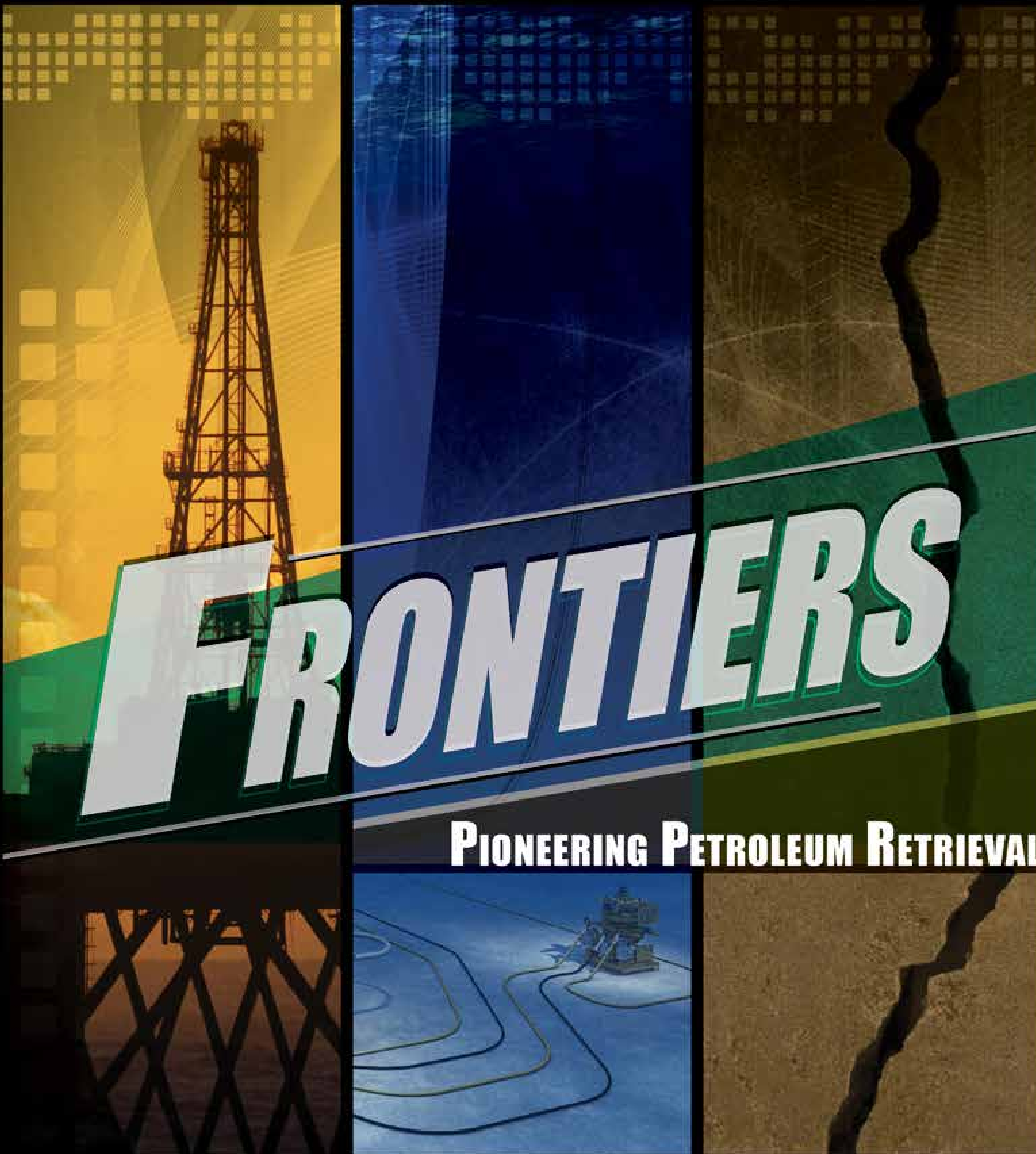
University of Houston Cullen College of Engineering

[ParameTErs]

Fall 2013



UNIVERSITY of HOUSTON
CULLEN COLLEGE of ENGINEERING

Dean's Message

Engineers aren't just the thinkers, doers and creators of our modern world – they are the pioneers of our time, boldly exploring the vast and unknown frontiers of our planet with one very simple goal in mind: to make the world a safer, cleaner and better place to live.

Perhaps the biggest challenge we currently face as engineers is how to meet the increasing demand for energy. Developing new technologies and methods to efficiently and safely retrieve petroleum in order to meet world energy demand is the new frontier – and one which researchers at the Cullen College are determined to pioneer.

Frontiers can exist almost anywhere. There are frontiers of the mind, of the landscape, of research, of connection, of self-discovery. One must understand this to realize the significant work of our Cullen College pioneers, who are engineering the future of Houston by first engineering the future of petroleum production and retrieval.

Houston is and will continue to be the Energy Capital of the World. We are Houston's university – the University *of* Houston – and by the strength of that title, the UH Cullen College of Engineering has a unique motivation to address the realities of the modern petroleum sector with its research, curriculum and output of highly skilled graduates entering the energy workforce. To this end, the Cullen College of Engineering has been, and will continue to be, committed to doing its part.

We dedicate this issue of *Parameters* to the Cullen College's ongoing efforts to support Houston's energy industry and infrastructure with the tools, technologies, expertise and research required for its continued growth and success. From drilling wells thousands of feet below the surface of the sea to shale oil and gas reservoirs right below our feet, wherever the next frontier in energy exists, the UH Cullen College of Engineering will be pioneering the future of petroleum production.

Warm regards,

Joseph W. Tedesco

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

Dean
Joseph W. Tedesco

Associate Dean for Research & Facilities
Hanadi Rifai

Associate Dean for Graduate Programs & Computing Facilities
Suresh K. Khator

Associate Dean for Undergraduate Programs
David P. Shattuck

Chairs

Biomedical Engineering
Metin Akay

Chemical & Biomolecular Engineering
Mike Harold

Civil & Environmental Engineering
Kaspar Willam

Electrical & Computer Engineering
Badrinath "Badri" Roysam

Industrial Engineering
Gino Lim

Mechanical Engineering
Pradeep Sharma

Parameters is published biannually by the University of Houston Cullen College of Engineering, Office of Communications.

Communications Director
Audrey Grayson

Editor
Toby Weber

Graphic Designer
Rachel Ward

Photography
Thomas B. Shea, Rachel Ward

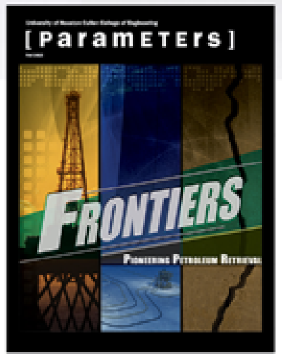
Contributing Writers/Editors
Esmeralda Fisher
John Lienhard

Contact us:
Office of Communications
Cullen College of Engineering
University of Houston
E301 Engineering Bldg. 2
Houston, Texas 77204-4009

Phone 713.743.4217
Fax 713.743.8240
E-mail parameters@egr.uh.edu
Website www.egr.uh.edu

Contents

ON THE COVER



Frontiers

Intelligent oil fields, subsea engineering and unconventional reservoirs are the new frontier of petroleum exploration and production – and the Cullen College of Engineering is pioneering research in all three areas.

FEATURES

PARAMETERS - FALL 2013

Lead News

UH Announces Plans & for NEW Multidisciplinary Research Engineering Building

The University of Houston Cullen College of Engineering has grown tremendously in recent years, with research expenditures and enrollment at or near all-time highs. To keep this momentum, UH and the college have announced plans to construct a new Multidisciplinary Research and Engineering Building (MREB).

The four-story, 120,000-gross-square-foot facility will sit next to the two main engineering buildings in the footprint of the college's old Y-Building, which was demolished last year. The facility will support both academic and research programs, including lecture spaces, research labs, computational training facilities, a visualization lab, a high-performance computational server room, and a nuclear magnetic resonance spectrometer lab.

Groundbreaking is scheduled for 2014, with occupancy beginning in 2016.

According to Joseph W. Tedesco, Elizabeth D. Rockwell Dean and Professor of the college, the tremendous growth the college has undergone in recent years has put space within its existing facilities at a premium. This new research building will provide the infrastructure needed to continue increasing student enrollment, hiring new faculty and bringing new research funding to the college.

"This new facility will provide a catalyst for the Cullen College to rise among the 50 best engineering programs in the nation," Tedesco explained. "We will be able to increase our annual research expenditures to $36 million, which should in turn promote approximately $612 million worth of economic activity in Houston alone. Our graduate student population will grow by 250 students and we will have the state-of-the-art research facilities needed to attract leading faculty, including members of the prestigious National Academy of Engineering."

In addition, the building's multidisciplinary nature will foster collaboration across the campus while serving as an efficient investment of resources. The new building will house major core facilities that serve the critical needs of the university's research foci, both in energy and health, that will be available to researchers not just in the engineering college but across the entire university. Such an approach minimizes investments and limits the creation of redundant instrumentation facilities. It also will bring researchers from different disciplines together in a shared space, leading to the exchange of ideas and the formation of new research partnerships.

Now, the current focus for this project, said Tedesco, is fundraising. Though UH has committed to funding a large portion of the $51 million facility, the Cullen College community must do its share, he explained.

www.egr.uh.edu/newbuilding

"The commitment from the University of Houston is strong, but we need the support of our alumni and friends to make this building a reality. We are tasked with raising $10 million for this much-needed facility. So far, we have secured $1,780,350 from our alumni and friends," Tedesco said. "I ask our alumni, friends and supporters to explore our plans for this building. See what we plan to do and what we can do, and then help the Cullen College of Engineering become an even greater resource for our university, our students and our community."

Build the MREB, Build the ENGINEERING CAPITAL of the WORLD

Houston is a world-class city and a global leader in innovation. Now, we have a chance to be a global leader in engineering research.

Houston can make this happen.

The University of Houston can make this happen.

The MREB will...

Retired Astronaut Named
Aerospace Engineering *Director*

Former astronaut Bonnie Dunbar, professor of mechanical engineering and biomedical engineering at the University of Houston Cullen College of Engineering and head of the UH STEM Center, has been named the new director of the college's aerospace engineering graduate program.

Dunbar, who earned her Ph.D. in mechanical/biomedical engineering from the Cullen College in 1983, has spent her entire professional career in the aerospace field, including stints at The Boeing Company and the Rockwell International Space Division. She joined NASA as a payload officer/flight controller at the Lyndon B. Johnson Space Center in 1978 and was selected to be an astronaut in 1980. She flew on five space shuttle missions, logging more than 50 days in space. She also had two turns at NASA headquarters in Washington D.C., one as the first deputy associate administrator of the Office of Life and Microgravity Sciences and Applications.

After her last flight in 1998, Dunbar served as an assistant director at NASA Johnson Space Center for university research and as an associate director for space and life sciences, followed by five years as president and CEO of the Seattle Museum of Flight.

In 2013, she returned to UH to lead a new STEM center (science, technology, engineering and mathematics) dedicated to improving STEM education and literacy and encouraging more young people to study these fields in college.

In her newest role, Dunbar will work to grow enrollment in the aerospace engineering graduate program. She will also seek to establish research collaborations with other organizations and institutions in order to encourage more research in the field.

PE Building Gets $1m Gift
From ConocoPhillips

ConocoPhillips has donated $1 million to the University of Houston to support the ConocoPhillips Petroleum Engineering Building. The company has now given a total of $3 million to this facility, with previous gifts of $1 million in 2012 and also in 2011.

The facility is located at the UH Energy Research Park, which the university envisions as a premier research and education facility for students and faculty, as well as a unique environment for the best minds to forge new business approaches to the ways energy is created, delivered and used.

An important element of this vision is the ConocoPhillips Petroleum Engineering Building, which in 2011 became the new home for UH's popular petroleum engineering (PE) program. The building houses three teaching laboratories, three classrooms, a computer lab, faculty offices and a student lounge.

"ConocoPhillips is pleased to continue our support of the University of Houston's Energy Research Park and the petroleum engineering program," said Jeff Sheets, ConocoPhillips' Chief Financial Officer and the company's executive sponsor for the University of Houston. "The University of Houston plays a vital role in educating the next generation of top-quality and diverse engineering graduates for the energy industry."

In addition to its long-standing master's degree option, UH's petroleum engineering program launched a bachelor's degree option in fall 2009. The undergraduate program, which is designed to fill the gaps in the industry's aging workforce and equip graduates with the skills needed in the evolving energy world, has grown from about 20 students in the inaugural semester to 550 students this fall.

ConocoPhillips also is giving $125,000 to UH to help fund a number of programs in the Cullen College of Engineering, the C.T. Bauer College of Business and the College of Natural Sciences and Mathematics.

