MECHANICAL
ENGINEERING
Technology that moves the world
THE MAGAZINE OF ASME
No 05
138

UNDER THE ICE

AN AUTONOMOUS SUBMERSIBLE ROBOT EXPLORES AN UNKNOWN WORLD BEFORE IT MELTS AWAY.

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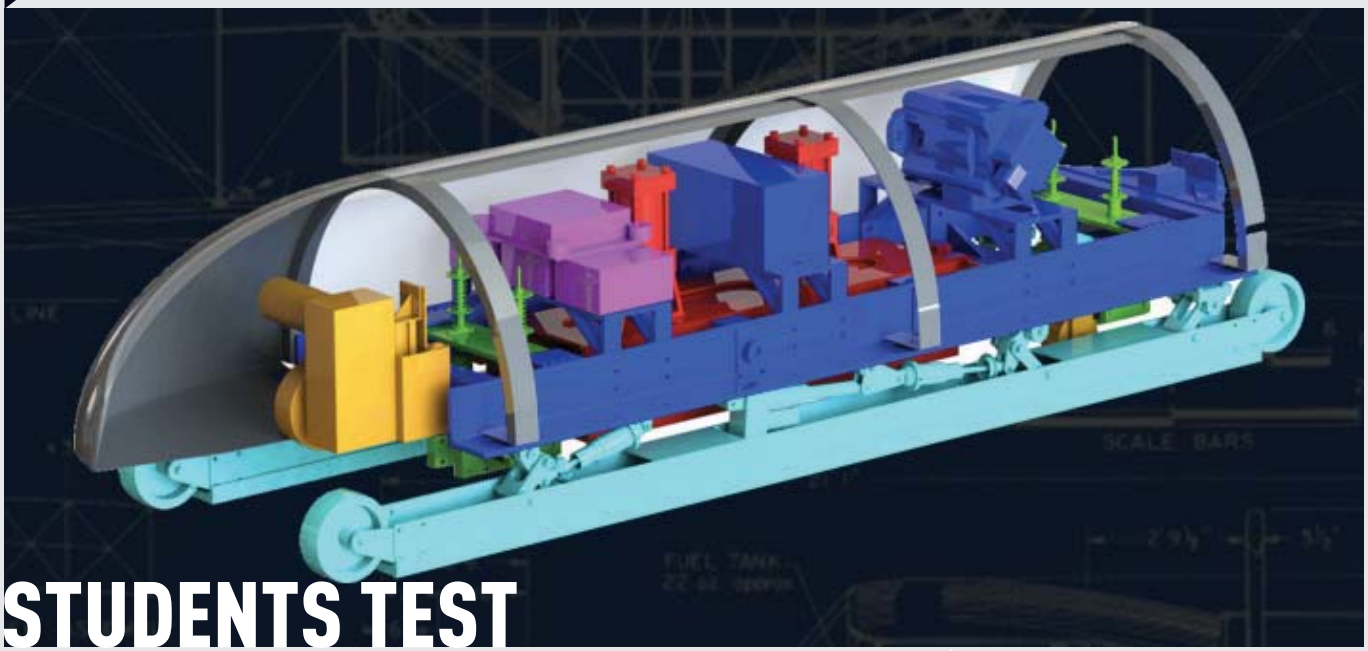
MAY 2016



STUDENTS TEST HYPERLOOP'S VIABILITY

A **TEAM OF GRADUATE STUDENTS** from the Massachusetts Institute of Technology won a competition to design a working transportation pod for the Hyperloop—the tubular system proposed by Elon Musk to move people and freight at very high speeds. The competition, sponsored by SpaceX, is a major initial step in proving the concept's feasibility and speeding its development. The bullet-shaped pod is based on passive magnetic levitation technology capable of speeding along at a whopping 110 m/s with a hydraulic braking mechanism that uses wheels at the front and either side of the pod.

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A ROBOT FOR THE EVERY-FACTORY

CAPABLE OF WORKING NEXT to a human, quickly learning and performing multiple repetitive tasks, and handling less than precise situations, ReThink Robotics' "Sawyer" is poised to singlehandedly change manufacturing.

VIDEO: INNOVATION AND THE FUTURE OF BIOENGINEERING

DR. BILLY COHN, INVENTOR of the continuous flow heart, talks about the importance of innovation and creative thinking to the future of both bioengineering and mechanical engineering.

TREATING BODY AND MIND FOR EPILEPSY PATIENTS

EPILEPSY CAN GO BEYOND the realm of the physical to seriously affect an individual's psychological state. A new medical device helps relieve the physical symptoms of epilepsy, which may lead to improved well-being for patients as well.

NEXT MONTH ON ASME.ORG

ANAEROBIC DIGESTERS REDUCE FOSSIL-FUEL DEPENDENCE
Anaerobic digestion is the process by which bacteria break down organic matter in an oxygen-free environment to form biogas and a digestate. Large-scale digesters can generate electricity while significantly reducing greenhouse gas emissions.

VIDEO: INNOVATIONS IN DIGITAL MANUFACTURING AND DESIGN
Digital manufacturing is helping manufacturers improve their time to market and shorten product development cycles. Dean Bartles, executive director of the Digital Manufacturing and Design Innovation Institute, discusses how the Chicago-based organization is furthering the research in digital manufacturing.

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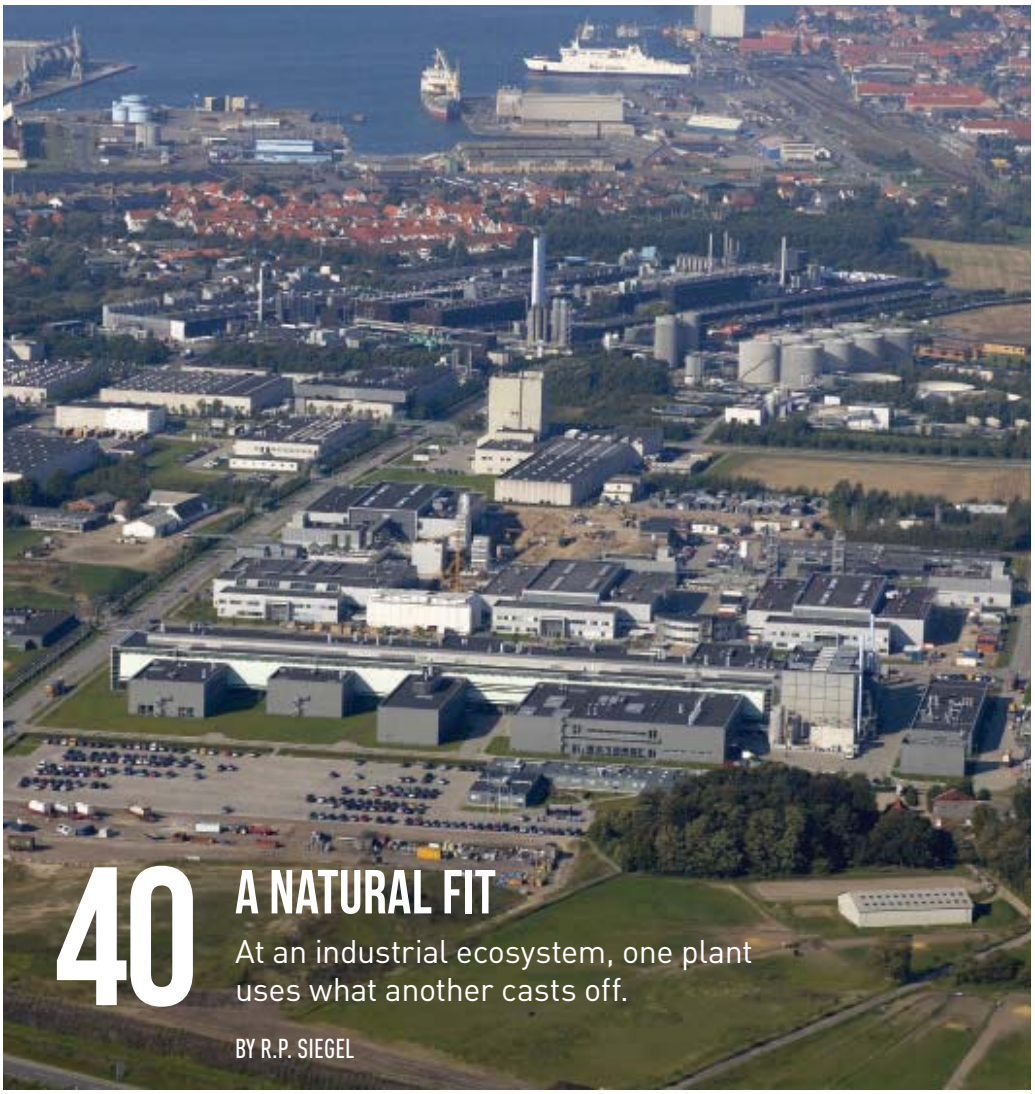

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SETTING THE STANDARD






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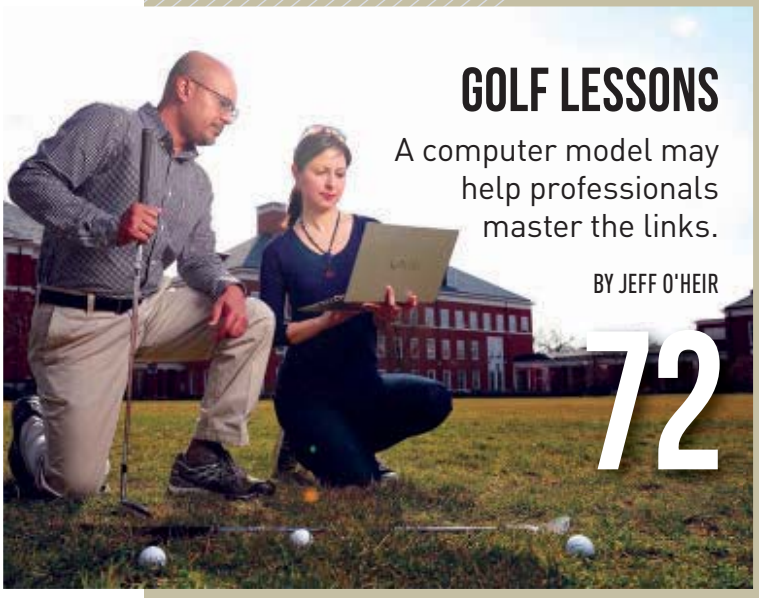

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Give me the place to stand, and I shall move the earth
—Archimedes

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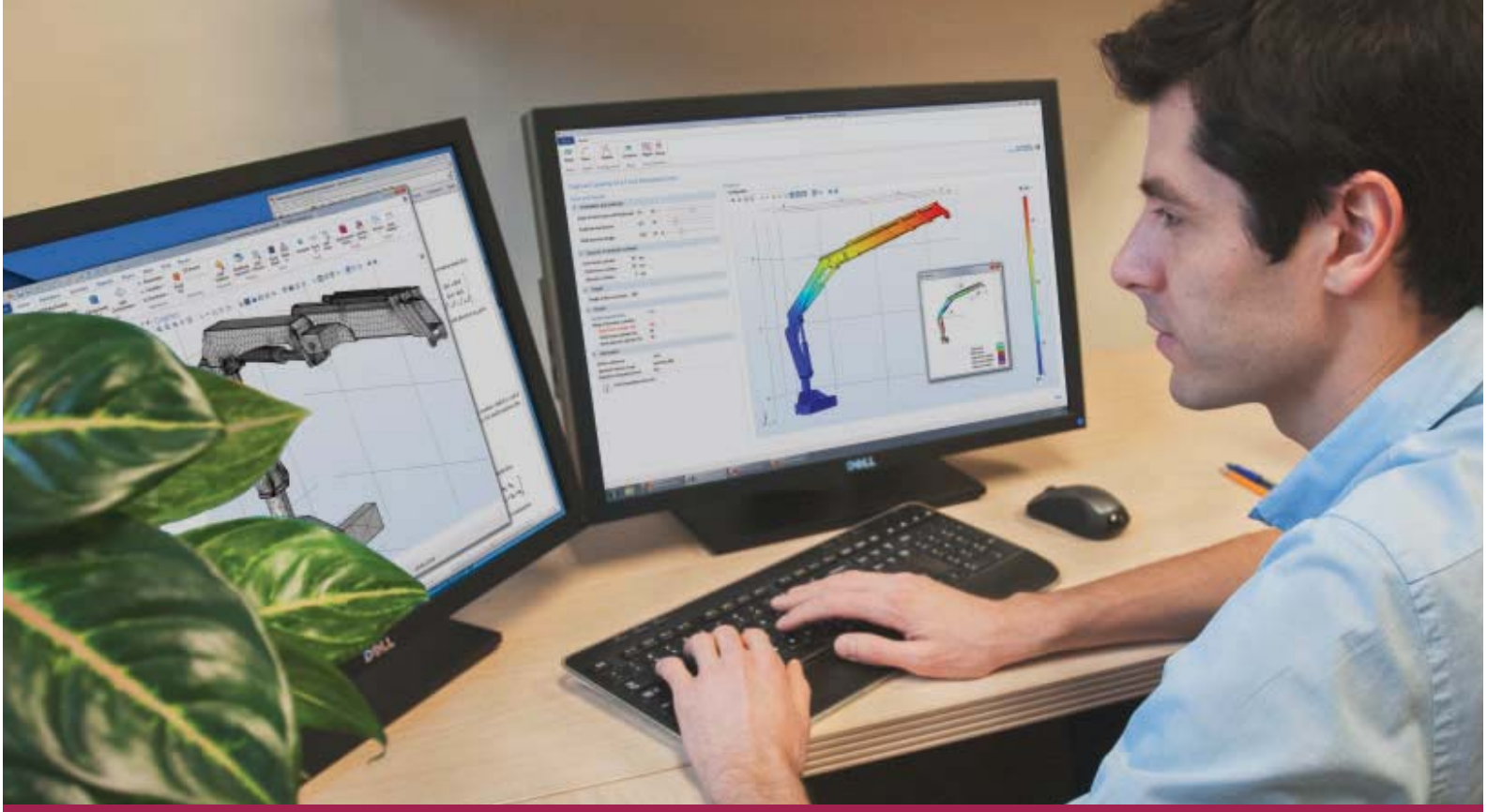

