin, Shuo Song, Md Kamrul Alam and Dong Liu, all of UH; Jiangdong Deng of Harvard University; Geng Ku of the University of Kansas; Suchuan Dong of Purdue University; and Zhiming Wang of the University of Electronic Science and Technology of China. Bao, Wang and Lin also have appointments at the University of Electronic Science and Technology of China.

Bao said more work is needed to better understand how the gold nanoparticles form the plasmonic-acoustic cavity and to determine better ways to generate a liquid stream, among other things. But there will be a number of applications for the newly discovered principle.

"Laser streaming will find applications in optically controlled or activated devices such as microfluidics, laser propulsion, laser surgery and cleaning, mass transport or mixing," the researchers conclude.

Learn more in the September issue of *Science Advances*

FUNDAMENTALS

SPEEDING UP INDUSTRY:

Engineering Professors Discover Fundamental Effect in Monolayer Catalysts

BY LAURIE FICKMAN

Two professors at the UH Cullen College of Engineering have discovered that size is critical to the performance of the monolayers of catalysts, the fundamental substance that speeds up reactions in a variety of industries from petrochemical to manufacturing. **Stanko Brankovic,** professor of electrical and computer engineering, and **Lars Grabow,** professor of chemical and biomolecular engineering, published their findings in the *Journal of the American Chemical Society*, one of the most prestigious journals for scientific work in the field of natural sciences.

Capping a two-year project for Brankovic and his Ph.D. student Qiuyi Yuan, their work brings attention to the fundamental effect of finite size in platinum (Pt) catalyst monolayers. "This was ignored in the current understanding of the catalyst monolayers activity," said Brankovic. He and Yuan measured carbon monoxide absorption in Pt monolayers on Palladium (Pd) single crystal surfaces. What troubled Brankovic were inconsistent findings.

Launching the team

It didn't take long for Brankovic to mention the puzzling phenomenon to Grabow, whose primary research interest is in running complex computer simulations to predict how and why some Pt monolayer catalysts perform better than others in certain chemical reactions.

"Lars had a hunch that the observed results and monolayer catalyst performance are due to local strain induced by finite size effect," Brankovic said.

> "We all knew that we were on the verge of some big discovery."
>
> - STANKO BRANKOVIC

The finite size effect relates to the bonds that form between atoms in a 2-D cluster. In a body of atoms, the atoms in the center of the cluster form strong bonds with the surrounding atoms. Atoms located on the periphery of the cluster, however, have asymmetric bonding because there are no atoms on the other side to keep them in equilibrium. As a result, the smaller clusters have more compressive strain and are less active than the bigger ones, inherently making the catalyst monolayer activity size dependent, something the team calls the "finite size effect."

Grabow, along with his graduate student Hieu Doan, ran computer simulations to explain experimental data and identify structures that could obtain favorable catalytic properties due to the finite size effect. Using theoretical calculations to test their hypothesis, Grabow and Doan confirmed that the finite size effect contributed to the catalyst monolayer activities.

"They found that the finite size effect in the Pt/Pd system is huge and has a dominant role in determining its catalytic properties, which is the information that can bring much more new development in catalyst monolayer synthesis. The morphology of the catalyst monolayer controls their activity," Brankovic said.

"It turned out that everything Lars and Hieu had calculated matched perfectly with the experimental data. We all knew that we were on the verge of some big discovery," he added.

Both Brankovic and Grabow are winners of prestigious National Science Foundation CAREER Awards, which partially funded this research. Additional funding came in the form of a University of Houston GEAR Award, which offers seed funding to young researchers looking to get projects inside their laboratory off the ground.

HEALTH & MEDICINE

Putting More MUSCLE in Artificial Muscles:

Zheng Chen Wins NSF CAREER Award

BY JEANNIE KEVER

A University of Houston engineer has received a $500,000 CAREER award from the National Science Foundation (NSF) to develop artificial muscle and tendons for dexterous, compliant and affordable prostheses.

Zheng Chen, Bill D. Cook Assistant Professor of mechanical engineering at the Cullen College, said the resulting prosthetics would be more comfortable and work more efficiently than current models, which involve motorized metallic parts.

Chen, director of the Bio-inspired Robotics and Controls Lab at the UH Cullen College of Engineering, works with smart materials to devise improved prostheses. These smart materials – Chen works with dielectric elastomers – have built-in actuation and sensing capabilities, allowing them to more closely mimic human muscles.

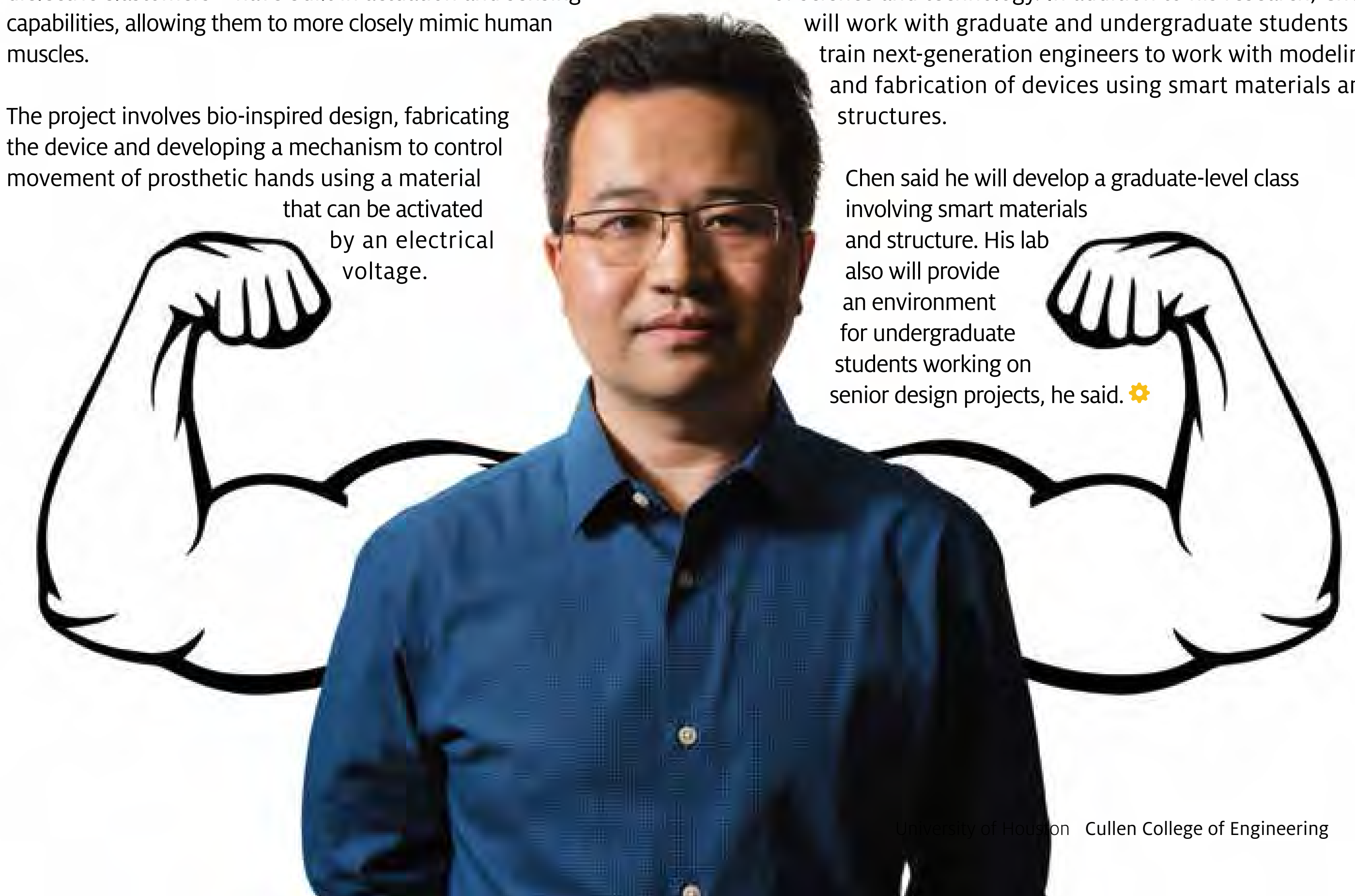
The project involves bio-inspired design, fabricating the device and developing a mechanism to control movement of prosthetic hands using a material that can be activated by an electrical voltage.

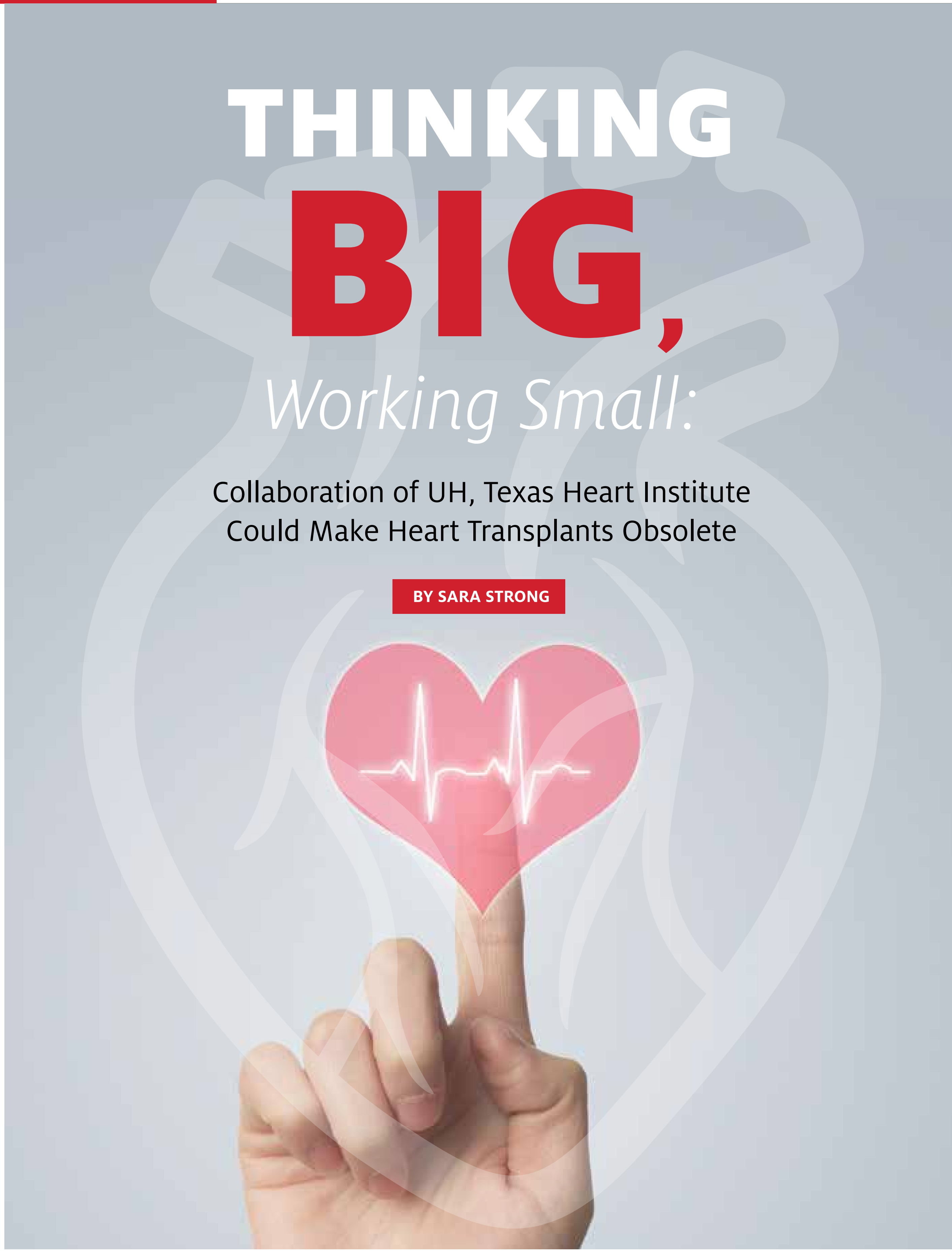
Chen and his colleagues have developed a prototype of artificial muscle and tendon structure. "It achieves some performance, but we need to improve the performance," he said. "It is an integrated sensor and actuator, so the person can sense objects, grasp and participate in other activities."

He will use nanotechnology to push the material to achieve the necessary performance; it then will be used to construct artificial muscle and tendons.

NSF CAREER awards are granted to promising junior faculty members who exemplify the role of teacher-scholars. Recipients also do educational outreach to promote a better understanding of science and technology. In addition to his research, Chen will work with graduate and undergraduate students to train next-generation engineers to work with modeling and fabrication of devices using smart materials and structures.

Chen said he will develop a graduate-level class involving smart materials and structure. His lab also will provide an environment for undergraduate students working on senior design projects, he said.





THINKING BIG, *Working Small:*

Collaboration of UH, Texas Heart Institute Could Make Heart Transplants Obsolete

BY SARA STRONG

In the United States, more than 6.5 million people live with varying stages of heart failure. About 4,000 of those suffer with hearts so compromised that a transplant is the only treatment current medicine can offer. Yet only about half that many transplant-suitable hearts become available each year.

Fortunate patients who do get a match still face heavy challenges. Having already suffered rigors of very advanced heart failure, they then face the trauma of lengthy transplant surgery, with its risks and prolonged deep anesthesia, followed by the side effects of lifelong anti-rejection drugs.

That is the outlook now, but change is coming.

Ralph Metcalfe, professor of mechanical and biomedical engineering, oversees a revolutionary research project with William Cohn, director of the Center for Technology and Innovation at the Texas Heart Institute. Results are so promising that Metcalfe predicts radical improvement in treatment of failing hearts will happen within a decade.

"This device, once perfected, can have as much impact on society as the polio vaccine had in the 1950s," he said. "Breakthroughs are coming very fast."

Working under the guidance of Metcalfe and Cohn, mechanical engineering Ph.D. candidate **Alex Smith** studies how blood flows through a next-generation mechanical blood-pumping device. This will not be like the larger and more cumbersome pumps of past decades, but a small device that can be implanted without major surgery, even removed later if appropriate.

In Texas Heart Institute laboratories in the basement of St. Luke's Hospital in the Texas Medical Center, Smith focuses on refining the size, shape and angle of a pair of tiny spinning impellers that propel blood through the pump. He also monitors individual blood cells to spot any damage they may incur on their trip through the device.

The goal is to develop better, less invasive treatments that can happen early in the course of cardiovascular problems, long before critical stages of heart failure manifest. Potential benefits are enormous.

"If you look at the causes of death in 2015, the most recently reported year, about 23 percent were related to heart disease. Heart failure is a major part of that," Metcalfe said.

> "This device, once perfected, can have as much impact on society as the polio vaccine had in the 1950s. Breakthroughs are coming very fast."
>
> - RALPH METCALFE

About two decades ago, Metcalfe witnessed the journey of a colleague whose damaged heart eventually limited his blood flow to only 10 to 15 percent capacity. With such poor blood circulation, cells throughout the body suffer a lack of oxygen, which damages the liver, kidneys, lungs and other organs. "The quality of life goes down very significantly," he said.

For Metcalfe's colleague, the call came on Christmas Eve in 1996 that a donor heart was being readied for him. "Usually things go fairly well from there, but not in this case," Metcalfe said. Despite all efforts, the body rejected the organ and the patient died three days after surgery.

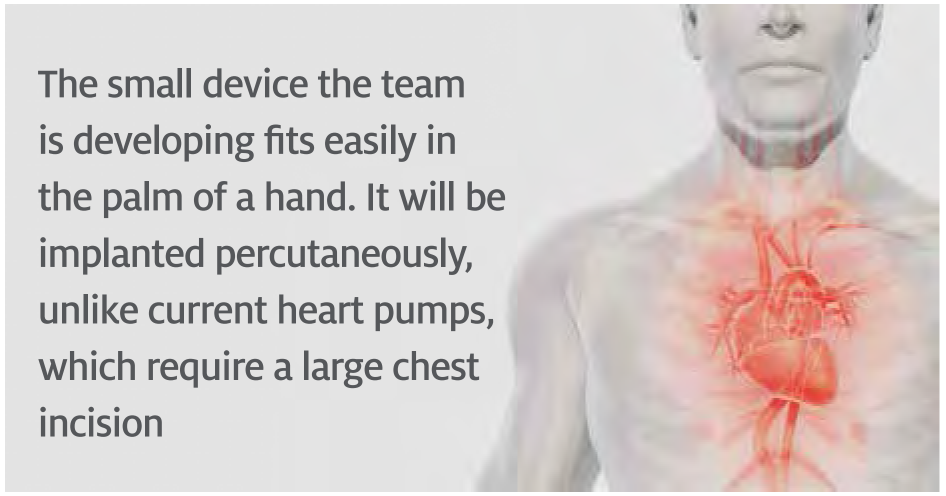
Inspired by what he had witnessed, Metcalfe began to consider the human cardiovascular system. His expertise in fluid mechanics from his original specialty of computational fluid dynamics provided an ideal link with medical innovators' skills when it came to the challenge of developing much-improved cardiovascular devices.

The device that the team now works to refine offers the potential of saving millions of heart patients, plus improving quality of lives, while it sidesteps the most difficult parts of current protocols. For some patients early intervention might even provide enough rest for the heart to actually heal, something infrequently heard of in today's state-of-the-art practices.

Back in the lab, performance of the particular heart pumps under study – called LVADs, or left ventricular-assist devices – depends in great measure on the small impellers Smith works hard to perfect. To maintain ideal speed and pressure, the impellers must maintain a flow that is neither so mild the pump is inefficient nor so forceful that cells become misshapen or otherwise damaged by shear in the blood flow. 3-D printers replicate Smith's designs in about eight hours, a process that used to take a machinist months to craft by hand. "This is a huge advance, hard to overemphasize," said Metcalfe.

Looking back

But we're getting ahead of the story. The background actually begins in the 1960s when the first artificial hearts were implanted. It was a decade rich with its own scientific breakthroughs. The race to the Moon was on. Silicon chips and integrated computer circuits had kicked off an electronics revolution. A vaccine at last foretold victory over polio. And so much more was unfolding.



> The small device the team is developing fits easily in the palm of a hand. It will be implanted percutaneously, unlike current heart pumps, which require a large chest incision

In medicine, the biggest news was made by human-organ transplants. First a liver was transplanted in Colorado, then hearts in South Africa and later in Houston.

At the Texas Medical Center and its newly chartered Texas Heart Institute, heart-pump research pioneers like Denton Cooley and Bud Frazier as well as Michael DeBakey at nearby Baylor College of Medicine pondered whether an artificial device might become a safe stopgap for patients awaiting transplants of human hearts, or perhaps even become a lasting alternative. Research intensified, and the first implantations of mechanical heart pumps soon followed.

"DeBakey wanted it to happen before a man got to the Moon," Smith said. The first successful total artificial heart was implanted in April 1969, beating the Moon landing by only a few months.

Those early artificial hearts were huge and heavy, but only a small part of the mechanism is implanted into a patient's chest. The rest of the (often noisy) equipment was left outside of the body, either bedside or on a cart that trailed the patient. Survival was measured in weeks at first, then in months. Today, patients often live a decade with their circulatory system at least partially dependent on an implanted mechanical pump with a wearable external battery.

Current artificial heart pumps are not replacements for a biologic heart. Instead, they are assistants that function alongside a weakened heart, helping do the job of pumping blood. These LVADs are implanted close to the patient's own heart, in the subclavian artery and vein, located in the upper right chest. They most often are considered a "bridge-to-transplant" treatment, a way to carry a very sick patient until a suitable donor heart is found.

The heavy, bulky equipment that functioned outside a patient's body may be long gone, but the heart pumps now being implanted are still ungainly enough to cause discomfort.

Tiny miracles

The small device the team is developing fits easily in the palm of a hand. It will be implanted percutaneously, meaning it will be passed through an incision in the skin, most likely into the subclavian vein just beneath the collar bone, then carried to the heart's atrial septum (the wall separating the left and right atria). By contrast, implanting a current heart pump requires a surgeon to make a large incision and open the patient's chest.

These new devices in some cases – perhaps most – will be lifelong helpers for the heart. But for some, the device is expected to give the heart enough of a rest that it can actually heal. (In the future, stem cells may facilitate the healing.) Intervening early in the disease process, before the heart is too seriously damaged, allows the best chance for such healing to happen.

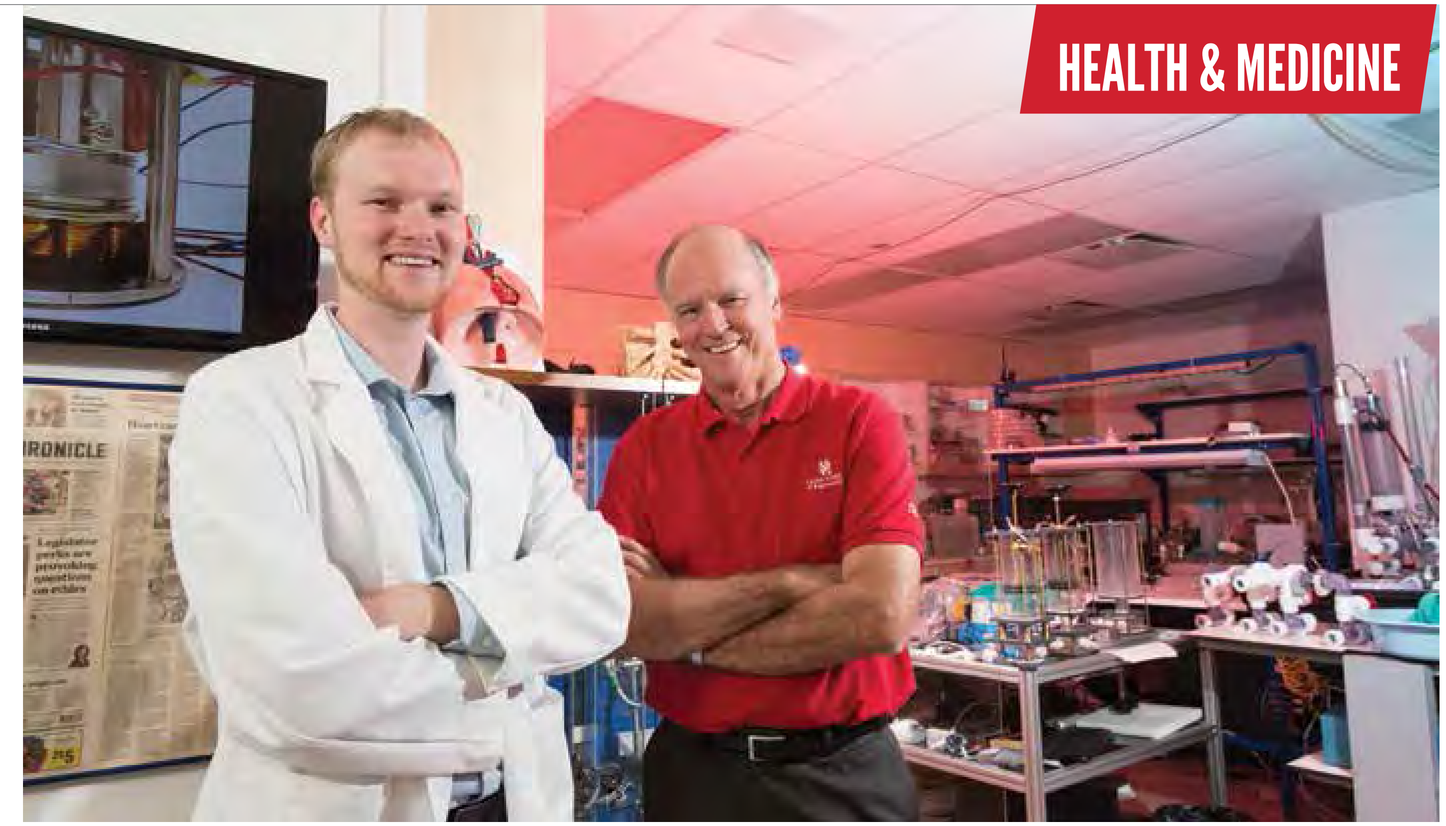
"It's like an athlete whose injury is immediately immobilizing on the playing field," Metcalfe explained. "By being immobilized, the injured area heals quicker. We haven't been able to immobilize a living heart, of course. But with this device, many unhealthy hearts may get the rest they need and be able to recover."