UH Launches Global Subsea University Alliance

Leaders of the world's top subsea engineering programs gathered at the University of Houston in May for the first meeting of the Global Subsea University Alliance, a group dedicated to establishing worldwide standards for subsea engineering education.

The UH Cullen College of Engineering is the United States' clear leader in subsea engineering education. It started the country's first academic program in subsea engineering in 2011 and in 2012 began offering the nation's first master's degree in subsea engineering, which focuses on the equipment and infrastructure used in the underwater portion of offshore petroleum exploration and retrieval.

Given the abundance of offshore resources and the need to extract them efficiently and safely, subsea engineering talent is in high demand. The lack of uniform standards surrounding subsea engineering education, though, can throw a wrench in petroleum companies' recruiting and hiring process, said Matt Franchek, founding director of the subsea engineering program and a professor of mechanical engineering at the Cullen College.

"When you're hiring a mechanical engineer, you know what you're hiring. When you hire an electrical engineer, you know what you're hiring. But when you hire a subsea engineer, you don't know what you're hiring. Everybody has their own version or variation," he said.

The alliance seeks to remedy that problem by establishing a global subsea curriculum in coordination with companies that operate in the sector. The first step, Franchek said, is a course-by-course, lecture-by-lecture evaluation of the world's top subsea engineering programs, all of which belong to the alliance. In addition to the University of Houston, these include programs at Curtin University in Australia, Federal University of Rio de Janeiro (Brazil), the National University of Singapore, the University of Aberdeen (Scotland), and the University of Bergen and the University of Stavanger (both in Norway). All were present at the meeting, as were two major players in the subsea sector, Cameron and FMC Technologies.

Alliance members will then see what these programs have in common and establish a core curriculum for the discipline. They will also determine the strengths of each individual program and form committees to establish standards for specialties, such as flow assurance, subsea processing and system design and control.

The group will also work to grow subsea engineering as an academic discipline by sharing its curriculum with other institutions looking to establish their own programs and likely offering some form of program certification, Franchek said.

ENGINEERING extras

UH Creates Energy & Sustainability Minor

» The Cullen College of Engineering is one of four colleges at UH that have come together to offer an energy & sustainability minor. The program, housed in UH's college of business, will cover the history of energy production and use as well as climate change and its impact on energy use. Students will also be tasked with understanding emerging energy sources and analyzing energy consumption patterns with environmental issues.

Cullen College Researchers Featured in The New Yorker

» The May 6 issue of The New Yorker includes a feature on the discovery of a previously unknown set of ruins in the Honduran Rainforest by researchers with UH's National Center for Airborne Laser Mapping. The center, led by civil engineering professor Ramesh Shrestha, used Light Detection and Ranging (LiDAR) technology to create topographical maps of previously unexplored sections of the rainforest. They created these maps in a partnership with documentary filmmakers searching for Honduras' legendary lost city of Ciudad Blanca.

First PE B.S. Students Graduate

» The first class of petroleum engineering (PE) students in UH's new petroleum engineering undergraduate program earned their diplomas this May. While UH has long had a graduate PE program, its undergraduate program was launched in 2009. The program has been met with tremendous early success: it has been profiled as a model alliance between higher education and industry by the Business-Higher Education Forum and now boasts roughly 550 students.

UH Hosts Pan American Mechanics Conference

» The Cullen College of Engineering served as the first U.S.-based host of the Pan American Congress of Applied Mechanics. PACAM XIII took place from May 22 to 24 in Houston, with about 120 people in attendance. The conference, held every two years, is designed to promote progress in the broad field of mechanics by exposing engineers, scientists and advanced graduate students to new research developments, methods and problems in mechanics.

cullen college news   @uhengineering

Frontiers

Pioneering Petroleum Retrieval

World energy demand will spike in the coming decades, and it's indisputable that much of that new demand will be met by increased petroleum production.

Retrieving these resources efficiently and safely is in everyone's best interest. That means new technologies must be developed to record and interpret reservoir and well data, ideally in real time at the sites themselves. New methods for understanding and safely extracting resources from unconventional reservoirs must be devised. And petroleum retrieval in ultradeep water must be improved to address environmental concerns and economic realities.

The University of Houston and its Cullen College of Engineering have taken the lead in all of these areas. With the creation of the 74-acre Energy Research Park, the establishment of university-wide energy research initiatives and the appointment of a chief energy officer, the university has created the framework to support rapid, coordinated growth in energy-related research.

The college, meanwhile, has established new, cutting-edge research and academic programs that address emerging and vital needs of the petroleum sector. Among these is the development of sensing technologies that will bring intelligence right to the oil field. With its subsea efforts – including the only subsea engineering academic program in the nation – the college is developing the tools and technologies that will allow industry to safely retrieve resources lying miles below sea level. And a new petroleum engineering undergraduate program and its recently recruited, world-class faculty are addressing the most pressing issues in petroleum retrieval, with a special focus on unconventional reservoirs.

By Toby Weber I Photos by Thomas B. Shea

Intelligent Oil Fields

For the largest industry on the planet, time is money at an incredible scale. Stopping well production for a short time can easily cost hundreds of thousands of dollars or more. Smoothing out the retrieval process to reduce delays and provide the best information in real time will make drilling faster, safer and more efficient. At the Cullen College, researchers are developing new technologies which can provide far more information on wells, reservoirs and downhole conditions faster than ever before.

SIMPLIFYING RESERVOIR DATA

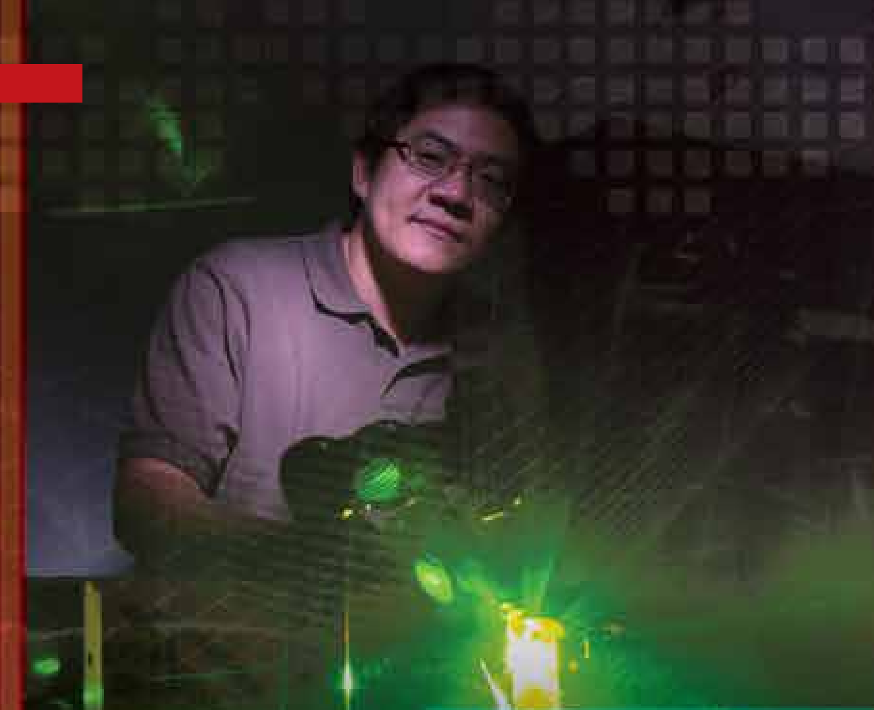
The importance of reservoir data to the petroleum industry absolutely cannot be overstated. Some pieces of data, though, just aren't as important as others.

The formulas and algorithms that transform raw reservoir data into information on where petroleum is located must calculate huge sets of data, known as matrices. Just like many sections of rock don't provide a hint on where oil is located, many of these matrices are sparse, made up almost entirely of zeros, which simply aren't useful in locating petroleum.

Zhu Han, associate professor of electrical and computer engineering, is developing sparse algorithms that will drastically reduce the computing power needed to interpret reservoir data, making these analyses both faster and more affordable.

At the center of this effort is a relatively new theorem in the field of sparsity optimization, which seeks to simplify processes by removing clearly irrelevant information from a set of data. (Han has direct experience in applying sparsity theory to real-world issues. This past summer, Cambridge University Press published a textbook he co-authored, "Compressive Sensing for Wireless Networks," which deals with sparsity optimization.)

When dealing with these reservoir matrices, Han's algorithms will essentially remove the zeros. Standard reservoir data analysis can then be performed. Afterwards, the zeros can be re-inserted into their proper spots in the matrices, providing a picture of the probable locations of petroleum.



***Wei-Chuan Shih**, assistant professor of electrical and computer engineering*

DOWNHOLE on a CHIP

Knowing where petroleum is located in a reservoir is only part of the information needed for production. What petroleum is like in the ground, where it's subjected to high temperatures and pressures, can make a big difference in how it's retrieved. Determining this downhole state is difficult, though. A mixture of oil and gas in a well, for instance, can easily convert to pure oil when it's exposed to the milder temperatures and pressures of the surface.

The petroleum industry addresses this problem by shipping large quantities of oil from a well to a lab, where scientists analyze it by recreating the well's temperature and pressure extremes. This is both onerous and time consuming, with weeks sometimes passing before a sample's downhole condition is determined.

Assistant professor of electrical and computer engineering **Wei-Chuan Shih** has proposed another method: recreate the downhole environment in a single microfluidics chip that could be used at the well site or even sent downhole.

The device Shih is developing measures just a few square inches, enough to hold a small petroleum sample. Different components will expose the petroleum to the heat and pressure of a well. "The goal is to build in heaters and pressurizers like chambers that can change volume. That's the long-term idea," said Shih. "For now, though, you can imagine it like a miniaturized flow loop with all the other elements on the side."

While those elements would recreate the well environment, Shih is also developing optical fiber sensing probes that could handle the actual analysis. The probes will extend out of a box, with one fiber feeding light into the chip and another receiving the light that has been exposed to the sample. Electronics in the box will analyze how the light behaves and changes as it passes through the heated and pressurized petroleum. By printing small electrodes on the fibers themselves, additional data on the sample's electrical properties can also be gathered. The two sets of information should be more than enough to determine the state of the downhole petroleum, said Shih.

"If we can shift this analysis to microfluidics, the temperature cycle and the pressure cycle can be much faster. That's applicable to lab sites, well sites and even downhole. You wouldn't have to ship oil to the other side of the world to analyze it."

SIMPLE SENSING through FIBER

While Wei-Chuan Shih is working to recreate the downhole environment at the surface, assistant professor of electrical and computer engineering **Jiming Bao** is developing a simple sensor to detect that environment.

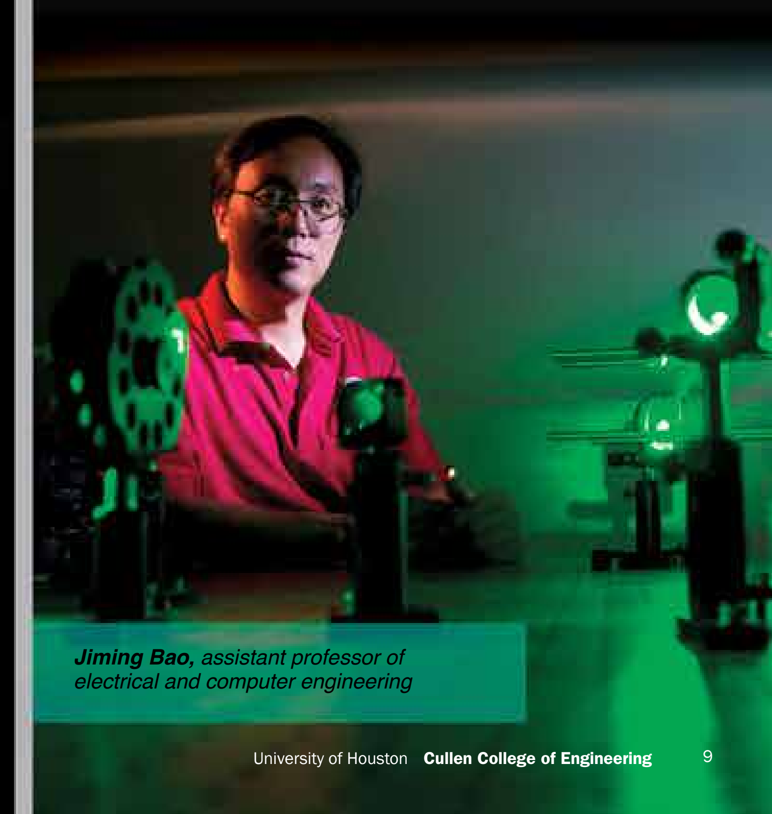
In Bao's system, a lone strand of fiber will be connected to electronics at a well's surface. At the other end of the fiber is a light or air cavity (depending on what exactly is being measured) with another small piece of fiber optic cable that sits just a short distance from the larger fiber.