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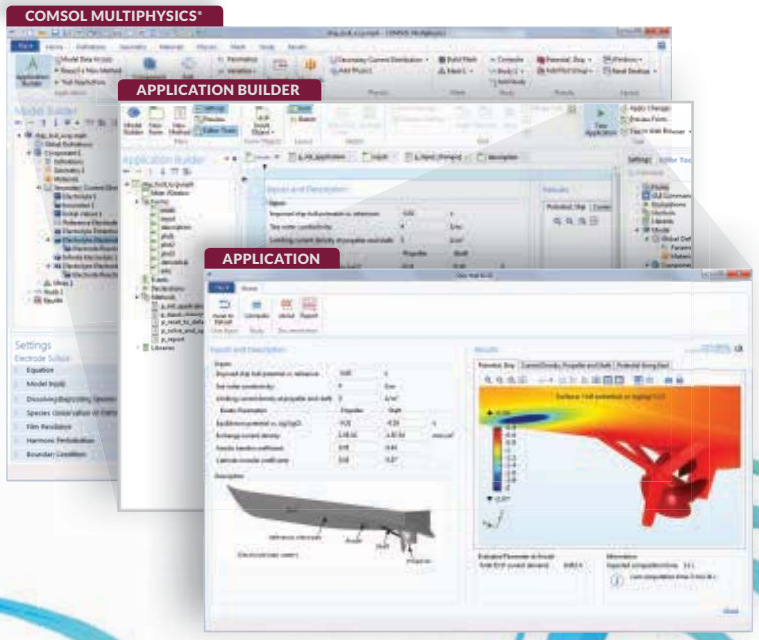


COMSOL

John G. Falcioni
Editor-in-Chief

GROWING STEM BY BUSTING MYTHS

The moment I knew for sure that Jamie Hyneman and Adam Savage had some serious chops was about 10 years ago, when I spotted a long line of engineers waiting for their autographs after they spoke at an engineering software conference. They had arrived.

This happened a few years after Hyneman and Savage had already established themselves as televisions stars, and it turns out that there was much more to their show, *MythBusters,* than strong ratings. *MythBusters* began on the Discovery Channel in 2003 and was a quick hit. But the pseudo reality show—and the special effects specialists who hosted it—hit a sweet spot among engineers as well.

In each episode, Hyneman and Savage would try to expose or confirm an urban legend, such as: Can a penny dropped from the top of a skyscraper kill a person standing on the ground? Can chatting on a cell phone while pumping gas cause the pump to blow up? Will launching a chicken at an airplane disrupt its flight, or will the bird be blown away? (You'll have to catch the re-runs for answers.)

But it was more than simple amusement that made the show noteworthy. For engineers and other technologists, *MythBusters*—which ended its run earlier this year after 248 episodes that covered 2,950 experiments, explored 1,050 myths, and created 900 explosions—elevated public interest in science, technology, engineering and math (STEM) and helped usher in the so-called Maker movement.

The show also hit home because at their core, engineers are tinkerers who elevated their passion with a university degree.

The two hosts, an odd couple of sorts (one was the straight man to the other's gags) were not engineers—though Hyneman received an honorary doctorate, in 2011, for his role in popularizing science and technology—but they took a engineering and scientific approach to their experiments. Because they were tinkerers, things didn't always go right. That was part of the appeal.

Like some others before them—Bill Nye the Science Guy for one—Hyneman and Savage will be remembered for exposing science and engineering through the public forum of television. When news broke that *MythBusters* would be canceled after 14 seasons, Twitter was flooded with users crediting the show for their interest in science and technology. Many college students sent messages of thanks for inspiring them to study engineering.

MythBusters didn't pretend to be more than it was when it came to the engineering and scientific rigor of its experiments. But the program was fascinating because it toiled in finding answers through engineering and science—and because it was good television.

To find theses answers, the hosts built the contraptions they used to test the myths. While they're not credited with creating the Maker or the Do It Yourself movements, their garage tinkering reinforced those movements. It bolstered those who like to build, who like to fix, and who are curious.

MythBusters stimulated the young and the old... and the engineer. **ME**

FEEDBACK

What impact do shows like MythBusters *have on engineering? Email me.*

falcionij@asme.org

LETTERS & COMMENTS

NOVEMBER 2015

Reader Willis calls climate models both "speculative" and "inaccurate."

« One reader rails against counterproductive thinking. And in a comment, another reader examines a "free energy" claim.

NEITHER US NOR THEM

To the editor: When Llewellyn King wrote in his December 2015 comment ("U.S. Loves Engineers, Treats Them Badly"), "Math and engineering are the keys to maintaining our place in the world and keeping the Chinese, and a few others, at bay," I had to question that. Would that type of thinking reflect a thought pattern which is appropriate for modern times?

No society is authorized to hold another society "at bay." In other words, no one has the right to hold someone else "down." At a time when so many countries are enjoying world peace, doesn't the pattern of thinking which says "Let's hold someone down" seem to be counterproductive?

All people can regard advancements in technology (such as India's recent success with its Mars Orbiter Mission, also called Mangalyaan) as a contribution to human progress. All societies should be moving forward in a progressive march to produce better lives for everyone.

No one in the United States should want to hold anyone else "down."

Kenneth W. Freelain, P.E., *Takoma Park, Md.*

A QUESTION OF MODELS

To the Editor: The November 2015 letter ("Climate Science") asserting the climate change predictions are based on observations, experiments, and dynamic simulations omits several relevant facts. The IPCC issues a political summary

COMMENT

NO FREE LUNCH

An engineer looks at a perpetual motion machine.

A friend of mine asked me if I knew about a new "power generator" and provided a link to a video done by the company selling it. The first thing that I noticed was a claim that 4.2 kW of energy input produces 12 kW. At that point I felt my job was done and that I could proclaim the machine to be a fraud with a specific name: A perpetual motion machine of the first kind, since it creates energy out of nothing.

Over the years I have been asked about many machines like that one and it was easy to explain to my friend why they are a fraud.

This particular one has an industrial company behind it with branches in Germany and Serbia, as well as YouTube lectures and presentations to promote it. All that documentation made it difficult to convince the novice that it is an elaborate scheme to part him with his hard earned money—a lot of money, since even the smallest version costs €15,000.

The fascination of many people with the claims of getting free energy makes them forget that if such claims are to be true, then the world that we live in would be totally different.

The promotional material for the machine is rather vague, but it appears that the elaborate prototype in the video consists of a tank of water in which a number of containers at the bottom are filled with air from a compressor. The air lifts the container to the surface; the air is then let out and the containers fall back to the bottom for a new cycle. The motion of the containers is supposed to power a generator.

The mysterious and confusing thing for many people may be the appearance that the buoyancy force that the machine has succeeded in harnessing appears to be an infinite source of energy.

While the first law of thermodynamics argument (or the principle of mass-energy conservation) is enough to make a definitive judgment about the machine, it is possible to analyze it in detail using a simple model. Consider a water tank and one container. The container is supplied by compressed air from the compressor through control valves. Once the air pushes the water out of the container, the buoyancy force pushes the container to the top of the tank and generates work in the process. At the top the water displaces the air and the container sinks to the bottom again.

The possible output from such a setup is directly proportional to the pressure of the water column through which the buoyant container rises. But the work of the compressor to put air in the container, which is the energy input for the system, is proportional to the

which often does not agree with the technical section. Which IPCC section should be followed?

The letter asserts the scientists supporting the (catastrophic) climate change predictions are bright and well-educated, so are the scientists who question the predictions. Who should be believed?

The present IPCC climate change predictions are based on unvalidated computer models which fail to reproduce known historical and current climate events. The 114 climate models fail to predict the current 18-year plateau in atmospheric temperatures. They predict climate sensitivity estimates (temperatures) much higher than are being measured and fail to include the temperature influence of the Pacific Decadal Oscillation. The models are excellent dynamic simulations, just not particularly accurate.

Until a computer model can reproduce known temperature changes consistently without continuous changes of internal variables, the results are speculative. The inaccurate models are not science but guesswork, and they are being used to force significant changes in society and energy policies.

Frederick Willis, P.E., *Haddonfield, N.J.*

FEEDBACK Send us your letters and comments via hard copy or e-mail memag@asme.org (subject line "Letters and Comments"). Please include full name, address and phone number. We reserve the right to edit for clarity, style, and length. We regret that unpublished letters cannot be acknowledged or returned.

pressure of the water column plus the atmospheric pressure. That total is multiplied by its natural logarithm. Therefore, if we take the ratio of the output work to the input work then the numerator is always smaller than the denominator, which means that there is less output work than there is input work.

This doesn't even factor in the different losses due to friction, fluid resistance, and other simplifications.

Running an analysis for a tank of a height of 3 m, we found that in the best case scenario, the machine wastes more than one-third of the energy provided, and that makes the whole thing quite ironic for people who buy it for the purpose of "generating" energy. **ME**

M.N. TARABISHY is an engineering consultant with a focus on renewable energy. Previously, he worked as a research engineer at Ford Motor Co. and has been a visiting professor at the Illinois Institute of Technology in Chicago.

CUSTOMIZED FOR COMFORT

PERSONALIZED WORKSTATIONS SLASH BUILDING ENERGY COSTS

Buildings use about half the energy in the United States, and close to half of that powers heating, ventilation, and air conditioning (HVAC) systems.

Next time you're at work, stroll around and you'll see why. The spacious lobby, high-ceilinged rooms, empty office spaces—they're all typically heated to about 70 °F or cooled to about 73 °F.

That's incredibly wasteful, said Edward Arens, director of the Center for the Built Environment, an industry-university research consortium based at the University of California, Berkeley. "Buildings are way overdesigned and overconditioned for what people actually need," he said.

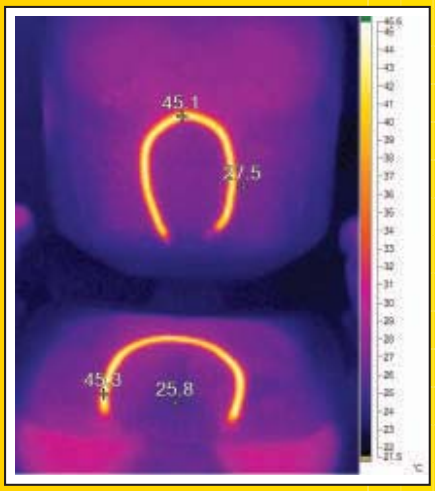
Arens aims to change that. In March, at the ARPA-E Energy Innovation Summit in National Harbor, Md., he and his colleagues presented a "personalized comfort system"—a set of devices that warm or cool parts of the body that are especially sensitive to heat or cold. They're designed to let workers maintain the temperature they prefer, no matter how warm or cool the office is, and they cut building energy costs dramatically.

The system's components include an under-desk foot warmer that uses an average of 20 W, a 5 W wrist warmer and a heated mouse that keep hands warm, 2 W heated insoles, and a 1 W desk fan that blows a light breeze across the worker's face from as much as six feet away.

Arens's team also hacked a commercial ergonomic office chair to heat or cool the body for an office worker's comfort, using heating coils in the seat and the back, an air plenum inside the chair, and a wicking, non-insulating fabric.