If complete healing is accomplished, the LVAD will be removed and the heart left to function on its own, healthy and strong. Those patients could expect full lifespans and enjoy normal lifestyles.

Looking even further into the future, Metcalfe foresees TAHs, total artificial hearts, to be designed along the same concepts as these next-generation LVADs, just more complex. As the technology races ahead, some basic challenges remain. For example, left-right blood flow must be balanced, Smith points out. In ideal function, a heart's left side must dependably propel oxygen-rich blood as far down as a body's toes and, defying gravity, up to the brain. At the same time, its right side must pulse more gently to move oxygen-hungry blood for a refueling through the lungs, located just inches away. A healthy biologic heart instinctively adjusts. A mechanical pump must be designed to respond to differing needs.

Blood-cell shear produces a different challenge. Just as wind shear affects aircraft flight patterns, too much speed or pressure can affect blood flow by deforming cells. Excessive deformation under high shear can cause

HEALTH & MEDICINE



Alex Smith (left) and Ralph Metcalfe are working to make heart transplants obsolete

cells to break, burdening the kidneys with the task of cleaning up the pieces of broken cells. On the other hand, a flow that is too slow or under low shear stress can lead to coagulation or clotting.

Blood flow conditions change continuously. Make just one simple cough, Smith explains, and pressure in your lungs and heart spikes sharply then quickly settles again. A well-functioning heart adjusts just fine. A more serious coughing spell does the same but more intensely and for longer – still not a big deal for a healthy heart. But how do you design a mechanical pump to cope when changes in the environment can be extreme and frequent, and can happen without warning?

"A lot of my work started with managing pressure and flow. Now it's shifted to the process of energy transfer," Smith said.

Far reaching studies

Metcalfe, Cohn and Smith are joined by investigators as far as China and as close as the lab next door. The project links UH with the Texas Heart Institute, St. Luke's Hospital and Rice University in Houston, as well as Soochow University in China, Griffith University and ICETLAB at Prince Charles Hospital in Australia, Gunma University in Japan, and University of Cambridge and University of Bath in the United Kingdom.

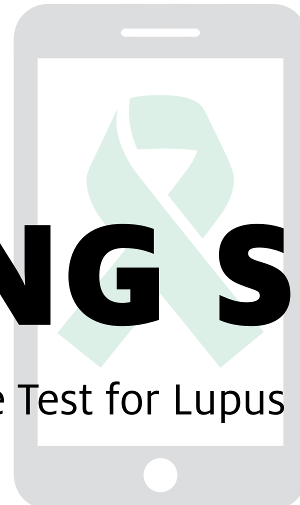
In October, Smith presented a paper at the International Society for Mechanical Circulatory Support that will become one chapter in his soon-to-be-completed dissertation. In addition, a paper based on his thesis work has been accepted for publication in the *International Journal of Artificial Organs*. Smith came to UH with biomedical engineering bachelor's and master's degrees from Texas A&M. His advisor there prompted him to change his career path a bit.

"Not only did he recommend a potential mentor, but also that mentor had a project," Smith said. Metcalfe welcomed Smith to the LVAD project and became his advisor for doctoral studies at UH. In addition, Smith joined the Texas Heart Institute in January 2014, gaining Cohn as a second mentor and advisor.

But you could say Smith's first mentor appeared much earlier and lots closer at hand, with his chemical engineer father joining him in tinkering around the family home in Kingwood, just northeast of Houston.

"My first car had been my mother's car when she was pregnant with me," Smith recalled. Over the years, father and son kept the 1983 Volvo running so well that it was recently passed to its next driver. (In case you're wondering: 500,000 miles and "green, on what little paint was left.") Across the hall, just steps from his own Texas Heart Institute lab, Smith's sister, Stephanie, who followed her big brother into biomedical engineering studies, works on a different cardiovascular project for the Texas Heart Institute in collaboration with an industrial partner.

Although Smith's doctoral degree may be in hand soon, he expects his professional involvement in this LVAD project to continue for at least a decade and perhaps far beyond as future developments take him deeper into this revolution in cardiovascular treatments.



COMING SOON...

A Smartphone Test for Lupus Nephritis Flares

BY LAURIE FICKMAN

With a four-year $1.4 million grant from the National Institutes of Health (NIH), two University of Houston engineering professors are developing a home test kit for kidney nephritis, or inflammation, in patients who have Systemic Lupus Erythematosus.

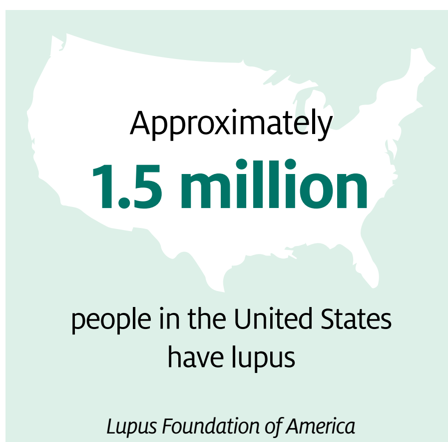
Chandra Mohan, Hugh Roy and Lillie Cranz Cullen Endowed Professor of biomedical engineering, is uncovering new urinary biomarker candidates for lupus, an autoimmune disease that leads to chronic inflammation in multiple organs, including the kidneys. Using that information, **Richard Willson,** Huffington-Woestemeyer Professor of chemical and biomolecular engineering and professor of biochemical and biophysical sciences, is creating a smartphone-based app and test kit prototype based on the technology underlying home pregnancy tests.

To Willson, the technology of the home pregnancy test is almost mystical in its promise.

"The home pregnancy test format is one of the most remarkable technical developments that anybody ever made," said Willson. After all, he said, you can buy them inexpensively and they allow people – at home, with no medical training – to measure human chorionic gonadotropin (the pregnancy hormone) with high reliability, at parts-per-billion concentrations.

Willson is taking this a step further, creating a test for candidate biomarkers of kidney inflammation, using a smartphone to take pictures of the sample test and a custom smartphone app to read the results quantitatively.

Approximately 1.5 million people in the United States have lupus, according to the Lupus Foundation of America. Those of African, Asian and Native American descent are more likely to develop it than are Caucasians and 90 percent of those with the disease are women.



"The population that is underserved by medicine is disproportionately affected by lupus, making it largely a disease of the underserved," said Willson noting that providing treatment and mitigating health risks in underserved communities is a growing focus of UH Health.

Nephritis flares are often hard to recognize because their symptoms often masquerade as something else. A sufferer might think they have a cold or the flu, or are just tired.

"With this home test, they can know for sure and go get thoroughly investigated and treated," said Willson. That immediacy is no small thing, according to Mohan, who used to be a practicing physician.

"The largest cause of death and severe disease for most patients with lupus is involvement of the kidneys," Mohan said.

The science of biomarkers and diagnostics of iPhones

Samantha Stanley, a graduate student in the Mohan laboratory, has been researching and validating specific proteins in the urine of lupus patients who developed kidney disease, laying the groundwork for this unique research. (Not coincidentally the kidneys make urine, so that's a good place to go to get the information.)

The traditional test for renal involvement is biopsy sampling of kidney tissues, but it is invasive and cannot be repeated frequently. That's when Willson pivoted to thinking about the home pregnancy test format.

"The current technology is basically a yes/no system and not quite sensitive or quantitative enough," said Willson. Proteins that are candidate nephritis biomarkers are naturally occurring in the body, but they are elevated when you have nephritis, so their test had to indicate protein levels.

Richard Willson (left) and Chandra Mohan are developing smartphone-based diagnostic tests for kidney inflammation

The test uses glow-in-the-dark nanoparticles to detect those levels, an idea that came to Willson one night while putting his young daughter to bed. He removed one of the glow-in-the-dark stars on her ceiling and brought it to a graduate student working in his lab, Andrew Patterson. Patterson worked to fashion a test stick with the strontium aluminate nanoparticles inside, decorated with antibodies to target proteins.

In the presence of the target of interest, the particles accumulate in a line like the particles in a pregnancy test. For sensitive, quantitative analysis of the test, the researchers created a slip-on iPhone accessory to hold the test stick while the iPhone camera takes multiple shots of the particles through a custom app. The brighter the nanoparticles, the higher the levels of the target protein. It turns out the photos can measure the particles accurately, and the app can deliver results instantaneously.

Early versions suggest the idea works; the NIH grant will be used to further refine the work.

"We have already published reports showing this technology is about 100 times as sensitive as a regular test, and measuring brightness with a phone is quite quantitative," said Willson. "Now that we are both sensitive and quantitative, we can potentially measure the lupus nephritis markers."

Claudia Pedroza, associate professor at the UT Health Science Center in Houston and a biostatistician, is collaborating with the team, as are UH Assistant Professor Jakoah Brgoch, a phosphor chemist, Research Associate Professor of chemical and biomolecular engineering Katerina Kourentzi, and Sanam Soomro and Heather Goux, graduate students in biomedical engineering and biochemistry, respectively.

Biomanufacturing the Next Generation of

CANCER-KILLING IMMUNE CELLS

BY AUDREY GRAYSON

Back in the days when all medicines were made out of chemicals found in nature, manufacturing drugs was somewhat of a breeze.

Take aspirin, for example. The chemical makeup of aspirin is simple; when you look at the drug under a microscope its molecules all look exactly the same. Aspirin is as easy to characterize as it is to manufacture.

But a newer class of drugs known as biopharmaceuticals, which are drugs derived from living systems such as proteins, are much more difficult to characterize and manufacture.

Living cells – like living people – undergo constant changes. How do you classify a living organism? How do you describe a system that is constantly in flux? And, more confounding, how do you reliably manufacture identical living systems the same way each time, billions of times over?

The answers to those questions are at the crux of an emerging field of cancer treatment called immunotherapy, which harnesses the body's own immune cells (called T cells) to recognize and kill cancer cells. It's a promising field, but only remains effective in about 20 percent of cancer patients.

Navin Varadarajan, associate professor of chemical and biomolecular engineering at the Cullen College, received more than $500,000 from the National Science Foundation (NSF) to boost the biomanufacturing of T cells for immunotherapy by identifying the key qualities that allow certain immune cells to become cancer killers.

Engineering cancer killers

Immunotherapy works by engineering immune cells to seek out, recognize and attack cancer cells inside the body. T cells, like any living organism, require nutrients to survive, but tumors are very low-nutrient environments. Varadarajan's task is to design immune system cells that can survive without life-sustaining nutrients long enough to kill off the tumor cells.

"If the T cells are not able to survive inside of the tumor without nutrients then they won't be able to fight off the cancer cells," Varadarajan said. "We want to know what allows certain immune cells to survive and not others."

Working with postdoctoral researcher **Irfan Bandey** and MD Anderson collaborator Michael Rytting, Varadarajan will profile immune cells using his novel research platform called TIMING, which allows the team to study single-cell interactions between T cells and tumor cells. The immune cells will then be infused into mice models of leukemia; Whichever T cells persist and succeed in killing their opponents will be characterized once more using the single-cell assay.

Postdoctoral researcher Irfan Bandey is engineering cancer-killing immune cells

"We need to create a map connecting the metabolism of the T cell to its ability to fight off the tumor cell successfully in order to say, 'These are the characteristics in the cells that we need in order to fight off the tumor cells,'" said Varadarajan.

Ultimately, Varadarajan hopes to give oncologists the ability to predict how effective immune cells will be at killing a cancer before a leukemia patient receives a transfusion of T cells.

But first things first: "You have to know what you want before you figure out how to make a billion copies of it," he said.

Navin Varadarajan is working to give oncologists the ability to predict how effective immune cells will be at killing a cancer before a patient receives a transfusion of T cells

Researchers Report Better Way to Create

ORGANIC BIOELECTRONICS

BY JEANNIE KEVER

With increasing scientific and medical interest in communication with the nervous system, demand is growing for biomedical devices that can better record and stimulate the nervous system, as well as deliver drugs and biomolecules in precise dosages.

Researchers with the University of Houston and Pennsylvania State University have reported a new fabrication technique for biocompatible neural devices that allows more precise tuning of the electrical performance of neural probes, along with improved properties for drug delivery.

"For years, scientists have been trying to interact with the nervous system, to diagnose Parkinson's disease, epilepsy, multiple sclerosis, brain tumors and other neural disorders and diseases earlier," said **Mohammad Reza Abidian,** associate professor of biomedical engineering at the UH Cullen College and lead author of a paper describing the fabrication technique in the journal *Advanced Materials*. "In our laboratory we create micro- and nano-devices to communicate with neurons."

The paper, titled "Conducting polymer microcups for organic bioelectronics and drug delivery applications," was featured as the journal's cover story in November. A video produced by the journal's publisher, Wiley, accompanied the article to explore the research in more depth.

Abidian said the new fabrication method allows researchers to precisely control the surface morphology of conducting polymer microcups, improving performance. They used electrojetting and electrodeposition methods for fabricating conducting polymer microcups on the surface of bioelectronics.

"We found that by varying the amount of electrical current and the length of deposition time of these conducting polymers, we can change the size, thickness and roughness, which is related to the electrical properties of the polymer," he said. "We show that conducting polymer microcups can significantly improve the electrical performance of the bioelectrodes."

> "For years, scientists have been trying to interact with the nervous system. In our laboratory we create micro- and nano-devices to communicate with neurons."

- MOHAMMAD REZA ABIDIAN

Typical polymers are often used as an insulating material because they don't generally conduct electricity. The discovery of electronically conducting polymers in the 1970s was recognized with the Nobel Prize in chemistry in 2000.

"The primary requirement of neural devices is to provide high density electrodes that are biologically compatible with neural tissue, efficiently transduce biological signals to electronic signals and remain functional for long periods of time," the researchers wrote.

But current technology still relies upon metallic materials, which are highly conductive but incompatible with neural tissue. The miniaturization required for the devices also limits the electrical performance, Abidian said.

Conducting polymers, in contrast, must mimic biological tissue in four ways: their soft mechanical properties simulate those of biological structures; their mixed electronic/ionic conductivity promotes efficient signal transduction; their transparency allows the simultaneous use of optical analysis techniques; and their facile functionalization with biomolecules helps tune biological responses.

The new fabrication method involves the electrospraying of monodisperse poly microspheres on gold substrates, followed by an electrochemical polymerization process. Then the researchers control the applied electrical field for the fabrication of conducting polymer microcups, Abidian said, which in turn allowed them to control the surface morphology.

Additional authors on the paper include Martin Antensteiner and Milad Khorrami, both with UH, and Fatemeh Fallahianbijan and Ali Borhan with Penn State.

Could a Saliva Test be Next for LUPUS?

BY LAURIE FICKMAN

The symptoms of systemic lupus erythematosus (known as SLE or lupus) can fool you. You might think you're tired or have a cold when, in fact, you may actually have this autoimmune disease that leads to chronic inflammation in multiple organs. Blood tests or a kidney biopsy can confirm the diagnosis and extent of organ involvement, but these tests are invasive and often uncomfortable.

At the University of Houston, **Chandra Mohan,** Hugh Roy and Lillie Cranz Cullen Endowed Professor of biomedical engineering, is proposing a simpler test. With a $386,599 grant from the National Institutes of Health, he'll investigate biomarkers for a lupus test that uses only saliva.

In a blood test for lupus, anti-double stranded DNA (anti-dsDNA) antibody markers are very high in someone who tests positive for the disease. Scientists have found that the anti-dsDNA also shows up in saliva.

"Now we need to find out if salivary anti-dsDNA is at least as good if not better to test than blood anti-dsDNA," said Mohan. "If it is, then that is great, because wouldn't you rather give saliva than blood?" Testing saliva samples is particularly attractive for children and patients from whom blood is difficult to draw.

Lupus continues to be disproportionately diagnosed in the population underserved by medicine. Mohan is working to provide treatment and mitigate health risks in underserved communities, which is a growing focus of UH Health.

Preliminary studies reveal that saliva from people with SLE harbors antibodies and several proteins currently being pursued as potential blood biomarkers of SLE and lupus nephritis, or inflammation. Encouraged by these findings, the pilot study will investigate the different isotypes and specificities of autoantibodies and biomarker candidate proteins that are elevated in the saliva of SLE and lupus nephritis patients and establish their association with the disease. Clearly the easier option, saliva from a larger sample group will also be tested by Mohan while he and a colleague from Johns Hopkins School of Medicine, Professor Michelle Petri, also test other control conditions. Other researchers include Sanam Soomro, a graduate student, and Kamala Vanarsa, a research scientist.

Their work may pave the way for a home-based kit, similar to one Mohan is developing with UH engineer Richard Willson for urinary home testing of lupus nephritis flare-ups.

"The same kit could be used to test saliva, but with urine we already know some of the biomarkers to look for," said Mohan. "In the case of saliva, this grant will help us study what to look for and how to identify the proteins that are useful as biomarkers in saliva."

Mohan, a former practicing physician, has made lupus his life's work. In the 1980s, after receiving his medical degree in Singapore, many of his first, memorable patients had lupus.

"One of the things the patients and their families would always ask me was, 'Am I going to die?' and 'Is there a treatment?' At that time we hardly knew anything about lupus, and the literature was very sparse," said Mohan.

Those patients and their questions changed Mohan's life, and he dedicated himself to changing the outcomes and treatments for patients with lupus. He quit practicing medicine to pursue a doctoral degree at Tufts University in Boston, where he focused on the cellular immunology of lupus. He's been at it ever since.

Mohan said if he was that young doctor today, he would have better answers for those patients and could offer better treatment options. And though he might not have imagined it then, maybe a way to test for the disease with, by far, the easiest bodily fluid to collect.

Breakthrough in DISSOLVING ELECTRONICS Holds Promise for Biomedicine

BY JEANNIE KEVER

Researchers from the University of Houston and China have reported a new type of electronic device that can be triggered to dissolve through exposure to water molecules in the atmosphere.

The work holds promise for eco-friendly disposable personal electronics and biomedical devices that dissolve within the body. There are also defense applications, including devices that can be programmed to dissolve in order to safeguard sensitive information, said **Cunjiang Yu,** Bill D. Cook Assistant Professor of mechanical engineering at the Cullen College and lead author of the paper, published in *Science Advances* and reported by *Science*.

The field, known as physically transient electronics, currently requires immersion in aqueous corrosive solutions or biofluids. Yu said this work demonstrates a completely new working mechanism – the dissolution is triggered by ambient moisture.

"More importantly, the transient period of time can be precisely controlled," he said. That means a biomedical implant could be programmed to disappear when its task – delivering medication, for example – is complete. Sensitive communications could be devised to literally vanish once the message was delivered.

And all those old cell phones littering kitchen drawers? New versions could be programmed to dissolve when they are no longer needed.

"We demonstrate that polymeric substrates with novel degradation kinetics and associated transience chemistry offer a feasible strategy to construct physically transient electronics," the researchers wrote. "Through the manipulation of the polymer component and environmental humidity, the progress of hydrolyzing polyanhydrides can be managed and thus the dissolution kinetics of a functional device can be controlled."

The time period can range from days to weeks, or even longer, they said.

The model constructed by the researchers works like this: Functional electronic components were built via additive processes onto a film made of the polymer polyanhydride. The device remained stable until ambient moisture triggered a chemical breakdown that digested the inorganic electronic materials and components.

The researchers tested a number of compounds, including aluminum, copper, nickel indium-gallium, zinc oxide and magnesium oxide, and developed various electronic devices, including resistors, capacitors, antennas, transistors, diodes, photo sensors and more, to demonstrate the model's versatility.