When a well operator wishes to take measurements of the downhole environment, he or she can simply send a pulse of light down the long fiber optic cable. The light will interact with the small fiber and then return to its source.

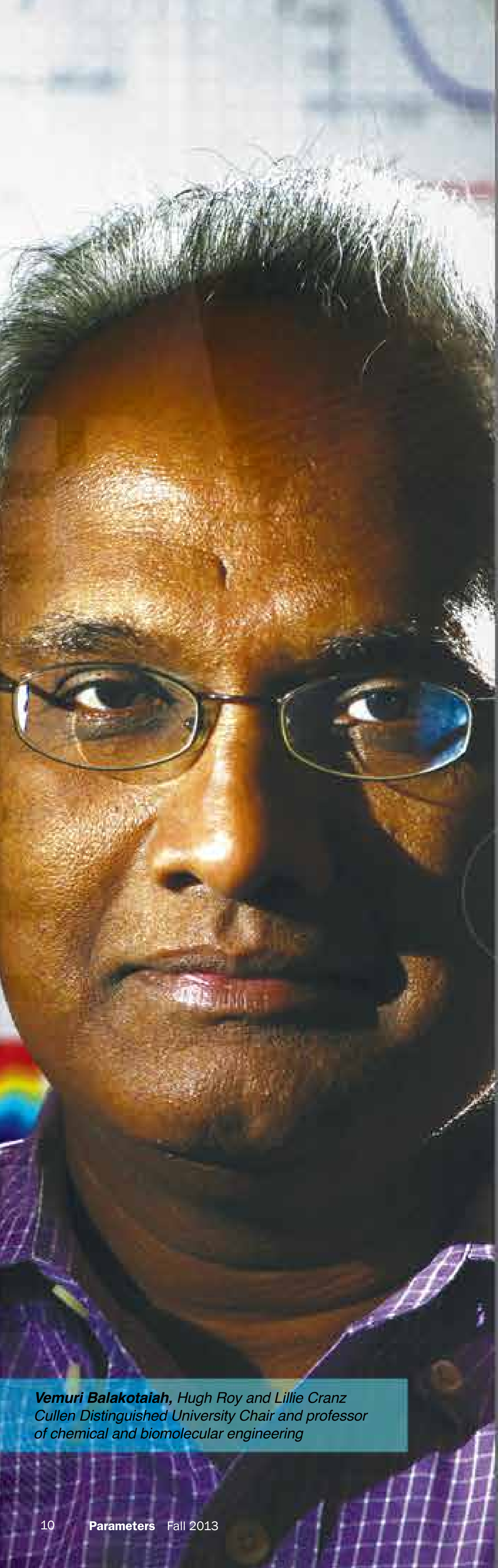
Environmental changes downhole, though, will cause extremely small variations in the distance between the two fibers and will likely slightly alter the spectrum of the light that is returned to the surface. That information can then be used to determine a well's temperature, pressure and even the properties of nearby rocks, Bao said.

Bao's work on this sensor covers the entire system, including device fabrication and signal processing. Last April, he published an article on the early achievements in building the device in the American Institute of Physics' Review of Scientific Instruments. The next step, he said, will be to test it in the field with the proper packaging to protect it from damage – a goal he is currently working toward.

The sensor, noted Bao, can be used in any area where taking environmental readings is difficult or dangerous. "It can be used for pipeline monitoring, downhole sensing and in offshore applications. It can even be used in non-petroleum related fields, like nuclear energy generation, or really any situation where you would need to sense conditions from a distance."



***Jiming Bao**, assistant professor of electrical and computer engineering*



Vemuri Balakotaiah, Hugh Roy and Lillie Cranz Cullen Distinguished University Chair and professor of chemical and biomolecular engineering

DESIGNING DRILLING ACIDS

Technologies such as the ones being developed by faculty like Wei-Chuan Shih and Jiming Bao allow petroleum companies to know the conditions down an oil well. Researchers like **Vemuri Balakotaiah** help these companies make the most of that data.

Balakotaiah, Hugh Roy and Lillie Cranz Cullen Distinguished University Chair and professor of chemical and biomolecular engineering, develops stimulation techniques for oil and gas wells based on acid injection. The idea: dissolve just a small portion – about 1 percent – of the rock that feeds to an oil well. This 1 percent, though, dissolves in long, fractal-like branches (called wormholes), increasing the rock permeability near the wellbore and the flow rate of oil back to the well by 10 to 100 times.

One of the challenges of this work, though, is simply getting the acids to the desired spots in a well – spots that are, of course, determined through data gathered by sensing technologies.

Supported by Halliburton Energy Services, much of Balakotaiah's current research addresses this problem. Depending on the rock properties and arrangement of the different rock layers, he identifies acids that are designed to fill and block the layers of high permeability. These diverting acids can reach other targeted portions of the rock formation further down the well and lead to more uniform stimulation of the layers.

"Some polymers and cross-linkers are added to the acid. This makes it gel in the high-permeability domains. These acids block those domains so when you inject more acid later, it will go down to the low-permeability areas," he said.

While drillers have been using dissolving and diverting acids for decades, the high-temperature, high-pressure and high-cost experiments needed to develop these acids have prevented researchers from fully understanding and optimizing these materials, said Balakotaiah. But thanks to increases in computing power, he and other researchers in this area have been able to greatly improve the performance of these acids.

"This is old technology. We've just been able to add more science to it," he said. "We're able to solve problems now because of computing power. We're able to see these structures form through simulations that couldn't be done 20 or even 10 years back."

BETTER BATTERIES for DOWNHOLE

Real-time sensing of downhole conditions is a valuable tool for petroleum companies. The ability to detect where oil or gas lies in a rock formation and determine how best to proceed with drilling at that very moment can allow these companies to retrieve resources much more efficiently.

One challenge to real-time sensing technology, though, is energy. Today, single-use batteries power many sensing tools. Since bringing downhole equipment to the surface can run into six figures, eliminating even one reason to do so can save huge amounts of money at every single well.

What's more, current batteries cannot function in environments above 150 degrees Celsius, which is far below the high temperatures found in many wells, presenting another hurdle to sensing downhole conditions.

Yan Yao, assistant professor of electrical and computer engineering and Robert A. Welch Professor in the Texas Center for Superconductivity, is tackling both problems at once by developing a rechargeable battery that can operate at 200 degrees Celsius.

Yao specializes in developing materials for multiple applications, including solar power and battery technologies for different uses. While this research is in its early stages, Yao is exploring the creation of an ionic liquid electrolyte that can function in a battery at high temperatures. He speculated that the recharging could be achieved by taking advantage of downhole conditions, such as thermal transfer or with a piezoelectric material that converts mechanical energy (essentially motion) into electrical energy.

"This is a high-risk, high-payoff project, but if it works it will result in a transformational battery for the oil and gas industry," said Yao.

WIRELESS POWER in WELLS

Better batteries aren't the only way to power downhole electronics. **Ji Chen,** professor of electrical and computer engineering, is working with industry to develop a wireless system that sends power downhole and, just as valuable, can be used to transmit data uphole at a high rate.

The system consists of a series of electromagnetic coils that wrap around the exterior of the pipe in a well. The coil closest to the surface can be fed power through a direct wired link. A new coil can then be located every several feet. Through attached electronics, power can be sent from the surface and then downhole, from one unwired coil to the next. Ultimately, the power will reach a coil located at the end of the drill itself, where it will be fed to reservoir sensing and recording equipment. That same power can then be used for communications equipment attached to the coil, which will allow well log information to be sent uphole at potentially millions of bits per second. Compared to today's levels of as low as 10 bits per second, this would give drillers access to vastly more information when making decisions about how to best retrieve oil from a well.

All this, though, is just in the R&D stage now. On top of the obvious mechanical hurdles to installing such a system, several electromagnetic issues must be worked out. The system, said Chen, must be able to sense and adapt to environmental changes that impact electromagnetism, such as how much oil or drilling mud it is surrounded by. In addition, the pipes that the coils surround must be modeled and their electromagnetic interference reduced in order to design a system that transmits energy at an acceptable level of around 10 percent. One method Chen has proposed to reduce this interference: fill the space between the coil and the pipe with strongly magnetic material that limits the interference.

"We're working with our industry partners to see if the technical and mechanical challenges can be overcome while we're exploring the electromagnetics part," said Chen. "If everything comes together, this could really change how petroleum companies do business when they drill."

WELL OPERATION WITH ALGORITHMS

Tools, sensors and materials are vital for efficient petroleum retrieval. Also needed are systems that help the well run smoothly from one second to the next. While the average human vastly outperforms the most powerful computers at certain tasks, others are better managed by computers. **Mike Nikolaou**, professor of chemical and biomolecular engineering with the Cullen College, is using the superior ability of computers to balance different variables in order to improve the efficiency and safety of petroleum retrieval.

"Think about juggling. You start with three balls. You cannot do this naturally; you have to train yourself," he said. "It's even worse if you have a dozen different plots on a screen that tell you about dozens of different variables. You cannot coordinate those easily if you're a human. A computer can do that very easily if you tell it what to do in a meaningful way. This is what we're doing."

One of Nikolaou's juggling acts involves maintaining pressure in a well, which must remain within certain boundaries. If the pressure within a borehole falls below or rises above these bounds, a catastrophic accident could result.

A number of different chokes, pumps and valves contribute to a well's pressure. Typically, said Nikolaou, these are controlled by operators at various locations of an oil rig, or sitting at a control panel.

This situation is simply not one that the human brain is wired to manage. That's why Nikolaou is developing algorithms for managed pressure drilling, in which a well's various valves, pumps and chokes are coordinated by a computer system to drill as efficiently as possible while maintaining safety. "It's an enclosed system to ensure pressure in the borehole stays within the very tight bounds that are necessary for safe operation," he said.

In a related project, Nikolaou is developing systems to manage the quality and properties of a well's drilling fluid.

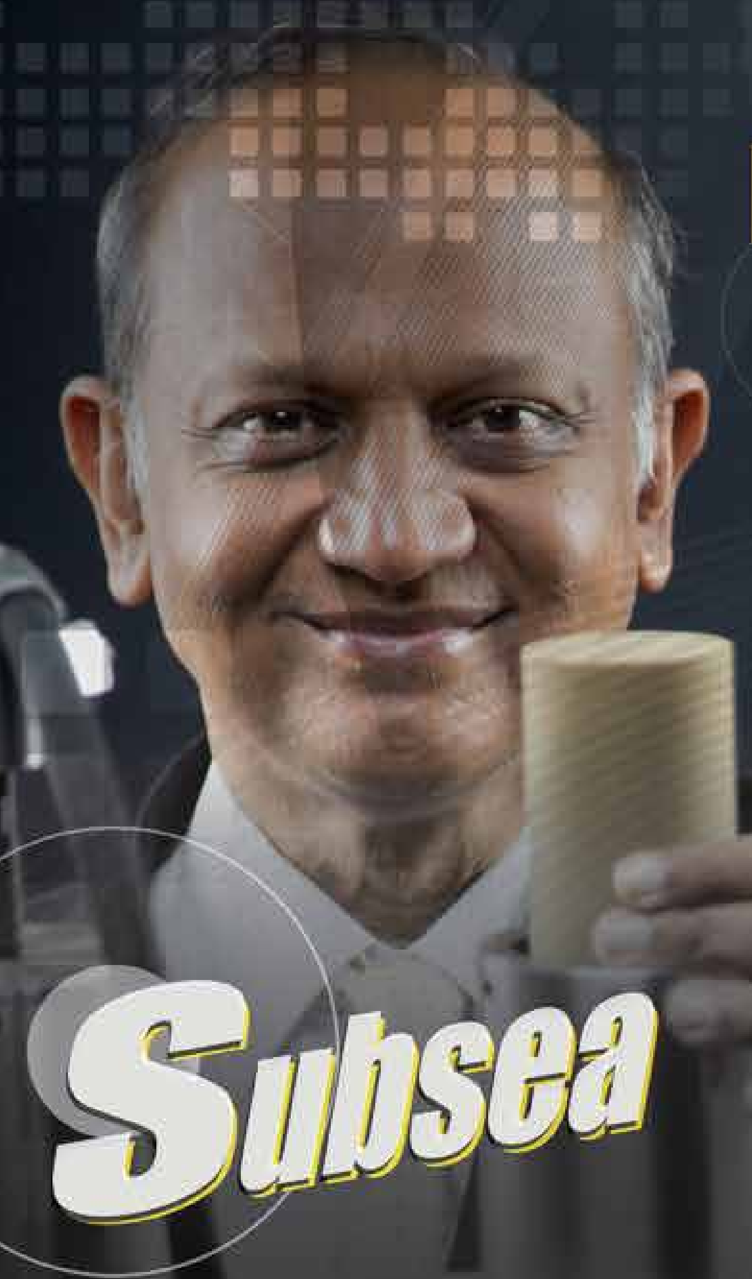
In addition to lubricating and cooling the drill, drilling fluids carry rock cuttings from the bottom of the well to the surface. Before the fluid is sent back downhole, the cuttings must be removed and the fluid's properties adjusted to meet the specific needs of the well at that time.