The combined wattage of the entire system is less than one-fiftieth of the 500-1000 W a typical building HVAC

To heat its occupant, U.C. Berkeley's customized chair uses 14-watt horseshoe-shaped heating coils in the bottom and back of the seat. To cool, it uses an air plenum inside the chair's seat and back, respectively, a 3.6-watt fan in the plenum that circulates the air inside imperceptibly, and fabric that lowers skin temperature and wicks away moisture.



system consumes to heat or cool a single person.

The chair also contains sensors that detect occupancy, temperature and humidity, and relays that data via WiFi to the building management system. This lets the building operator turn down the heat or reduce the AC in part or all of the building to save energy.

To see how much energy the office chair saved, the researchers had 25 U.C. Berkeley office workers work in the customized chairs for 16 months and report twice daily whether they felt warm or cool, and if they were comfortable. Most workers preferred office temperatures between 74 °F and 77 °F in ordinary chairs, but four of five people in the customized chairs were fine with office temperatures as low as 68 °F and as high as 80 °F. This saved an astonishing 60 percent on building energy costs.

An earlier six-month test of the foot warmers alone saved 48 percent of the total heating costs over a cool northern California winter.

The Berkeley project is unique in tailoring their localized heating and cooling technologies to individuals, said Jennifer Gerbi, program director for ARPA-E's DELTA program, which funded the work. "People feel comfort in different ways," Gerbi said, "and I think they're really amazing in looking at that." ME

DAN FERBER

SOLAR-POWERED FUEL SYNTHESIS

Researchers have reversed the process of combustion to make liquid fuels from carbon dioxide, water, and sunlight. If they can scale up the process, it could recycle carbon dioxide emitted by combustion back into fuel without adding additional carbon to the atmosphere.

"Researchers have been trying to use solar power to make fuel for decades, but so far they have been able to make only single-carbon products like methane and methanol. No one had been able to get past these one-carbon products and make longer chain hydrocarbons that we use in fuels," said Brian Dennis, a professor of mechanical engineering at the University of Texas at Arlington. Dennis and Frederick MacDonnell, chair of the school's chemistry and biochemistry department, led the research.

Dennis and MacDonnell, who share a lab, had been investigating conventional chemistry—catalysts, heat, and pressure—to turn natural gas into long-chain hydrocarbons for fuel. Then they began a separate project to combine carbon dioxide and water to make similar molecules using solar power to drive the reaction.

"We were trying to do photochemistry the way other people did it, at room temperature and in liquid water, and we got the idea that maybe we could do photochemistry using higher pressures and temperatures," Dennis said.

To prove the concept, Dennis built a custom reactor. It consisted of a quartz tube that operates at 200-300 psi pressures and around 200 °C, surrounded by an ultraviolet light source.

The researchers embedded titanium dioxide with cobalt particles over 5 percent of its surface, then seeded the inside of the reactor with the combined catalyst. They then ran carbon dioxide and water vapor through the reactor. The UV light generated electrons in the titanium dioxide, which catalyzed the breakdown of water into hydrogen and oxygen. The hydrogen and carbon dioxide then combined to form hydrocarbons on the cobalt catalyst.

Currently, only 13 percent of the system's output consists of the type of long molecules found in liquid fuels—molecules with more than five carbons. Dennis hopes to boost their yield by optimizing conditions within the reactor.

Meanwhile, he aims to increase output by replacing titanium dioxide, which is sensitive to only 3 percent of the spectrum, with a photocatalyst driven by visible light, which makes up more than 40 percent of the spectrum.

He plans to reduce costs by building future reactors with plate glass, which is less expensive than quartz, and by using the same type of parabolic mirrors used in solar thermal systems to heat reactants and focus light on the catalysts.

"The biggest advantage of our technology is its potential low capital cost," Dennis said. "We want to get costs down so we have a shot at commercializing it." ME

The University of Michigan test facility known as Mcity.

AN EMPTY TOWN FOR AUTONOMOUS CARS

A fake city provides the backdrop for "real-world" tests of self-driving vehicles.

Just when is an automated car ready to hit the road? How does a car manufacturer test a driverless vehicle enough to know it can handle every situation the nation's streets have to offer? How can you put connected vehicles in dangerous scenarios without simultaneously putting conventional vehicles, and their flesh-and-blood passengers, in dangerous scenarios as well?

The answers can be found at a University of Michigan facility known as Mcity. This test track—or test environment, as its facilitators call it—is a ghost town that puts autonomous and connected vehicles through their paces.

The model municipality allows for a wild variety of driving conditions. Its 32 acres includes five miles of road for test cars to travel. Those roads are asphalt, concrete, gravel, brick, and dirt. They can be two, three, or four lanes wide, and they can pass through tunnels, circle around roundabouts, and travel under stoplights. There are curves, ramps, bike lanes, hydrants, and benches. And to complete the feeling that the place is a fake town, akin to the decoy Rock Ridge at the end of *Blazing Saddles*, there are moveable "buildings" that are nothing more than facades, as well as cutout pedestrians, both stationary and mechanized.

"We made sure all the designs were diverse, with different curve designs, intersections, and pedestrian crossings," said Huei Peng, a mechanical engineer at the university and the associate director of its Mobility Transformation Center. "They're all a little bit different."

That way car manufactures can know their vehicles have been tested in situations found across the country.

> **"IF YOU JUST BLINDLY DRIVE YOUR CAR ON REGULAR STREETS, IT TAKES 100 MILLION MILES TO EXPERIENCE A FATAL CRASH. WE BELIEVE THAT IN OUR TEST ENVIRONMENT, IT'S MORE ACCELERATED."**
> **— HUEI PENG, UNIVERSITY OF MICHIGAN MECHANICAL ENGINEER**

But the pavement, the structures, and the layout of Mcity are only one part of what makes it an ideal testing ground. The rest is to be found in the numbers behind the scenes.

"If you just blindly drive your car on regular streets, it takes 100 million miles to experience a fatal

continued on p.29 »

INDIAN COAL IMPORTS DECLINE

India is one of the largest destinations for exported coal. But thanks to an expansion in its domestic mining industry, India's coal imports are set to decline this year and likely next year, too, according to the fuel broker Mjunction Services.

The forecast was first reported in the *Economic Times of India*.

From a level of 185 million metric tons in 2015, coal imports are on course to decline to as little as 155 million metric tons this year and possibly down to 150 million tons in 2017.

The CEO of Mjunction, Viresh Oberoi, told the newspaper that the decline in imports stems from less demand by power plants in the interior of the country. Plants near the coast, which have easier access to ports, would see a small increase in imports.

India is the third largest coal producing nation in the world, and the government is looking to increase domestic coal production even more. According to the *Economic Times*, the government plan is for 1.5 billion metric tons of coal production by 2020. **ME**

BRAZIL PORTS MOVE 1 TRILLION TONS

Cargo movement at Brazil's main ports registered a record in 2015, totaling 1,006 billion metric tons, the national ports office reported in February. Brazil's National Water Transport Agency forecasts another record for 2016.

The data was reported in the *Rio Times*.

According to official data, the largest category of cargo passing through Brazilian ports was bulk solids, responsible for 63 percent of the movement. Of the 633 million metric tons of solid bulk transported, 365 tons—or 58 percent—was iron ore, followed by soybean products.

Bulk liquids accounted for 22 percent of port tonnage, with slightly more than half of that being petroleum.

Containers made up less than 10 percent of cargo. **ME**

BETTER SANITATION DESIGN THROUGH OBSERVATION

IT'S NOT ENOUGH TO JUST BUILD IT. Engineers must consider human factors when coming up with sanitation options that people will want to use.

About 68 percent of the world's population has access to improved sanitation facilities, according to the World Bank. That ranges from near universal access in developed counties to a low of only 7 percent in South Sudan.

But providing access isn't enough. We don't know how many people actually use the toilets they have or whether they use them hygienically. In a survey of 180 studies and reports, my colleagues and I found that only about 5 percent of those publications reported on latrine use, and that was usually at the household rather than the individual level. Learning why and how people use toilets can hep us improve the user experience, and thus increase hygienic use. The research we found suggests that regular, hygienic latrine use depends on several factors.

MEN OR WOMEN: A study in Ethiopia showed differences between use by men, women, girls, and boys. And in India, for instance, women are more likely to use latrines than men.

YOUNG OR OLD: Use of toilets by children and disposal of children's feces is a particular area of concern. Children's feces may be more likely than adult's to be contaminated with pathogens that cause diarrhea. But many mothers believe children's feces are harmless. In Cambodia, for example, only 20 percent of children's feces were disposed of in an improved sanitation facility, according to the *2010 Demographic and Health Survey*. Burying of children's feces is especially common in sub-Saharan Africa and Southeast

Antonia dos Santos, in his home village of Lisadila, East Timor, manufactures and sells these concrete toilets.
Photo: Dean Sewell/Oculi/Agence Vu for WaterAid/ Australian Department of Foreign Affairs and Trade

Asia. Disposal of child feces with garbage (such as in a diaper) is widely practiced in middle- and high-income countries and is becoming increasingly common in urban areas of low-income countries. An expert consultation on the safety of these two disposal methods found almost unanimous agreement they should be considered neither safe nor improved.

RELIGION AND CULTURE: Several studies have found that providing toilets does not ensure their use when there are significant and culturally engrained behavioral barriers to using latrines. In India, a survey of around 3,200 households found that having a household latrine is widely seen to damage the purity of the home. Most Hindus are opposed to emptying their own latrine pits, and people from the lowest caste, the so-called untouchables, resist emptying latrine pits because this work is widely seen as degrading and reinforces their low social status. These factors can lead rural Indians to build latrines with very large pits that seldom require emptying.

In Nigeria, men might not want to share latrines with women. Excretion is also considered to compromise the purity of those with Voodoo powers. In parts of eastern Africa, myths hold that men do not defecate, and by custom, in-laws do not use the same site for defecation.

DRY OR WET: Customs and beliefs that have been enshrined in tribal life and societies of most West African countries affect technology choice, hygiene behaviors, and the general institutional set up of actors. WaterAid Nigeria found that "a low-quality toilet is an embarrassment for the family." Instead, "people have a strong desire for an 'ideal' water-based toilet", because it is easily cleaned, connected to modern urban life, and aesthetically pleasing. But a water-based toilet is often excessively expensive, costing between 44 percent and 77 percent of an average family's annual income.

WIPING VS. WASHING: Some people wipe after defecation using paper or some other substance. Other people wash, using water and their hand, which requires a separate water supply from those used for flushing and handwashing.

WHERE YOU GO: A study in Ethiopia found a distinct difference between latrine use at home and away from home. About 33 percent of adults practiced open defecation at home, versus 77 percent at a workplace.

Given the many human factors to consider when coming up with sanitation options that people will use, we need a new way of thinking. Combining design thinking with the science of behavior change might be better a way forward than any infrastructure-focused approach. ME

SUSAN DAVIS is founder and executive director of Improve International.

S-CURVE CONTINGENCY

For working professionals—those, that is, who opted not to join the ranks of management earlier in life—**the S-curve catches up to you sometime in your 50s.**

It is important to understand that everyone's career—yours, mine, and the boss's—is a trajectory. We start off modestly and then come up to speed. For a while after that, it can look like there's no direction but up. But then usually a career tails off at the end.

Ideally, but rarely, your career keeps rising until you voluntarily decide to leave. Typically a good career will at worst plateau at the end.

However, I have known people in their fifties who were demoted and laid off. Even when I was in industry 20 years ago, most of us in our thirties had contingency plans in case we were laid off after fifty.

I suggest your best career plan is to determine what your organization (and other organizations in your field) value in older employees, regardless of your personal views. It is not that this ensures that you will be a valued asset in your fifties, but it certainly is one aspect of a proactive approach to your career.

Would you like to guess whether it is worse to be laid off or work for another five or more years as you are marginalized or live under the threat of layoffs? Clearly that's a trick question, because from my observation while it's easier to maintain your finances in the latter case, it is undoubtedly better to be laid off and move on with your self-respect and mental health intact.

Another contingency plan is to have your finances in order. Plan to have your house paid off by your early fifties. In addition, you should have additional investments outside of your retirement plan that can either provide passive income or be cashed out for living expenses.

Of course, it is preferable to have investments that generate income while maintaining or growing the capital investment.

One way to accomplish this is to turn your starter home, which you ideally bought in your twenties, into a rental. While hardly anyone who is not involved in realty wants to be a landlord, house rentals can provide significant, almost passive income.

You should also have an exit strategy that may involve going to another organization that may pay less but values you more. Have a backup career in mind, preferably consulting because of the income levels it can provide, but be prepared to work in almost anything.

A full-time income, regardless how paltry, coupled with other investment income can often provide enough funds to pay taxes and medical and living expenses as long as the money you made prior to reaching your mid-fifties has paid for housing and vehicles. That small income can cover you until your sixties when you can access your retirement account and Social Security.