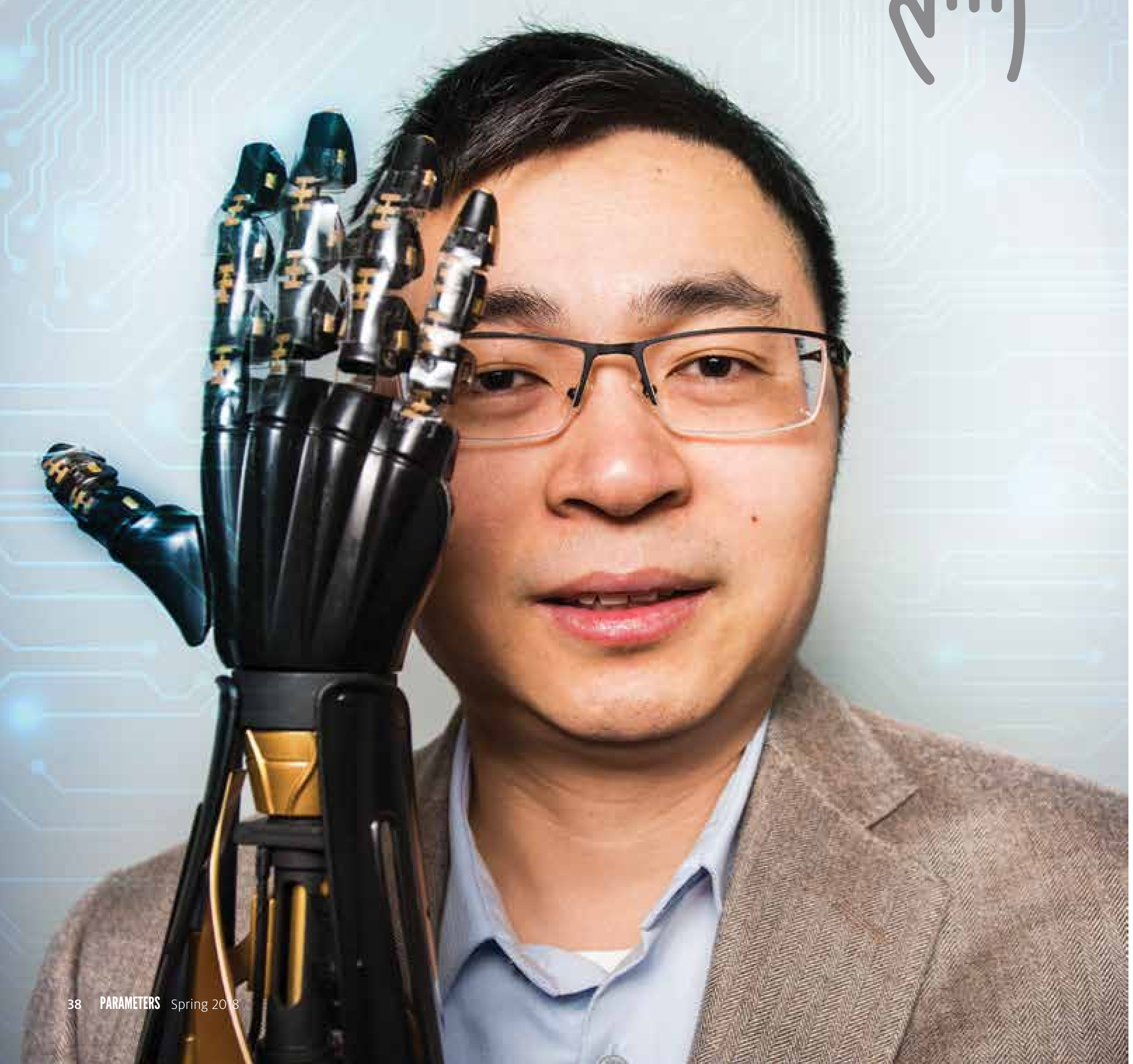
Imagine a world where medical devices are programmed to dissolve within the body

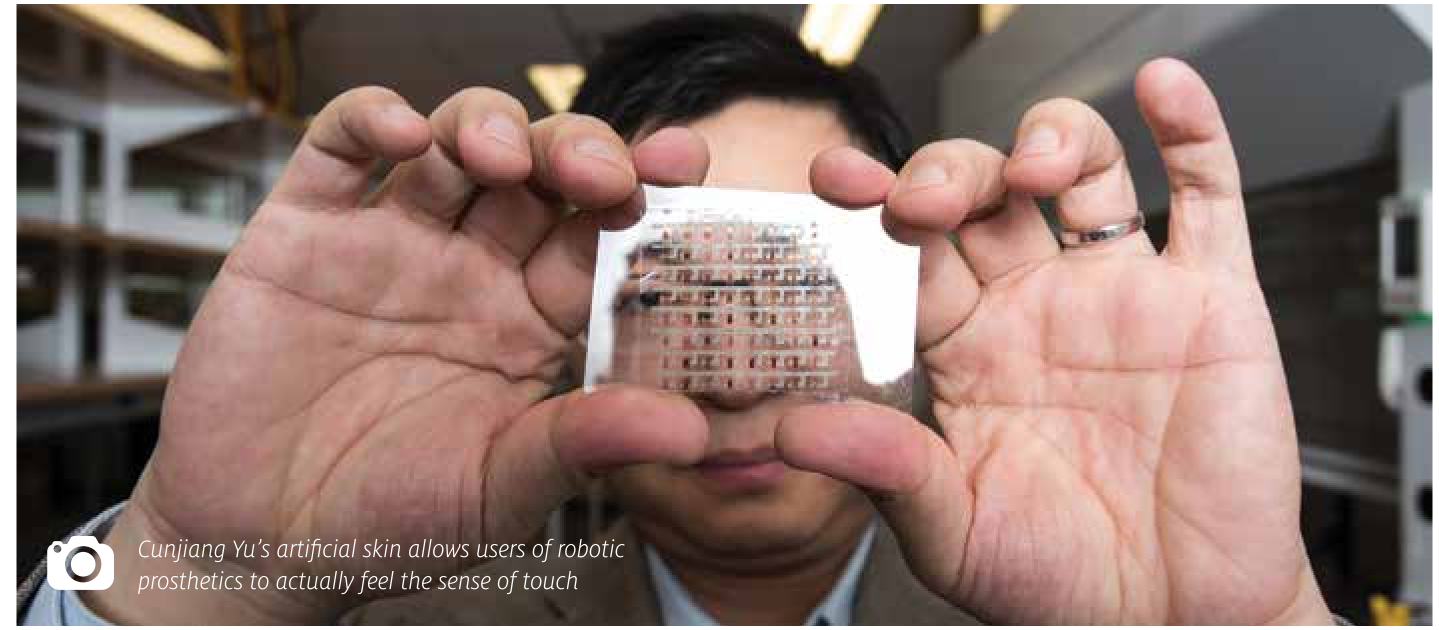
The lifespan of the devices can be controlled by varying the humidity level or by changing the polymer composition, Yu said.

In addition to Yu, authors on the paper include Yang Gao, Xu Wang, Kyoseung Sim, Jingshen Liu and Ji Chen, all from UH, and Ying Zhang and Hangxun Xu of the University of Science and Technology of China.

Artificial 'Skin' Gives Robotic Hand a SENSE OF TOUCH

BY JEANNIE KEVER





Cunjiang Yu's artificial skin allows users of robotic prosthetics to actually feel the sense of touch

A team of researchers from the University of Houston has reported a breakthrough in stretchable electronics that can serve as artificial skin, allowing a robotic hand to sense the difference between hot and cold, while also offering advantages for a wide range of biomedical devices.

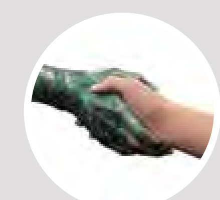
The work, reported in the journal *Science Advances*, describes a new mechanism for producing stretchable electronics, a process that relies upon readily available materials and could be scaled up for commercial production.

Cunjiang Yu, Bill D. Cook Assistant Professor of mechanical engineering and lead author for the paper, said the work is the first to create a semiconductor in a rubber composite format, designed to allow the electronic components to retain functionality even after the material is stretched by 50 percent.

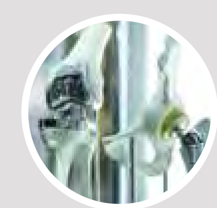
The work is the first semiconductor in rubber composite format that enables stretchability without any special mechanical structure, Yu said.

He noted that traditional semiconductors are brittle and using them in otherwise stretchable materials has required a complicated system of mechanical accommodations.

Stretchable electronics could be used for:



Artificial skins



Biomedical implants

Surgical gloves

That's both more complex and less stable than the new discovery, as well as more expensive, he said.

"Our strategy has advantages for simple fabrication, scalable manufacturing, high-density integration, large strain tolerance and low cost," he said.

Yu and the rest of the team – co-authors include first author Hae-Jin Kim, Kyoseung Sim and Anish Thukral, all with the UH Cullen College of Engineering – created the electronic skin and used it to demonstrate that a robotic hand could sense the temperature of hot and iced water in a cup. The skin also was able to interpret computer signals sent to the hand and reproduce the signals as American Sign Language.

"The robotic skin can translate the gesture to readable letters that a person like me can understand and read," Yu said.

The artificial skin is just one application. Researchers said the discovery of a material that is soft, bendable, stretchable and twistable will impact future development in soft wearable electronics, including health monitors, medical implants and human-machine interfaces.

Scientists Release a How-To for Building a Smartphone Microscope

BY JEANNIE KEVER

Add one more thing to the list of tasks your smartphone can perform. University of Houston researchers have released an open-source dataset offering instructions to people interested in building their own smartphone microscope.

The researchers describe the process in a paper published in *Biomedical Optics Express*, demonstrating that a basic smartphone equipped with an inexpensive inkjet-printed elastomer lens can be converted into a microscope capable of fluorescence microscopy, able to detect waterborne pathogens and perform other diagnostic functions.

Wei-Chuan Shih, associate professor of electrical and computer engineering, said fluorescence microscopy is "a workhorse," used in biology, medical diagnostics and other fields to reveal information about cells and tissue that can't otherwise be detected. The technique allows more information to be harvested from fluid, tissue and other samples, but not everyone has access to an optical microscope that can use fluorescence.

It could extend sophisticated imaging techniques to rural areas and developing countries, Shih said. But it also could have more widespread applications, such as allowing backpackers an easy way to test for pathogens in rivers and streams.

"We really hope anyone who wants to build it can," he said. "All the pieces can be made with a 3-D printer. It's not something that belongs just to the lab."

The work was partially funded with a $100,000 grant from the National Science Foundation's citizen science initiative, which encourages scientists to find ways to expand knowledge of and access to research.

Shih's lab created an inexpensive lens that can turn a smartphone into a microscope in 2015; he and members of the lab created a company to produce and distribute the inkjet-printed lenses, which attach directly to a smartphone camera lens.

They continue efforts to improve on that process, and in an article published last fall in *Applied Optics* they reported engineering a platform – constructed with low-cost parts including LEGO bricks and plastic imaging components – to ensure high-throughput quality inspection of the inkjet-printed lenses.

The lenses were used in the work reported in *Biomedical Optics Express*, which details how the researchers combined simple LED lighting with a 3-D printed cartridge designed to hold a conventional glass slide. The light and cartridge attach to the smartphone.

While conventional tabletop microscopes shine light through the sample from above, the Shih lab's technology launches the light from the side of the slide, which is about one millimeter thick. The LED light travels through the glass, refracting to allow the observer to view cell nuclei and structure.

That's both less expensive and less complicated to operate, Shih said.

"To pursue ultra-simplicity for open-source do-it-yourself fluorescence smartphone microscopy, we report the development of an integrated single lens add-on for multi-color fluorescence imaging," the researchers wrote. In addition to Shih, those involved with the project include Yulung Sung, an electrical and computer engineering doctoral student at the Cullen College, and undergraduate Fernando Campa.

Results from testing water samples for pathogens including Giardia lamblia and Cyrptosporidium parvum using the technology were compared with results obtained using a tabletop optical microscope. Resolution was slightly higher with the optical microscope, but the researchers reported resolution of two microns with the smartphone technology.

Shih said he looks forward to seeing the device used by people outside the scientific community.

"I feel more and more excited about seeing people adopt simple basic scientific gadgets," he said. "I think it will have more impact if we let people play with it, rather than trying to hold it as a secret. We should make it as easy and accessible as possible for everyone."

Saurabh Prasad writes algorithms to better analyze geospatial imagery

UH Engineer Changes How We Interpret GEOSPATIAL IMAGES

BY LAURIE FICKMAN

Saurabh Prasad, Cullen College assistant professor of electrical and computer engineering, reported a breakthrough in image interpretation that could overcome hurdles that prohibit accurate interpretation of imagery data. His work, tackling the challenges of object rotation, was featured on the cover of the journal *IEEE Transactions on Geoscience and Remote Sensing*, which showcases his article "Morphologically decoupled structured sparsity for rotation-invariant hyperspectral image analysis."

Hyperspectral imagery, which delivers intensely miniscule details over hundreds of wavelengths (colors) from hyperspectral cameras, presents interpretational challenges that Prasad is navigating around.

"You can't simply use off-the-shelf techniques to analyze such images effectively," he said. A big part of his work is designing new algorithms to leverage the potential in such data.

The challenge begins when the algorithms interpreting data are being created. To create an algorithm-based program that recognizes objects in images, the program must be fed hundreds, if not thousands, of examples of the object to learn recognizable features. But the program is stymied if the object under review is oriented a different way than its cache of training library photos. The "nuisance factors," as Prasad calls them, include varying illumination, sensor viewpoints, scales and orientation of objects in the images. Prasad's Hyperspectral Image Analysis Laboratory focuses on machine learning and image analysis algorithms that are robust to these confounding conditions.

"In this paper we developed a method to specifically account for orientation variability. With this work, we make new inroads into the field of sparse representation-based image analysis, where optimal image analysis can be undertaken by exploiting the underlying sparsity in signal representations," said Prasad. He can train the machine using any orientation of an object and apply the sparse representation based model to any other orientation. The method includes partitioning an image into its geometric components, which enables Prasad to design algorithms to ensure robustness to orientation changes.

Reviewing satellite (or aerial) images from hyperspectral cameras, scientists can tell whether a soccer field is covered with natural grass or Astroturf. The images are that precise and detailed.

"In a sense, every pixel has a chemical fingerprint," said Prasad. Examples of this intense ability to peer into chemicals on the ground are the NASA images collected over ground zero after 9/11, in which the extent of the debris field was interpreted by remote sensing.

"That is the power of hyperspectral imaging," said Prasad "Because of such images, they had an idea of how far the concrete and different kinds of dust, like gypsum and wallboard, had spread, something that would be very challenging with traditional color images."

Color camera images provide information on three colors: red, green and blue. Hyperspectral cameras provide information on hundreds of thousands of colors and are not constrained by the visible part of the spectrum; they peer beyond the visible into the infrared portion of an image.

It's so complicated it's beyond human interpretation, especially with images spanning a wide geospatial scale.

"At the end of the day we want machines (algorithms) to assist us in understanding such images," said Prasad. "Humans are limited in capacity to interpret such large and complex data. It requires an algorithm-based approach."

And so he wrote one.

The Next BIG Thing:

The big ideas and brilliant minds that are shaping the future in Houston & beyond.

BY RASHDA KHAN

Throughout history, engineers and their inventions have changed the world, made possible the impossible and shaped human civilization. Ingenuity and innovation are hardwired in our genes.

The first wheel was invented by a human ancestor who didn't know the word "engineer," but definitely understood engineering.

Armed with knowledge, imagination and curiosity, engineers have always used existing resources to create new tools, technologies and possibilities. They paved the way for building the pyramids of Egypt and launching the International Space Station, a multi-nation collaborative habitat that flies about 248 miles above the Earth.

> "**Airplanes are beautiful dreams. Engineers turn dreams into reality.**"
>
> - HAYAO MIYAZAKI

Career choices are evolving.

You may rethink what you want to be when you grow up.

This creative evolution continues to this day. At the University of Houston Cullen College, the spirit of engineering and the attitude of doing is magnified by Houston's thriving **medical, energy, aerospace** and **data industries.** Committed to building a better world for future generations, UH engineers are pioneering innovations and laying down the framework for the next generation of engineering talent, jobs and frontiers.

In this issue of *Parameters* we explore the booming engineering fields that will shape the economic landscape of the future and the Houston engineers at the forefront of discovery and education.

SPACE CITY'S ENGINEERS LAUNCH TO THE MOON AND BEYOND

The skies have held wonder and inspiration for generations of human beings.

Our ancestors looked to the stars to navigate across the oceans and discover new lands. Now engineers, scientists and entrepreneurs are working to rocket into space and establish a human outpost on the Moon before traveling further.

"What if the first sea explorer never set sail because it was too dangerous or not cost effective enough? There would be no discovery and who knows where we would be today," says **Tyler Gilliland,** who is pursuing dual masters' in aerospace engineering and space architecture at the UH Cullen College of Engineering.

"Because there were those explorers and they found ways to engineer innovation, we are where we are today," he continues. "Space is our next ocean, our next frontier."

UH graduating space pioneers

The Cullen College's space architecture graduate program – the only program of its kind in the world – is housed at the Sasakawa International Center for Space Architecture (SICSA) and draws star-struck space enthusiasts like Gilliland from all over. Students are immersed in first-hand knowledge of NASA, its contractors and the dynamic commercial space flight industry.

The multidisciplinary master's program teaches students to think outside the box and consider not only how a particular development works, but how it works with other systems as part of a greater whole.

Also, professors and students keep in mind that everything — whether it be a rocket or a habitat — is designed for human use.

"At the space architecture program, we have the task of trying to think of everything — from mission planning to what to do with waste," Gilliland says. "It teaches you on a holistic or systems-level scale what it takes to keep humans alive and thriving in space."

Clare Luckey, who moved from Michigan to pursue her master's in space architecture at UH, checks out a Mars diorama at SICSA

The program's students are pushing boundaries and attracting accolades.

SICSA had a strong hand in designing the shiny futuristic-looking Houston Spaceport under construction at Ellington Airport. The project is envisioned as a hub for aerospace operations, including building rockets, designing micro satellites, unmanned aerial vehicles, spacecraft manufacturing and other activities.

When **Sam Ximenes,** an alumnus of the space architecture program, won the contract to conduct an economic feasibility study for the project and look into the design and construction aspect, he turned to his alma mater for help.

Ximenes' company XArc (Exploration Architecture Corp.) and SICSA student **Nejc Trost** identified potential markets for the spaceport and put together economic projections for the project. Their design was presented at

Space architecture students Thomas Lagarde (left) and Tyler Gilliland (right) talk about the future of space exploration with Professor Olga Bannova (center)

the Space Center Houston in 2013.

Both Ximenes and Trost brought a lot to the table: Ximenes was a member of the design team for Spaceport America, and Trost published a book on spaceport design based on a thesis he wrote while attending the University of Ljubljana in Slovenia and had 3-D rendering experience gained through his space architecture studies at UH.

The space architecture program was a selling point for Arturo Machuca, general manager for Ellington Airport and the Houston Spaceport.

"Every conversation we have with companies that are contemplating locating here, or are already here, workforce is the immediate concern," Machuca said in a previous interview with UH Media Relations.

Then there are student projects:

Thomas Lagarde, a master's student from France, and three other students — **Victor Kitmanyen, Timothy Bishop** and **Zachary Taylor** — designed a solar-powered habitat that would allow a 12-member crew to live and work on Phobos, one of the two moons of Mars.

The International Space Station (ISS), the only facility with humans in space right now, can accommodate six.

The student project, which used a series of hooks to anchor the base of the habitat to Phobos to keep it from floating away into space, won first place at the American Institute of Aeronautics and Astronautics design competition in 2017.

Also in 2017, another UH student team came in second to MIT's team in the Revolutionary Aerospace Systems Concepts Academic Linkage forum. **Suzana Bianco** and **Shunsuke Miyazaki** designed a commercial space station with separate modules for sleeping, dining and working in for a better work-life balance for future space dwellers.

The students analyzed elements of the ISS to evaluate how long they would last and what could be reused. They also reviewed all stages of their station development, created a cost analysis and prepared a business plan for their design.

> **"There's a ton of commercial companies emerging in the aerospace industry. I think they're going to flood the market with jobs."** - TYLER GILLILAND

The U.S. Bureau of Labor Statistics projects that

171,900 jobs

will open up for aerospace, computer hardware, electronics and mechanical engineers between 2014 and 2024

Olga Bannova, director of the space architecture program, is proud of her students and encourages them to attend conferences, present at forums and tackle challenging competitions.

"If you have ideas, share them. There is always the potential that it'll get better," Bannova says.

Since Bannova and her students are building careers pondering about humans in space, we asked them to share their thoughts on future space developments.

Credit: SpaceX

2018:
A gateway to opportunity

2018 has already had some big space-related milestones.

With the dramatic launch of SpaceX's Falcon Heavy rocket — complete with billowing steam, burning flame and a bright red Tesla Roadster driven by a mannequin called "Starman" — this year was seen as a game changer, a power thrust to American space ambitions.

The event was witnessed around the world and heralded by many as the sign of a new space age.

It proved rocket dreams are not only possible but economically viable, reigniting the dream of colonizing the universe. The launch also bolstered the success of private commercial enterprise.

"Right now the [global] space industry is mostly supported by governments and tax-payers in terms of funding, resources and projects, but that's not enough to have the big push that is needed," Bannova says. "Having the space arena more open for commercial opportunities as well as public-private partnerships is crucial."

Success helps build confidence and will lead to governments trusting commercial partners more and more, she adds.

"Elon Musk being a star, an 'Iron Man' for our age, and Jeff Bezos, the richest man on our planet, investing all his money in aerospace," doesn't hurt either when it comes to building confidence, says Lagarde.

In late 2017, the Trump administration put forward a space policy directive calling for NASA to work with "private sector partners," the return of people to the Moon and an eventual mission to Mars and then beyond.

> **"Working in the space industry doesn't mean you have to be a rocket scientist. It's very important, but there are other jobs as well. The industry is looking for people who can think outside the box and bring different perspectives. That's exactly what our students do."** - OLGA BANNOVA

Lagarde imagines governments will eventually assume a role more focused on scientific research and regulatory oversight.

However, this shift from public to private has been taking place for some time now.

"About 20 or 30 years ago, if you wanted to do anything space-related the only jobs would be at NASA or companies like Boeing and Lockheed that contracted with NASA," Gilliland says. "Now there's a ton of commercial companies emerging in the aerospace industry — SpaceX, Virgin Galactic, Blue Origin, Bigelow Aerospace, Axiom Space to name a few. I think they're going to flood the market with jobs."

The U.S. Bureau of Labor Statistics projects that 171,900 jobs will open up for aerospace, computer hardware, electronics and mechanical engineers between 2014 and 2024.

Bannova says she's always fielding calls and emails asking for students to fill internships or jobs.

> **"I have a lot of open doors being in HOUSTON, which is SPACE CITY."** - TYLER GILLILAND

"Working in the space industry doesn't mean you have to be a rocket scientist. It's very important, but there are other jobs as well," she says. "The industry is looking for people who can think outside the box and bring different perspectives. That's exactly what our students do."

Gilliland is working as an intern at Intuitive Machines, a company that works closely with Axiom, which is building the world's first private, commercial Earth-orbiting space station. He hopes the internship will turn into a full-time job, but is also looking at other options.

"I have a lot of open doors being in Houston, which is Space City," he says, adding that the city is home to the world-renowned NASA Johnson Space Center and numerous commercial aerospace companies.

Lagarde echoes his optimism.

"It's a unique field and we're a very small group and our expertise is very wide," he says. "We can fill a lot of different positions in the industry."

Why the Moon? Why Mars?

Going to the Moon and Mars is not wishful thinking, but a necessary step for humankind.

Lagarde is annoyed by a sentiment he keeps hearing: "There are so many problems on Earth, why do they want to spend all this money on space?"

"People don't realize that every dollar invested in the space industry comes back 10-fold to Earth. It's a necessity. We have to go to space," says Lagarde.

His current research centers around sustainable agriculture in space and recycling human waste for use in futuristic greenhouses.

"The risks are getting way too big on our planet. The biggest problem we have right now is water — if our population keeps growing while there's decreasing access to potable water, we're going to have a crisis," he adds. "There's a lot of water in space."

Add to that possibilities of human population outstripping land, food and other resources in certain areas of the world, antibiotic-resistant bacteria and the possibility of a disease-related crisis, or a gigantic asteroid hitting Earth, he points out.

"The risk of a catastrophic failure of our ecosystem is getting bigger every day and having an outpost or base somewhere else on another planet might prove pretty useful for our kind in the future," Lagarde says.

And the Moon has to be a stepping stone.

"Without developing the Moon, it'll be harder to go any further because there are resources there," Bannova says. "It has to be a place we can go, stay and work, creating fuel depots and deep space ports."

Once the infrastructure is in place and there are space freighters carrying cargo and people back and forth between Earth and its outposts, a whole new world of jobs and opportunities will open up.

"We're going to need everyone from drillers and rock movers to coffee baristas," Gilliland says. "Whatever it takes to make a society on another planet is what you're going to have to copy and take with you."

Funding will be an issue, but Lagarde says humans are economically driven. "If we tell them there's a lot of zinc, iron, water and oxygen up there and they just have to take it, I think we're going to see people change their minds very quickly about the cost and investment in space," he says.