Using data from sensors in a solid separations system, Nikolaou's algorithms will ensure that the drilling fluids have the best possible properties to ensure drilling efficiency and ultimately improved economics.

"Humans are good at certain tasks and computers are good at others, like controlling several variables simultaneously," said Nikolaou. "These projects are about having computers manage those tasks that they are best at."

Mike Nikolaou, professor of chemical and biomolecular engineering

Features



Cumaraswamy "Vipu" Vipulanandan,
professor of civil and environmental engineering

Subsea

Along with intelligent oil fields and unconventional resources, ultradeep water is the new frontier of petroleum retrieval. The challenges inherent in drilling thousands of feet below sea level – including massive temperature and pressure swings, corrosive seawater and the inaccessibility of infrastructure at the sea floor – make engineering advances vital to safe and sustained drilling. At the Cullen College, researchers are developing materials, models and monitoring systems that address all of these challenges and promise to make subsea drilling safer and more efficient.

SMARTER MATERIALS for SUBSEA

One of the challenges of subsea drilling is simply knowing what's going on at the well site, thousands of feet below sea level.

Sensors placed in the cement that forms a well are an imperfect solution. If there is failure due to contamination of the drilling mud or cement, fluid loss, circulation loss, or hardening of cement, drillers will be blind to what's happening in that area. A failure during well creation or operation could then take hours to days to detect.

Cumaraswamy "Vipu" Vipulanandan, professor of civil and environmental engineering and director of the Center for Innovative Grouting Materials and Technology (CIGMAT) at the Cullen College, is working on an alternative thanks to a $2.5 million grant from the DOE-funded Research Partnership to Secure Energy for America, along with an additional $500,000 in support from oil field services firm Baker Hughes.

By introducing extremely small amounts of nanoparticles, polymers, coupling agents and other additives to the cementing slurry and drilling mud, Vipu can give these materials greater sensing properties. Essentially, as they encounter some mechanical stress, temperature change or chemical reaction – caused by a crack in the well, for example – their electrical resistivity will change.

By placing simple electrical leads on the outer casing of the well, the modified smart material itself will then become a sensor that monitors the health of every inch of the well. Resistivity changes will be identified and their source located in near real time, allowing drillers to immediately react to any problems either during well creation, when the cement is still wet, or during operation, after the cement has hardened.

But that's not the only subsea effort Vipu is undertaking. He has also developed a large-scale testing facility to study deepwater pipe-soil interaction. Often, as sections of subsea pipelines are pushed back and forth by the flow of very hot and high pressure oil and gas, they form barriers out of the soil they rest on. Later, movements of pipe into and/or over these barriers can cause additional wear and tear, ultimately shortening the pipe's service life and risking leaks.

Vipu is studying pipe-soil interactions and developing mitigation methods to limit axial and lateral movements of the pipes. While much of this effort is proprietary, he said that some aspects make use of smart materials for controlling and monitoring pipe movement. In addition, these studies factor in how different mitigation techniques work in different subsea soil conditions.

In a third subsea-related project, Vipu is developing biosurfactants, which are more environmentally-friendly than standard surfactants.

Like all surfactants, these biosurfactants are designed to thoroughly mix the different liquids in a drilling mud to create an emulsion, making them more effective and more sensitive to electrical resistivity changes. This electrical sensitivity can be exploited to monitor changes in the mud, including changes caused by exposure to materials that shouldn't be there, like excessive sea salt levels. And like standard surfactants, they can also be used to disperse oil caused by a spill or well leak.

The big difference between the two, though, is their environmental impact. Standard surfactants are chemical compounds. They don't break down easily, and introducing large quantities of these materials into the ocean raises significant environmental concerns. Biosurfactants are organic and biodegradable, making them much more environmentally-friendly.

"One of the concerns after any large oil spill is that the cleanup efforts could cause damage to the environment," said Vipu. "With biosurfactants, much of that concern could be eliminated."

AUTOMATING SUBSEA OPERATIONS

While more environmentally-friendly materials for oil spill remediation are essential, researchers at the Cullen College are working on a subsea operations model that can help drastically reduce the risk of an accident in the first place while also maximizing the return on these multimillion dollar investments.

With the support of companies such as Transocean, GE Oil & Gas, National Oilwell Varco and Weatherford International, these researchers have developed and continue to refine a subsea operations model that can be used for both design and management.

The model accounts for a diverse range of factors including subsea system health, material and component fatigue, multiphase flow and separation – and even the less obvious factors such as the price of oil on a given day. All of these are coordinated to make the planning and operation of subsea fields as safe and efficient as possible.

"There are so many different embodiments this infrastructure can take. How do we put it all together? Our compact models can search through hundreds of thousands if not millions of simulated scenarios and pinpoint 'this is the optimal one to have in terms of price, performance, maintenance and reliability,'" said **Matt Franchek**, professor of mechanical engineering and founding director of the college's subsea engineering program. Franchek, along with fellow mechanical engineering faculty members **Karolos Grigoriadis** and **Gangbing Song**, lead the development of analysis-led design for subsea systems.

Once a subsea operation is running, the model can be used to predict problems in advance, alert operators to system maintenance and even coordinate different maintenance projects. To assist with these tasks, said Franchek, these models can factor in data taken from the sensors of the subsea operation being monitored, allowing it to provide the most accurate predictions and guidance.

To continually improve the accuracy of the model, several real-world subsea operations regularly feed the system data. When the model diverges from the ground truth, it can combine mathematics and physics to identify the problem and update itself automatically, Franchek said.

And in those few cases when the model is unable to identify and repair the causes behind a real-world/model discrepancy? Franchek sees those as not a problem, but as an opportunity. "If the system says it does not understand the mechanism at work," he said, "that's a great knowledge discovery project."

EXTENDING PIPELINE LIFE

In addition to building better operations models, Cullen College researchers are creating components that can extend the life of underwater infrastructure. **Gangbing Song**, professor of mechanical engineering, has developed a tool that reduces the wear-and-tear on one of the most vulnerable pieces of a subsea operation.

One of the challenges of setting up subsea production, said Song, is fitting different sections of pipeline exactly together. Small differences in sea floor levels can affect the distance that a specific section of pipe must cover. Subsea operations, then, often use a piece of pipe called a jumper, which consists of two upside down U-shapes, one next to the other. With this shape, the jumper has the flexibility to be stretched out or compressed as needed.

This flexibility, though, also makes the jumper susceptible to the movement of the water, leading to large vibrations that can cause leaks and shorten the pipe's service life.

In response, Song has developed a dampening system that greatly reduces jumper vibrations through energy absorption.

The system has two metal rods which come together to form a sideways "L," with the end of the shorter rod attached to the pipeline. The end of the longer rod sits inside – but doesn't touch – a donut-shaped circle comprised of a layer of viscoelastic material.

The L-shaped rods, said Song, are tuned to the same mechanical frequency as the jumper. When the jumper is subjected to forces that cause it to vibrate, it instead sends that energy to the rods. The longer portion of the L-shape rod then swings and hits the viscoelastic material, which absorbs the energy. The end result: the vibration of the jumper pipe itself is greatly reduced.

"This system can cut the vibration of the jumper pipe and increase its lifecycle," said Song. "That will add to the safety and improve the flow assurance of gas or crude."

SURFACE SENSING at SEA

No matter how good the infrastructure, the extreme conditions of subsea means that leaks are inevitable. This is especially problematic at unmanned drilling platforms, where there's literally no one around to notice oil on the surface. There are roughly 5,000 of these platforms in the Gulf of Mexico alone. To meet daily monitoring requirements, petroleum companies must fly a helicopter to these locations and have a person with binoculars scan for oil – a solution that is both expensive and prone to error.

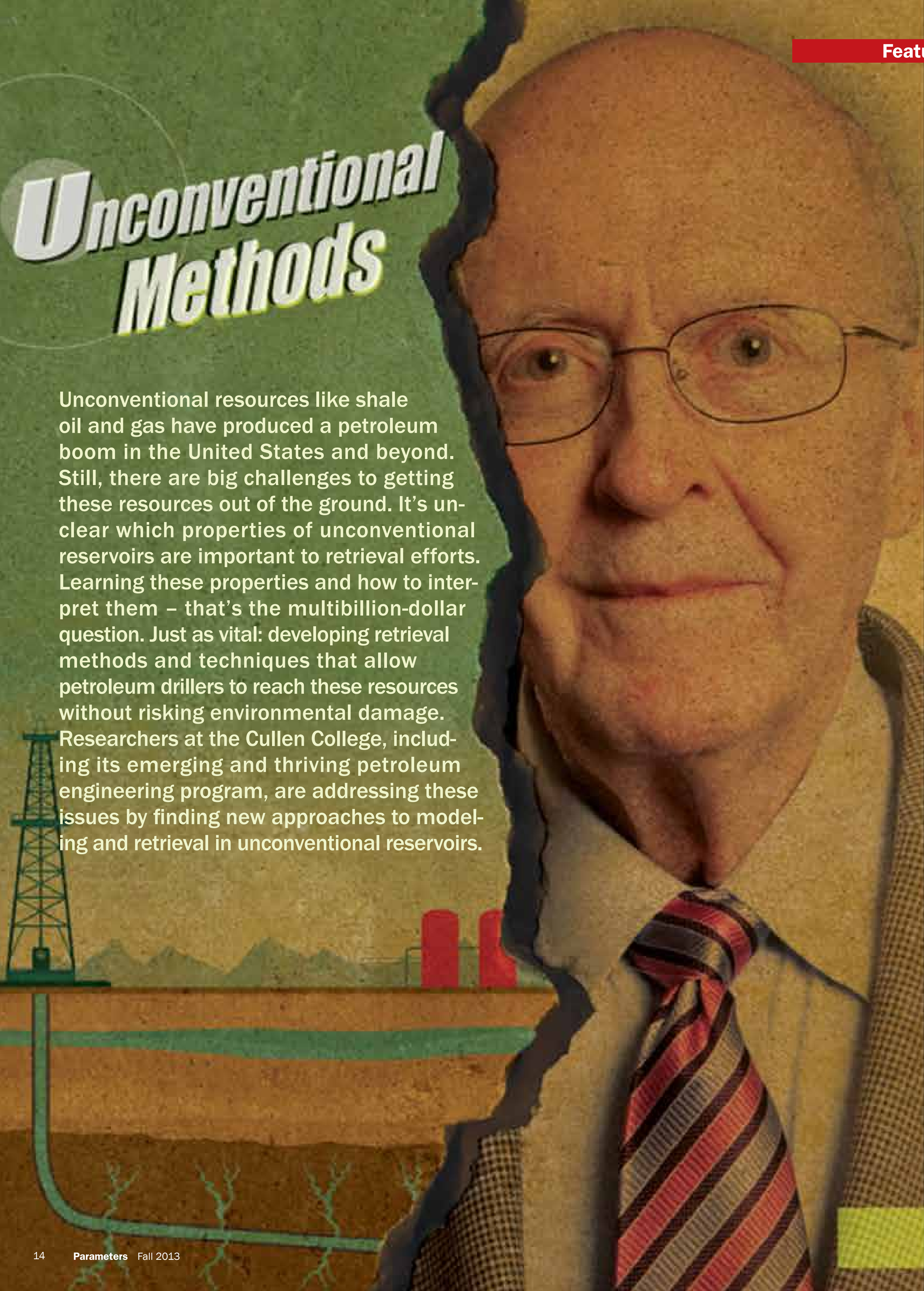
Wei-Chuan Shih, assistant professor of electrical and computer engineering, received a three-year, $740,000 grant from the Gulf of Mexico Research Initiative (GoMRI) to develop an alternative: a sensor that promises to cost less and be more accurate than helicopter flyovers.

The system uses hyperspectral imaging to detect oil on the water's surface by searching for infrared radiation over large patches of water. Algorithms then look for the infrared signal of patches of oil among the infrared signal of water.

Once completed, platform owners/operators should be able to attach this new system to unmanned platforms. When oil leaks from a well, the sensor will detect it and alert a nearby manned platform, likely via Wi-Max, a version of Wi-Fi with a range of several miles. All told, Shih expects the system to cost in the $20,000 to $50,000 range.

"Scientifically, this is a new idea, doing hyperspectral infrared imaging," Shih said. "Oil has different surface properties than water. The emissivity [the ability to emit energy by radiation] of water is very different from oil. Our model allows us to extract the presence of oil on top of water."