HAVE A BACKUP CAREER IN MIND, PREFERABLY CONSULTING BECAUSE OF THE INCOME LEVELS IT CAN PROVIDE, BUT BE PREPARED TO WORK IN ALMOST ANYTHING.

All of this may sound severe, but many of my friends and others in their fifties whom I know are completely demoralized by their career situations. All but one are trapped, where they cannot or will not leave their positions due to the income.

The one that is not trapped is able to retire from his federal job because he has worked for 30 years and is over 55. He actually laughs about it and hopes they lay him off. ME

RONALD A.L. RORRER, P.E., is an associate professor in the department of mechanical engineering at the University of Colorado, Denver.

BERGQUIST

THERMAL SOLUTIONS FOR ENERGY STORAGE AND CONVERSION

Henkel's BERGQUIST brand of thermal products consists of many industry leading thermal materials used to dissipate heat and keep electronic components cool. Henkel brings high standards and focused leadership, supplying such well recognized names as GAP PAD™, Gap Filler, SIL-PAD™, BOND-PLY®, HI-FLOW® and TCLAD™ to the automotive and electronic industry.

ROBUST DIELECTRIC MATERIALS

Henkel's brand of BERQUIST thermal materials offer a wide variety of thermally conductive products to protect and cool components in power generation, conversion and storage applications.

SILICONE-SENSITIVE APPLICATIONS

The increased use of camera and sensor applications have created the need for products that possess low volatility silicones or are completely silicone-free.

LOW PRESSURE MOLDING MATERIALS

Henkel's broad portfolio of printed circuit board (PCB) protection materials safeguards electronic components from damaging environmental factors, such as extreme temperatures, fluids, corrosive elements, shock and vibration.

Henkel Excellence is our Passion

www.henkel-adhesives.com/thermal

ME: CARB just certified your renewable tri-generation process at the Orange County Sanitation District under their Low Carbon Fuel Standard. Could you tell us how that process works?

C.B: We locate a fuel cell power plant configured for hydrogen production at a wastewater treatment facility. The fuel cells utilize readily available waste biogas as a 100 percent renewable fuel source to generate electric power, thermal energy, and renewable hydrogen. The power and heat produced support the wastewater treatment facility's operation, while the renewable hydrogen can be used for fueling stations for fuel cell electric vehicles.

The certification means that each kilogram of hydrogen fuel supplied is eligible for one LCFS credit that can be sold or traded to offset petroleum fuel use. That enhances the economic profile of the renewable hydrogen produced by our fuel cell power plants, which is already economically competitive with gasoline.

ME: Your company calls this process "carbon negative." Could you explain what you mean?

C.B: Our power and hydrogen generation process is net carbon-neutral due to the use of renewable biogas. CARB then subtracts the offset from using 100 percent renewable hydrogen compared to gasoline-based internal combustion engines. This brings the assessed carbon intensity below zero. Specifically, CARB assessed the carbon intensity of our solution at -0.82 gCO2/MJ. In comparison, electrolyzers converting solar power have a CARB-defined carbon intensity of 0 gCO2/MJ, and traditional steam reforming can range from approximately 82 CO2/MJ to 152 CO2/MJ.

ME: At the turn of the century, hydrogen – and fuel cells generally – were touted as the next big thing. We still don't have a "hydrogen highway." What happened?

C.B: Widespread consumer adoption of fuel cell vehicles is dependent on a convenient fueling network, yet infrastructure investment requires a clear line-of-sight for strong consumer demand. In addition, the source or method of generating hydrogen is important to ensure sustainability throughout the complete value chain.

The renewable hydrogen market potential for transportation is forecasted to be sizeable. Both Hyundai and Toyota have FCEVs commercially available today and many other automobile manufacturers have announced plans to commercially launch FCEVs including General Motors, BMW, Honda, Audi, and Mercedes.

Q&A CHIP BOTTONE

CHIP BOTTONE HAD A CONVENTIONAL energy industry career path with stints at the Southern Company and Ingersoll Rand. But in 2010, he joined FuelCell Energy where, as president and CEO, he is working to transform the global power industry with megawatt-class stationary fuel cell power plants. FCE recently received a low-carbon certification from the California Air Resources Board (CARB) for a process that creates electricity, hydrogen, and process heat.

ME: What's your vision for where fuel cells fit in the overall energy infrastructure over the next 20 years?

C.B: I foresee much greater adoption of distributed power generation in many different forms to reduce reliance on transmission and meet sustainability targets. Further, I expect widespread understanding of the total cost of power that incorporates societal impact of pollutants, carbon emissions and residual waste streams, generally levelizing the cost of power across different regions and different forms of power generation.

Over the next 20 years, fuel cells will be widely adopted for utility and commercial scale power generation, transportation (including cars, trucks, and buses), and even consumer electronics. I expect to see fuel cells as common as internal-combustion engines and turbines are today.

Fuel cell parks of 10 to 30 MW will be common in urban areas, enhancing grid resiliency. Microgrids will be common in suburban towns, particularly in coastal areas that are subject to storm-related outages. These will be anchored by fuel cells, incorporating solar as well.

Natural gas-fired power generation will adopt fuel cell carbon capture to zero out carbon emissions.

Fuel cell electric vehicle adoption will grow markedly, particularly in urban areas that want to reduce smog and particulate emissions, and where home EV charging is not practical. **ME**

R.P. SIEGEL is a writer based in Rochester, N.Y.

Stretchable electronics conform to the bend in a knuckle.

Photo: EPFL

CIRCUITS THAT STRETCH

Imagine a prosthetic hand that provides more detailed tactile information than bare skin.

Stephanie Lacour, a researcher at the Swiss Federal Institute of Technology in Lausanne, laughs when she shares some of the far-fetched ideas that have been proposed for the new process for engineering electronics into stretchable material that her team has developed. But by making stretchable electronics more practical, her team's innovation could lead to artificial skin for robots, wearable devices and connected clothing, or tools to monitor biological functions such as neural information in the brain or spine.

For several years, Lacour's team has been exploring ways to improve soft electronic circuits. With each attempt, they faced the challenge of creating a thinner, more flexible material that maintained its electrical properties and functionality after being stretched and twisted over and over again.

"We were looking at ways to engineer liquid metal in a way that's more suitable for electronics," Lacour said. "We want to be able to design patterns in any shape we want on a 2-D plane."

The researchers overcame the challenge by developing new deposition and structuring techniques and by choosing the right alloy to produce a highly elastic, conductive, and stable material.

They applied a partially liquid (biphasic) film of gallium-gold alloy to a polymer strip. Gallium—which melts at 30 °C and remains a liquid at room temperature—has strong electrical properties. Gold helps the gallium maintain its conductivity by preventing it from separating when applied to the polymer. Multilayered stretchable circuits are integrated in the film.

Extensive testing shows the material can be stretched up to four times its original length in all directions millions of times without cracking or interrupting its conductivity, according to a paper published in the journal *Advanced Materials.*

Lacour said her team was working to ready the material for use in commercial applications.

"We have good robustness and replicability," she said. "Now we really have to explore how to scale up the technology for commercial use." ME

SPONGIER TISSUE, STRONGER BONES

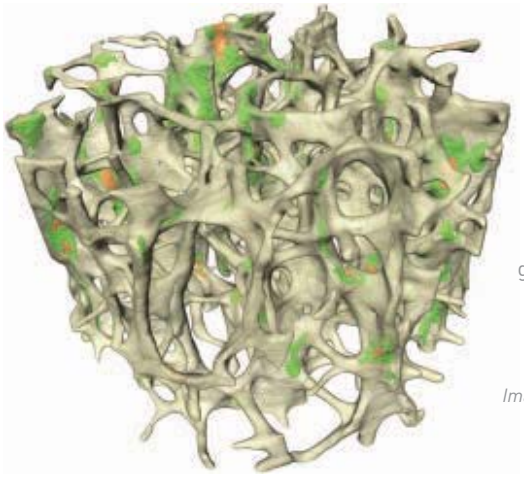
Engineers are constantly searching for new materials to make more resilient parts for automobiles, aircraft, and machines used in remote or hard-to-reach locations.

Now researchers who study treatments for osteoporosis-related fractures have discovered that the spongy tissue found at the end of long bones and vertebrae could help engineers design materials that bounce back and continue to perform after they are damaged.

Long bones like the femur are made of two types of tissues: a hard, compact outer shell called cortical bone and a less dense material called cancellous bone. Cavities within cancellous bone host blood vessels or marrow, but they reduce the strength and rigidity of the spongy bone compared to the cortical bone, which makes up 80 percent of the bone mass.

Christopher Hernandez, an associate professor at Cornell University's Sibley School of Mechanical and Aerospace Engineering and the Meinig School of Biomedical Engineering, and his team at first thought that the tiny cavities found in cancellous bones would promote crack growth. This would be a particular problem for people with osteoporosis, which causes more mass loss in the spongy bone than elsewhere. Instead, they found that cancellous bone—which is made up of a soft exterior and a stiffer interior—bounces back to almost its original form right after it's damaged and before the healing process begins.

"We were very surprised," Hernandez said of the findings.



Cancellous tissue, depicted in a computer graphic, forms at the end of bones, near joints, and in vertebrae. *Image: Christopher Hernandez*

The material heterogeneity actually drives damage to the center of the bone's struts, which makes their surfaces more tolerant of flaws. In contrast, the surface treatments manufacturers use to strengthen materials often reduce surface ductility, Hernandez said.

The findings also upend the belief that the mechanical function of cancellous bone serves the same purpose as foam in engineering applications: to absorb energy and make the structure more lightweight.

"This is important mechanically because when you take a whole spongy bone and crush it, the damage is going to the middle of the strut, so it recovers most of its deformation and prevents it from snapping," he said. "It makes the structure more tolerant of stress concentrations. That's something mechanical engineers are always worried about, because that's where cracks start and grow from."

Hernandez's research is supported by grants from the National Institutes of Health and the National Science Foundation. His team published its findings in *Proceedings of the National Academy of Sciences*. **ME**

BIG NUMBER

51%

Share of U.S. Crude Oil Produced With Fracking

BACK IN 2000, OIL WELLS ENHANCED by hydraulic fracturing produced only 2 percent of the oil unearthed each day in the United States, and as recently as 2011, they made up less than 17 percent. But since then, fracking has exploded. Today the method yields more than 4.3 million barrels per day of oil, mostly from shale and other tight rocks in Texas, Montana, and North Dakota, according the U.S. Energy Information Administration, which pulled together data from DrillingInfo and IHS Global Insight.

MATERIALS ENHANCE HEALTH

BY MANIPULATING THE PHYSICAL characteristics of matter at its smallest sizes, researchers can create materials that are stronger, more flexible, and more durable at the macro scale. This month we touch base with two labs that are doing just that, one creating biomaterials for stem cell transplants and tissue regeneration, and the second manufacturing customized medical devices and implants for newborns.

In their struggle to keep premature newborns alive, physicians depend on catheters to infuse medications and nutrients into their patients. But off-the-shelf neonatal catheters are risky: Preemies often have unusual physiolgy, and a standard device may inadvertantly puncture a vein.

Randall Erb, professor of mechanical and industrial engineering at Northeastern University in Boston, hopes to overcome those problems by using 3-D printing to make reinforced catheters customized to each infant.

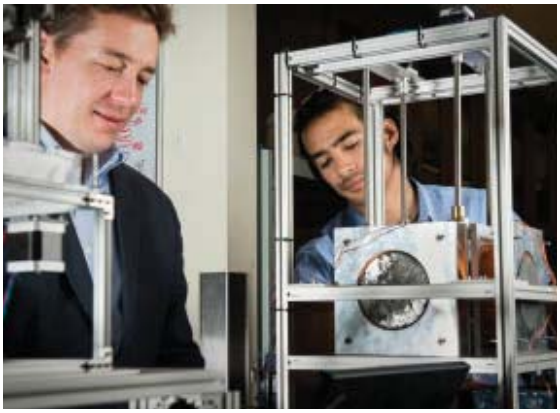
Reinforcement is important because neonatal catheters are much smaller and thinner than adult catheters, and may break easily. Erb's advance involves using magnets to orient ceramic reinforcements around catheter curves and holes to strengthen them. The result is a delicate catheter with surprising durability.

"Traditional 3-D printing has enabled the creation of materials with complex and programmable geometries," Erb said. "However, making complex geometries out of ceramic-reinforced composite materials is a challenge, since local control over the ceramic elements is required to increase strength and toughness."

Erb hurdles that challenge by coating alumina or glass, two common ceramic reinforcements for polymers, with small amounts (usually less than 0.1 percent by weight) of iron oxide. That is enough to enable the magnets to grab the fibers. Erb then uses the magnets to steer the fibers to form reinforcement architectures to strengthen the complex geometries of the printed parts.