> **"Hopefully our future generations will talk about how they can colonize the next star. Those are the things I dream about at night."**
>
> \- TYLER GILLILAND

> **"People don't realize that every dollar invested in the space industry comes back 10-fold to Earth."**
>
> \- THOMAS LAGARDE

Gilliland envisions a move toward commercial application of space — such as utilizing the Moon's resources and taking advantage of a zero gravity environment to create products that can't be produced on Earth or to generate improved versions of earthly commodities.

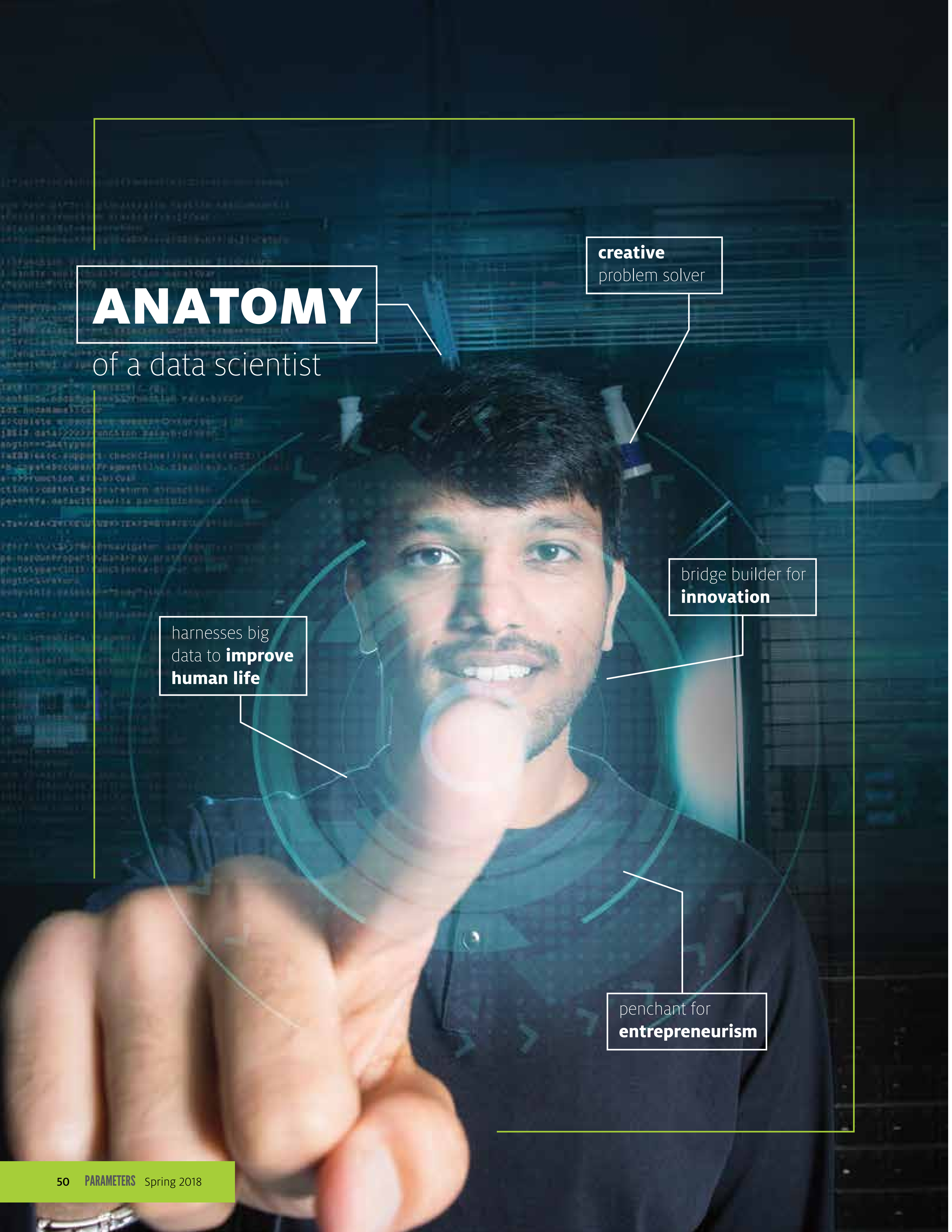
There are applications that NASA is already employing on the ISS that can be jumped to a broader market, such as pharmaceuticals and fiber optics.

While none of this will come easily, UH engineers are proving that it's possible. "We have to have the confidence that we can do it. Just like building the world's tallest building…this is going to be the next feat," Gilliland says. "It's going to take a lot, but I think we can."

He has grand hopes for the future.

"Hopefully our future generations will talk about how they can colonize the next star," Gilliland says. "Those are the things I dream about at night." ■

To check out more exciting SICSA projects, visit
http://sicsa.egr.uh.edu/projects

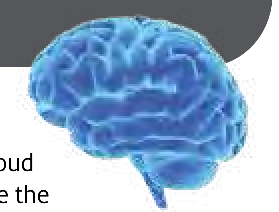


HARNESSING THE POWER AND PROMISE OF BIG DATA

Information is flowing free in the digital age and collecting data on everything — from the mundane to the paramount — has never been easier.

We wear activity trackers on our wrists that count our steps and burned calories; we use a multitude of apps several — sometimes hundreds — times a day; we purchase goods and services with credit cards and spend substantial amounts of time surfing the web. Invisible streams of data are gathered by sensors placed at buildings, roadways, bridges and even your smart television.

> **Nearly every field is now trying to use data science and combine products with machine learning and artificial intelligence.**
>
> - PENGYU YUAN



The advent of Cloud storage has made the storing of data and accessibility much easier, adding fuel to the collecting frenzy.

The collection and use of data is not new.

"Every scientist, medical doctor, retailer, every banking executive has always been using data," says **Andrea Prosperetti,** a National Academy of Engineering member and Distinguished Professor of mechanical engineering at the University of Houston.

"What has changed is the amount of data available and the speed at which this data can be accessed," says Prosperetti, who has been tapped to lead UH's new Institute of Data Science. "The quantity that is becoming available is so enormous that the quantitative change becomes a qualitative change."

In other words, the flood of information can be overwhelming to unprepared humans.

A little further on campus in Engineering Building 1, **Hien Van Nguyen** — an assistant professor at the Cullen College of Engineering and director of the Houston Ubiquitous Learning Algorithms (HULA) Research Lab — agrees with Prosperetti.

"We need to get more advanced in machine learning and data analytics because...if we don't develop the technology to understand this data, then we are throwing away precious pieces of information that can be used to save the lives of many people and do a lot of good," says Nguyen, who works with medical data and machine learning.

Fortunately, technology exists that allows real-time or nearly real-time processing and analysis of the data. So do the experts and minds to conduct research and teach future generations at UH.

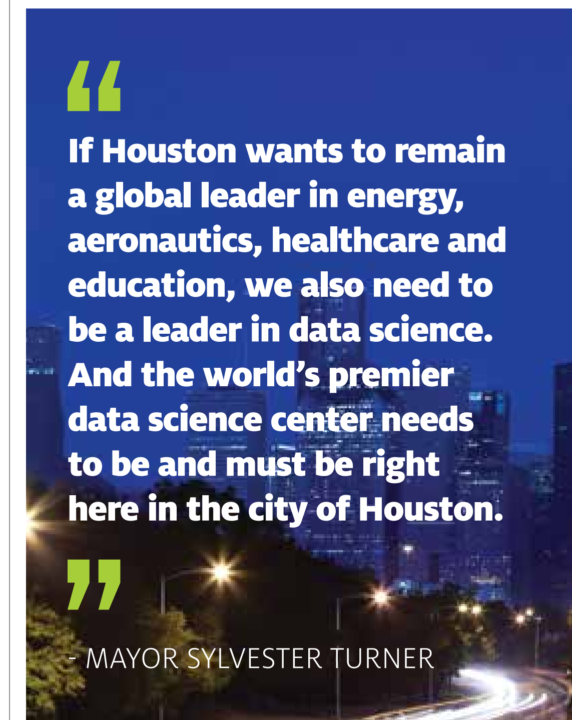
Demand for data science and analytics jobs will grow

+28%

by 2020

Training tomorrow's data tamers

While Houston's economy is greatly influenced by the energy, aerospace and medical sectors, there is a shift toward an information sector and a growing demand for a



data-skilled workforce. A recent report by IBM, Burning Glass Technologies and the Business-Higher Education Forum predicts that demand for data science and analytics jobs will grow 28 percent by 2020.

Mayor Sylvester Turner emphasized the need to attract big data brains in his 2017 State of the City address: "If Houston wants to remain a global leader in energy, aeronautics, healthcare and education, we also need to be a leader in data science. And the world's premier data science center needs to be and must be right here in the city of Houston."

UH is meeting that need head on.

In October 2017, UH announced its Data Science Institute focusing on cyber and physical security, drug development and discovery, sustainability and healthcare.

Professor Hien Van Nguyen (front right) discusses machine learning and data analytics with electrical and computer engineering students inside the UH Center for Advanced Computing and Data Science

"It's going to change our lives," Prosperetti says. "The potential impact of something like this is far-reaching and tremendous."

He expects the Institute will transform the city of Houston, its economy and its University — from the academic to the research level.

Prosperetti received several pieces of good news in January: the proposed structure of the Institute was approved, he was granted a budget of $370,000 and the Cullen Foundation contributed $2 million to the endowment for the Institute.

His next step is to hire experts in data analytics as staff and lecturers to start classes by this fall. Offerings would include undergraduate courses, a master's program in data science, and courses, workshops and seminars tailored to working professionals.

"I want to set up an industrial advisory board," Prosperetti says. "Houston is a very large city with a very large industrial base and they're famished for this kind of expertise. We have to produce a workforce that has the right skills and that's why we want a close collaboration with local industries."

Prosperetti also hopes to work with the city of Houston on implementing the concept of a "smart city" on the local level, which would use data science to make decisions related to transportation, air quality, housing needs, flooding and more.

> **"Houston is a very large city with a very large industrial base and they're famished for this kind of expertise."**
>
> - ANDREA PROSPERETTI

Even though the Institute is still being established, it's already attracting student interest.

Elias Urena-Matos, a UH doctoral student representing Enventure — a non-profit organization for Houston's life science and healthcare entrepreneurs — contacted Prosperetti to discuss working together on a project focusing on data science.

"I think a partnership between Enventure and the new UH Institute of Data Science would be a great opportunity for students and our community," Urena-Matos says, adding that he wants to make the most of resources available at the University and the nearby Texas Medical Center. "We [Enventure] help students prepare for the real world. Positions from statistician to data scientist for clinical data are already in demand and the future is even brighter in data science and healthcare."

Aryan Mobiny, a doctoral engineering student working with Nguyen, likes the idea of the Institute and its mission to train future professionals in data skills.

"I think it's good to teach people earlier about data science because the world is moving that way," Mobiny says. "There is definitely a need for it. Many students are interested in learning about data science but they have no idea what is involved or how to go about it. It's like a monster to some of them — one they can't beat."

UH offers a variety of data science offerings.

The department of mathematics has a master's degree in statistics and data analysis and the department of computer science offers a master's track in data analytics.

The subsea engineering program at the Cullen College — the nation's first subsea engineering program — offers a course called "Guide to Engineering Data Science" and a graduate-level certificate in data analytics.

"In the oil and gas industry, they look at a lot of data from each and every aspect," says **Phaneendra Kondapi,** director of the subsea engineering program. He says industry professionals study data collected during seismic surveys to decide where to drill; from equipment readouts to ensure reliability, productivity and safety; and during the drilling process.

"Once oil starts producing, it's a real time process. You're looking at pressure, temperature, fluid flow rates, density, viscosity. You're looking at a variety of data with a lot of different parameters," Kondapi says. "You get the data every 30 seconds…so that's a lot of real-time data."

These data analytics subsea engineering courses were created as a response to the energy industry's needs and are taught by experienced industry professionals from companies like Halliburton and TechnipFMC.

"All engineers could benefit from knowing data analytics," says Kondapi. "The basics are the same so any engineer can take the course."

The future is all about the intersection of machine learning and more traditional fields, Nguyen says. He is excited that UH offers classes from an interdisciplinary approach such as cybersecurity and machine learning.

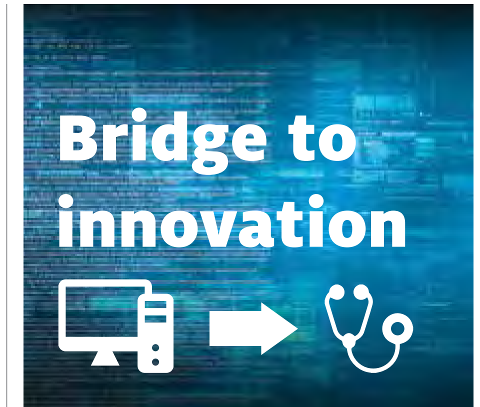
"It's similar to IT skills back in the day. If you knew how to deal with a computer, you had an edge over those who didn't," Nguyen says. "Those who master the skills of working with data and machine learning will have an edge."

He envisions a future where everything from software to equipment will be based on data sets and controlled through machine learning, which allows computers and systems to learn to act and improve from experience, without having to explicitly program them.

Opportunities will be available in every industry and company. "Nearly every field is now trying to use data science and combine products with machine learning and artificial intelligence," says **Pengyu Yuan,** another of Nguyen's doctoral students. In other words, there will be jobs, plenty of jobs.

Both Kondapi and Nguyen are looking forward to collaborating with the Data Science Institute.

> **"If we don't develop the technology to understand this data, then we are throwing away precious pieces of information that can be used to do a lot of good."**
>
> - HIEN VAN NGUYEN



Cullen College professors and students are using data and machine learning in their research to open up new possibilities.

Aaron Becker, professor of electrical and computer engineering, recently returned from a robotics conference where the buzz word was "deep learning," which is part of the machine learning family. It enables computers to learn complicated concepts by building them out of simpler ones.

Every year Becker takes a team of undergraduate and graduate students to the NASA Swarmathon, a competition wherein students from around the nation develop algorithms and computer code to control a "swarm" of tiny robots to perform specific tasks on Mars. The competition allows students to apply their classroom knowledge to real-world challenges.

"One of the problems we had was low quality sensors and blurred images," Becker says. "However, that is a good problem for classification machine learning." He hopes by setting parameters regarding what to look for and using machine learning, the team will get better results.

"Applying some of the algorithms will decrease our false-positive rates incredibly," Becker says. "We're betting this will improve our competition scores this year."

Becker and his students are also working on a more challenging goal — the targeted delivery of drug particles to a specific part of the body to eradicate disease.

The professor plans to apply machine learning to low-resolution images of a patient's vasculature (arrangement of blood vessels in an organ or body part).

"With some of these new techniques in deep learning we're going to be able to concentrate on identifying tumor sites," Becker says.

Nguyen and his students are also using machine learning to make a positive impact on the medical field. One of his research projects involves working with MD Anderson Cancer Center, the world's largest cancer hospital.

"We're using machine learning to analyze gazes of radiologists as they interpret medical images to find the sources of diagnostic errors, and then design a system to mitigate those errors."

In another project, his students use deep learning to teach computers to find abnormalities in chest radiographs by showing them hundreds of thousands of examples.

"I expect such a system to be very valuable in under-developed regions where patients do not have access to well-trained radiologists," Nguyen says.

Big plans for big data

"The role of science and technology is to give people possibilities," Prosperetti says. The possibilities offered by data and UH's new Institute of Data Science are immeasurable.

But there is also an element of danger.

"We live in a time of robots, automation, artificial intelligence and more. One wonders what will happen to people who do not have the right skills. We don't want them to become like the displaced workers of a former mill town," Prosperetti says. "We have to make sure the workforce of the future is equipped to deal with this tremendous impact.

"I think this data science enterprise can be incredibly important in achieving that objective and that gives me a strong incentive to make it a success."

THE NEW DOCTOR IS IN:

Houston's University engineers the future of healthcare tech and talent

The term "engineer" tends to bring to mind hard hats, wires, computers, valves and pistons. We think of them working on boilers, engines and other machinery. Engineers, however, are also central to medical discovery and innovation. This is especially true at the UH Cullen College of Engineering, located a few miles from the world's largest medical complex, where biomedical engineers are conducting groundbreaking medical research and developing treatments and tools to improve patient care and outcomes.

Imagine a bioengineered artificial heart or kidney available to a transplant patient without a wait; implanted devices that can monitor patients' cholesterol and glucose levels; an early detection system for cancer or a new cure for lupus. All of these things and more are being made possible through the work of UH biomedical engineers.

Metin Akay, founding chair of the biomedical engineering department and the John S. Dunn Professor of biomedical engineering, envisions a bright future for the rapidly changing field.

"Biomedical engineering is about what we can do for society. It is about improving the quality of healthcare and reducing its cost for people all over the world," Akay says. "At every step in developing our academic and research programs, we want to ensure we are upholding this important fact."

Training tomorrow's biomedical workforce

And at that Akay has certainly been a success. Since joining the college in 2010 he has transformed the biomedical engineering program from a fledgling operation with only two faculty members to a full-fledged department boasting 20 world-renowned professors and more than 280 students.

As an accomplished biomedical researcher, Akay has a keen understanding of the technological and scientific innovations that will have the greatest impact on society.

"We have built an innovative basic and translational research environment that integrates the research and academic programs to meet the demands of an ever-changing global economy that continues to drive healthcare technology, management and delivery," Akay says.

He sees neural and rehabilitation engineering, biomedical imaging and bionanoscience as areas with the biggest opportunities for biomedical engineers to make an impact. "Our research strengths, like our academic program, are focused along these three thrust areas," Akay adds.

> **"We need to develop new technologies to reduce the cost of healthcare and improve quality. We need to be ahead of the game."** - METIN AKAY

An environment of entrepreneurism pervades the department's academic and research programs, with students and faculty encouraged to tackle projects that can be easily translated into clinical settings. Doctoral students' dissertations are expected to result in patents.

"Ideally, these projects will get taken up by an existing healthcare device or technology company or even be the basis of a student-run start-up," Akay says. "There should be some return on investment on our research and effort."

With his eyes on the future of the field, Akay shapes the biomedical engineering curricula to address current and future trends in healthcare.

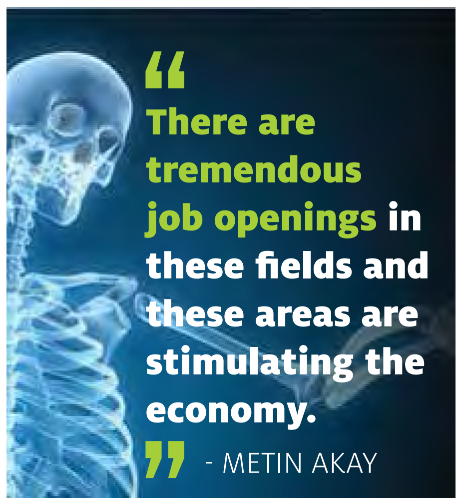
"Engineering affordable technologies will reduce the cost and increase the quality of healthcare," he says.

The field is growing, especially in areas involving data, such as biodata science, computational medicine and bio-analytics. "These are the areas we need to pay attention to," Akay says.

Another area garnering attention involves nano or micro-scale technologies used in early diagnostics, therapeutics and treatments.

"There's an ever-increasing emphasis on point-of-care devices, which allows bioengineering products, technologies and platforms to be brought into patients' homes," says **Chandra Mohan,** Hugh Roy and Lillie Cranz Cullen Endowed Professor of biomedical engineering and vice chair of the department.

For example, he says, researchers are working on devices and software that would allow patients to self-test various body samples — urine, blood, saliva and stool — at home, relay the results to a medical professional electronically and get the treatment needed.



> **"There are tremendous job openings in these fields and these areas are stimulating the economy."**
> - METIN AKAY

"And that means the patient begins to play a larger role in his or her own healthcare because of the enabling power of modern technologies," Mohan adds.

Akay says the biggest advantage of these precision technologies will be in the field of rehabilitative medicine. A stroke patient or a person recovering from a spinal cord injury could go home earlier.

"That would reduce the length of their hospital stay and their medical costs," Akay says. "They will be more involved in their own rehabilitation and maybe get more motivated working in their home environment."

These developments will be especially useful in developing countries and remote areas with limited access to medical resources, he adds.

"We need to develop new technologies to reduce the cost of healthcare and improve quality. We also need to have a dynamic educational and research program," Akay says. "We need to be ahead of the game."

Bioengineering excellence

UH's biomedical engineering department is already strategizing for success.

The department has an industry advisory board, which provides constant feedback on industry needs, new developments and economic changes.

"We use that information to really leverage our academic program," Akay says.

As a result of that feedback, the department will focus more on computational medicine and the biodata sciences, "because there are tremendous job openings in these fields and these areas are stimulating the economy," Akay says.

The emphasis on innovation and needed skills permeates at the most basic level, including core courses.

"We teach physiology, but it's not the traditional physiology," Akay says. "We teach quantitative physiology, which means that the student should be recording data hands-on and also analyzing this data using computers and computational tools."

In addition, classes not only teach theory, but also have intensive lab sections to provide students with project-based learning opportunities. A new internship program offered in the department provides undergraduate students the opportunity to conduct hands-on, design-oriented research over the summer, which gives them an edge when they apply for industrial internships and full-time jobs after college.

Smartphone diagnostic tests and improved treatments for heart attacks are just a couple of the ongoing projects at UH Engineering

Faculty and student research plays a key role in the biomedical engineering experience at UH.

"Our faculty are extremely productive. They are leaders in their respective fields and even more important, we have developed an 'open-door' culture you won't see elsewhere," Akay says. "Students don't need to make an appointment, they can just walk into the department chair's office."

Breaching new frontiers

Access to faculty translates into access to exciting and innovating research. Several UH biomedical engineering faculty are making great strides in the field:

Mohan, a renowned expert on the genomics and proteomics of lupus and other autoimmune diseases, is one of seven lupus researchers around the country tapped by the Lupus Research Alliance to address fundamental questions in research, remove barriers to new treatments and possibly find a cure for lupus and its complications. For this complex work, the Alliance recently awarded Mohan a $600,000 grant.

Professor **Kirill Larin** made news earlier this year by using a technique developed in his lab called OCE, or optical coherence elastography, to map the mechanical properties of the heart. He and James F. Martin of the Baylor College of Medicine are using OCE to compare healthy and damaged heart tissues in mice. They plan to use the results as a foundation to assess if a heart medicine is working or not for heart attack patients.

Assistant Professor **Tianfu Wu** and his research group created an ultra-sensitive biosensor — called the Ultrasensitive polymeric sensing system (UPSS) — to detect disease and toxins early, before a crisis. The device can test patient samples as well as environmental samples. Wu hopes UPSS will be a part of regular medical exams one day.

Assistant Professor **Nuri Ince** and his former graduate student Su Liu study pediatric and adult brain patterns with machine learning algorithms and identify patterns that would help locate epilepsy seizure onset zones in record time. His work is expected to revolutionize medical understanding of seizures and patient treatment in addition to cutting medical costs.

Associate Professor **Sergey Shevkoplyas** and his students developed a low cost, paper-based screening test for sickle cell disease. The professor and his colleagues validated the test at the newborn screening laboratory of the Angola Sickle Cell Initiative, which is a collaboration between the Texas Children's Hospital, Baylor College of Medicine, the Ministry of Health of Angola and Chevron. Shevkoplyas is currently in Africa conducting clinical trials.