Unconventional Methods



Unconventional resources like shale oil and gas have produced a petroleum boom in the United States and beyond. Still, there are big challenges to getting these resources out of the ground. It's unclear which properties of unconventional reservoirs are important to retrieval efforts. Learning these properties and how to interpret them – that's the multibillion-dollar question. Just as vital: developing retrieval methods and techniques that allow petroleum drillers to reach these resources without risking environmental damage. Researchers at the Cullen College, including its emerging and thriving petroleum engineering program, are addressing these issues by finding new approaches to modeling and retrieval in unconventional reservoirs.

ESTIMATING UNCONVENTIONAL RESERVOIRS

Unconventional reservoirs are booming, but that doesn't mean they're well understood. One of the biggest challenges in retrieving resources from these formations is forecasting how much oil and gas they can be reasonably expected to produce. In **John Lee,** the Cullen College has one of the world's leading authorities researching rapid approximate methods to estimate recoveries from thousands of wells in short periods of time.

Lee, professor and Hugh Roy and Lillie Cranz Cullen Distinguished University Chair in the petroleum engineering program, has one of the most impressive résumés of any petroleum engineer in the world. He is a member of the National Academy of Engineering and the Russian Academy of Natural Sciences; he has authored three best-selling textbooks published by the Society of Petroleum Engineers (SPE); he has received the SPE's top technical award and its top service award; and was the Academic Engineering Fellow that led the Security and Exchange Commission's efforts to re-write the rules for defining and reporting petroleum reserves.

One of the main reasons unconventional reservoir estimations are lacking, said Lee, is simply a lack of information. Petroleum companies have only drilled extensively in these areas for the past few years. As a result, until recently there wasn't enough data to understand how these reservoirs behave and to verify estimation theories and techniques against reality.

But that is changing, he said. "Some reservoirs now have sufficiently long production histories that we have opportunities to identify important flow regimes [essentially the different ways oil flows in these formations], such as linear and boundary-dominated flow for wells throughout large resource plays."

By analyzing these flow regimes, and in some cases adding reservoir characterization information (like the locations and properties of their different rock formations), Lee is developing simulations of long-term reservoir performance, which could estimate reserves better than currently possible.

In addition, Lee is developing production-forecasting methods for these reservoirs that combine different flow models with the analysis of production data from many wells in many fields.

The ultimate goals, he said, are the creation of methods to understand what levels of oil and gas production can be expected in different unconventional formations, as well as what criteria should be applied to evaluate simple production forecasting models.

"There's no question that unconventional reservoirs are a big part of the future of petroleum retrieval," he said. "By improving reservoir forecasting, companies can invest their time and resources in these reservoirs as wisely as possible."

***John Lee,** Hugh Roy and Lillie Cranz Cullen Distinguished University Chair and professor of petroleum engineering*

MODELING SHALE WELLS

While John Lee focuses on reservoir estimations, associate professor of petroleum engineering **Guan Qin** specializes in understanding unconventional wells and getting the most out of them. In January, he received a $642,860 grant from China National Petroleum Corp. to develop a new set of models for hydraulic fracture propagation. These models cover individual wells and gas flow in shale formations. Fracture propagation in such formations typically involves nano-scale rock pores and micro-scale fractures.

These models, he said, will be derived based on the integration of microseismic data gathered by geophones, as well as well logs and petrophysical data. There are two main goals to this project. First, he is creating algorithms that take microseismic data around the time and location of each possible fracture to predict the fracture network using hydraulic fracturing stimulations.

Second, and probably more valuable, Qin plans to develop algorithms that use these data sets to extract information that can potentially guide the hydraulic fracturing design. Due to the computational intensity of this effort, Qin plans to implement such an algorithm on an advanced graphical processing unit/central processing unit – a GPU/CPU system – to improve their numerical efficiency.

"The goal is simple: How to optimize hydraulic fracturing stimulation design. Hopefully we can provide some guidance on how to create a fracture network to get the best flow rate," he said.

HONORING GEOLOGY in ESTIMATIONS

The Cullen College has experts in unconventional reservoir modeling and well fracturing. In **Mike Myers**, a 30-year Shell veteran who joined the college full-time last spring, it boasts a specialist in the actual rocks that make up these formations.

This is an effort, he acknowledges, that is at its beginning stages. "We are in shale gas where we were 50 to 75 years ago with conventional reservoirs. We don't even know what measurements to make."

A committed experimentalist, Myers is focused on remedying that issue by measuring the fundamental rock properties of well-characterized rock samples at in situ conditions. His efforts include finding methods to determine hydrocarbon saturation in shale rocks and determining which of their properties reveal important information on petroleum locations and amounts.

While other researchers are exploring the nature of shale rocks, Myers takes the approach that the experiments must be conducted in conditions that simulate the downhole environment. "We study the rocks at temperature, pressure and with the appropriate fluids or gases. If you're gathering data you should gather it under accurate conditions. That gives [people who perform reservoir and well simulations] real data to work with," he said.

Myers carries this commitment to the ground truth to his thinking on how these reservoir and well simulations should be carried out. Too often, he said, such simulations rely on "effective" measurements of geological properties, i.e., geological data that is adjusted to fit real-world outcomes. To build better simulators and gain a better understanding of a reservoir and its different sections, he said, geological measurements and conditions must be accurately reflected in the equation.

***Richard Liu**, professor of electrical and computer engineering*

LOGGING UNCONVENTIONAL FORMATIONS

The Cullen College's booming petroleum engineering program has brought new research initiatives in the area of well interpretation. With its Well Logging Lab and Consortium, though, the college also boasts one of the best-established and most esteemed groups in the area of recording and interpreting well properties. For more than three decades, the lab has been a leader in this field, with supporters including BP America, Chevron, ExxonMobil, Halliburton, Saudi Aramco and Schlumberger.

But the changing nature of petroleum drilling and retrieval is introducing new problems for the Well Logging Lab to solve, said **Richard Liu**, professor of electrical and computer engineering and the lab's director.

One of these problems involves horizontal drilling, a common practice in unconventional reservoirs, like shale oil and gas formations. Petroleum companies are today retrieving resources from relatively thin layers of rock that lie roughly horizontal in unconventional formations. These companies have equipment capable of being steered while drilling horizontally. What they lack, however, is a good way to ensure that the drill stays within its targeted layer of rock.

Traditional methods of well logging, Liu said, aren't able to immediately provide the location of the top and bottom of resource-rich rock layers. The Well Logging Lab, then, is developing new analytical methods that can produce this information in real time.

Another project involves gathering more basic, more essential information on shale reservoirs. In conventional rock formations, electrical resistivity alone can reveal a lot about a well, said Liu, but in shale formations, electrical resistivity levels don't tell nearly as much. The Well Logging Lab is developing new methods of sensing the properties of these formations.

"How do we identify shale and shale layers that have oil and gas? So far this problem is not well studied," said Liu. "We're working with companies to find indicators of petroleum. For example, the dielectric constant, dispersion characteristics, conductivity, maybe resistivity. We think we can combine them with other measurements to identify shale layers with oil and gas."

PERFECTING CEMENT SEALS

Data acquisition and interpretation isn't the only area Cullen College researchers are focusing on in unconventional resources. Faculty are also undertaking more nuts-and-bolts efforts, including research that addresses environmental concerns.

Much of the opposition to hydraulic fracturing comes from fears of groundwater pollution. Fractures allow gas to flow through the rock, up a well's metal casing and to the surface. Gas, it is theorized, can also escape through the space between this metal casing and the rock formation, raising water and air pollution concerns.

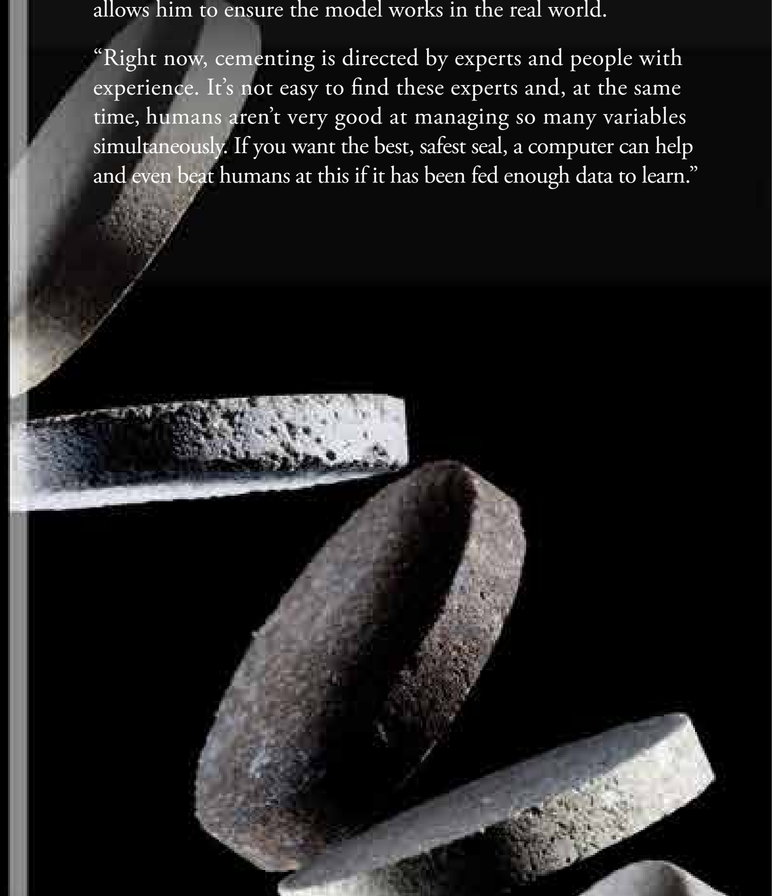
To prevent these leaks, petroleum companies fill in the space between the well and casing with cement. While the concept is simple, said **Mike Nikolaou**, professor of chemical and biomolecular engineering at the Cullen College, the execution is complicated.

"There are multiple pipes of different diameters. There are rock formations of different consistencies and there are significant changes in temperature and pressure from one place to another," he said. The result: potentially imperfect seals between the rock and casing that may result in gas leaks.

Nikolaou, then, is working on multiple projects with the same goal: developing computer models that will provide instructions for near-perfect cementing throughout a well. Simply feed the properties of a well into the model and it will provide the cement mixture and conditions that will seal the well as completely as possible.

Working with data provided by industry partners, Nikolaou's models will balance the dozens of variables that can change the cement mixture's key properties, such as viscosity, strength, adhesion and curing time. Those same industry partners, he noted, are conducting experiments using cementing mixtures the model recommends for specific conditions. This information, he said, allows him to ensure the model works in the real world.

"Right now, cementing is directed by experts and people with experience. It's not easy to find these experts and, at the same time, humans aren't very good at managing so many variables simultaneously. If you want the best, safest seal, a computer can help and even beat humans at this if it has been fed enough data to learn."



FLUIDS for TIGHT FORMATIONS

While well and reservoir interpretation is vital, developing new methods to overcome the old problems of unconventional formations is also greatly important. One way to retrieve oil from the pores of conventional reservoir rocks is to use displacement fluids. These fluids are injected into a rock formation, enter the rock pores and literally push the oil out.

This approach doesn't work in all cases, though. The pores in so-called "tight formations" can be so small that these displacement fluids can't enter, leaving valuable resources inaccessible.

One possible solution: change the properties of the displacement fluid through the addition of nanoparticles – an approach being explored by **Jacinta Conrad**, assistant professor of chemical and biomolecular engineering with the Cullen College, and **Ramanan Krishnamoorti**, professor in that same department and the University of Houston's chief energy officer.

The addition of nanoparticles, said Conrad, should change fluid properties like surface tension or viscosity, allowing the liquid to enter and flow through tight formations.

Working with polystyrene particles measuring from 100 to 400 nanometers, Conrad is conducting tests to see how nanoparticle-infused fluids behave in simple model systems of micropillar arrays fabricated by Scott Retterer of Oak Ridge National Laboratory.

"The efficacy of such strategies depends on being able to control where the nanoparticles go within these structures. The micropillar array is a very simple model, but it allows us to evaluate, for example, if the nanoparticles transport through the pillars or if they spread out," she said.

While nanoparticles of different sizes are being tested, that likely won't be this project's main focus, said Conrad. Instead, the effort will center on altering properties like nanoparticle shape and surface chemistry. "Both of those properties change how the particles move and we haven't explored them yet. Those are two axes that are more interesting to us than making smaller and smaller nanoparticles."

***Jacinta Conrad**, assistant professor of chemical and biomolecular engineering*

FRONTIERS WRAP-UP

Intelligent exploration and retrieval, subsea, and unconventional reservoirs are the future of petroleum research and the petroleum industry as a whole. The University of Houston Cullen College of Engineering has taken the lead in all three areas with forward-looking educational programs and cutting-edge research. But equally vital to the Cullen College's success in pioneering the future of petroleum retrieval is its partnerships with local industry.