"In a printed structure, we can now control the ceramic fiber orientation in every single 50 μm voxel of space," said Erb, referring to the 3-D grid created by computer-assisted design programs. "This allows us to produce composites with the highest resolution and control of reinforcement architecture to date."

To do this, Erb's team modified



Randall Erb and Joshua Martin's 3-D printer orients reinforcements with magnets.
Photo: Adam Glanzman/ Northeastern University

Erb's lab explores how magnets can control fibers and also deliver medicines to tissues. *Photo: Northeastern University*

an open-source stereolithographic printer by adding large electromagnetic solenoids to the frame. The researchers then rewrote the control code to apply magnetic fields autonomously during printing. The new code enables the system to orient the reinforcements in different directions while printing a single layer.

"Although this slows down the print, a 5-by-5 inch sample takes only 30 seconds per layer to texture and print, depending on the design complexity of the ceramic reinforcement architecture," Erb said.

Erb's team has received a $225,000 Small Business Technology Transfer grant from the National Institutes of Health to develop neonatal catheters with a local company. ME

PRINTING WITH MAGNETS

THE LAB Directed Assembly of Particles and Suspensions Laboratory, Northeastern University in Boston; Randall Erb, director.

OBJECTIVE Controlling the formation of composite microstructures during 3-D printing to optimize their properties and performance.

DEVELOPMENT Printing neonatal catheters customized to the specific geometries of individual newborn babies.

Stem cells contain all the genetic information needed to make any type of tissue, but getting those cells to express themselves on command is tricky. A team at Harvard University's Laboratory for Cell and Tissue Engineering, including director David Mooney and post-doctoral fellows Ovi Chaudhuri and Luo Gu, has developed a better way to encourage stem cells to develop into bone cells.

Surprisingly, it involves adjusting the mechanical properties of the environment surrounding the cells.

The researchers started by testing the stiffness of the bone cell microenvironment. Ordinarily, it is viscoelastic: like chewing gum, it relaxes with stress and dissipates energy over time when a strain is applied.

Mooney's team then synthesized hydrogels with different stress relaxation responses to mimic the viscoelasticity of different bone microenvironments, and placed stem cells into them. The more viscous and less elastic the matrix, the more likely it was that the stem cells developed into bone cells and formed bone-like material.

Controlling matrix viscoelasticity enables the team to exploit and control stem cell behaviors, said Chaudhuri. Yet to achieve precise control, the team needed to tease out how stress relaxation affects stem cells independently from stiffness. That meant synthesizing a molecule where those two properties were not dependent on one another.

They started with alginates, sugars naturally derived from algae, then added side chains to the molecules. "This interferes with the packing of individual polymer chains, making it easier for them to move relative to each other and thus altering the rate of stress relaxation," said Gu.

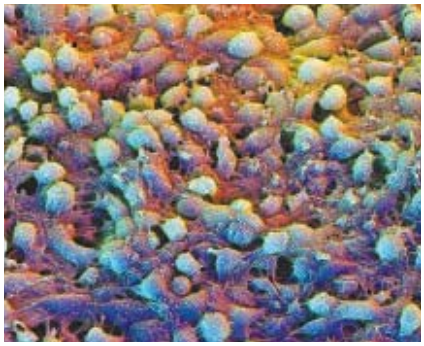
The research team is currently testing some of the biomaterials in animals for bone regeneration.

CONTROLLING THE MATRIX

THE LAB Laboratory for Cell and Tissue Engineering, Harvard University, Cambridge, Mass., David Mooney, director.

OBJECTIVE Finding uses for biomaterials for tissue engineering, immunotherapy, and drug delivery.

DEVELOPMENT Synthesizing a hydrogel to promote bone growth and tissue regeneration or targeted tissue destruction.



Stem cells cultured on a hydrogel, whose mechanical properties prompt them to form bone. *Credit: Wyss Institute at Harvard University/Harvard SEAS*

It turns out that matrix viscoelasticity and stress relaxation play a significant role in many biological processes. Mooney's team hopes to exploit this type of regulation to design biomaterials for stem cell transplantation and regenerative medicine.

"We hope this discovery highlights the importance of matrix stress relaxation in directing cell fate and activities," said Mooney. "Perhaps in the future stress relaxation will be used as a design parameter for regenerating or engineering bone, as well as an array of other tissue types." ME

MARK CRAWFORD is a geologist and technology writer based in Madison, Wis.

BURNING SUGAR FOR POWER

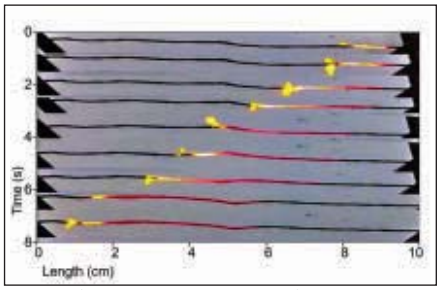
A new type of portable power source can produce electricity from nontoxic fuel sources such as sugar, and it could prove to be more efficient, sustainable, and safer than today's commercial batteries and fuel cells. The method produces electricity by guiding fuel combustion along tiny wires made of carbon nanotubes—a physical phenomenon discovered just six years ago.

In 2010, chemical engineer Michael Strano of the Massachusetts Institute of Technology and his colleagues discovered that if they coated submicroscopic wires called carbon nanotubes with a combustible material, the material decomposes to produce heat waves that propagate down the wire. These waves carry electrons like an ocean wave carries a band of surfers. This generates an electrical current.

But there were two big problems with those early experiments. The current produced was far too small to do anything useful, and the nanotubes were coated with volatile TNT.

The team continued to experiment, and found that using sucrose—simple table sugar—as the combustible made the process of converting heat to electricity up to 10,000 times more efficient. Today the process is 1 percent efficient, compared with 13 percent of a lithium battery. But the sucrose-fueled tubes generate a level of power close to today's best batteries, and an energy density comparable to where batteries are today, Strano's team recently reported in *Energy & Environmental Science*.

And it will only get better, Strano said. "As we get that efficiency higher and higher, the size of the device needed to generate power gets smaller and smaller."



Photos (stacked top to bottom) show the combustion of sugar-coated nanotubes.

Those devices, which resemble small boxes, can already power motors and lights. With different combustible materials, Strano said, the technology will be able to power autonomous vehicles and other electronic products, reducing or eliminating the need for an external power source. The new power technology, which uses no metals or toxic materials, should be commercially available in about three to four years, Strano said. ME

A NEW TOOL FOR SOPHISTICATED SIMULATIONS

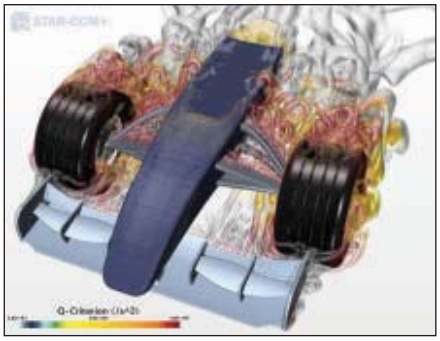
To simulate a flame within a combustion engine, an engineer may focus on where it's hottest. He could ask simulation software to depict temperatures above a certain number and zoom in.

But the close-up would lose essential context, said Matthew Godo, Star-CCM+ product manager at simulation software maker CD-adapco. The flame's structure would now be less clear.

A new visualization technique in version 11.02 of Star-CCM+ software can help. The technique, called Data Focus, solves for problems of fluid and solid flow, heat transfer, and stress, individually or combined. It also allows an up-close look at parameters within a Star-CCM+ simulation.

Using Data Focus, an engineer could set a minimum temperature to remove the cooler areas of the simulated flame, while preserving its original color scheme.

Data Focus also allows engineers to more deeply interrogate simulation results. For example, simulating a combustor



Data Focus reveals the turbulent wake behind the front end of a race car.

design might reveal areas with overly high temperatures and a mixture fraction indicating unburned fuel.

Data Focus could then help uncover the cause of these unexpected results, Godo said. The software would visualize zones in the combustor with both high temperatures and unburned fuel.

Where high temperatures and unburned fuel occur together, Godo said, "You can see it inside the combustor simulation and say 'That's where I need to improve my design.'"

The software can peer inside a wide variety of other simulated processes, such as a mixer, the fan that cools a computer, and even airflow around a bobsled. "Data Focus is a way to get at exactly what you want to see, where it's happening, inside a simulation," Godo said. ME

JEAN THILMANY is a writer in St. Paul, Minn., who covers design and engineering.

A COOL PROCESS FOR COLD SOLDERING

Solder two metals without using heat? No problem. It's as easy as turning on a blender or whipping up a batch of salad dressing.

That's the simple analogy Martin Thuo and his team of engineers gave to explain the process behind a new heat-free soldering technique. The technique solves some of the past challenges of using undercooled, or supercooled, metal particles for complex fabrication and engineering projects. The process can be used for cold soldering circuit boards and other heat-sensitive materials, metal repair and casting, industrial coatings, and 3-D printing.

"I tell my students you don't need expensive equipment to do good engineering" said Thuo, a professor of materials science and engineering at Iowa State University in Ames. "I call it frugal innovation."

Researchers have widely studied undercooling, the process of lowering the temperature of a liquid or gas below its freezing point without it becoming a solid. But few have made headway using undercooled metals in practical applications because of their instability and low yields, the team wrote in a paper recently published in *Scientific Reports*.

"The challenge with undercooling is that you could not find an easy way to keep the liquid metal away from anything that causes solidification," Thuo said.

To create a stable undercooled metal in bulk, the team added molten Field's metal—an alloy of bismuth, indium, and tin undercooled at 62 °C—to an acidic carrier solution and emulsified the liquids using a simple Dremel multi-speed rotary tool with a shearing implement attached to it. The team has also used a regular kitchen blender and reports the process is pretty much the same as mixing oil and vinegar to make salad dressing.

Thuo refers to the technique as SLICE, short for "shearing liquids into complex particles." It essentially cuts the liquid metal into nanoparticles. An oxide shell forms around the liquid metal core particles, which protects them from solidification. When those shells are fractured, the liquid metal coalesces and immediately solidifies at room temperature. For heat-free soldering or repairing a metal surface, simply apply the liquid metal to a metallic surface and use some type of mechanical force—in one of his experiments, Thuo used a small, solid glass cylinder like a rolling pin—to break the shells and fuse the metals. ME

continued from page 12 »

AUTONOMOUS CARS

crash," Peng said. "We believe that in our test environment, it's more accelerated."

To accelerate that testing, Peng and his colleagues have amassed an incredible amount of driving data. They've recorded more than 1.2 million hours of driving, which translates to 35 million miles of driving, more than 5 million separate trips, and 400,000-odd lane changes. With such a storehouse of data, Peng—and auto manufacturers—can zero in on riskier road scenarios and driving behaviors.

"When we analyzed human driving data, we extracted the dangerous part of the statistic," Peng said. "In other words, we will be able to emphasize or amplify the number of dangerous lane changes. For the safe lane changes, we don't have to test them. That's how we accelerate testing."

Similarly, the data allow for better testing of so-called diabolic scenarios. "You could try to brainstorm scenarios and impose them on vehicles," Peng said. "But the question is, how severe? What is the speed, the timing, the relative direction? Some companies try to come up with challenging scenarios, but I don't know how they determine those values. We will choose them based on observations of human behaviors, really bad ones, but ones that represent real-world driving. We try to play these risky behaviors on the test track."

Thanks to the heightened risk of any test, the runs tend to be short. The testers can then examine what happened, tweak perception and control algorithms, and go back and try it again. Once they've finessed their system to handle one dodgy situation, they can run a similar scenario at different locations in Mcity.

So in 20 years, or ten, or whenever it may be, when you're getting some extra snooze in on the way to work, playing cards with the kids on the way to Mount Rushmore, or just enjoying the view with your full attention, you'll know your automatic vehicle will get you there safely thanks to that simulated town: Mcity, Mich. ME

MICHAEL ABRAMS is an independent writer based in New York City.

"CO_2 EMISSIONS ARE A MARKER of [a company's] inefficiency. When you develop teams to pay attention to that, it's almost like putting on a magic pair of goggles to see waste and inefficiency that would otherwise be invisible to you."

Former U.S. Vice President Al Gore to attendees at the ARPA-E Energy Innovation Summit in March. Gore now chairs a firm called Generation Investment Management, which invests only in companies it considers sustainable.

ORTHOPEDIC BIOMECHANICS: KEYS TO THE SKELETON

DAVID A. HOELTZEL, COLUMBIA UNIVERSITY, NEW YORK

A professor of orthopedic biomechanics 30 years ago examined the human skeleton and its response to stresses and strains, including the total replacement of knee and hip joints.