In addition to these projects, the department boasts several active research collaborations with industry, government and academia. A partnership with Pharmacyclics Inc., a biomedical start-up based in Silicon Valley, could potentially yield a new drug to treat autoimmune diseases, and an ongoing collaboration with Medtronic is generating cutting-edge neurotechnologies within the department.

UH biomedical engineering professors also partner with the University of Texas Health Science Center, the Methodist Hospital Research Institute, the UTMB Galveston National Laboratory and Sandia National Laboratories.

> **"We use part of our funds to have about 15 to 25 students a year work as paid interns in faculty research labs."**
> - METIN AKAY

Student researchers

Akay says the department encourages students to get involved in research with financial and networking support.

"We use part of our funds to have at least the juniors — about 15 to 25 students a year — work as paid interns in faculty research labs," he says. "This is critical."

It improves retention, equips students with research experience, gives them an opportunity to get their names on published papers and inspires them to pursue their own work, Akay adds.

Megan Goh, a biomedical engineering undergraduate student, worked in the Biomedical Imaging Optics Lab led by Larin and has already used that experience to open other doors.

In 2017, she participated in the National Science Foundation's Bio-X Summer School in Crete, Greece, where she worked with and learned from leading researchers in the biomedical engineering field. While there, she presented work about the use of optical coherence elastography to characterize the biomechanical properties of biological tissues.

Goh has also won the Houston Scholars Program's competitive independent research grant three times and used it to investigate how concussions might affect biomechanical properties of the brain in mice models.

"Research within the biomedical field really piques my interest. I wanted to figure out more about the human body, how we function, how the systems of the body correlate to each other, and how engineering can be applied to assist in the medical field," she says. "So biomedical engineering was a really good fit for me. I want to go into the neuro-engineering focus."

Biomedical engineering faculty members don't just cultivate the careers of college students — many UH engineers lead outreach events with K-12 students across the Houston area. Mohan and other faculty in the department work with about six to eight high school students in Houston every summer. The students work on research projects in different labs in the department for eight to 10 weeks, culminating in a presentation that summarizes their research.

"For a lot of them, it's their first exposure to research and some of them do end up going into biomedical engineering," Mohan says.

What's next?

There are exciting times ahead for biomedical engineering and many of them will be happening right here on the UH campus.

Akay is excited about the opening of the UH School of Medicine targeted for 2020. "I think we are a natural partner for the new medical school and can help support it," he says.

The combination of engineering and medicine offers great opportunities. "The next generation of medical doctors should be really knowledgeable about technology," Akay says. "Not only how to use it, but also in terms of invention, modification and application. I think it's very critical."

The department is already putting together a pre-med program and courses that will help support UH's medical school.

"Students from biomedical engineering do way better on medical school admissions tests. So this is an easier route to get into medical school because of the training they get in biomedical engineering, and our pre-med program will build on that foundation," says Mohan, who is helping develop the program.

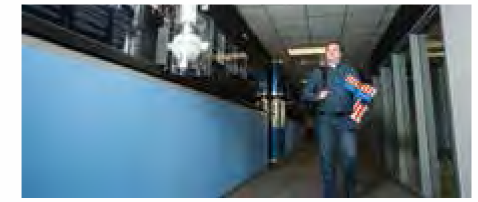
Mohan believes a workforce of physician-engineers are required for realizing the future of healthcare. "Physicians who have biomedical engineering as a background would probably be a different breed of physician because the way they think is different – they think like an engineer," Mohan says. "Engineers are basically problem-solvers and I think that would be a definite advantage."

With its unique blend of healthcare and entrepreneurism training as well as its proximity to the Texas Medical Center, Akay believes the UH Cullen College will become one of the world's premier destinations for biomedical engineering academics and research.

"We are building an environment of entrepreneurship and a healthcare-focused academic curriculum to meet the demands of the economy and healthcare technology, management and delivery," he says. "By doing this we can build one of the most respected and successful biomedical engineering programs in the United States and even the world."

Career Advice

From Engineering Professors & Students



Internships are invaluable.

An internship tells you if you're cut out for a certain job or field, and if you actually like doing what you're doing in school and not just telling yourself that you like it.

- TYLER GILLILAND, *space architecture student*

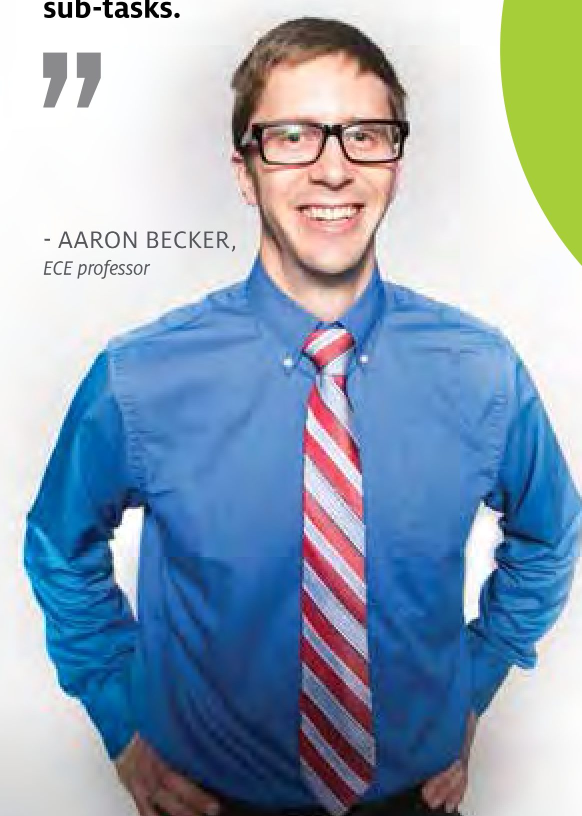
Opportunities sometimes show themselves in unusual ways, so do not close doors just because life is not going the way you expect.

- CHRISTINE STROH, *chemical engineering student*

You have to think like an engineer —

take a complex problem and divide it into achievable sub-tasks.

- AARON BECKER, *ECE professor*



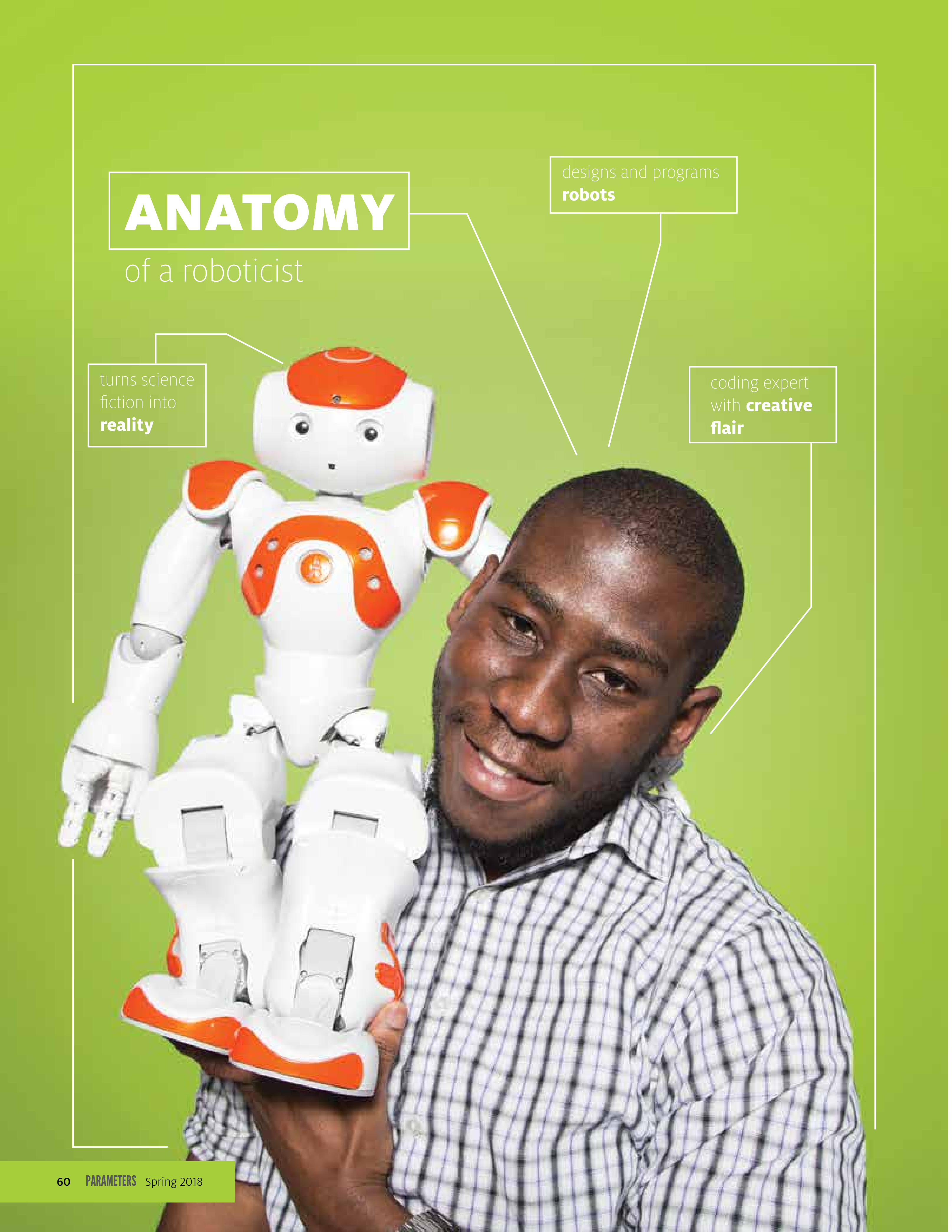
Find something that has personal meaning for you.

That internal motivation makes a difference.

- MEGAN GOH, *biomedical engineering student*

Don't be afraid to reach out to faculty members and ask questions before you apply for a program you're interested in. Prospective students often travel here and meet us, or they email me. Sometimes they even do Skype interviews.

- OLGA BANNOVA, *space architecture director*



WIRED FOR ROBOTS:

Houston's engineers shape the future of robotics

"The iconic technology of this century will be robotics," announced Matthew Ondler, president and CEO of Houston Mechatronics, at Aramco Innovation Day at the Houston Petroleum Club in late 2017.

Such a declaration can evoke mixed feelings – excitement in some, trepidation in others.

Robots have fevered human imagination for decades. Plenty of books and movies present scenarios of robot takeovers as well as the mistreatment of robots by their makers. Uneasiness weighs heavy in these stories.

"That always happens when we are dealing with a new technology," says **Aaron Becker,** assistant professor of electrical and computer engineering at the Cullen College.

> **We're at the cusp of great growth potential in terms of robotics and artificial intelligence.**
>
> \- AARON BECKER

Advances in robotics, artificial intelligence and machine learning will mean change, but also huge growth potential, he says. "Some of it will be seamless, and others will come with disruption."

Not only are more robots in our future, but there are plenty of them in our present. NASA robots like the Mars rovers Spirit, Opportunity and Curiosity are used to explore the far reaches of outer space. About a dozen large robots worked 5,100 feet underwater for months after the 2010 Deepwater Horizon disaster to stop the oil spewing from a shattered wellhead on the seafloor.

And then there are the bots in our purses and pockets.

"We're now carrying around these super computers in our pockets and we use them to take pictures of cats," Becker says, adding that smart phones and computers are already using artificial intelligence to help us. People use them to answer all sorts of questions — not to mention find driving directions, schedule appointments and more.

Professors and students at the UH Cullen College of Engineering are harnessing today's technology and research to create the next generation of robotics and roboticists.

From science fiction to reality

It sounds like something straight from the movies: a paraplegic man wearing robotic legs and a skullcap covered in electrodes takes his first triumphant steps. He controls the robotic exoskeleton using only the power of his thoughts.

This is a regular occurrence inside the laboratory of **Jose L. Contreras-Vidal,** Hugh Roy and Lillie Cranz Cullen Distinguished Professor of electrical and computer engineering. One of the world's leading researchers in the field of noninvasive brain-machine interfaces, he considers the growing field of wearable robotics a valuable medical technology to help patients with disabilities.

"This is research at the forefront of robotics," he says. "We're using robotics to assess the performance capabilities of the patient and also work with the patient's body to rehabilitate and restore movement. It is both a diagnostic tool and a rehabilitative tool."

He's excited about the pediatric exoskeleton his research lab will begin testing this summer in collaboration with TIRR Memorial

Robots & Artificial Intelligence in the Movies

1. Blade Runner
2. The Terminator
3. A.I. Artificial Intelligence
4. 2001: A Space Odyssey
5. Metropolis
6. iRobot
7. Wall.E
8. Ex Machina
9. The Iron Giant
10. The Matrix

Hermann, the best rehabilitative hospital in Texas and second best in the nation. The trial will involve children between 4 and 8 years of age with cerebral palsy and spinal cord injury.

He hopes the pediatric exoskeleton will be available to the general public within three years, pending approval by the Food and Drug Administration (FDA).

Just down the hall from Contreras-Vidal, a team of researchers led by mechanical engineering Assistant Professor **Cunjiang Yu** is taking the integration of man and machine to the next level. Yu and his Cullen College students **Hae-Jin Kim, Kyoseung Sim** and **Anish Thukral** created artificial electronic skin with a rubber composite semiconductor that allows the end-user of a robotic hand to actually feel the sensation of touch.

> **We want to be known as the center of excellence for robotics, but also for robotics teaching and education.**
>
> \- JOSE L. CONTRERAS-VIDAL

The researchers expect their work to advance the use of stretchable electronics for a wide range of applications, such as artificial skins, biomedical implants and surgical gloves.

Meanwhile, in Becker's laboratory undergraduate and graduate students are working on ways to steer swarms of tiny robots through the human body to deliver medication and cure disease. This work will have implications for another of Becker's projects involving underwater robots, in which electrical and computer engineering professors **Zhu Han, Miao Pan** and **Jiefu Chen** are building bots that can swim, collect data and deliver information from the depths of the ocean floor. These deep water droids can provide crucial information on environmental monitoring, offshore exploration, disaster prevention and military surveillance.

"We're at the cusp of great growth potential in terms of robotics and artificial intelligence," Becker said.

Training the brains behind the machines

> **This is an opportunity for UH to train**
>
> 
>
> **the new workforce of the future.**
>
> \- JOSE L. CONTRERAS-VIDAL

Houston is poised to make the most of technological advances in robotics because of its robust medical, oil and gas and aerospace presence.

Contreras-Vidal, Becker and other peers are working on a proposal to create a core robotics facility on campus. The facility, focused on medical robotics, will be a space where faculty can teach and conduct research.

"We want to be known as the center of excellence for robotics, but also for robotics teaching and education," Contreras-Vidal says.

The Cullen College employs robots in every aspect — from research to outreach. Engineering undergraduates take robots to local schools where they teach youngsters to program them to dance, talk or perform other tasks. At G.R.A.D.E. Camp, a popular summer program offered by the Cullen College, UH engineering professors and students teach middle school girls how to program LEGO robots to navigate through a maze.

Meanwhile, the University is developing new graduate and undergraduate classes focusing on neuro-robotics, medical robotics, machine learning and data analytics.

Becker says many UH classes not only teach essential fundamentals, but also have project-based components so students can apply those lessons.

"Our students can build working prototypes in a semester," he says. "They can download machine learning algorithms and apply them on the robots they build in my class."

UH students can also take advantage of other resources on campus. A new Makerspace in the MD Anderson Library offers a dedicated space outfitted with a variety of kits, supplies and tools for programming and electronics projects. Students and faculty can use the space to tinker, design and invent prototypes.

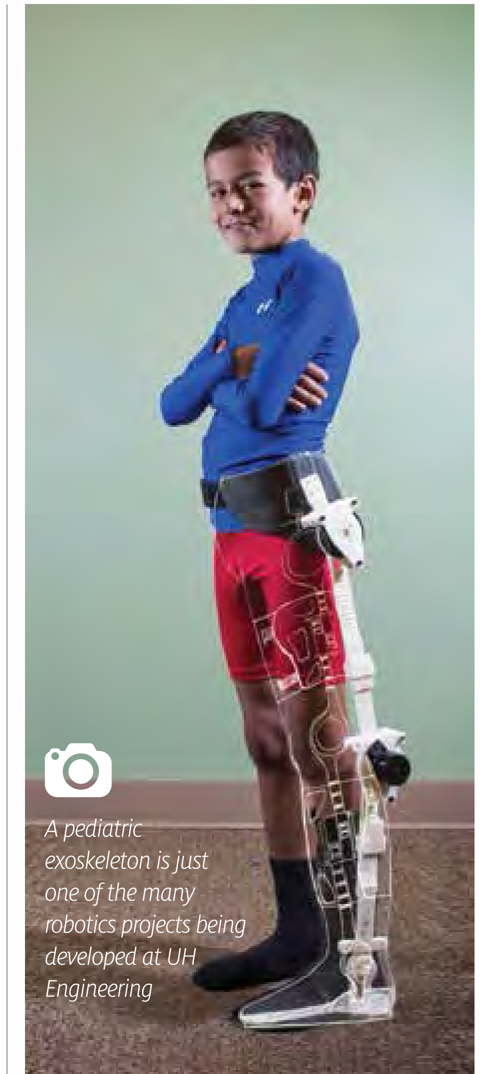
Jose Luis Contreras-Vidal (center) and his students demonstrate how their mind-controlled robotic exoskeletons work

> **People shouldn't be intimidated about the field of robotics because everyone had to start somewhere. They should start with something small, and you can jump in at any time. There are resources on campus, there are tons of YouTube videos and other online resources. Even though robots seem real big and real scary, someone has to learn to program them or build them, and that can be you.**
>
> \- LILLIAN LIN

The Swiss Army Knife of modern engineers:

Tips to get ahead as told by Professor Aaron Becker

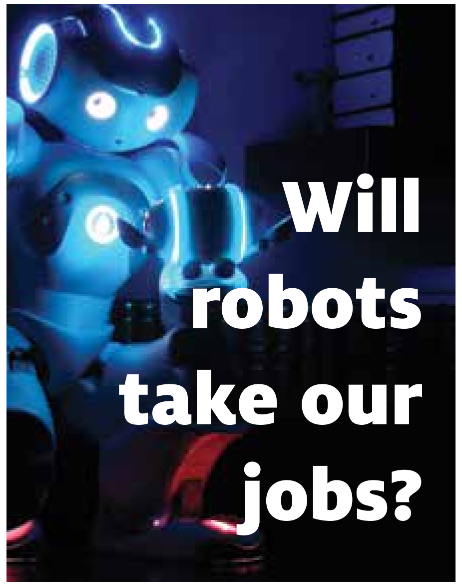
1. **Learn a programming language.**
2. **Think like an engineer – learn how to take a complex problem and divide it into achievable sub-tasks.**
3. **Continuous self-learning is vital. You have to stay up-to-date and educate yourself because that's how you'll be competitive.**
4. **Work in teams because you get more done when you work together.**
5. **Learn to communicate your ideas.**



A pediatric exoskeleton is just one of the many robotics projects being developed at UH Engineering

"We have an excellent engineering program, an excellent business school, and we've got an Innovation Center — an incubator for entrepreneurship — that is fabulous," Becker says, adding that working together allows brilliant ideas to be turned into selling products. "Coupling these colleges together is a big competitive advantage for our students."

Contreras-Vidal, who is also the director of the National Science Foundation Industry-University Collaborative Research Center (IUCRC) for Building Reliable Advances and Innovation in Neurotechnology (BRAIN) at UH, is looking forward to partnering with the UH's School of Medicine that's scheduled to open in 2020. "This is an opportunity for UH to train the new workforce of the future," he says.



Will robots take our jobs?

One of the most prevalent scenarios spun out by naysayers is that robots will be replacing humans in numerous jobs.

> “If you lose a robot, even if it costs thousands of dollars, that’s nothing in comparison to losing a human life.”
>
> - LILLIAN LIN

Becker instead worries that population changes may mean there’ll be plenty of jobs, but not enough people to fill them. He envisions a future with robo-companions who encourage humans to do their exercises, take their medications, get their tasks done, and can even recognize medical emergencies and call for help. He hopes one day technology will make it easier to identify and intervene in mental health situations before they become crises.

“I think there will be more natural interaction with machines in our lives that will augment our abilities and help us remain productive and an integral part of society for longer,” Becker says.

New technologies create the need for new types of professionals who can effectively use these new tools.

“Right now, most physicians are not technologically savvy, especially in terms of emerging technologies,” Contreras-Vidal says. “We need to create a new type of physician — a neuro-engineer physician — and you have to embed the new technology in the training. We need someone who understands the technology, can prescribe the technology and customize it to the needs of a particular patient at a particular time because we change.”

Lillian Lin, an electrical and computer engineering undergrad student who works in Becker’s Lab, says the jobs most likely to disappear are what many roboticists call the “three D’s” – dirty, dangerous and dull.

“You have jobs like working in a factory line and putting on the same piece over and over and over again,” she says. “Someone can make mistakes, because they get tired or bored or distracted, but a robot would automatically do the correct thing over and over again because it’s been programmed to do it.”

> “**As a Carnegie-designated Tier One public research university,** we want to be on the cutting-edge here and build technologies to help society.”
>
> - AARON BECKER

She says one of the projects in Becker’s lab involves sensors that can detect human life. Lin envisions a future where robots might help dig people out of the rubble after an earthquake or take on mining jobs on Earth and maybe even Mars.

“If you lose a robot, even if it costs thousands of dollars, that’s nothing in comparison to losing a human life,” she says.

However, she’s not too concerned about future job prospects. “A lot of people fear that robots will take over people’s jobs, but you’ll always have jobs — you’re going to have to have people who take care of robots, who make sure that the robots are doing their jobs properly,” Lin says. “Just like there are managers for people, there are managers for robots.”

Robots are here to stay, and their lives will be inextricably tied to our own. Becker takes the optimistic view that robotics will benefit humans and allow them time to follow their passions.

He likes to quote U.S. President John Adams (1735-1826) when discussing the future of robotics:

“I must study politics and war so that my sons may have liberty to study mathematics and philosophy. My sons ought to study mathematics and philosophy, geography, natural history, naval architecture, navigation, commerce and agriculture in order to give their children a right to study painting, poetry, music, architecture, statuary, tapestry and porcelain.”

Becker believes the words are still relevant today.

“There’s so much we don’t know about space, so much we don’t know about our oceans, so much that we don’t know about the human body. There are people who will react to all this by becoming Amish. While that is an option, it’s a retreat from the pursuit of more knowledge,” he says.

“As a research lab and a Carnegie-designated Tier One public research university, we want to be on the cutting-edge here and build technologies to help society.” ■

National Academy of Engineering Member

S. M. FAROUQ ALI JOINS UH ENGINEERING FACULTY

BY AUDREY GRAYSON

Petroleum engineering legend and National Academy of Engineering (NAE) member **S. M. Farouq Ali** joined the University of Houston Cullen College of Engineering this fall as a distinguished professor of petroleum engineering. His arrival brings the total number of NAE faculty at the Cullen College to 14.