Located in the Energy Capital of the World, the Cullen College of Engineering has a responsibility to address the realities of the modern petroleum sector with its curriculum, its research and its output of highly skilled graduates entering Houston's STEM workforce. To this end, the college is devoted to doing its part.

Some of the Cullen College's recent highlights in pioneering petroleum retrieval include:

- Re-launching its undergraduate program in petroleum engineering in 2009. The program has received significant support from businesses in the sector and has even been lauded by the Business-Higher Education Forum as a "model partnership" between industry and academia.
- Becoming a clear international leader in the field of subsea engineering. In the past year alone, the college launched the nation's only master's degree program in the field, established partnerships with universities around the world with strengths in subsea engineering education and research, and became a founding member of the Global University Subsea Alliance, which is seeking to expand and help set standards for subsea engineering education. All of this was achieved with the strong support of companies in the subsea industry. These businesses support the program's faculty – many of whom currently work full-time in the subsea sector – by providing funding and offering valuable guidance on its curriculum.
- Receiving industry support for multiple research projects, including developing new drilling acids, modeling shale fracture networks, logging the properties of conventional and unconventional wells, developing models of subsea operations, writing algorithms for well operation, creating new types of sensors for detecting offshore oil leaks and much, much more.

Energy initiatives at UH don't stop with the Cullen College, of course. The university has taken several steps to support energy-related efforts in recent years, including creating an Energy Research Park to foster public/private partnerships and appointing chemical and biomolecular engineering professor Ramanan Krishnamoorti as UH's chief energy officer. By leveraging the university's commitment to energy leadership, its close proximity to practically every major company in the petroleum sector and its deep in-house expertise, the Cullen College will be pioneering petroleum retrieval efforts for years to come.

BME Professor With
NIH Pathway to Independence Award

Yingchun Zhang, an assistant professor of biomedical engineering, has won a three-year grant worth nearly $690,000 from the National Institutes of Health's Pathway to Independence Program, one of the most prestigious funding vehicles at the NIH. Like the National Science Foundation's CAREER Award, this program is designed to help young investigators launch long-term, successful research careers.

The grant will support Zhang's efforts to develop new diagnostic tools for female incontinence by using his patient-specific modeling and non-invasive electrical source imaging techniques.

Much of this project is centered on a computational model of the pelvic area Zhang has developed. This is one of the most comprehensive models of its kind, Zhang said. It factors in the size, shape and weight of several internal organs as well as the "pelvic floor," the collection of muscles and ligaments that provides foundational support for these organs.

Often, incontinence is caused by weakness in the pelvic floor. When a person's pelvic muscles contract, the pelvic floor should continue to strongly support the internal organs. But weak support from the pelvic floor causes the organs to shift downward, leading to incontinence.

With this model, Zhang plans to conduct a large number of computer simulations of the pelvic area. By changing different parameters, he should be able to determine exactly which muscles and ligaments can lead to incontinence when weakened.

Additional work, he said, will allow him to develop a diagnostic system for female incontinence related to the pelvic floor. By entering a patient's specific parameters (such as bladder size and internal pressure when coughing) into a pelvic area model, this tool should allow physicians to determine exactly which parts of the pelvic floor are causing the problem.

This in turn should lead to better interventions. One common treatment for such incontinence involves providing additional support to the pelvic floor through a surgically inserted mesh or sling device.

While this is effective, said Zhang, "we want to do a better job. Eventually, when a patient comes in, we want to perform some diagnostic tests, enter her parameters into a model and find out exactly where that mesh should be inserted and attached."

Zhang's work extends beyond the pelvic floor, though. Incontinence also occurs when pressure inside the bladder exceeds the pressure that keeps the urethra closed. There is much about urethra closing pressure that is unknown, however.

Zhang, then, is developing a probe that measures this pressure using electromyography, which measures the electrical activity of muscles. With this data, he should be able to determine which muscles contribute to urethra closing pressure in a healthy individual. What's more, physicians using the probe in a clinical setting should be able to determine the exact muscles that aren't providing their expected closing pressure and are thus causing incontinence.

photo by Thomas B. Shea

Crystal Formation Theories
to be Tested in Space

Thanks to a recent grant from NASA, a Cullen College of Engineering professor's theories on crystal formation will be tested onboard the International Space Station.

Professor of chemical and biomolecular engineering **Peter Vekilov** won a $100,000 grant to study how proteins in a liquid solution nucleate, or form crystals.

Crystallization processes that work well in a small volume of solution (one milliliter) often do not work at all when scaled up to industrial-size levels of 100 or 1,000 liters. Vekilov believes that this is largely due to sheer flow: essentially, the flow of liquid in a system at uneven speeds. When it occurs around dense, protein-filled droplets that are precursors to nucleation, sheer flow changes how nucleation occurs, possibly by impacting how the proteins in these droplets are folded.

There is no practical way to test this theory on Earth, however. Even in small containers, gravity induces sheer flow, while chemicals that can eliminate sheer flow in a solution change the chemistry of nucleation.

The only answer, then, is to study a pure solution in a micro-gravity environment. "We have relevant scientific questions that can only be answered by doing experiments in space. We hope to see a difference between the nucleation rate on Earth and in space," said Vekilov.

By analyzing data collected through experiments on the International Space Station, Vekilov hopes to develop a deep understanding of sheer flow's impact on protein crystal nucleation. From there, he said, researchers should be able to design experiments that mirror the sheer flow in industrial-scale crystal production, ultimately leading to more efficient commercial operations.

NSF Grant to Support
Polymer Adhesive Research

Polymer composites are used to make everything from wind turbines to aircrafts and automobiles. Typically, objects made of polymer composites contain multiple components that are held together with polymer-based adhesives. But often the properties of these adhesives fall short, leading to failure at the connection between the components. While it's obvious that better polymer-based adhesives are needed, creating them is a challenge. Often, steps taken to increase the strength and stiffness of the polymer also result in decreased ductility and toughness (essentially the ability to absorb energy without breaking).

Megan Robertson and Mina Dawood, assistant professor of chemical and biomolecular engineering and civil and environmental engineering, respectively, have received a $300,000 grant from the National Science Foundation to develop new polymers for adhesives that do not make such a tradeoff. Though the execution of their idea is challenging, the approach itself is a simple one: mix two polymers together to get the best qualities of both.

Specifically, Robertson and Dawood will combine traditional epoxy resin polymers, which provide strength and stiffness, with a high-ductility polymer known as polydicyclopentadiene.

To create the polymers, researchers start with a liquid solution comprised of the small molecules that are the precursors to the polymer. The solution is then hardened through a curing reaction, causing the small molecules to chemically bond and form the polymer. This curing reaction is typically carried out at an optimal temperature or in the presence of a catalyst to speed up the reaction.

If all of the precursors to the epoxy resin and polydicyclopentadiene are mixed and then cured simultaneously, Robertson said, they will ideally form two large polymer networks that are completely intertwined but not chemically bonded together. The end product is known as an interpenetrating network. **The fact that both networks extend throughout the entire specimen ideally will provide the best properties of each individual network, resulting in a material that is strong, stiff, ductile and tough.**

Finding two compatible curing processes for the two different polymers is one of the biggest challenges of this project, said Robertson. Another hurdle, Robertson said, will be simply keeping the polymer solutions thoroughly mixed together, since they will naturally tend to separate prior to curing.

Seed Funding Supports Catalysis & Nanofabrication Research

Demetre Economou

Stanko Brankovic

Two Cullen College of Engineering faculty members recently won awards from the University of Houston's seed funding program, GEAR, or Grants to Enhance and Advance Research, which are awarded by the university's Division of Research.

Demetre Economou, Hugh Roy and Lillie Cranz Cullen Distinguished University Chair and professor of chemical and biomolecular engineering, received funding to address one of the biggest challenges to the future of nanotechnology: commercial-scale production.

Currently, many techniques for building nano-scale devices work well in the lab, but the amount of time and effort they require make them impractical for mass production.

Among these is the process used to etch away at a thin film of material (often silicon) one layer of atoms at a time. Such etching can be used in multiple nanotech applications, including the creation of new types of nanoscale transistors, which promise to dramatically increase computing power.

Existing etching techniques have two separate major steps that together take a few minutes to etch away a single layer of atoms, making them unsuitable for commercial use. First, a silicon film is placed in a vacuum chamber and exposed to chlorine gas atoms, which bond with the top layer of silicon atoms. The film is then exposed to a beam of neutral particles or ions that have enough energy to remove the bonded chlorine-silicon molecules but are too weak to eat away at the stand-alone silicon. Between these two steps, though, the chamber has to be evacuated from any residual chlorine.

Economou's solution is to have the chlorine supply and the ion source in the same chamber, separated by a curtain of inert gas. The silicon film would be placed on a rotating susceptor inside the chamber, repeatedly exposing it first to the chlorine and then the ions as it spins.

"This is a continuous process. As the silicon film rotates, it goes over the chlorine, absorbs the chlorine, and then goes over to the ion beam, which removes the bonded chlorine and silicon. Then the process repeats itself," said Economou.

Such an approach, he said, would be about 100-times faster than traditional atomic-layer etching techniques, making it well suited for commercial manufacturing operations.

The second GEAR award went to **Stanko Brankovic,** associate professor of electrical and computer engineering. Brankovic will use the funds to develop a new method of fine-tuning the properties of catalysts, which are used to set in motion or speed up chemical reactions.

In particular, he's working with platinum monolayer catalysts, which consist of atoms of platinum measuring just a few billionths of a meter forming a thin layer of material.

The atoms of this catalytic material often come together to form clusters. At the nanoscale, the size and shape of these clusters result in an unusual phenomenon: the clusters create within themselves some type of strain or stress. This comes in two varieties: compressive strain, in which the clusters push in on themselves, or tensile, in which they pull out.

These strains can have a major impact on catalyst performance, Brankovic said. The tensile strain sends more electrons to the surface of the particle, speeding up the chemical reactions they're meant to impact, while compressive strain has the opposite effect and result.

By changing how these catalysts are made, Brankovic believes he can adjust the type and amount of strain they experience. This should allow him to fine-tune catalyst performance. The result would be nanoparticles and nanocluster catalysts that are far more efficient, and hence far less expensive, than those being used today.

"Modern catalysis is all about getting more from less," said Brankovic. "Depending on the size and shape of these clusters, you can see a difference in performance of a couple hundred percent. What that means is if you hit the right spot in terms of size, you can use a factor of three or four times less of a catalyst."

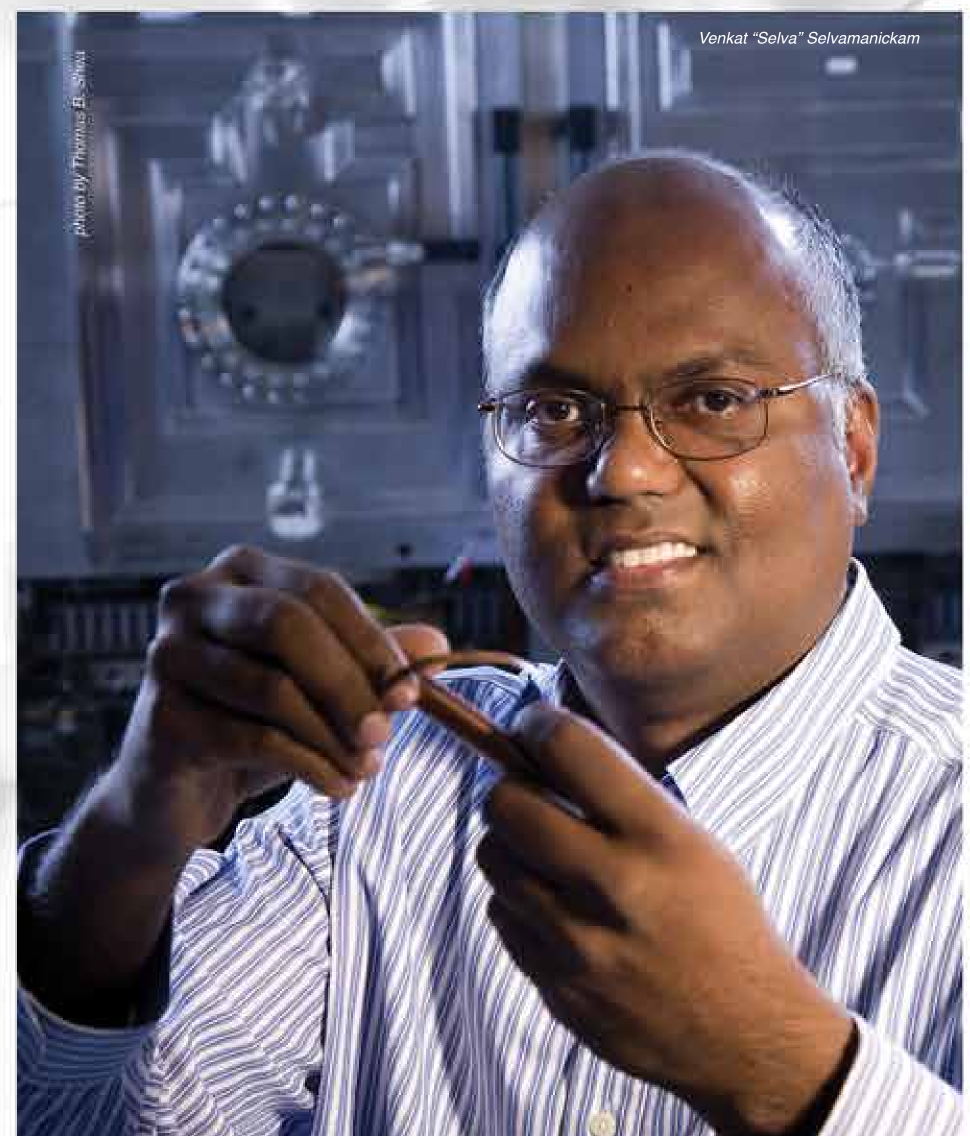


photo by Thomas B. Shea

Venkat "Selva" Selvamanickam

Research Developing **Alternative Energy** *Solutions*

Given the variable nature of wind and solar power production, energy storage devices are critical to the widespread deployment of these technologies. Existing storage devices, though, lose too much energy during conversion for storage and discharge, and don't distribute the energy they hold quickly enough.