Total joint replacement has become one of the most common and successful orthopedic surgical procedures. It can partially or completely eliminate the debilitating pain that often results when problems such as osteoporosis (decreased bone mass and density—a common disease of the elderly) prevent a bone fractured in a fall from repairing itself.

In the early 1960s, Sir John Charnley, a British orthopedic surgeon and researcher, pioneered a technique that used polymethyl methacrylate (an acrylic bone cement) as a grouting agent to affix structural replacements of partially degenerated skeletal members to bone. Since then, the technique of cemented fixation has been used with numerous joints other than the hip, including the knee, elbow, ankle, and wrist, with varying degrees of success.

Although cemented prostheses enjoy considerable longevity in adults, they are less successful in younger patients. This is because the cement is unable to sustain, without fracturing, the higher loads and stresses experienced by that age group. Biological fixation (also known as bone ingrowth fixation) is a successor to cemented fixation that may revolutionize the field of orthopedic total joint replacement. Here, a porous medium is bonded to the surface of the implant. The medium can be applied by a sintering process or by diffusion bonding of metal beads or wire mesh to a titanium or cobalt alloy substrate. Provided that an appropriate pore size is selected (the range is between 50 and 400 microns), bone has been found to grow into the porous surface of the implant and to affix itself without requiring cement.

The bone/implant interface is currently being researched. Of crucial importance are quantifying the conditions under which bone will grow into the implant, determining the location of the porous surface on the implant to achieve optimum load transfer into the bone, and quantifying potentially toxic metallic ions released from the surface of the implant. Researchers in Sweden appear to have ascertained the conditions under which bone will chemically bond to the titanium-oxide surface coating on titanium implants. A research group at the University of Gothenburg, under the direction of Tomas Albrektsson, has found that incremental bone removal, prior to insertion of the implant, will ensure adhesion of bone to the implant. They refer to this bonding of bone to metal as osseointegration.

The future of orthopedic implantations in active patients under 40 years old may well depend on the ability of bone ingrowth and osseointegrated implants to function well under loading conditions that cemented implants cannot sustain. Long-term clinical study is needed to prove the merit of these procedures. **ME**

LOOKING BACK

Fusing metal to bone was still controversial when this article was published in May 1986.

METAL AND BONE

Today, according to the U.S. Centers for Disease Control, 719,000 total knee replacements and 332,000 total hip replacements are conducted each year. The osseointegration technique that David A. Hoeltzel wrote about 30 years ago not only is used on many of those joint replacements, but also is being explored as a means to create a sturdy anchor to attach prosthetic limbs directly to the skeleton. If the technique proves to be successful, it may one day eliminate the uncomfortable interfaces between the socket of the prosthesis and the skin of the amputee.

BY THE NUMBERS: TRUCK PRODUCTION SHIFTING GEARS

Commercial vehicle demand is increasingly decoupled from economic growth. While global gross domestic product is forecast to rise by better than 2.6 percent in 2016, the medium and heavy-duty commercial vehicle market is expected to grow by only 2.2 percent.

Commercial Vehicle Market & GDP Growth (percent), 2016

Region	GDP Growth Estimates	Medium-Duty Vehicles	Heavy-Duty Vehicles	Overall CV Growth
North America	2.7–2.8	5.4	(9.3)	(2.7)
South America	1.4–1.5	(12.0)	(9.5)	(10.7)
Europe	1.6–1.7	1	6.2	5.1
China	6.5–6.6	(2.1)	(3.6)	(3.2)
India	7.6–7.9	26.6	31.8	30.0
Russia	(0.5)–(1.0)	(2.5)	(14.1)	(10.8)
Global	2.6–2.9	4.7	1.0	2.4

The container ship is the symbol of the globalized economy. Those mammoth vessels shuttle from port to port stacked high with standard 40-foot containers that hold everything from precision parts to cheap textiles.

But the real workhorse of the global economy is the heavy-duty truck which carries those containers from factory to port or from port to the end consumer. Heavy vehicles made up 63 percent of the 2.62 million commercial trucks sold worldwide in 2015, according to the consulting firm Frost & Sullivan. After years of robust growth, big rig sales in 2016 are expected to stall.

The forecast is contained in the report, *2016 Outlook of the Global Medium-Heavy Duty Truck Industry*, published in February.

Much of that slowdown in global sales is due to China, where more than one-third of the world's heavy-duty commercial trucks are purchased. Frost & Sullivan sees a combination of factors, ranging from too much domestic debt, too little growth in overseas consumer demand, and improved reliability and durability in the Chinese-made trucks, all continuing to work against sales there. Heavy-duty commercial vehicle sales are forecast to decline by 3.6 percent from 2015 levels. The total sales for both medium- and heavy-duty vehicle in China is expected to be 750,000 in 2016; as recently as 2014, more than a million were sold.

It isn't just China, however. The economic and political crisis in Brazil are expected to drag down big truck sales in Latin America, and similar forces look to decimate commercial vehicle sales in Russia. Even North America, which is forecast to have moderate economic growth throughout 2016, is forecast to see declining heavy-duty truck sales in the aftermath of a buying spree from 2012 to 2015.

On the other hand, India is expected to boom, and sales of heavy-duty commercial vehicles are forecasted to explode with it. Frost & Sullivan predicts heavy truck sales in India will go up by nearly 32 percent in 2016; some of that is due to a ban on older trucks in parts of the country, necessitating upgrades. Unfortunately, the percentage increase is from a relatively modest level, so the total growth in sales for all commercial vehicles is only 72,000 units.

Those sales trends may well affect the anticipated rollout of autonomous vehicle and other high-end technologies in commercial transportation. "Developed markets will draw attention towards advanced services such as driver behavior management, video safety, and prognostics," the report states. But with much of the near-term market opportunity located in less developed countries, Frost & Sullivan predicts that the demand for more advanced technology such as "telematics, safety, video-based monitoring, prognostics, asset maintenance, platooning, online freight aggregation, and mobile based brokering" in commercial vehicles will be muted. ME

JEFFREY WINTERS

TRIAL BY ICE

A NEXT-GENERATION OCEAN ROBOT EXPLORES THE ARCTIC'S DEEPEST SECRETS.

BY LINA ZELDOVICH

Chris Judge has been playing videogames since he was three, so it is not unusual to find him staring at a screen with an X-Box controller in his hand. And thanks to the hours he spent beating Tecmo Super Bowl and Super Mario Bros. he has developed a suite of related skills, from hand-eye coordination to the visuospatial ability to keep track of an avatar's location in a three-dimensional maze.

In the summer of 2014 Judge, an engineering assistant with the Woods Hole Oceanographic Institution in Massachusetts, was holding a videogame controller aboard the German icebreaker RV *Polarstern* in the Arctic Ocean. The joint American-German research team he was part of selected him, because of his gaming prowess, to pilot a newly built sea robot on a unique mission. Nereid Under Ice was designed specifically for exploring the underside of Arctic sea ice, an area so far off-limits to scientists.

As the two ton, bright orange vehicle lowered into the water, two other important com-

ponents followed: a tow body and a depressor, which would quickly drag Nereid down. Once Nereid was under the keel of the ship, safe from dangerous ice floes or currents beating against the hull, the depressor and tow body were to decouple. The tow body would trail behind the robot as it swam away, unspooling as much as 20 km worth of hair-thin fiberoptic Gigabit Ethernet cable through which the robot would transmit video and other data. The depressor would remain under the ship, passing data to Polarstern's computers via a thick, heavy duty cable, impervious to nature's forces.

Through a webcam, Judge saw Nereid reach the water, and waited for the depressor and tow body to unlink, but the release command failed.

That sort of error had never happened during Nereid's rigorous testing, but the team was prepared to deal with failures at sea. Clad in the puffed-up suit dubbed "the Gumby" to guard against the -20 °C cold or an accidental fall into the water, engineer John Bailey was already heading to the rescue in a small boat, toolbox in hand. The latch linking the tow body and the depressor failed to unlock so Bailey had to pry it open by hand. (The team later

discovered that two latch parts with different coefficients of thermal expansion had jammed together in the cold.)

In spite of the sub-zero temperatures, Bailey tossed off his gloves, which were too thick to gently strike the screwdriver's butt with the hammer.

"I called it 'forcing with finesse,'" Bailey said. "It moved a small bit every time, but it seemed like forever."

After 20 minutes the latch relented, and Nereid whirred away free, to explore secrets under the ice.

EXPLORING THE CEILING

Climate change may be global, but it is affecting the Arctic region more intensely than anywhere else on Earth. Researchers want to study the changes occurring in the Arctic ice pack and the ecosystems beneath it to learn more about what's happening there now—and to improve predictions of what may happen there over the next few decades.

"The idea of going under the ice was long on the wish list," said Antje Boetius, a professor at the Alfred Wegener Institute for Polar and Marine Research in Bremerhaven, Germany, who led the efforts on *Polarstern*.

Getting a good look at life under the ice was very hard to accomplish. Scientists have to approach the region via icebreakers, which disturb the habitat. To get a true picture, they had to get away from the ship.

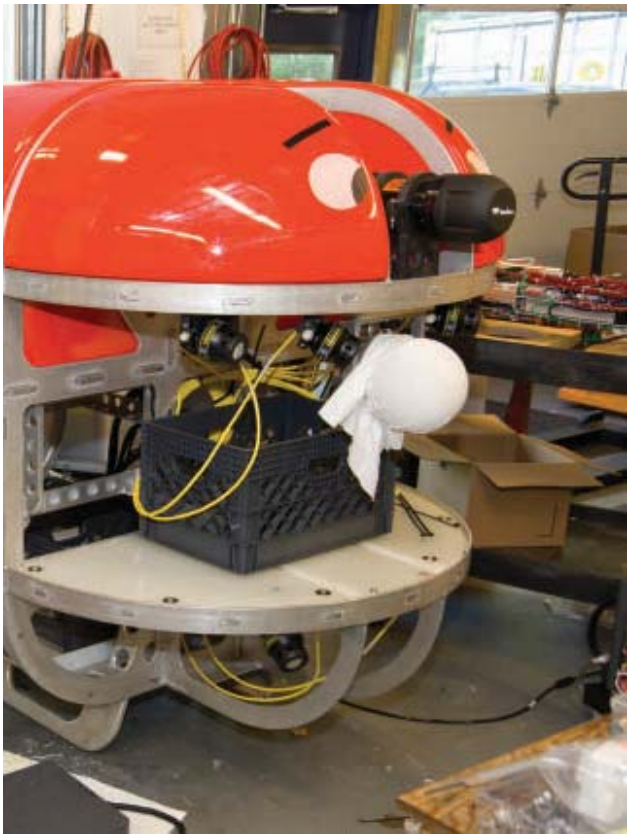
That meant robots, particularly advanced ones able to travel long distances while still transmitting back images and sounds. Standard ocean robots come in two types, neither of which are well-suited to the task. Remotely operated vehicles (ROVs) rely on human control to accomplish their missions and so need a constant connection to their operators via cables. The lengths and weights of those cables limit the ROV's mobility, and in Arctic conditions, those cables can be broken easily by drifting ice floes, leaving the million-dollar equipment lost at sea.

The other type of robot, autonomous underwater vehicles (AUVs), have more intelligence than ROVs, but usually only enough for a few pre-programmed tasks like taking samples and photos, but not for weaving through protruding ice parts and hovering under icecaps.

In order for Nereid to successfully move and work under ice and glaciers, the team designed it as an ROV-AUV hybrid, able to switch between the two modes as necessary.

Maneuvering and landing on the ice ceiling (like touching down on the seafloor, only upside down), would require human navigation. As Nereid sent real-time visual data to the computer screen through the lightweight fiber tether, the team would direct it to look into cracks and crevasses, photograph algae pools, or slowly ascend onto its landing skids to take water samples underneath ice. The thin fiber cable could still be its Achilles' heel, but if it got snagged and broken, Nereid was

Mechanical engineer Tom Lanagan (left) works on the Nereid during its construction. Later, the robot is deployed off the back of the R/V *Tioga*.
Photos: Tom Kleindinst , WHOI



programmed to turn on its AUV mode and return to the ship.

That's no simple task. Unlike the so-called blue-water vehicles that operate in the open ocean, Nereid couldn't just head straight to the surface.

"Under ice it's not a great plan," said Michael Jakuba, who led Nereid's design team. "You would need to break the ice, which is difficult and may hurt the robot."

To find its way back, Nereid not only had to remember the path it had taken, but also know where to turn or dive to avoid protruding ice pieces or other obstacles. And because ice floes drift continually, Nereid's navigational software had to keep track of their movements, adding error corrections to its homeward path.

To maximize the vehicle's reliability in the event of the communication fiber breaking, the team implemented a variety of recovery features and levels of redundancy. If the fiber got cut, they could guide the robot from under the icecap by radio signals. If Nereid got stuck under ice, they would find it using an avalanche beacon.