Farouq Ali comes to UH from the University of Calgary where he served as the Encana/Petroleum Society Chair and Professor of chemical and petroleum engineering. He has over 40 years of experience in industry and academia, having served as a professor at Pennsylvania State University, the University of Alberta and the University of Regina.

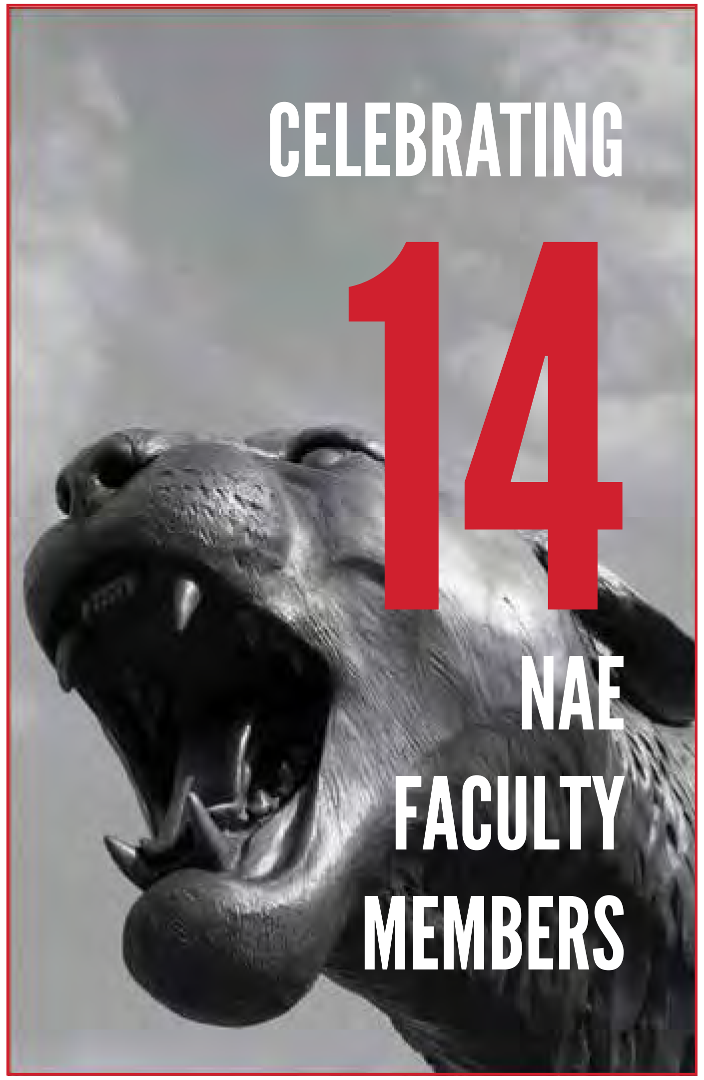
Considered one of the world's leading experts in reservoir engineering, oil recovery and simulation, Farouq Ali advises oil companies and various governments on oil policy and production strategies. He has authored more than 500 papers, conducted more than 200 petroleum reservoir studies and designed over 30 major oil fields projects.

Farouq Ali earned his master's and doctoral degrees in petroleum and natural gas engineering from Penn State University. As a graduate student he conducted pioneering research on micellar-polymer flooding, a process in which a micelle solution is pumped into a reservoir to recover oil. The technique has since become the industry standard for enhanced oil recovery.

He is also credited with some of the earliest experimental work on steam flooding, a method of injecting steam to extract heavy crude oil from an oil reservoir. Today steam injection is one of the primary enhanced oil recovery techniques in use.

Farouq Ali has been honored with awards from the Society of Petroleum Engineers, the Canadian Institute of Mining and Metallurgy, the Association of Professional Engineers and Geoscientists of Alberta and the Russian Academy of Sciences.

"We are honored to welcome Dr. Farouq Ali, a worldwide legend, to our ranks of distinguished engineering faculty at the Cullen College," said Joseph W. Tedesco, Elizabeth D. Rockwell Dean of the UH Cullen College of Engineering. "His arrival at UH marks a victory for our students, our university and the city of Houston."



Our department is at the forefront of healthcare, and Dr. Reddy's work is expected to revolutionize the early detection and characterization of gynecological cancers.

- BADRI ROYSAM

CULLEN COLLEGE RECRUITS LEADING RESEARCHER

In Gynecological Cancers

BY JEANNIE KEVER

The Cancer Prevention and Research Institute of Texas awarded UH $2 million to recruit cancer researcher **Rohith Reddy,** who focuses on next-generation technologies for detecting gynecological cancers. Reddy, formerly a postdoctoral researcher at Harvard Medical School, became an assistant professor in the Cullen College's department of electrical and computer engineering.

The Institute, known as CPRIT, began making awards to Texas institutions in 2009 after voters approved a 2007 constitutional amendment committing $3 billion to cancer research and prevention. The 2017 awards to UH are part of $102 million in grants for 60 academic research, prevention and product development projects.

Reddy's research involves innovative instrumentation for diagnosing gynecological cancers. Badri Roysam, chairman of the electrical and computer engineering department, said the work fits with the optical imaging and computational techniques that the department brings to healthcare diagnostics and treatment.

"Our department is at the forefront of healthcare, and Dr. Reddy's work is expected to revolutionize the early detection and characterization of gynecological cancers," Roysam said. The department received a CPRIT recruitment grant in 2014 to hire David Mayerich, now a successful assistant professor of electrical and computer engineering who works in biomedical imaging.

Reddy's project involves translating cancer genomics research into outpatient settings, allowing for targeted imaging-guided tissue extraction for biopsy and the identification of cancer markers.

Renowned cancer researcher Rohith Reddy joins the electrical and computer engineering faculty

Jeff Rimer earned the 2018 Hackerman Award for his pioneering crystallization research

Crystallization Expert Jeffrey Rimer Wins Welch Foundation's 2018 HACKERMAN AWARD

BY JEANNIE KEVER

Jeffrey Rimer, an associate professor of chemical and biomolecular engineering at the Cullen College known for his groundbreaking work in crystal engineering, has received the 2018 Norman Hackerman Award in Chemical Research.

The award is given by the Welch Foundation to chemical scientists working in Texas and is designed to encourage the fundamental understanding of chemistry. It is named for Norman Hackerman, who served as chairman of the foundation's scientific advisory board from 1982 to 2006.

"Dr. Rimer is widely recognized as an outstanding teacher and mentor, as evidenced by the deep scholarship and innovation produced in his lab," said Peter B. Dervan, Bren Professor of chemistry at the California Institute of Technology and chairman of the Welch Foundation scientific advisory board. "He has become a leader in the emerging field of non-classical crystallization."

> "Dr. Rimer is widely recognized as an outstanding teacher and mentor, as evidenced by the deep scholarship and innovation produced in his lab."
>
> - PETER B. DERVAN,
> *Welch Foundation scientific advisory board chairman*

Rimer said the award is especially gratifying because of the foundation's support for fundamental science. His lab has received funding from the foundation since 2012.

"To receive an award from the Welch Foundation is special. It is very rare to have an organization that funds fundamental, science-driven research," he said. "Welch funding has been transformative by allowing me to expand my research program into different areas."

In 2016 Rimer reported that a natural fruit extract can dissolve calcium oxalate crystals, the most common component of human kidney stones, suggesting a major advance in drug development. That work is continuing, with human clinical trials underway and research to find new drug candidates ongoing.

He earlier reported new techniques to view zeolite surface growth in real time, work which has applications in the petrochemical industry.

He received the 2016 Owens Corning Early Career Award and 2017 FRI/John G. Kunesh Award from the American Institute of Chemical Engineers, as well as multiple teaching and research excellence awards from UH.

Joseph Tedesco, Elizabeth D. Rockwell Dean of the UH Cullen College of Engineering, said it's difficult to overstate the impact that Rimer's work has had on the world.

"Dr. Rimer is responsible for some of the most significant breakthroughs in the field of crystallization in the last few decades, but his equal devotion to teaching the next generation of innovators, problem-solvers and entrepreneurs is what truly makes him shine in his field," Tedesco said. "This Hackerman Award is well-deserved recognition of the caliber and breadth of his work."

Rimer said his work with crystallization is an example of the benefits of basic research. "If you focus on the fundamentals, then you can branch out into different research areas," he said. "The materials may change, the applications can be dramatically different, but the fundamentals provide a foundation that ties them together and fosters cross-cutting, interdisciplinary research. When you take a set of practices or techniques from one field of research and find ways to uniquely apply them to others, this is often an effective approach to materials design that can lead to new paradigms."

Olafs Daugulis, Robert A. Welch Chair of chemistry at UH, received the Hackerman Award in 2013.

The Welch Foundation, based in Houston, is one of the nation's largest private funding sources for basic chemical research. Since 1954 it has distributed $866 million in research grants, departmental programs, endowed chairs and other special projects at educational institutions in Texas.

The Hackerman Award, which was announced in February, includes a bronze sculpture and $100,000.

UH Engineer Chosen for MIT Technology Review's 35 INNOVATORS UNDER 35

BY JEANNIE KEVER

An engineer at the University of Houston known for his work in developing stretchable semiconductors and electronics has been named to *MIT Technology Review's* "35 Innovators Under 35" list of researchers with Chinese citizenship.

Cunjiang Yu, Bill D. Cook assistant professor of mechanical engineering, was cited as a "pioneer" for his work in the emerging field of soft electronics and breakthrough work on developing stretchable semiconductors and rubbery transistors, sensors and integrated electronics and systems.

Last year Yu drew attention when he reported a breakthrough in semiconductor materials with instilled mechanical stretchability, much like a rubber band, and a new class of rubbery electronics and sensors that can serve as an artificial skin, allowing a robotic hand to sense temperatures and even translate sign language.

The material is both stretchable and semiconducting, a major advancement of the classic silicon semiconductor. Yu and his lab discovered a new mechanism for producing the material, which relies upon readily available components and could easily be scaled up for future commercial production.

It would have a broad range of applications from artificial skin to robotics and biomedical devices, Yu said. His lab is currently working to improve the performance of the material for use in integrated electronics and implantable medical devices.

MIT Technology Review publishes an annual list of top innovators and entrepreneurs. This is the first year it has offered a Chinese edition.

Although he has worked in the United States for more than a decade – he earned a Ph.D. in mechanical engineering at Arizona State University in 2010 and has been at UH since 2013 – Yu remains a Chinese citizen.

The awardees are selected by the editors of the magazine in collaboration with a panel of judges from major institutions and corporations including the Massachusetts Institute of Technology, Stanford University, Tsinghua University, Peking University and Alibaba.

The 35 innovators list is broken into several categories – in addition to pioneers, the others include inventors, entrepreneurs, visionaries and humanitarians.

Those chosen as pioneers are noted "for bringing fresh and unexpected solutions to areas ranging from cancer treatment to internet security to self-driving cars." Yu is one of eight pioneers.

PROMES Director Jerrod Henderson Earns

INSPIRING STEM LEADER AWARD

from INSIGHT Into Diversity Magazine

BY LAURIE FICKMAN

Jerrod Henderson is increasing student retention and success with innovative academic success strategies

Each year *INSIGHT Into Diversity*, a magazine and website devoted to increasing and embracing diversity in higher education, recognizes leaders from underrepresented groups who are making a difference in the science, technology, engineering and math (STEM) fields with the Inspiring Leaders in STEM Awards. The awardees are chosen based on their success and commitment in launching community-oriented outreach programs and initiatives that engage underrepresented students in the STEM fields.

"These men and women work to motivate and encourage the next generation of young people to pursue STEM education and careers via teaching, mentoring, research and groundbreaking discoveries and innovations," according to *INSIGHT*.

Only 40 individuals were chosen to receive the honor, including UH Engineering's own Jerrod Henderson, one of the leaders of the Cullen College's efforts to increase student success and retention through the use of innovative academic success strategies geared toward first-generation college students.

First generation, first year success

The United States might boast one of the highest college attendance rates in the world but, according to the Pell Institute for the Study of Opportunity in Higher Education, large gaps remain in college success with only 11 percent of first-generation students earning an undergraduate degree compared to 55 percent of their peers, in a recent measurement period.

In the Cullen College, out of 3,700 enrolled undergraduates in fall 2017, 971 were first-generation students, or just over one-fourth.

Being a first-year engineering student at the Cullen College means one thing: You will be a part of the First Year Experience Program and you will be required to take two courses – "Introduction to Engineering" (ENGI 1100) and "Computing & Problem Solving" (ENGI 1331).

That one-two punch right out of the gate is all about laying the proper foundation. That's the mission of the First Year Experience: To improve student success and retention in upper level engineering courses.

"The point of these courses is to teach students problem-solving strategies and to expose them to different engineering fields so they are better equipped to decide what kind of engineer they'd like to become," said Henderson, also an instructional assistant professor of chemical engineering. "A new student may not exactly know yet."

"What we find," Henderson continued, "is first-generation students haven't had some of the opportunities we're providing in the First Year Experience like study groups or tutors."

> *I believe strongly in student success and getting students through the first year, which is so crucial to their success as engineering students.*
>
> \- JERROD HENDERSON

He knows firsthand.

"I am a first-generation college student, and so it's a part of my passion," said Henderson. "I'm also an ethnic minority who achieved a Ph.D. in engineering, putting me in about the 1.5 to 2 percent category of black males to obtain that degree."

College was encouraged in Henderson's close-knit North Carolina community. His parents shared with him the recognizable parental refrain: Do better than us.

"So they pushed," he said. And he succeeded. Now it's his turn to push.

"I believe strongly in student success and getting students through the first year, which is so crucial to their success as engineering students," said Henderson.

And if the back-to-back courses aren't enough to set a student on the path forward, there is always the "PROMES."

PROMES

PROMES (pronounced "promise") seems a fitting name for this acronym (and homophone of promise). It stands for the Program for Mastery in Engineering Studies, which helps students grasp tough engineering concepts and study skills early. It's one of the most enduring academic programs, having formed in the early 1970s to help underrepresented minority students.

But most importantly, Henderson says, it offers a community for students who can get easily lost.

"PROMES is open to all students and serves as a community and guide for students who want to be successful," said Henderson. The program offers a PROMES section of ENGI 1100, requiring them to go the extra mile.

They must attend the UH Engineering Career Fairs and work on an 'elevator pitch' about themselves, and take workshops like the "Guaranteed 4.0 Learning System," developed by an engineer. It teaches mastery of study and skills to do your best work, and if you don't make the 4.0 GPA, the author of the program pays you $100.

Who said engineering couldn't be immediately lucrative?

Engineering student success

Henderson arrived at the UH Cullen College in 2016 after co-founding the St. Elmo Brady STEM Academy – an educational intervention aimed at exposing underrepresented fourth and fifth graders to hands-on, inquiry-based STEM activities – at the University of Illinois Urbana-Champaign.

"Creating opportunities for our students to become successful and nurturing their success along the way is critical to the long-term outlook for our students, the Cullen College and the engineering ranks at-large," said Joseph W. Tedesco, Elizabeth D. Rockwell Dean of the Cullen College of Engineering. "Before we launch the next generation of great engineers, we foster their ability to learn and belong in our engineering community. These are lifelong skills they will take with them."

"I couldn't be prouder of Dr. Henderson for earning this tremendous and well-deserved honor," he added.

About the magazine

<< Featured in the September 2017 Issue

Established over 40 years ago, *INSIGHT Into Diversity* is the oldest and largest diversity magazine and website in higher education, connecting potential employees with institutions and businesses choosing to embrace a workforce more reflective of our local and national communities.

Department of Defense Awards UH Engineer for Career in

ADVANCING IMMUNOTHERAPY

BY AUDREY GRAYSON

For UH chemical engineer **Navin Varadarajan,** it isn't enough to conduct laboratory research, publish papers, earn grants and win awards for his work in immunotherapy, which utilizes the body's own immune cells to attack tumors. Varadarajan said he yearns for something more – a connection to the people who he hopes will eventually benefit from his work in the Single Cell Laboratory at the UH Cullen College of Engineering.

"When you're working with cells, it's just like any experiment, but when you can connect the cells you're studying to a patient, it changes everything," said Varadarajan, who had a life-changing experience while conducting HIV research with collaborators at MIT in 2009.

"While I was working with clinicians in Boston we were able to connect the patients whose cells we were studying in the lab with the experiments. It really had that, 'Wow!' effect on me." Since then Varadarajan said he couldn't disassociate the cells he studies in the lab from the people they came from. "It's made me a better researcher, a better engineer."

Perhaps that's what caught the attention of the Department of Defense Peer Reviewed Cancer Research Program, who awarded Varadarajan a Career Development Award for his pioneering work in immunotherapy for treatment of melanoma.

The award supports researchers who are still early in their careers and pairs them with cancer researchers with advanced experience in the field.

A powerful pair

Varadarajan chose MD Anderson Cancer Center's Patrick Hwu, a prominent tumor immunologist who researches adoptive T cell therapies, as his research mentor. It's a powerful pairing by any measure: Varadarajan brings to the table a novel research platform that will allow the duo to study interactions between single T cells and cancer cells, while Hwu brings decades of expertise on CAR T cell therapy, a method of engineering T cells to seek and kill cancer cells.

Varadarajan and Harjeet Singh of MD Anderson Cancer Center propose to study single cell interactions between tumor cells and T cells, the body's cancer-killing immune cells, to monitor metabolic changes in the cells over time. Varadarajan will receive up to $360,000 over three years to complete the research.

"When you're working with cells, it's just like any experiment, but when you can connect the cells you're studying to a patient, it changes everything."

- NAVIN VARADARAJAN

For Varadarajan, the opportunity to work with one of the world's most renowned cancer immunologists is a reward in of itself. So when Hwu suggested that he shadow him in the clinic when he sees patients, Varadarajan could hardly contain his excitement.

"Oh, my gosh. It's a really big deal," he said, adding that the opportunity will allow him to scratch a longtime itch. "As a researcher I don't get to interact with patients otherwise ever. I've always had an inclination to understand the clinical aspects of immunotherapy. It adds a human element to it."

The final battle

Immunotherapy is currently effective in only 20 percent of cancer patients. Researchers know that not all immune cells are created equal – some T cells are much better at killing off cancer cells than others.

Much like people, cells need nutrients to survive. The environment inside of a tumor cell is not nutrient-rich, so T cells must fight for available resources in addition to battling the cancer cells. Oftentimes the immune cells die from lack of nutrients before the battle with the cancer cells even begins.

"What qualities must a T cell have in order for them to be excellent killers of tumor cells? If we know these characteristics we can engineer immune cells to survive and fight the cancer cells," said Varadarajan.

Varadarajan's lab will implement a genetically-encoded sensor made of proteins that will sit inside of the T cell and collect information on the metabolic state of the immune cell over time.

"We want to understand the metabolic changes that took place that allowed the T cell to persist and kill the cancer cell," said Varadarajan. "This should bring us one step closer to manufacturing cancer-killing cells for melanoma and other cancers."

Image Processing Expert and ECE Chair Named IEEE FELLOW

BY AUDREY GRAYSON

Badri Roysam, chair of the electrical and computer engineering department at the UH Cullen College of Engineering, has been named a 2018 Fellow of the Institute of Electrical and Electronics Engineers (IEEE).

The honor is the IEEE's highest grade of membership and is reserved for those with "an outstanding record of accomplishments" in an IEEE field. No more than one-tenth of 1 percent of IEEE's voting members can be named Fellows in a given year.

In naming Roysam as a Fellow of both the 2017 and 2018 classes, the IEEE cited his contributions to image processing algorithms for biological microscopy.

Roysam is indeed world-renowned for his accomplishments in the field of image processing. The inventor of a novel software platform called FARSIGHT, Roysam is credited with pushing medical imaging to new heights by allowing researchers to rapidly analyze images of human tissue collected from laser-scanning microscopes by quantifying specific molecules of interest in cells and tissue. To date scientists have used it for everything from analyzing brain tissue after injury to studying the effectiveness of experimental medications.

Since inventing the FARSIGHT software Roysam has undertaken a variety of research projects aimed at providing far superior imaging analyses than ever before possible. In 2011 Roysam received more than $5 million from the Defense Advanced Research Projects Agency (DARPA) to explore why neural devices implanted in the brain inevitably fail over time.

The following year Roysam joined forces with UH chemical engineer Navin Varadarajan to apply the TIMING software to study the best ways to modify human immune cells to fight against cancer.

Throughout his career as both a researcher and an administrator, Roysam says the IEEE has played an integral role in his success.

"The IEEE has been one of the most important technical societies to me both personally and professionally," he said. "The organization has introduced me to the latest developments in my field through its prestigious publications and has allowed me to connect with some of the brightest minds in my field through its meetings and conferences. To say that I am honored to be named a Fellow of such a respected organization is an understatement."

Roberto Ballarini Uses Online Platform to INSPIRE NEXT GENERATION of Civil Engineers

BY AUDREY GRAYSON

For **Roberto Ballarini,** chair of the Cullen College's civil and environmental engineering department, the decision to become a professor was as much about inspiring the next generation of civil engineers as it was a passion for his field.

Early in Ballarini's career, his zeal to inspire students to pursue engineering careers required him to travel all over the country to meet with students in K-12 classrooms. Nowadays hectic travel schedules are replaced by live video streams connecting Ballarini to hundreds of students across the U.S. each year from the comfort of his office at the UH Cullen College of Engineering.

That's thanks to an online platform called Nepris (www.nepris.com), which connects curious K-12 students with science, technology, engineering and mathematics (STEM) professionals through live video conferences.

Speaking with *Civil + Structural Engineer Magazine*, Ballarini explained how the Nepris platform allowed him to reach more potential engineering students than ever before.

"What was attractive to me about Nepris was that I could talk with students in real time, and be able to see them and answer their questions, without having to travel back and forth to the school," he told *C + S Engineer Magazine*. "It gives me a much broader reach than I would have otherwise."

Talk to the Animals:

Mechanical Engineering Grad Student Studies Animal Kingdom's Master Navigators

BY SARA STRONG

Sana Krichen thinks often like a bat – and a shark, and a sea turtle, and several types of birds. For Krichen, who is a doctoral candidate in mechanical engineering, understanding how certain animals can detect magnetic fields is a key part in determining how those species navigate their way as they fly through the world (or swim, crawl, run, or hop).

Some animal navigators can rely on the Earth's magnetic field to sense whether they're traveling north or south. A subset of these animals can do even more. Using a kind of sixth sense called magnetoreception, some species are able to implement an internal geophysical positioning system to understand where they are and where they're heading next.

But how precisely these animals detect the Earth's very weak magnetic field is the topic of much scientific debate. Many mechanisms have been proposed to explain the phenomenon, though none are able to explain how magnetoreception converts magnetic fields into electricity inside the cells of some animals.

Krichen provides a detailed model to explain the mechanisms underpinning animal magnetoreception in an article published in October in the journal *Physical Review E*. Her conclusions may spark challenges from other scientists, but she remains open to all comments.

"Our work provides perhaps the first and arguably a very simple explanation for this," Krichen said. She performed the research under the supervision of Pradeep Sharma, professor and chair of the mechanical engineering department, and Professor Liping Liu from Rutgers University.

The sixth sense

The animal kingdom's expert navigators vary widely in shapes and sizes. They include migrating species, such as giant sharks that cross the great oceans, and several species of birds, like the small European robin. But while not all types of birds possess the natural ability to be excellent navigators, several non-migrating animals do, including lobsters.