One possible solution: superconducting magnetic energy storage (SMES) devices.

Venkat "Selva" Selvamanickam, M.D. Anderson Chair Professor of mechanical engineering and director of the Texas Center for Superconductivity, is collaborating on a $2.15 million grant from the Advanced Research Projects Agency-Energy to Florida-based Tai-Yang Research Company (TYRC) to develop an SMES technology that stores energy with 95 percent "round trip" efficiency and can quickly discharge the energy it holds.

There are two essential elements to any SMES device: a ribbon of superconducting material that transports electricity without losing any power in the form of heat; and the design of the coil that the superconducting ribbon is formed into. As electricity travels through the superconductor, the coil shape converts the electricity into magnetic energy.

This magnetic field, though, presents a problem. "The magnetic field flux line [essentially the pull of magnetism] that the coil generates can move through and within the superconducting wire," said Selva. "That can hurt the wire's ability to carry electricity and lower overall device performance."

The research team is addressing the problem in two ways. Selva is working to improve the performance of the superconducting ribbon itself. By introducing small defects into the material, the flux lines can be held in place, allowing electricity to move through the superconductor unfettered. TYRC, meanwhile, is designing a coil that generates a magnetic field that introduces lower mechanical strain on the superconducting ribbon than traditional SMES systems, limiting the field's impact on ribbon performance. Combined, said Selva, these advances should improve the storage capacity of existing SMES devices by two to ten-fold versus standard SMES systems.

Harold Receives UH's Highest Faculty *Honor*

We can all breathe a little easier with Mike Harold around.

That's not a cliché. Harold, M.D. Anderson Professor and chair of chemical and biomolecular engineering, has spent much of the past 13 years working to improve air quality in the Houston region and beyond. As founding director and principal investigator of the Texas Center for Clean Engines, Emissions and Fuels (TxCEF), he has helped develop technologies that reduce harmful vehicle emissions, performed testing and verification on emission-reducing technologies developed by outside groups, and worked to improve fuel economy for medium- and heavy-duty vehicles.

Thanks largely to his work with the center – including his efforts as an educator, scholar and colleague – Harold has won the Esther Farfel Award, the University of Houston's most prestigious faculty honor.

Harold has a long history with UH. He earned his Ph.D. in chemical engineering from the Cullen College in 1985. After graduating, he took a faculty position at the University of Massachusetts Amherst, where he became a tenured associate professor.

Wanting to see more of his research applied toward solving real-world problems, he left UMass in the early 1990s for an R&D position with the DuPont Company. In the late 1990s, though, the company began to shift its focus away from Harold's areas of expertise, leading to his return to UH.

His first stint as department chairman ran from 2000 to 2008. It was during this period that he founded TxCEF, then known as the Texas Diesel Testing and Research Center. "I saw starting the Diesel Center as an opportunity to help solve some of our pressing air pollution problems faced in the Houston region. The technical challenges were aligned with the research expertise and interests of myself and some of my faculty colleagues. The Diesel Center activities exposed us to practical issues that had fundamental roots. We could attack the practical issues with applied research and the fundamental roots with basic research," he said. "It's been a great match. The center catalyzed a collaborative spirit within our department, which helped lead to the hiring of people like Bill Epling, Jeff Rimer and Lars Grabow, who I'm happy to be working with along with senior colleagues like Vemuri Balakotaiah and Dan Luss."

In addition to being a vehicle for research and service, the center has proven to be a good training ground for graduate students, said Harold. These students have gone on to win positions at other research institutions and have been hired to continue their research at prominent companies in the engine and emissions treatment sectors.

In recent years Harold's work has expanded to include not just engines and emissions, but also the development of biofuels from aquatic biomass and high-purity hydrogen generation for fuel cells. He also began his second stint as department chairman earlier this year.

While this is a heavy workload by practically any standard, in many ways it is what Harold was looking for when he came to the Cullen College as a professor 13 years ago. "The main reason I returned to academia was to be a leader and manager and to do technical work at the same time. As a professor I've tried to seek that balance," he said. "The Farfel recognizes faculty who manage to do that well. That's why receiving this honor is pretty special."

Professor Wins ONR, ARPA-E AWARDS *for New Battery Development*

Yan Yao, assistant professor of electrical and computer engineering and Robert A. Welch Professor with UH's Texas Center for Superconductivity, has won two major battery research grants in recent months – one from the Office of Naval Research (ONR) and one from the Department of Energy's Advanced Research Project Agency-Energy (ARPA-E).

The ONR grant, awarded through its Young Investigator Program, is valued at nearly $660,000. It will support Yao's research into batteries that use magnesium ions and aluminum ions instead of lithium ions. While safer and potentially cheaper, these alternatives move more slowly through dense crystal structures in batteries than lithium ions. As a result, real-world batteries that use these ions are larger, heavier and store less energy than their lithium-ion counterparts.

Yao's solution is to modify the existing battery materials to increase the mobility of the ions so they can diffuse more quickly during charging and discharging. He will collaborate with experts in atomic-scale simulations to predict how the multivalent ions move inside different crystal structures. They will verify their findings with in situ transmission electron microscopy experiments, after which they will build, test and optimize new batteries.

The ARPA-E grant focuses on developing improved batteries specifically for electric vehicles (EVs). Though the final amount of the award is still being negotiated, the application sought $760,000 for just one year of work.

Yao and his collaborator, Jeff Xu, a principal scientist with the Southwest Research Institute, will use the funding to develop an entirely new type of battery that could extend EV driving range while lowering vehicle price.

The only existing batteries strong enough to power a full day's worth of driving use electrolytes that are both expensive and extremely flammable. EVs, then, are built with material whose only purpose is to shield the battery. This lowers the battery's effective energy density and drives up costs.

Yao's solution: develop a lithium-ion battery that uses a water-based electrolyte. Dubbed aqueous lithium-ion batteries, they should be cheaper and safer than existing EV batteries.

While aqueous lithium-ion batteries have been built in laboratories, their performance has not been good enough to draw industry investment. Put simply, there are no materials on the anode and cathode sides that combine to generate a commercially acceptable amount of energy in a functioning aqueous environment.

Yao, though, has struck upon an entirely new class of material that can be used for the anode, which is the most problematic part of aqueous lithium-ion batteries. Though he can't reveal the exact compounds he's experimenting with, he can say that they are organic compounds, meaning they contain at least one of the four organic elements: carbon, hydrogen, oxygen and nitrogen.

At the end of the one-year project the team is expected to produce a fully-functioning and characterized prototype battery. "We've got a lot of work to do in one year," said Yao. "In the end we want to have a prototype and a patented technology that someone can build a business around."

photo by Thomas B. Shea

Gino Lim

Associate Professor and Chairman
Department of Industrial Engineering

Career Overview

Gino Lim received his Ph.D. in industrial engineering in a University of Wisconsin-Madison multidisciplinary program that combined industrial engineering, computer science and mathematics. He focused on developing algorithms to solve large scale non-linear optimization problems. His work included the development of a system to determine how to optimize cancer treatments. The algorithms he developed are currently being used to optimally deliver beams of radiation in order to completely irradiate a tumor while sparing healthy tissues.

Research Interests

As a professor, Lim continues to address real-world issues with algorithms that solve large-scale linear and nonlinear optimization problems. He is developing tools to optimize radiation delivery to tumors for proton therapy. He is also developing a system to simplify operating room and nurse scheduling at Houston's M.D. Anderson Cancer Center, the top-ranked cancer hospital in the nation. This system factors in roughly 10 million variables, including the contracted hours of nurses, their specialties and their schedules; operating room hours; the predicted lengths of surgeries; and operating room availability. In addition to healthcare, Lim is also active in security-related research. With funding and cooperation from multiple federal, state and municipal agencies, he is developing a real-time flood mapping system for Houston-area first responders. He has also worked with the Texas Department of Transportation to create evacuation plans for the Houston Metropolitan area – an important resource for a city in a hurricane zone. This algorithm factors in population levels in different zip codes, the capacity of major intersections and highway on-ramps, and the locations and directions of major cities to which evacuees will flock. Most recently, he has received a grant to develop mathematical models to enhance maritime security for large ports such as the Port of Houston. This, said Lim, is exactly the type of problem he wants to address. "You can solve purely mathematical problems, but they don't necessarily work in reality. I'm interested in solving problems that yield tangible benefits to society."

Accolades

BIOMEDICAL ENGINEERING

Kirill Larin won an Excellence in Research and Scholarship Award from UH.

CHEMICAL AND BIOMOLECULAR ENGINEERING

Jacinta Conrad won a Junior Faculty Research Award from the Cullen College.

Mike Harold won an Excellence in Research and Scholarship Award from UH. He also received UH's highest faculty honor, the Esther Farfel Award (see p. 22).

Thomas Holley won an Outstanding Professor Award from the Cullen College.

John Lee was named Engineer of the Year by the Gulf Coast Section of the Society of Petroleum Engineers.

Jeffrey Rimer won a Junior Faculty Research Award from the Cullen College.

Gila Stein won an Excellence in Research and Scholarship Award from UH.

Navin Varadarajan won an Outstanding Professor Award from the Cullen College.

Peter Vekilov won the Senior Faculty Research Award from the Cullen College.

CIVIL AND ENVIRONMENTAL ENGINEERING

Debora Rodrigues won an Outstanding Professor Award from the Cullen College.

Cumaraswamy "Vipu" Vipulanandan received the Abraham E. Dukler Distinguished Engineering Faculty Award from the college's Engineering Alumni Association.

ELECTRICAL AND COMPUTER ENGINEERING

Zhu Han won a best paper award at the IEEE's 2013 Wireless Communications and Networking Conference for his article, "UMLI: An Unsupervised Mobile Locations Extraction Approach with Incomplete Data."

Dmitri Litvinov won an Excellence in Research and Scholarship Award from UH.

Stuart Long won an Outstanding Professor Award from the Cullen College.

Dave Shattuck won the Career Teaching Award from UH.

Wei-Chuan Shih received an Excellence in Research and Scholarship Award from UH.

Donald Wilton received the inaugural Computational Electromagnetics Award from the Applied Computational Electromagnetics Society.

Yan Yao won the Young Investigator Award from the U.S. Navy's Office of Naval Research and the 2013 Ralph E. Powe Junior Faculty Enhancement Award from the Oak Ridge Associated Universities.

INDUSTRIAL ENGINEERING

Ali Ekici won an Outstanding Professor Award from the Cullen College.

MECHANICAL ENGINEERING

Haleh Ardebili received an Outstanding Professor Award from the Cullen College.

Bonnie Dunbar was inducted into the Astronaut Hall of Fame. She was recently named director of the college's aerospace engineering program.

Karolos Grigoriadis received the Fluor Corporation Faculty Excellence Award and the W.T. Kittinger Teaching Excellence Award from the Cullen College.

Venkat "Selva" Selvamanickam won the Entrepreneur/Innovation Award from the college's Engineering Alumni Association.

New Faculty

Yandi Hu, Ph.D.

Assistant Professor, Civil and Environmental Engineering

Hu's main research interests focus on relieving the emerging energy/water shortages and their associated environmental problems. These include geologic carbon dioxide sequestration, the prevention of scale formation during oil production, and water pollution remediation using natural and engineered nanoparticles.