And if all else failed, the team had an emergency ice-breaking procedure devised. They would drill holes in the ice and deposit heavy weights on Nereid's top, sinking it to the depths safe from the *Polarstern*'s massive ice break-

Andy Bowen (right), director of National Deep Submergence Facility, briefs Rear Admiral Matthew L. Klunder and former Wood's Hole director Susan Avery during a 2013 tour of the Nereid workshop.
Image: WHOI

ers—and then float the robot back to the ship.

Nereid also has to withstand extreme Arctic temperatures, so its materials had to be tested even before it was assembled. Nereid's upper shell, for instance, is made from blocks of orange-colored syntactic foam made from tiny hollow glass spheres coated with epoxy glue. Before fabricating the shell, lead technology engineer Casey Machado had to ensure that the foam could hold up to the Arctic cold.

"I put a few foam samples in a -40 °C freezer and then hit them with a hammer," she said. "And I saw what got broken and what didn't—to get a sense of what materials worked together."

(In retrospect, the latch problem Nereid had on its first dive probably should have been obvious too, Jakuba said, but it only manifested itself in extremely cold temperatures.)

The engineering team rigorously tested other systems. To check such basic features as navigation and imaging, the team dunked Nereid into a big tank at WHOI facilities. To test the robot's ability to track the ice floes' movement above, they used a particular type of Styrofoam which Nereid's instruments perceived as ice.

"The idea was to rotate the proxy ice over the robot," Jakuba said, "so we pushed it around, and the vehicle measured its velocity."

During the next round, Nereid went swimming in the ocean while doing some science under the WHOI docks. "There were all sorts of little critters and algae and other things there," Machado says. "So we were able to see that the vehicle does what it was designed to do, and can land under something like that, and take a close look at it."

Finally, shortly before the expedition, Nereid went through the integration testing in Tromsø, Norway, a city located above the Arctic Circle. Tromsø is known for its frigid temperatures, albeit still milder than the areas where the actual research took place. (The latch worked in Tromsø.) The team tested everything except diving under the mounds and valleys of frozen water. Any surprises at sea they would have to solve on the fly.

The robot was now ready for trial by ice.

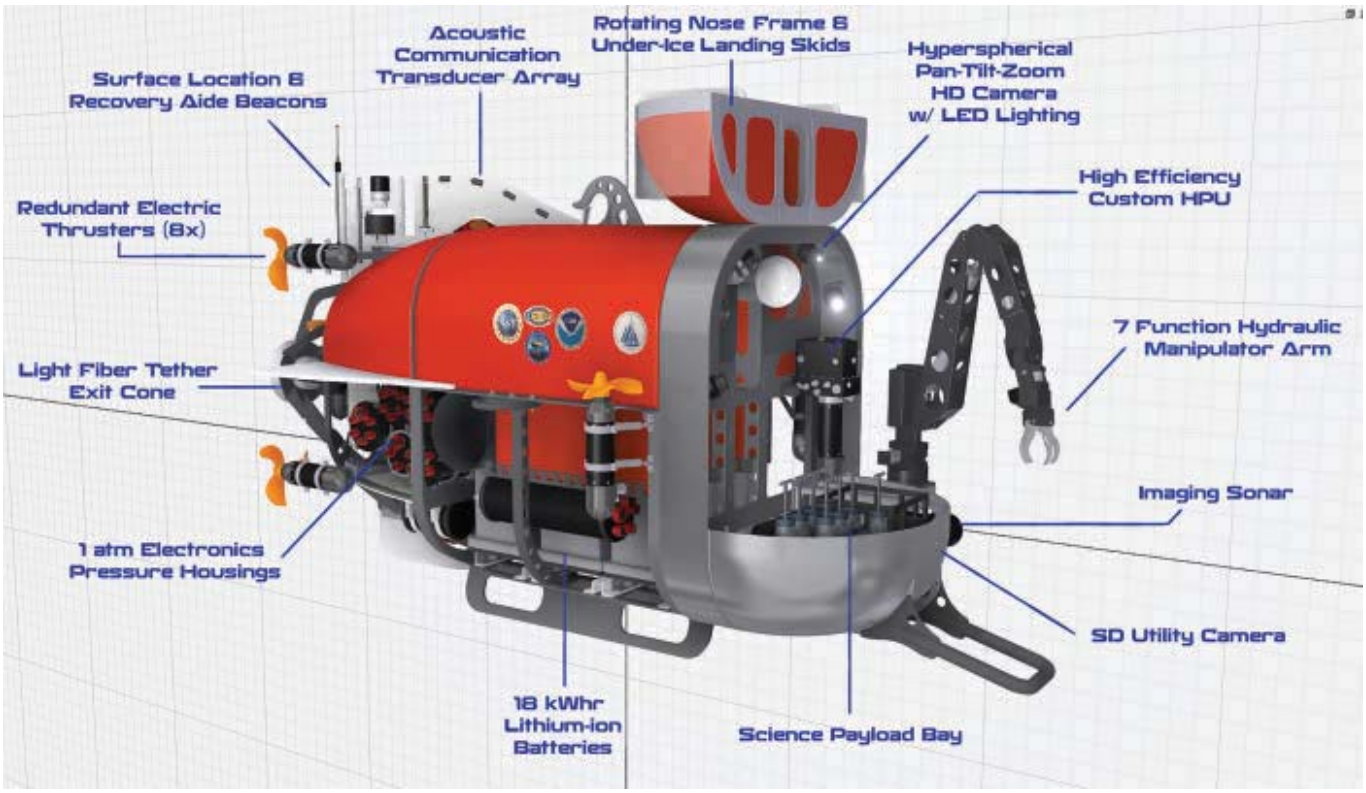
REACHING THE UNREACHABLE

In the *Polarstern*'s control room, Judge and Boetius traversed the under-ice world through Nereid's eyes. Judge described the experience as "video game-esque," including the first-person view.

"I had a map of where I was heading, just like in most games, and a record of where I was going and where I've been," he said. "And I drove the vehicle with an X-box 360 controller."

It was surprising how much life existed beneath the ice, said Boetius, who directed the exploration, pointing where to move and what to see. Following Nereid and zooming in and out of images on the screen made Boetius feel as if she sat inside a huge aquarium, sneak-peeking at the underwater Arctic secrets.

"When ice breakers break the ice, it changes the habitat," she explained—it kills some organisms and messes up the environment of others. Nereid left the underside life undis-



turbed, letting the team observe the algae blooms and rare creatures.

"I saw gelatinous organisms you hardly ever see because ships would squish them with their propellers," Boetius said. "These organisms are beautiful, they look like ballerinas in the water."

At the end of the first exploratory sortie, Judge turned Nereid around to head back to the ship. The water currents had shifted the communication fiber into the vehicle's path and the robot ran over it, cutting it and severing communications with the ship. The team added extra software features to avoid this in the future, but it did provide a field test for Nereid's homing ability. It worked perfectly. The robot returned without a hitch.

On another flight, the team had to quickly haul Nereid out of the water to prevent a huge fast-moving ice floe from hitting its front camera, which, as Judge put it, "costs more than my house."

Some flights were smooth and successful. Judge recalls that after one five-hour exploration, the navigation system led him back exactly to the spot where the robot had launched—the hole in the ice made by *Polarstern*'s ice breakers.

"There was a great sense of achievement," he said.

There was also a pervasive sense of exploring the great unknown. In one flight, Nereid traveled over the fairly unexplored Arctic Gakkel Ridge system and its hydrothermal vents—fissures in sea floor that shoot up hot water—allowing Boetius to survey life over these unique environs.

Once Nereid is outfitted with a manipulator arm, which Machado expects to happen later this year, it will be capable of advanced sampling tasks such as breaking off pieces of ice, scooping sediment into vials, and capturing animal matter. Boetius hopes it can also bring back fluid samples from the hydrothermal vents to offer insights into their ecosystems which sometimes host unique bacteria and life forms.

The ability to explore these previously unreachable places opens new frontiers for polar science that until now were only a dream.

"This robot was an eye opener," Boetius said. "Just to see what happens in this ice-cold water when 400 °C degree water shoots up would be amazing." ME

LINA ZELDOVICH is a writer based in Woodside, N.Y.

A Natural Fit

It started with a deal for flare gas and grew into an industrial ecosystem: One plant uses what another casts off.

By R.P. Siegel

There's amazing symmetry in natural processes. Breathe deep and think of oxygen. It's a waste product of photosynthesis.

On the other hand, one of the key ingredients for that process is carbon dioxide, a byproduct we create by the metabolism of food. Much of our nourishment comes from the oxidation of sugars developed by photosynthesis. It's a simple example of symbiosis: What one organism leaves, another uses.

This kind of cooperation can also be applied by industry. Gypsum captured from the flue of a coal-fired power plant can become the raw material of a factory making drywall sheets. The effluent cooling water from the power plant can become the preheated boiler feed water for a refinery. The sulfur extracted by the refinery can be sold to a manufacturer of sulfuric acid.

That is the kind of symbiosis that characterizes a unique industrial park in the town of Kalundborg, Denmark. Known as the Kalundborg Symbiosis, it is a community of eight companies that cooperate with each other to everyone's benefit, because one company's waste becomes another's feedstock.

The relationship increases efficiency and reduces waste-handling. The result is an industrial cluster that has reduced its environmental footprint and improved the bottom line of each of the participating companies.

The Kalundborg Symbiosis comprises four major industrial companies, the local electric and water utilities, a wastewater treatment plant, and a solid waste facility. They form a network in which materials and energy flows are cooperatively exchanged. In these exchanges, byproducts of one operation become raw materials or inputs of another.

According to materials provided by the Symbiosis Center Denmark, a newly formed, state-sponsored outreach and development agency, the results add up to annual reductions of 275,000 tons of CO_2 and three million cubic meters of water, based on data collected in 2008.

The Kalundborg Symbiosis recently celebrated its 40th anniversary. As the symbiosis has grown, both in complexity and effectiveness, it has developed numerous ways in which businesses can reduce their impact on the environment without sacrificing competitiveness.

Mette Skovbjerg, who heads the Symbiosis Center, says it began with a scarcity of resources, particularly groundwater, in Kalundborg, a small city situated at the head of a fjord on the west coast of Zealand. The city, with roots reaching back as far as 1170, is part of a larger municipality of the same name that covers almost 600 square kilometers and has a total population of about 50,000.

In 1959, the Asnæs Power Station, a large coal-fired plant, was constructed to serve the community. Two years later, the Tidewater Oil Co. built a refinery. Because of the shortage of ground water in the area, the refinery owners negotiated an agreement with the Kalundborg municipality to construct a pipeline to bring fresh water from Lake Tissø, about 10 km southeast.

In 1972, Gyproc constructed a drywall manufacturing plant. The company needed a lot of energy for drying the sheets and negotiated an arrangement with the refinery to utilize excess gas that was being flared off. Thus, the symbiosis was born.

Among the companies located in Kalundborg today, the biggest is Novo Nordisk, the world's largest supplier of insulin. The company, which was founded in 1923, located in Kalundborg in 1969, back in the days when insulin was still extracted

The Kalundborg Symbiosis

An industrial park in the Danish municipality of Kalundborg (see aerial photo below) links a refinery, a power plant, and several factories so they can use each other's products and wastes.