"We have our five senses. These animals have those plus an additional sense," Krichen said.

How do these species, large and small, steadily maintain their course and speed while other species easily get disoriented? How can loggerhead sea turtles leave the coast of Japan and cross the Pacific all the way to Baja California without distraction while humans... well, who hasn't wandered a parking garage, fumbling for a sense of where they left the car?

Krichen says the answer lies in magnetoreception, which is the potential to sense the Earth's north-south magnetic fields. As described in a 1970s article in the *Proceedings of the National Academy of Sciences*, scientists demonstrated the theory by fastening small

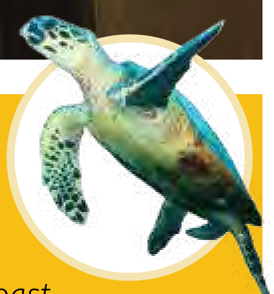
Sana Krichen proudly holds her published paper and 10-month-old son, Youssef

magnets onto the heads of birds known to be good navigators. As expected, the birds became disoriented and wavered off their paths.

Magnetoreception provided lots of answers, but it still left big questions. In particular, how do these animal species sense magnetism, which is undetectable by humans and other animals (as far as studies have shown)? Do these particular species possess an extra sensory gift?

"Each of our five senses depends on an organ," Krichen explained. "The sense of sight requires eyes, for example. Taste needs a mouth and smell needs a nose. Hearing requires ears and touch uses skin. Magnetoreception is a sense, too, but it involves no organ that we now know about."

While some scientists consider a "missing" organ does exist but is so small that it eludes searchers, others turn to alternate possibilities, such as chemical changes in the bodies of these animals. While these theories provide important insights, none is able to explain how the weak magnetic signals are converted to electricity inside of the animals' cells.



How do loggerhead sea turtles leave the coast of Japan and cross the Pacific all the way to Baja California without distraction, while humans lose their cars in parking garages?

The answer lies in magnetoreception.

Controversial internal GPS

After combing through the literature on this topic Krichen proposed a new model that puts to rest some of the open questions pertaining to animal magnetoreception.

A class of materials called magnetoelectrics can convert magnetic fields into electrical signals and vice versa. However the only magnetoelectric materials discovered so far are hard and exotic crystals, which certainly are not components of a biological cell.

So Krichen and her collaborators pursued a very different path. Through detailed mathematical modeling they found that although magnetoelectric materials don't exist inside of the animals, certain qualities of their cells allow them to behave like magnetoelectric materials.

Krichen found three conditions that must exist in order for a biological cell to behave as a magnetoelectric material. First, there must be a pre-existing electric field in and around the cell. Second, the cells must have magnetic permeability that is higher than that of a vacuum. (The insides of magnetosensitive species' cells contain iron oxide, which is magnetic.) Finally, the cells must contain a soft material. These squishy cells, as they are called, change shape when exposed to magnetic fields.

A weak pre-existing electrical current exists across all biological cells due to an imbalance of charges inside and outside each cell that act as a permanently attached battery pack. When a squishy cell deforms due to exposure to a magnetic field, it alters the operation of the "battery," causing a change in the flow of electricity across the cell.

The altered current flow alerts neurons in magnetosensitive animals, giving the animal a feeling that it's time to shift a wing or a fin or a hoof, just a bit, to get back on target.

In other words, these particular animals are expert at finding their way not because of any mysterious ability to sense magnetism; they keep from straying because changes in their perceptions of electrical signals alert them any time they falter off course. You might say these species have an inborn GPS that is not much different than your car's onboard GPS.

With so many theories competing for attention on the subject, Krichen and her advisors expect their article's conclusions to meet controversy.

"We're waiting on other scientists to test our ideas. People may disagree, and we're okay with that," she said. The team expects about six months to a year to pass before other scientists publish comments, maybe longer before practical applications might be considered.

Great things take time

Her newly-published article was submitted to *Physical Review E* about the same time Krichen and her husband, Ali Khadimallah, a mechanical engineering postdoctoral fellow at UH, learned she was pregnant with their first child. While both projects involved a lot of waiting, the baby arrived first.

Youssef Khadimallah is now 10 months old – happy, healthy, very busy. And his mother's breakthrough article, at last, has debuted after prolonged exchanges between reviewers and the investigators.

"You can gauge the controversial nature of the work and the rather long back and forth between reviewers and us simply by the fact that the paper finally got accepted as I am celebrating the 10th month of my first-born," she said. "I almost feel I have given birth to two babies!"

Krichen expects to have her Ph.D. in about a year and then plans to pursue postdoctoral research. Ultimately she will seek a faculty position in mechanical engineering – her "dream job," she said.

MAKING WAVES:

Grad Student's Wave Research Earns National Recognition

BY AUDREY GRAYSON

It's a common human experience: Sitting on a beach, watching as the waves lap against the sand. You feel your worries start to melt away as your mind focuses on the breaking waves, one after another. You notice the differences between them – how some build up height as they near the shore until they curl forward into a dramatic pipeline that's the stuff of surfers' dreams. Others seem to spill over themselves as they reach the shore, water and foam tumbling over the front of the wave and pouring onto the beach.

For **Andrea Albright,** studying the ways waves break is more than a practice in beachside relaxation. "There's a lot of questions about which kinds of waves drive erosion versus moving sand back onto the beach," said Albright, a graduate student in the Cullen College's geosensing systems engineering and sciences program.

Albright's research is providing answers to these questions. But it's not only her research findings that are making waves – her ability to explain the significance of her work has earned her the distinction of grand prize winner of the American Geophysical Union (AGU) 2017 Data Visualization and Storytelling Contest.

As one of six total winners chosen across the U.S., Albright received a $2,500 travel stipend to attend the 2017 AGU meeting last December in New Orleans. At the meeting Albright gave a presentation on her research using NASA's Hyperwall, a large video wall used to display multiple high-definition data visualizations and images.

A visualization problem

NASA's Hyperwall came in handy for Albright in presenting her work – visualization is key when it comes to understanding waves.

The shape of waves as they break has a big impact when it comes to coastal erosion, she explained. Some waves introduce energy into the water column, which is thought to move sediment towards the shore, altering the geography of the coastlines they break on. Others break more gently and are thought to slowly erode sand away from the shoreline as the wave retreats, pushing the coastline farther inland.

But understanding which types of waves impact coastal erosion (and how) has been a real challenge for researchers. Usually sensors are placed under the water to gauge how tall a wave is and how fast it's moving towards the shore, but that doesn't provide any information on the shape of the wave at the surface – a detail which, as it turns out, plays a big role in coastal erosion.

Researchers often supplement underwater sensors with video recordings of waves to extrapolate information on their shape and size.

"It's a challenge for oceanographers," Albright said. "How do you measure exactly how tall a wave is or how it's shape changes? It is difficult to extract that kind of quantitative information from a video."

Albright has a better way to visualize and study waves, one that takes us away from two-dimensional pictures and deep into 3-D space.

The wave of the future

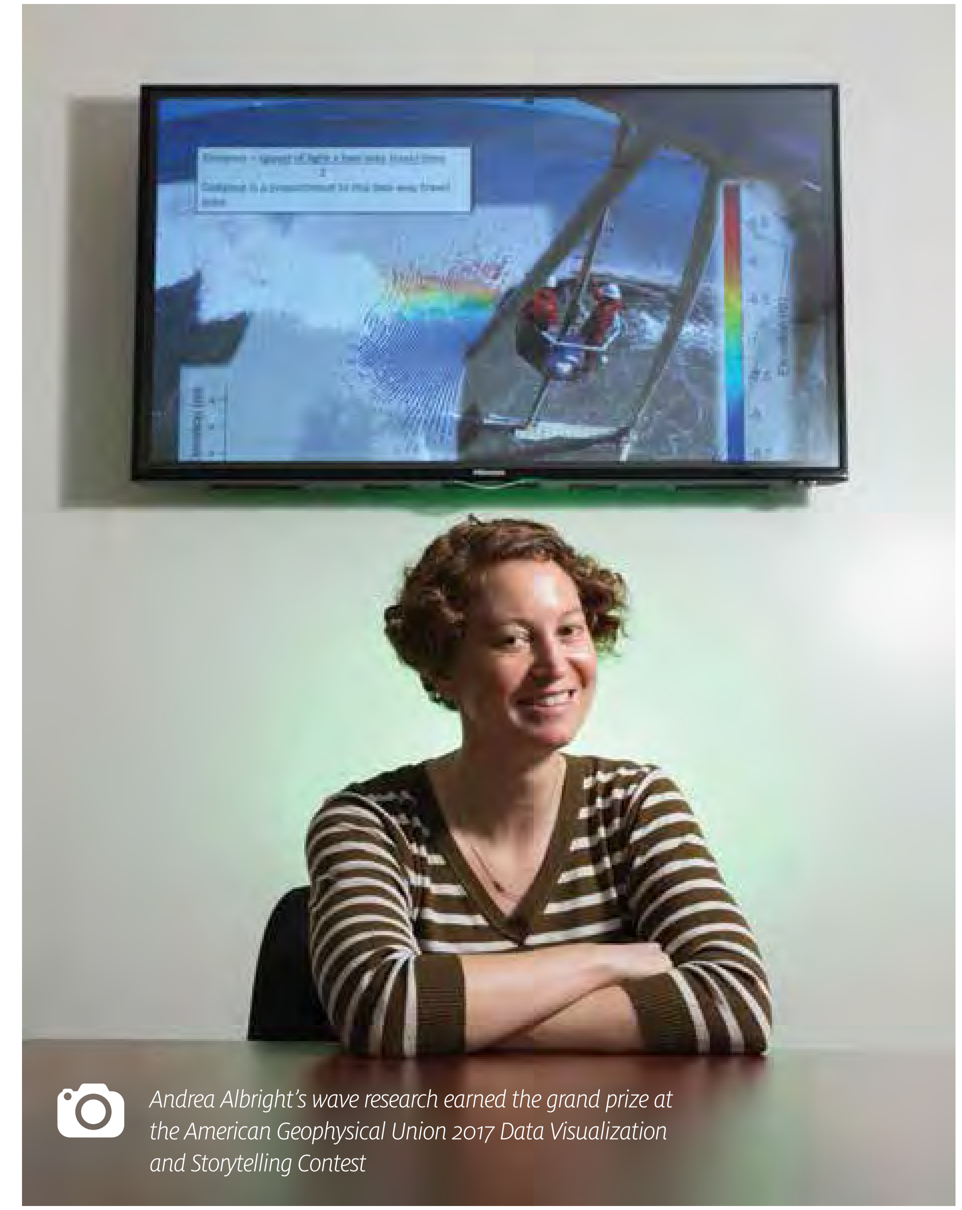
The geosensing systems engineering and sciences graduate program at the UH Cullen College of Engineering is the only program of its kind in the world. Administered through the National Center for Airborne Laser Mapping (NCALM) at UH, the program trains the next generation of scientists in the rapidly changing field of geospatial engineering, providing students with hands-on experience using state-of-the-art sensors and remote sensing technologies for a wide variety of Earth science applications.

The center's premiere technology is LiDAR, or light distance and ranging. It works by shooting thousands of laser pulses per second at the ground from a plane or terrestrial platform. How quickly that light returns to its source can be used to calculate its distance from the source. Researchers often use these data sets to produce detailed topographic maps. LiDAR data collected by NCALM has been used for a variety of applications, from archaeology to mapping coastal erosion.

The technology is relatively new and so widely applicable that novel uses for it are still being discovered. Part of Albright's work is applying LiDAR to the study of waves and coastal erosion, and the other part is explaining her work to a public that's never heard of this technology before.

"I had to focus on moving people away from two-dimensional photographs and into three-dimensional LiDAR space," Albright said.

And it's here, at the cutting edge of cutting-edge, that Albright finds herself riding the wave of the future.



Andrea Albright's wave research earned the grand prize at the American Geophysical Union 2017 Data Visualization and Storytelling Contest

Waving goodbye

Albright conducted her research at the U.S. Army Corps of Engineers Field Research Facility in Duck, a small town located in North Carolina's Outer Banks, a group of barrier islands just off the coast. Using a 35-foot-tall amphibious platform called the CRAB (an acronym for coastal research amphibious buggy), the team placed sensors beneath the water to capture information on the speed and height of the waves while another system collected water samples to quantify the amount of sediment each wave carried. The researchers positioned the LiDAR equipment on a long arm of a platform that extended over the water and shot thousands of laser beams at the waves below, calculating the distance each laser traveled from the platform to the surface of the water and back again.

"The consequence of shooting a swath of lasers is you can see the surface of the water as it moves, and we can actually make a movie of a wave as it's moving. It's a whole new way to look at this sort of phenomena," Albright explained. This data was supplemented by video footage of the waves shot by a GoPro camera attached to the CRAB.

The next step for the researchers is to combine data from each laser and calculate wave statistics, which describe each type of wave and how it breaks based on the individual properties of each wave. "The qualities of each wave will be used to characterize the wave types," Albright said.

When the research is completed and Albright is ready to wave goodbye, she hopes to leave the barrier island with data for wave models that will help in planning and remediation efforts for coastal erosion.

Amanda Nash displays her leadership award from the Black Engineer of the Year Awards Conference

PROMES SCHOLAR WINS STUDENT LEADERSHIP AWARD

for the 2018 BEYA STEM Conference

BY RASHDA KHAN

Amanda Nash, a first-generation undergraduate student at the University of Houston, likes to combine biology, engineering, research and awards.

"I love learning new things and trying to understand the world around me," Nash said. "I think it is so cool to think about everyday things from a scientific point of view."

The biomedical engineering senior at the Cullen College most recently won a Research/Student Leadership Award from the Career Communications Group Inc. and the Black Engineer of the Year Awards (BEYA) Conference.

As part of her win, Nash was recognized at the Student Leadership Awards Dinner at the 2018 BEYA STEM Global Competitiveness Conference in Washington, D.C. in February.

Nash, a Program for Mastery in Engineering Studies (PROMES) scholar, was one of 28 students chosen for the NYU School of Medicine Summer Undergraduate Research Program (SURP) in 2017. There, she studied developmental genetics and worked on a project focusing on the effects of cell polarization on embryonic development and the possible role of centrosomes in nuclear movement during this process. At the end of her SURP experience, Nash won the best poster award.

She later presented her SURP project at the Annual Biomedical Research Conference for Minority Students in Phoenix, Arizona. Out of 4,000 student presentations from around the country, Nash won the top presentation award for it.

As an undergraduate research fellow, Nash has been studying the remodeling of the extracellular matrix of mesenchymal stem cells derived from mice, rats and humans — something that could advance working with stem cells and increase the success of bone marrow transplants — in the UH research lab of Vivien Coulson-Thomas, assistant professor of optometry.

"The biomedical undergraduate research program was designed for students to be exposed to research. However, Amanda's experience has gone well beyond this and she has embraced the research project at a Ph.D. candidate level," wrote Coulson-Thomas, who has been working with Nash since 2016, in her recommendation for the BEYA award.

Nash's goal is to one day be a principal investigator and full professor.

UH Cullen College Recognizes

Outstanding Students

BY RASHDA KHAN

Every academic year, the University of Houston's Cullen College of Engineering celebrates student achievement by choosing an Outstanding Senior and an Outstanding Junior. Not only do the chosen represent hard work and dedication, but also passion and intellectual curiosity. They serve to inspire.

For 2017-2018, the two students are: Biomedical engineering senior **Megan Goh** and chemical engineering junior **Christine Stroh.**

These are their stories.

Cullen College Outstanding Junior

Christine Stroh

Graduation Year: 2019
Major: Chemical Engineering
GPA: 3.90

Christine Stroh credits her parents for her scientific bent, creativity and penchant for exploration. Both her parents are chemical engineers, but her father plays the saxophone and her mother is a flutist.

"They have a good mix and they help me see both worlds," said Stroh, who was drum captain and salutatorian in high school. "That's what allows me to explore."

She chose engineering because it combined her love of math and science with creativity, and chemical engineering because it offered her an array of options.

"Back in high school I didn't know what I wanted to do with my life," Stroh said. "With chemical engineering you have so many possible routes — you could go into the medical field, industry, grad school or start your own company," Stroh said. "I felt like it gave me more options to figure out what I wanted to do."

As part of exploring the medical field, Stroh participated in the UH Honors College Honduras Service Learning Abroad program with the Houston Shoulder to Shoulder Foundation. She spent a semester communicating with a clinic in Honduras and learning about diseases and medical care there. At the end of the semester, her group traveled to Honduras and worked with the clinic staff and their patients.

Stroh said her UH classes helped prepare her to deal with real-life work tasks at her internship at BASF Corp. in the summer of 2017.

"I was nervous because I didn't know what to expect," she said about the internship. "But thanks to my classes, I was like, 'I can do this, I know what to do.' Just the higher level thinking they teach and being aware of the resources helped."

Since then, she's landed another internship, this time with Albemarle Corp. at their facility in Silver Peak, Nevada. "They produce the lithium used in the batteries for Tesla's electric cars," Stroh said. "I am curious about battery storage and electric cars. It's not efficient yet, but it's the up and coming new thing."

The internships are another way to explore her options.

"I'm still narrowing down what I really want to do. BASF was a large [global] company with lots of interconnected parts, while Albemarle is smaller and more specialized," Stroh said. "Now I'm narrowing down which part of the industry I want to work in and still exploring."

Stroh is also an active member of Engineers Without Borders, belongs to the Phi Beta Delta International Honor Society and the Tau Beta Pi Engineering Honor Society and is a Phillips 66 Fueling Future Engineers Award winner.

Cullen College Outstanding Senior

Megan Goh

Graduation Year: 2018
Major: Biomedical Engineering
GPA: 3.98

Megan Goh, who played on the UH NCAA varsity women's soccer team, is no stranger to pain and injuries. She had her first surgery at age 14 for a torn ACL (anterior cruciate ligament) and suffered two concussions before starting college thanks to her passion for soccer.

Her experience with her injuries and working with medical professionals to heal and get back on the soccer field had a profound impact.

"I wanted to be able to help other people in my situation," Goh said. "So going into biomedical engineering was the best fit for me. It was kind of a marriage between problem-solving and the medical aspect, which has played a pivotal role in my personal life."

She won the Houston Scholars Program's competitive independent research grant three times and used it to investigate how concussions might affect biomechanical properties of rat brains. Goh's poster presentation on the project received the audience favorite award at the UH Undergraduate Research Day.

Additionally, Goh works as a biomedical engineering undergraduate fellow in the Biomedical Imaging Optics Lab led by Professor Kirill Larin and has served as a Harris Methodist Hospital intern.

Goh's passions and research interests have taken her all over the world.

She participated in the National Science Foundation's Bio-X Summer School in Crete, Greece, where she worked with and learned from leading researchers in the biomedical engineering field. Goh also presented work about the use of optical coherence elastography to characterize the biomechanical properties of biological tissues.

Goh visited India as part of a medical relief trip. She helped with medical exams, distribution of medical supplies and providing health education to more than 200 orphans and 2,500 villagers.

Volunteering is important to Goh. She has been invited to speak at several Houston-area elementary schools — introducing students to science and engineering concepts, conducting demonstrations, devising lesson plans and sharing how science and engineering are a part of everyday life.

"I try to be as involved as I can be in giving back to the community because I think the Houston community is amazing," she said.

Goh said her time at UH has been a blessing. "I have had a wonderful time in college where you just get to be a student and engage in all different kinds of experiences," she shared. "I have been blessed with a lot of opportunities here and have nothing but good words for my UH experience."

With her May 2018 graduation drawing closer, Goh is busy planning for the future. She's applied for overseas research positions as well as some graduate schools. Now she's studying for the MCAT and plans to apply to a few medical schools as well.

"I would love to apply for a M.D./Ph.D. program," said the master organizer. "I'm just waiting to see what works out."

From Lebanon, With Love:

Alumnus Abe Najjar Supports Electrical Engineering Students With Endowed Scholarship

BY AUDREY GRAYSON

As a child in Lebanon, **Abe Najjar** (BSEE '89, MSEE '91) never dreamed he would one day be working in Houston as an engineer for one of the largest engineering, procurement and construction (EPC) companies in the U.S. Najjar's parents encouraged him to strive for excellence in his studies, but the money for college just wasn't there.

Today Najjar finds himself 21 years into a successful career with Bechtel Corporation, where he serves as a senior control systems engineer – a reality made possible many years ago through the generosity of one individual.

"Thanks to a wealthy Lebanese man I received a fellowship to attend university in the U.S. and study engineering," Najjar said.

The opportunity to enroll at the University of Houston, he added, was the single most important aspect of his life. "My life would look a lot different today if I wasn't given that gift to attend the University of Houston. That's why I wanted to pay it forward and reward scholars by giving them the chance to get an education."

Najjar established an endowed scholarship for electrical and computer engineering students with financial need at the UH Cullen College, providing the gift of world-class engineering education to students who may otherwise be unable to afford tuition.

The power of passion

When Najjar first arrived in the Lone Star State, engineering wasn't on his list of potential careers. Originally a student in UH's hotel management program, a lack of passion for his studies coupled with a love of math brought him to the office of a counselor who suggested engineering as a possible path. "Once I got to the electrical engineering program at the Cullen College, I knew I was in the right place," Najjar said.

Najjar describes his college lifestyle as "monk-like" from that point forward. He focused on homework, studying and lab assignments, finding that the more of himself he devoted to the engineering coursework, the more he wanted to be an engineer.

After earning both his bachelor's and master's degrees in electrical engineering from the Cullen College, Najjar was faced with yet another turning point. Houston's oil and gas market was still on shaky footing after the oil bust of the 80s, making the job market more competitive for young professional engineers. After many months of job searching and interviewing, Najjar was considering a move back to Lebanon when a phone call from the Bechtel Corporation forever altered his path.

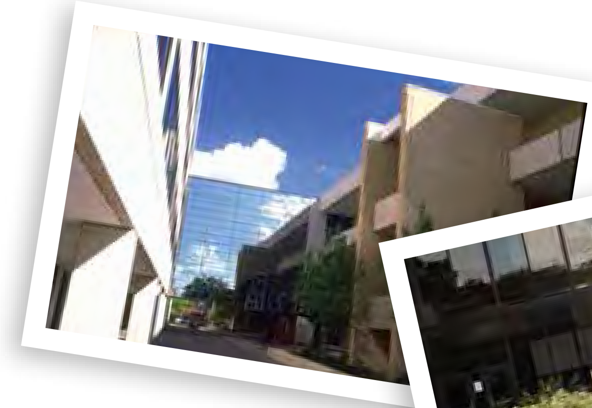
"I have been a citizen of the U.S. for 12 years now because of that phone call," Najjar said. "The rest, of course, is history."