Chandra Mohan, M.D., Ph.D.

Hugh Roy and Lillie Cranz Cullen Distinguished Professor, Biomedical Engineering

Mohan comes to the Cullen College from the University of Texas Southwestern Medical Center in Dallas, where he held the Walter M. and Helen D. Bader Professorship in Arthritis and Autoimmune Disease Research as well as the McGee Chair in Arthritis Research. His research has focused on the genetics of systemic lupus erythematosus, with additional studies aimed at tapping novel technologies to predict the onset and monitor the progression of chronic autoimmune diseases. Mohan is an elected member of the American Society of Clinical Investigation and the Kunkel Society.

Sergey Shevkoplyas, Ph.D.

Associate Professor, Biomedical Engineering

Shevkoplyas joins the Cullen College from Tulane University, where he served as an associate professor of biomedical engineering. His research focuses on blood microfluidics, with a particular interest in using microfluidic devices and systems to gain a better understanding of the dynamics of blood flow and of the traffic of various circulating cells in complex networks of microvessels. The goal of this work is the development of novel technologies for improving the safety and efficacy of blood transfusions, and for making blood products available for life-saving transfusions in resource-limited settings.

Tianfu Wu, Ph.D.

Assistant Professor, Biomedical Engineering

Before joining the University of Houston, Wu was an assistant professor of Medicine at UT Southwestern Medical Center. There, he focused on biomarker discovery and therapeutic interventions for autoimmune diseases. Wu will continue to develop and apply novel technologies into the future diagnostics and theranostics (diagnostics and therapy combined) for various chronic diseases.

Student News

Conversations With Engineering COUGARS

Vinh Phung is an electrical engineering senior whose long list of accomplishments includes scholarship awards, volunteering, leadership activities and internships throughout his undergraduate career at UH. He shares his thoughts on student life as an Engineering Cougar.

Tell us about your involvement with Tau Beta Pi.

As the oldest and largest engineering honor society in the U.S., Tau Beta Pi honors engineering students who have shown a history of academic achievement as well as a commitment to personal and professional integrity. Initiated into Texas Epsilon (Tau Beta Pi local chapter at UH) in November 2012, I got along quite well with the president so I decided to run for an officer position for spring 2013. As an activity coordinator, I helped out with planning for future sessions, meetings, regional conferences, socials and volunteering events.

What is one memorable event or activity at UH that you've been a part of?

Spring break of 2012 is absolutely one of the most memorable spring breaks to me and 11 other UH students. No beaches, no parties, no late nights – we had different plans. Twelve students spent the week tutoring children with the help of the teachers in a Louisiana Head Start program. For the children we were helping, we wanted them to feel loved, appreciated and cared for since some of them lost their parents during the disastrous Hurricane Katrina. It was a great experience that helped me realized how fortunate I had been, and how little one needed to do to warm a kid's heart.

What are your plans for your last year at UH?

Entering my last year at UH as a super junior, I really wish to work on campus and get more involved at UH and the Cullen College of Engineering. It really has been my second home. After graduation, I would like to work full-time in the oil and gas industry or pursue a Ph.D. in engineering. I am still not sure which path to take, so I'll keep my options open until I have to make my final decision.

Full interview available online at
www.egr.uh.edu/student-profile/vinh-phung

> "It was my honor to receive the Omron Foundation Scholarship. The University of Houston and the Department of Electrical and Computer Engineering have given me so many great things: dedicated professors, an amazing learning experience, good friends, a second home, and now the Omron Foundation Scholarship.
> I am truly thankful."

Experiential Learning: *Undergrad Research*

The summer semester offers a perfect opportunity for undergraduates to conduct engineering research under the mentorship of a faculty member. Cullen College of Engineering undergraduates selected for the Summer Undergraduate Research Fellowship (SURF) gained practical experience in research methods and a newfound interest in the science of innovation.

Energy Storage

David Pineda, a mechanical engineering junior, has been working in electrical and computer engineering assistant professor Yan Yao's newly-created Laboratory of Energy Materials and Devices on the construction of a vanadium redox flow battery system.

Similar to a fuel cell, the vanadium redox (reduction-oxidation) battery is comprised of a power cell in which electrolytes flow from external tanks into the central stack where reactions take place and electrons are created. The focus of Pineda's project is to create a platform, or small scale vanadium redox battery, for the development of inexpensive, novel materials used to replace electrolyte solutions and membrane.

While vanadium redox battery systems are not widely used, they hold potential for large-scale applications, including emergency power backup.

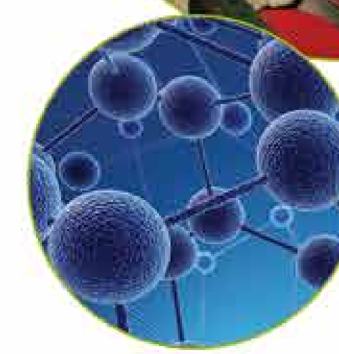
"One of the problems with the current energy grid is that it isn't able to adjust to fluctuations between main supply and consumer demand in the main supply," Pineda said. "During the day, when we need a lot of electricity, the power plant can only supply a constant maximum amount – it cannot downgrade or upgrade very efficiently. So at night, when less electricity is used, the day's collection of electricity is wasted. Energy storage is needed to bridge this gap, such that nighttime excess electricity can be used during the day when demand is at its highest."

The vanadium redox flow battery hasn't been widely applied due to its expense. The cost of the active material, vanadium, rises with high demand in the steel industry. Additionally, the cost of the proton exchange membrane (the component inside the central stack where positive ions flow to the negative side, creating a complete circuit) accounts for about 40 percent of the overall cost. The goal is to produce cost-effective materials that allow more efficient permeation of ions.

Drug Nano-Delivery

Ashish Bhattarai is a chemical engineering senior who is working under the guidance of chemical and biomolecular engineering assistant professor Megan Robertson on biodegradable polymers for biomedical applications. His project focuses on the encapsulation of dyes in PEO-PCL micelles to study drug molecule transfer.

Micelles form due to hydrophobe-water interactions in a solvent. Bhattarai encapsulates fluorescent dye molecules inside the micelles, with the goal of identifying the factors and rates that influence the drug molecule transfer. Bhattarai then tracks the kinetics of the dye molecule from the micelle using Fluorescence Resonance Energy Transfer, or FRET.



Modeling Hurricanes

Pranay Pasula, an electrical engineering senior, worked within the Electric Power Analytics Consortium, headed by electrical and computer engineering professor Zhu Han, to minimize power grid downtime caused by catastrophic events, particularly hurricanes. The group collaborated with CenterPoint Energy to mathematically model a hurricane. Using a stochastic process which generates thousands of iterations of random numbers to simulate the effects of high wind, rain and flying debris, the group will examine the simulated effects of a hurricane on a test grid in hopes of eventually applying these findings to any real grid present in the nation. The goal is to better allocate resources before a hurricane strikes to alleviate its effects on the power grid.

Learning to Use Coal

Taken from *The Engines of Our Ingenuity*, Episode #135

Dr. John Lienhard

Coal found its way into the European economy in the 13th century. Isolated reports tell of coal-burning by the ancients. But Marco Polo was still suprised by Chinese coal-burning in the late 13th century. He'd also have been suprised if he'd travelled to Northern Europe and England. By then the English were already using coal for smithing, brewing, dyeing and smelting. They were even exporting some of it to France.

Thirteenth-century millwrights had spent 200 years eating up European forests to make windmills and waterwheels. Wood was becoming too precious to use as a fuel. Wood was first replaced by surface coal – often called sea-coal because the more obvious outcroppings were found on the coast. By far the largest sea-coal deposits were English ones.

The reason we don't bring coals to Newcastle is that Newcastle, in particular, was surrounded by huge fields of sea-coal. It was mined in open cuts 30 feet deep. And Newcastle was soon girdled by a dangerous maze of water-filled trenches.

Sea-coal was filthy stuff – loaded with bitumen and sulfur. It created environmental problems from the start. An anonymous 14th-century balladeer vented his anger at its use:

Swart smutted smiths, smattered with smoke,
Drive me to death with din of their dints; ...
The crooked caitiffs cryen after col! col!
And blowen their bellows that all their brain bursteth.

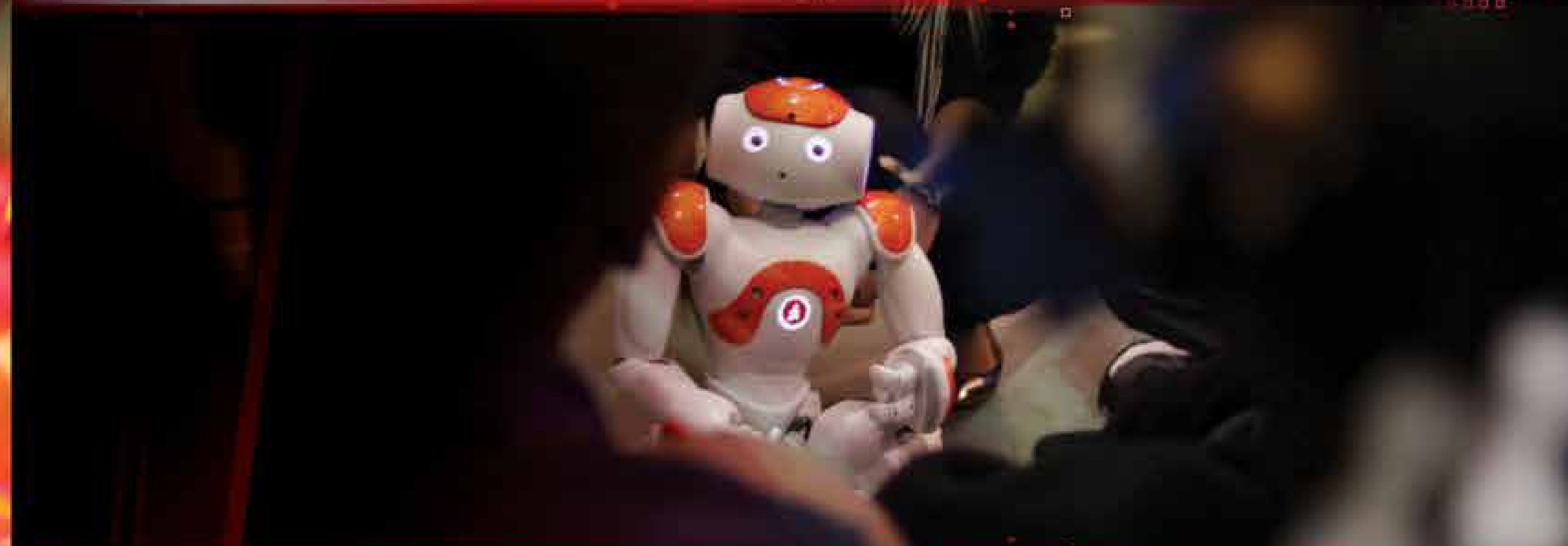
But the medieval population explosion drove people to use this foul fossil fuel anyway. For a hundred years medieval environmentalists fought with medieval industrialists over its use. Then famine and plague ended their argument until the middle of the 15th century. When the repopulation of Europe drove people back to coal, they were armed with the new techniques of metal mining.

Metals demanded a lot of charcoal for smelting. So wood shortages reappeared, magnified by rising populations and even greater demands for metal. But now people followed the coal seams into the earth – mining it the way they mined metal. That led them to the much cleaner hard coals we use today. These deep coals also served to replace wood in the smelting process.

So coal and metal drove one another deeper into the earth – until 17th-century miners were stopped by the underground water table. With their whetted appetite for fuel and metal, our 17th-century forbears became desperate to keep that appetite fed.

But by now our story sounds all too familiar. Human ingenuity creates new human appetites which are eventually met by new ingenuity. It's as frightening as it is heartening to see how we can always find 11th-hour ways to keep those appetites fed.

***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.*



First graders from the Garden Villas Elementary School took a field trip to the University of Houston last April to get a taste of what their college experience might look like if they decide to pursue careers in the STEM (science, technology, engineering and math) fields.

The students enjoyed activities ranging from a superconductivity demonstration to a dance-and-sing-along with a robot provided by the Cullen College's Department of Electrical and Computer Engineering. Afterwards, the youngsters gathered together on the floor, sitting Indian-style, to listen to a very special presentation by Dr. Bonnie Dunbar, former NASA astronaut who now heads the UH STEM Center and serves as professor in the Cullen College's departments of mechanical and biomedical engineering and director of the college's aerospace engineering program.

View these photos and many more on our Flickr page: http://www.flickr.com/photos/cullencollege.

UNIVERSITY of HOUSTON | ENGINEERING

UH Cullen College of Engineering
Office of Communications
E301 Engineering Bldg. 2
Houston, TX 77204-4009