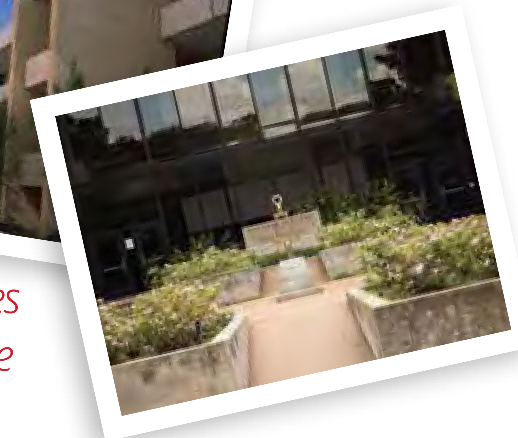
Lessons learned

Najjar's education didn't stop after graduating from the Cullen College. Once at Bechtel, Najjar said he learned some of the biggest lessons of his career, including how to ask for a raise, climb the corporate ladder and ensure your work is best suited to your passions.

"At the beginning I didn't want to speak up. I didn't want to make waves. It took me some time to learn that's not doing any good," he said.

A piece of advice Najjar often imparts to young engineers is to speak up early and often.





> *"Some of my best memories of my life took place inside those two engineering buildings at UH."* - ABE NAJJAR

Najjar learned this lesson early in his career after revealing his salary to a coworker who informed him he was underpaid for his position. Overwhelmed with anxiety, Najjar approached his supervisor to ask for a raise and was stunned by his response: "Why didn't you come to ask sooner?"

"In that moment I learned you can't just do your part and rely on your managers noticing. It takes two hands to clap. If you're doing your job and doing it well, then go to your supervisors and let them know your worth," said Najjar.

Najjar also urges new engineers to be open-minded in the face of new challenges and opportunities – even ones that don't seem ideal at first. "Don't be too choosey – when you're early in your career you may not know what your needs and preferences are yet. You may end up loving a job you thought you would hate, so give it a shot, stick it out. You never know what you might be missing out on."

This lesson is particularly palpable for Najjar. When he first arrived in Houston, Najjar couldn't imagine calling the Bayou City his beloved home. "I hated it!" he laughed. "Now when someone talks badly about Houston I become offended. I'm a Texan now! If I hadn't given it a chance I'd have never known how happy I could be here."

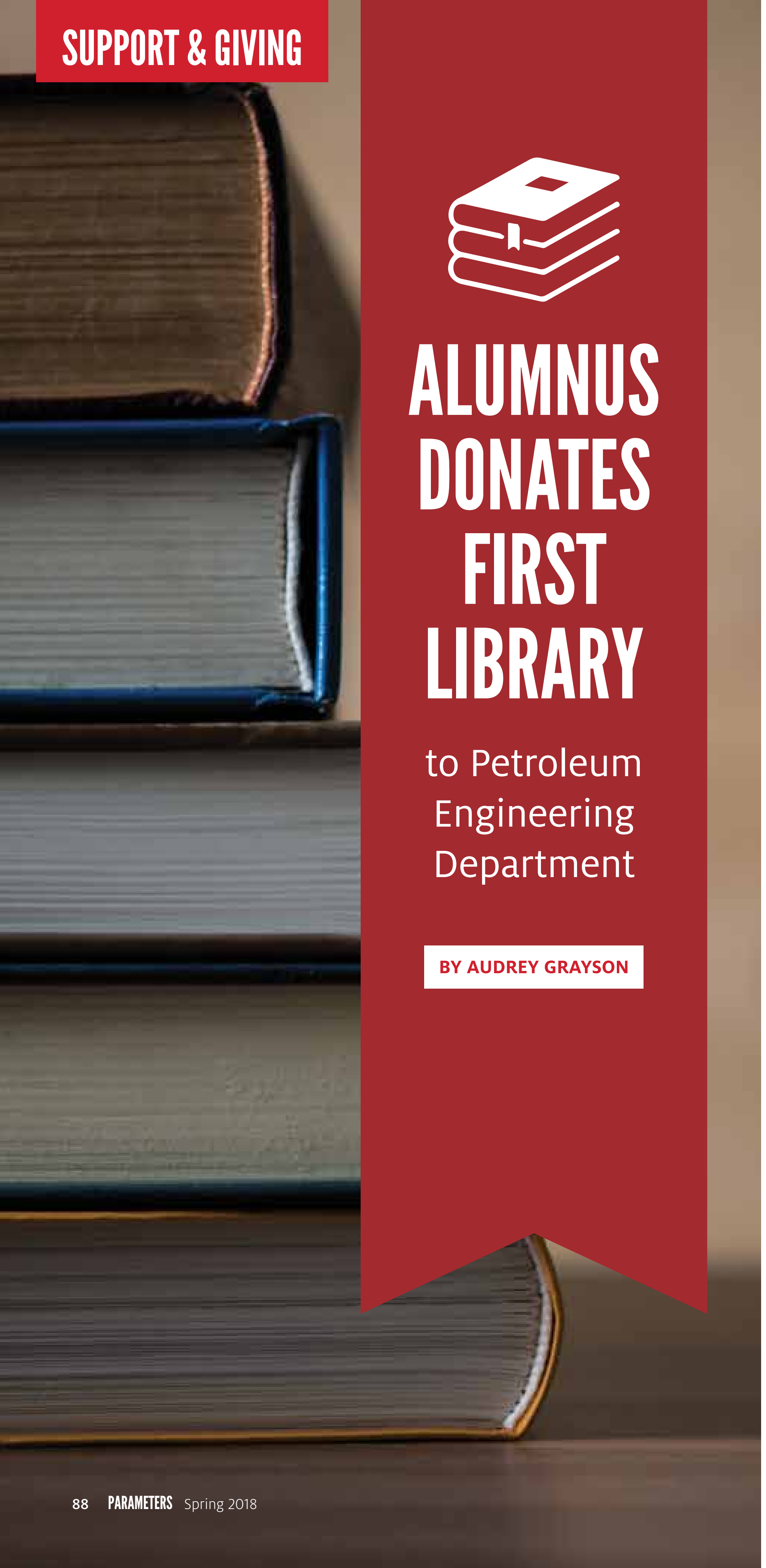
More information on the scholarship

The Abe Najjar Endowed Scholarship in Electrical and Computer Engineering was established with a bequest of $100,000 from Najjar's estate. A bequest scholarship allows donors to make a lasting and impactful commitment to UH engineering students without affecting their current finances. The endowed scholarship provides funding to engineering students indefinitely by distributing annual earnings from the fund.

Najjar set specific eligibility requirements for his scholarship, seeking to help academically-gifted students with financial insecurities. "One unique aspect of the scholarship is that it's based on financial need. If a student's GPA improves after receiving the scholarship, they will have an opportunity to receive even more funding through the scholarship the following year."

For Najjar, helping future engineering students pursue their dreams is his own dream come true.

"Some of my best memories of my life took place inside those two engineering buildings at UH. It was a special time in my life and it brought me a lot of success," Najjar recalled. "Being able to give other engineering students the same opportunities I had is one of my proudest achievements."



ALUMNUS DONATES FIRST LIBRARY

to Petroleum Engineering Department

BY AUDREY GRAYSON

Since earning his master's degree in petroleum engineering from the UH Cullen College in 1986, **Stuart Filler** has witnessed his alma mater undergo many positive transformations, eventually outgrowing its reputation as a "city commuter school" to break into the list of the nation's top-ranked research universities.

Most notably to Filler, vice president and project coordinator at Ryder Scott Company in Houston, was the relaunch of the Cullen College's petroleum engineering bachelor's program in 2009. With support from Ryder Scott and a swath of top energy companies across the region, enrollment in the program exploded to over 900 students by 2014.

As the fledgling program continued to soar, earning ABET accreditation in 2015, Filler said he felt compelled to give back to the college that opened up so many doors in his career.

"I earned my master's degree in petroleum engineering from UH in May of 1986, and I still credit that degree for allowing me to keep my job during those years," said Filler, recounting the oil bust of the 1980s that put thousands of Houstonians out of work and drove hordes of companies out of business.

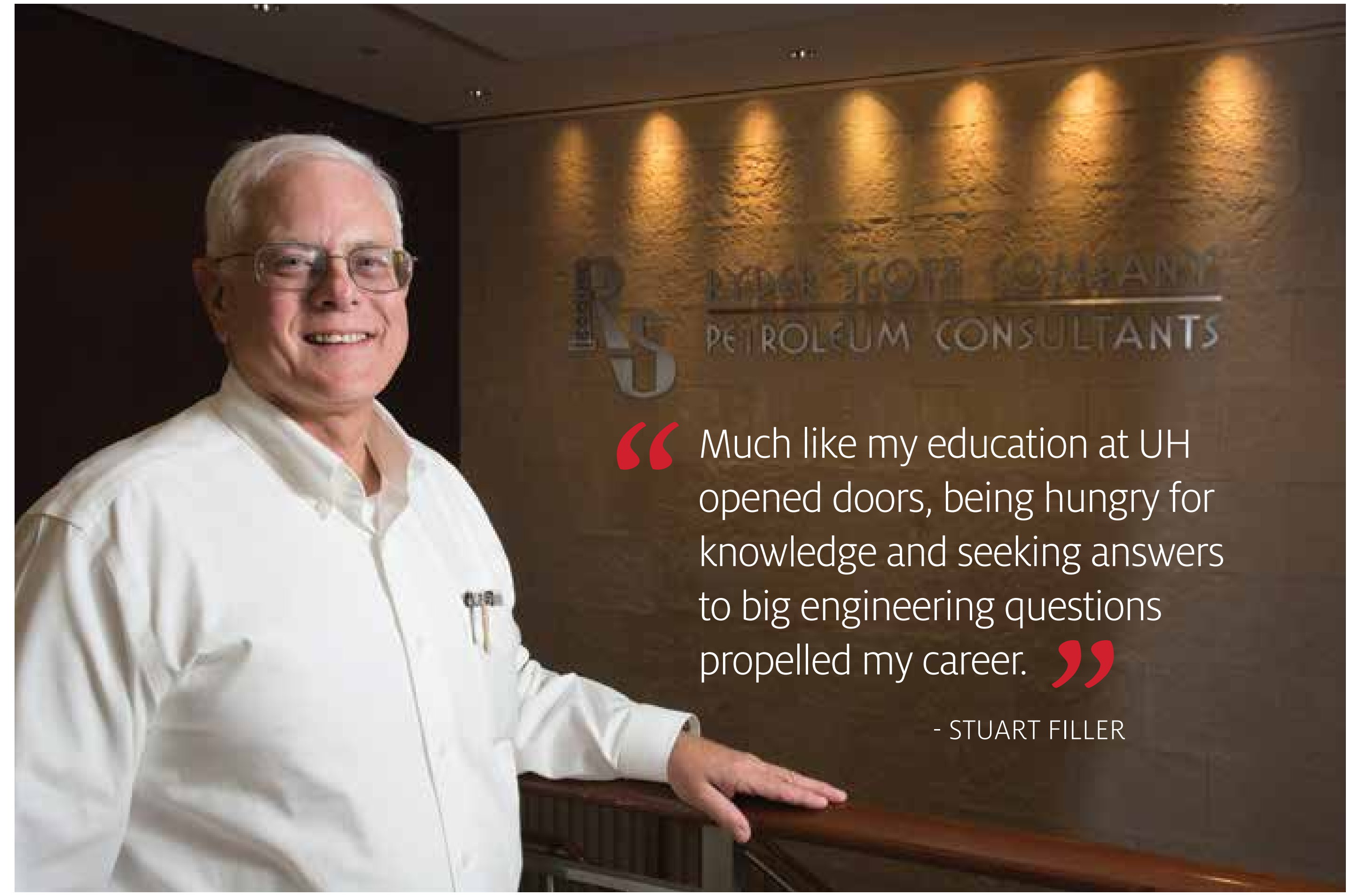
Finding that his education was a gift that kept giving to him over the course of his career, Filler saw a fitting gift for up-and-coming petroleum engineering students at UH – more than 200 of them, in fact, all lining the shelves of his office walls.

A new chapter

"I'm a bit of a bibliophile," Filler admitted, adding that his library of textbooks and documents often proved valuable in pushing his career forward. "Much like my education at UH opened doors, being hungry for knowledge and seeking answers to big engineering questions propelled my career."

So Filler loaded up his car with hundreds of technical books, textbooks and documents and drove them to the UH petroleum engineering department in UH's Energy Research Park.

Tom Holley, former director of the UH petroleum engineering program, helped Filler unload his car. Together they filled a series of empty shelves inside the department with books – gifts that can be opened again and again by countless students. And with that the first petroleum engineering department library was established.



Bibliography of success

Filler recalls his time as a UH petroleum engineering graduate student in the 1980s with both fondness and relief. "It was a rough time," he said. "I got my master's degree at just the right time and I truly believe it got me through those bust years."

Filler's long list of career successes include more than four years in the army, nearly 10 years as a senior advisor with Devon Energy and three years as a reservoir engineer at Southwestern Energy before joining Ryder Scott in 2014.

UH engineering programs, especially at the graduate level, are tailored for working professionals. Curricula are shaped with direct input from industry leaders and address both current and future workforce needs.

"One of the greatest strengths of the program were the professors," Filler said. "My courses were taught by a diversity of faculty members who really knew the business because they were the ones doing the business, and they brought that experience into the classroom."

Although the petroleum engineering program has grown exponentially since his college days, Filler noted many of the same qualities that drew him to the UH Cullen College remain today – with one exception: "UH has always had a great petroleum engineering program but now the program and its students are exponentially better."

Filler, for his part, likes to ensure Ryder Scott is tapping into the world-class engineering talent at UH, laying down the pipelines for petroleum engineering graduates to enter into the company ranks.

In working with new petroleum engineering graduates, Filler said he often reminds them not to chase the paycheck. "If you're doing it for the money, you're not going to be happy," he said, noting the high salaries in the field don't take into the account the bust years in the biz.

For all his years of experience, Filler said there's one more important piece of advice for new grads to keep in mind as they embark on their careers: "Be broad based and be willing to take a job that's not exactly what you want to do because you need to learn."

Fitting advice from a man who gave the broad gift of knowledge to those UH petroleum engineering students who are eager enough to seek it.

LIENHARD'S
LENS

BY JOHN LIENHARD

Meet Charlotte.

Her formal name would be *Araneus Cavaticus;* but she reminded us of the friendly barn spider in the famous children's book, "Charlotte's Web." She appeared late one fall night. We found her eyeing us from the center of a huge web, blocking our patio door. She'd sealed us in. Next morning, she and the web had vanished. That night, both were back again. And so it continued for the better part of a month.

Each morning, after she'd dined on insects she'd trapped during the night, she ate her web so as to reuse the material. Finally, she permanently retired to her cranny in the eaves, laid her eggs and died.

She had, by then, given us a remarkable engineering tutorial. Charlotte constructed her web by first spinning long, strong anchor fibers. She then filled in lighter cross members. Finally, she circled these members with dainty fly-catching strands that held tiny beads of sticky material. The result was a huge web of astonishing strength and beauty.

The silk itself took several forms depending on which of her six spinnerets she used to create it. The strength of the structural threads was roughly that of steel. But, unlike elastic steel, which stores energy as it's stressed, spider silk absorbs energy. That means a fly cannot trampoline off the web once it lands. Engineers have developed means for replicating this amazing material on a larger scale. Today you can actually buy fabric made of synthetic spider silk.

Charlotte's eggs eventually hatched and hundreds of her tiny children floated away, each on its own strand of silk. This time, the silk served as a paraglider. And we, drawn so deeply into the intricacies of her engineering mastery, have looked at spider webs with new eyes ever since.

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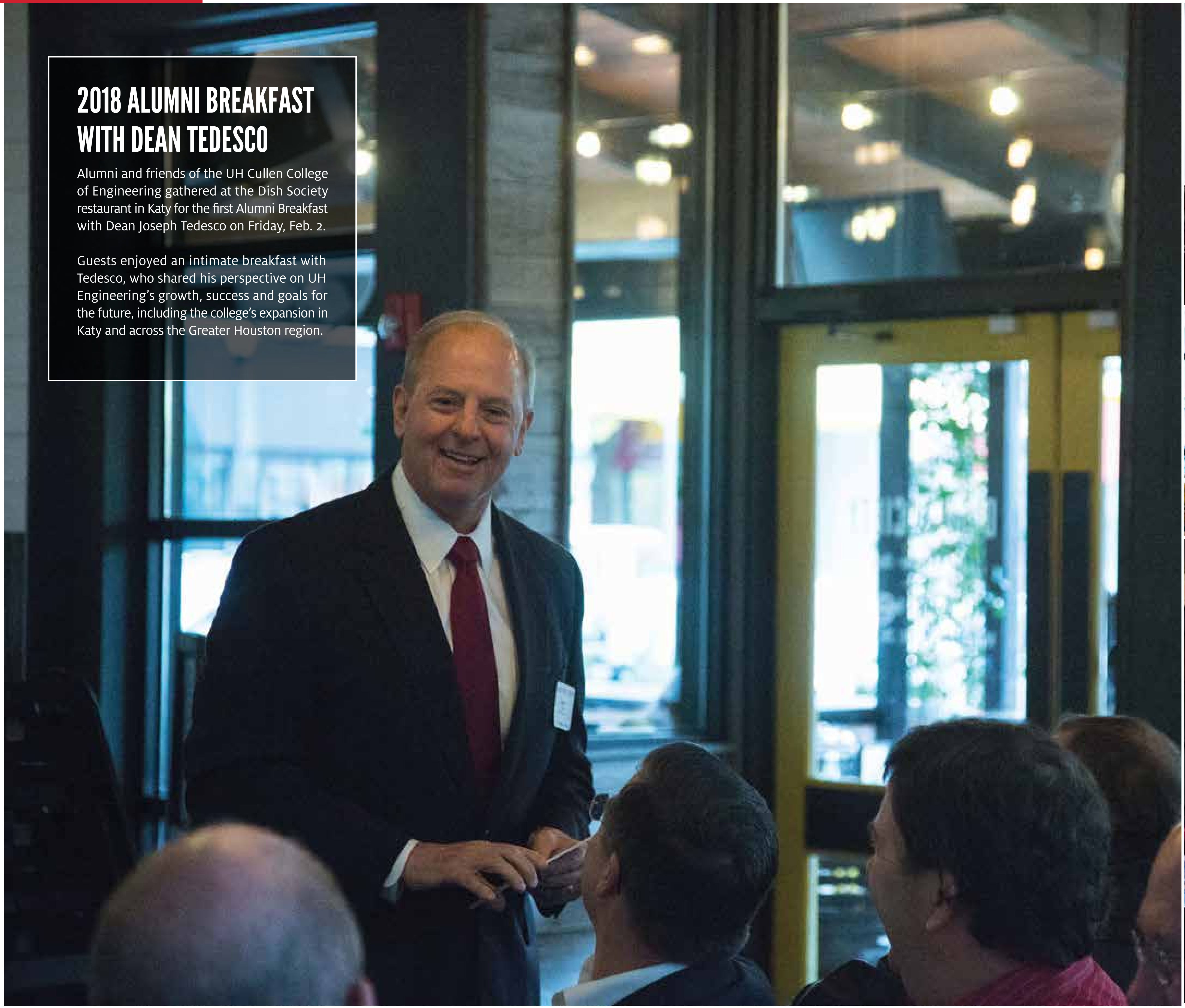
CHEVRON INSPIRES GIRLS TO ENGINEER THE FUTURE AT UH

The Cullen College hosted the third annual "Girls Engineering the Future: A STEM Event," sponsored by Chevron last March, which introduced over 1,000 Houston-area girls in grades 4^{th}-8^{th} to complex engineering principles through fun, hands-on activities.

2018 ALUMNI BREAKFAST WITH DEAN TEDESCO

Alumni and friends of the UH Cullen College of Engineering gathered at the Dish Society restaurant in Katy for the first Alumni Breakfast with Dean Joseph Tedesco on Friday, Feb. 2.

Guests enjoyed an intimate breakfast with Tedesco, who shared his perspective on UH Engineering's growth, success and goals for the future, including the college's expansion in Katy and across the Greater Houston region.



2018 WOMEN IN ENGINEERING SPRING EVENT

The Cullen College played host to the 3rd Women in Engineering spring event on March 7. The free event was funded by alumna Cynthia Oliver Coleman, P.E. (BSChE '71). The event took place at the UH Hilton and included female engineering students, faculty and alumnae. Attendees were inducted into the Women in Red Movement, which will serve as a registry of female students and alumnae to serve as mentors for one another. The Cynthia Oliver Coleman Rising Star Award was presented to Megan Goh for being named the outstanding senior for the Cullen College of Engineering.

To learn more about events and other ways to get involved at the Cullen College,

check out our events calendar online at www.egr.uh.edu/events or follow us on social media!

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View more photos online at

www.flickr.com/photos/cullencollege/albums

ENGINES OF OUR INGENUITY

Episode No. 1246

MOMENTUM

In another episode I talk about a museum docent who didn't understand the role of momentum in a demonstration she ran for school children. When my wife saw that, she said, "Look, a whole lot of people like me never learned about momentum. If it's important, why don't you explain it in a program?"

That's a tough challenge because we all have at least a gut sense of the concept. But what would you do if you had to define momentum? The dictionary calls it the impetus of a moving body – not much help there! Your gut sense is probably more accurate. When you say something gains momentum, you mean it's increasingly hard to stop. And that's absolutely correct.

In a physics class, we're told that you calculate the momentum of, say, an automobile by multiplying its velocity by its mass. So, to understand momentum we have to understand mass. Suppose you have a 6-pound rock. That rock would only weigh 1 pound on the moon but its mass would be the same as it is on Earth.

Years ago, when I first studied physics, I came home terribly frustrated trying to understand mass and momentum. I complained to my father that I couldn't see how mass differed from weight.

So, he picked up a paper weight and tossed it to me. "What happens when you catch it?" he asked. "It pushes my hand back," I said. "Okay," he went on, "How much would that weigh on the Moon?" "Only a sixth as much," I answered, wondering where he was headed. "All right then, what would you feel if I tossed it to you on the Moon?" And, just like that, the scales fell from my eyes.

Of course! Matter has a property independent of its weight. Catching a paper weight would feel just the same on the Moon as it would in my living room. A 6-pound weight is just the reaction of a certain mass to Earth's gravity. That object would have different weights on Jupiter or Mars. But it'd still have the same mass – even in outer space where it weighs nothing at all.

Now, back to momentum. Put an object in motion, and you give that mass a momentum, which is hard to stop or deflect. The momentum of a spinning skater can change form. With her arms outstretched, she spins slowly, but the outstretched tips of her fingers are really moving quite fast. With arms drawn inward, she spins faster, but the tips of her indrawn elbows move fairly slowly. What stays about the same is her net momentum.

Years ago, a construction worker told of a friend working on the side of a building. A wrecking ball swung toward him – gently and slowly. Instead of getting out of its way, he reached out to stop it. He didn't realize that, with its enormous mass, it also had enormous momentum even if it was moving slowly. The result? It slowly crushed him – left him lame. If he'd only had a proper gut sense of basic physics, he might still be walking today.

I'm John Lienhard, at the University of Houston, where we're interested in the way inventive minds work.

John Lienhard

The Engines of Our Ingenuity is a nationally recognized radio program authored and voiced by John Lienhard, professor emeritus of mechanical engineering and history at the University of Houston and a member of the National Academy of Engineering. The program first aired in 1988, and since then more than 2,800 episodes have been broadcast. For more information about the program, visit www.uh.edu/engines.

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