Energy

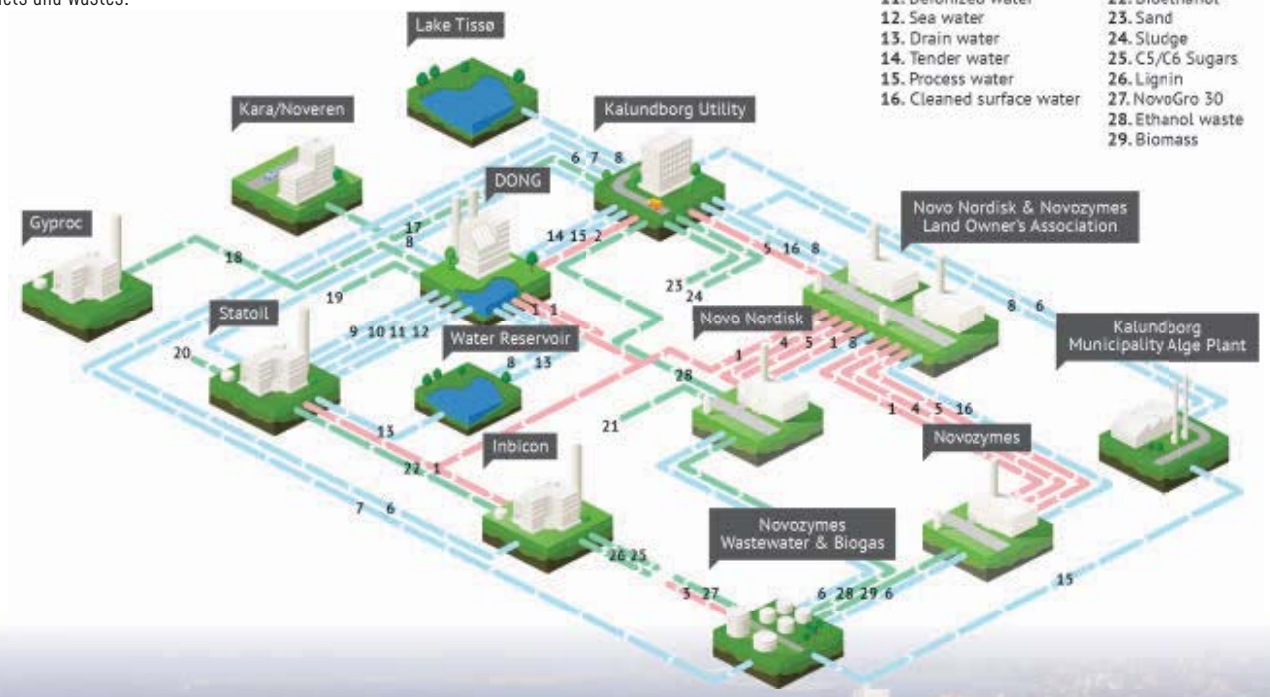
1. Steam
2. District heating
3. Power to grid
4. Warm condensate
5. District heating

Water

6. Waste water
7. Cleaned waste water
8. Surface water
9. Technical water
10. Used cooling water
11. Deionized water
12. Sea water
13. Drain water
14. Tender water
15. Process water
16. Cleaned surface water

Materials

17. Waste
18. Gypsum
19. Fly ash
20. Sulphur
21. Slurry
22. Bioethanol
23. Sand
24. Sludge
25. C5/C6 Sugars
26. Lignin
27. NovoGro 30
28. Ethanol waste
29. Biomass



> "The **Symbiosis came about** as the result of a spirit of collaboration and a response to the question: **Is it possible that a waste product** of one company could actually be a **raw material for another?**"
>
> — Michael Hallgren, senior vice president at Novo Nordisk Kalundborg

from pig pancreases. Today, the active ingredient is grown in yeast in an enormous one-million-square-meter facility, which produces roughly half of the world's insulin. The insulin is grown in a fermentation process. It is harvested, purified, dried, and then frozen. The fermentation process produces heat which is captured and reused internally.

Back in the 1970s, Novo Nordisk began providing agricultural sludge from this yeast production line to neighboring farmers. Around the same time, the operators of the power plant began providing fly ash to cement producers in the north.

Steam was the next development. At first, the power plant provided steam for district heating. Then, Novo Nordisk and Statoil collaborated to build a steam pipeline connecting the power plant to their facilities, allowing them both to shut down far less efficient boilers.

By this time, engineers in Kalundborg began to notice more opportunities as the efficiency benefits of resource sharing were becoming part of their respective business models. The Statoil refinery added a pipeline to carry warm cooling water effluent to the power plant for use as raw boiler feed water, improving the efficiency of the same boiler that was providing steam.

CIRCULAR THINKING

Take a walk through the Kalundborg Symbiosis today, and you would see something that looks a lot like any other industrial complex. The one thing that would likely stand out would be the network of pipes running at ground level and sometimes rising to cross streets, connecting the buildings with one another. The lines, which transport gas, water, steam, waste slurries, and other effluents, suggest a single interconnected organism in which each building plays the role of an internal organ.

Over the years further opportunities were recognized and implemented. A Statoil sulfur recovery plant sells sulfur to a sulfuric acid manufacturer. Biologically treated refinery effluent is used in power plant for cleaning and for fly ash stabilization.

Warm cooling water from the coal power plant runs to a fish farm that produces turbot and trout. Waste heat from the power plant is used for a bio-refinery that has produced 5.4 million liters of ethanol from waste materials generated around the site and by local farmers.

Agricultural fertilizer is recovered from the power plant's sulfur and nitrogen scrubbers. Calcium sulfate (gypsum) from its flue gas scrubber is a raw material used by Gyproc in the production of drywall. About 150,000 tons of gypsum are recycled each year.

Many of these symbiotic actions can be replicated elsewhere. But clearly having the facilities co-located, allowing material to be piped rather than shipped, makes symbiosis particularly attractive.

In 2013, Novo Nordisk and Novozymes, another Kalundborg partner company specializing in the production of enzymes, collaborated on the construction of an on-site biogas reactor that extracts methane gas from wastewater. The 35-meter-tall reactor feeds a gas turbine on site that generates 47,000 megawatt-hours per year—enough electricity for 12,000 homes—and reduces carbon emissions by an additional 21,000 tons.

"The Symbiosis came about as the result of a spirit of collaboration," said Michael Hallgren, senior vice president at Novo Nordisk Kalundborg, "and a response to the question: Is it possible that a waste product of one company could actually be a raw material for another?"

This idea of using waste as a raw material is now known as the circular economy. Kalundborg is held up as an example of this concept by organizations that seek to promote it, such as the Ellen MacArthur Foundation and the Nudge Sustainability Hub.

The Kalundborg partner companies have created their own circular economy, Hallgren said, and "have incorporated it into their DNA."

Hallgren pointed to the example of Novo Nordisk, a longtime leader in sustainability. Back in 2004, the company could see that its carbon emissions and water consumption were increasing proportionally with its revenues.

That raised a question: Could the company grow without

The green pipe stretching over the road in the Kalundborg complex carries steam from one facility, which considers it an unneeded by-product, to another that uses it for production.

the undesirable consequences? "That was the goal," Hallgren said, "but nobody knew how to do it."

Novo Nordisk initiated a partnership with Dong Energy, the operator of the Asnæs Power Station, to see what could be done.

Dong wanted to build windmills. According to Hallgren, Novo Nordisk told the power company, "You are the experts in energy. If you can support us in coming up with a lot of ideas—take a look at our production process and see where you can find savings—any money that we actually save we will reinvest in windmills."

Everyone got what they wanted. "They built a huge windmill park on the west coast of Jutland, and we agreed to buy all the energy coming out of there," Hallgren said. "Today all the power for our Danish production site is coming from windmills. We also looked at our own production, and the yeast strains to see if we could produce more per liter, because that would also reduce our use of resources including CO_2, power, and water."

The effort was successful. "We have decoupled our resource consumption from our sales," Hallgren said. "First of all, sales increased while CO_2 emissions remained flat. Then we made a commitment in 2006 to reduce CO_2 emissions to 10 percent below what we emitted in 2004. Emissions remained flat while sales grew until 2007 when the emissions began to decline." As sales continue to increase, the company must work ever harder to find ways to reduce emissions.

The project is by its very nature dynamic, and changes in one plant's operations ripple out to others in the Symbiosis. For instance, the 1,057 MW coal plant, which played such a key role in the growth of the symbiosis, is being phased out, giving way to wind power. As a result, Gyproc will need a new source of gypsum to replace the calcium sulfate it currently receives from the coal plant. Several facilities will need a new source of steam, and the members of the Symbiosis team are working on a project to build a smaller steam unit that will burn wood and produce power for the community.

Mette Skovbjerg, head the Symbiosis Center, pointed to municipality-initiated demonstration project involving the use of microalgae. Novozymes is taking off wastewater and using the algae to clean it. That process will also create byproducts which could either be used to produce more bioenergy or possibly more high-value oils.

This, Skovbjerg said, "is part of version 2.0 of the symbiosis where you don't just take a residual and turn it into a resource, but you are now creating high-value products from something that was essentially a waste."

As the thinking evolves, so does the value realized.

A FUTURE FOR WASTE

While the Symbiosis has more or less run itself without anyone promoting it for most of its existence, recent recognition by outsiders has led to more efforts to attract more businesses and to promote what has been done here. This includes the formation of Symbiosis Center Denmark and a national task force that conducted a feasibility study to explore additional opportunities for the Symbiosis concept beyond Kalundborg.

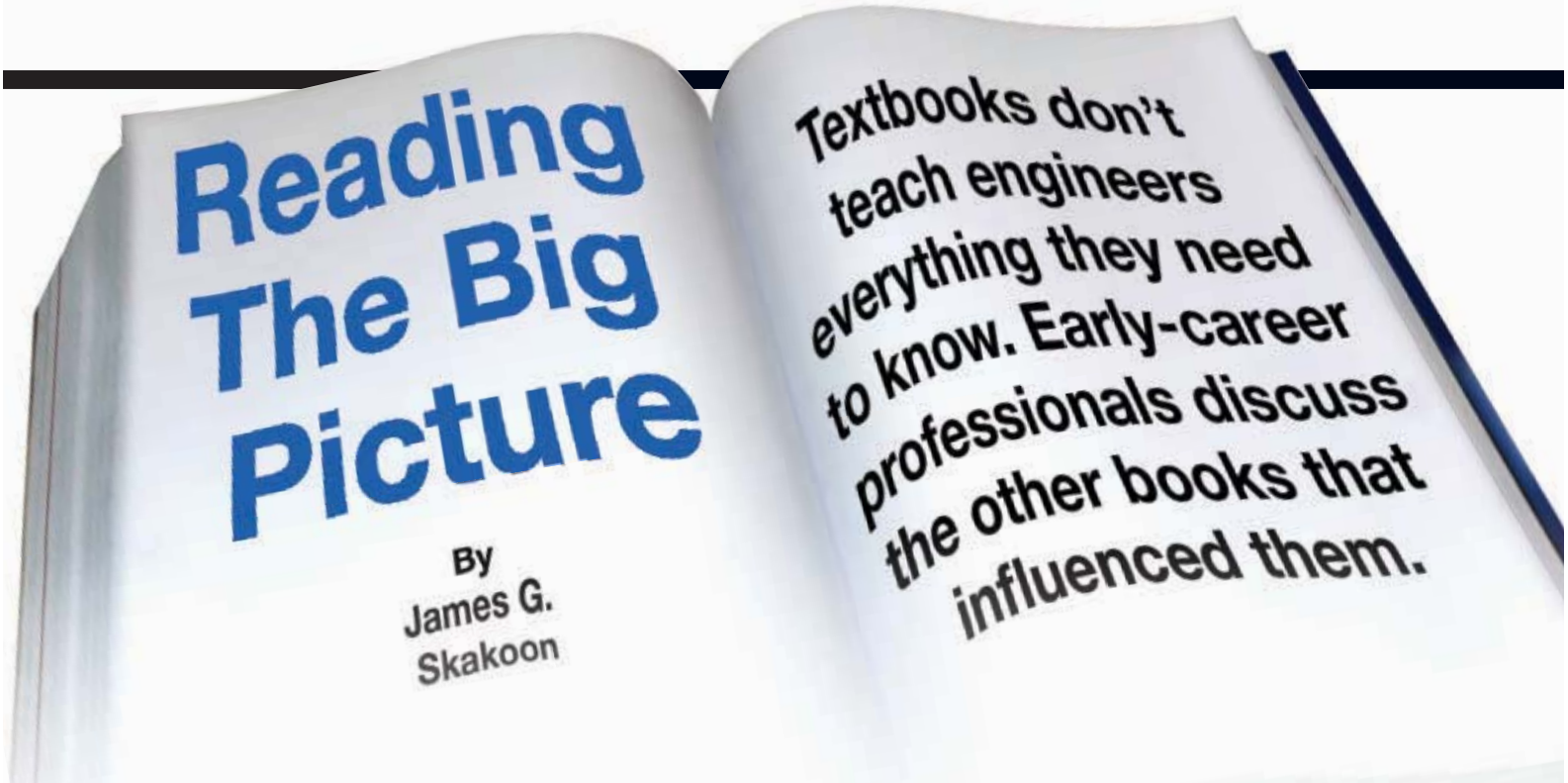
The task force found that a shift to a circular economy in Denmark could, by 2035, increase the GDP by up to 1.4 percent annually, increase exports by 3 to 6 percent, increase employment by up to 13,000, reduce Denmark's carbon footprint by 3 to 7 percent, and reduce the use of resources by as much as 50 percent.

The study looked primarily at manufacturing, but it mentioned that other industries, such as food and beverage processing and construction, could also benefit from symbiotic arrangements.

The advantages include greater productivity, lower costs, and reduced waste. Even so, getting companies to buy into the idea can take some finesse.

"What we do is not to persuade," Skovbjerg said, "but to explain to companies that this is not something that is going to make them more dependent, as much as it will help them optimize their use of resources, improve their bottom-line figures and their competitiveness."

R.P. SIEGEL is a writer based in Rochester, N.Y.



Reading The Big Picture

By James G. Skakoon

Textbooks don't teach engineers everything they need to know. Early-career professionals discuss the other books that influenced them.

BY THE TIME WE GRADUATE WITH OUR ENGINEERING DEGREES, WE PROBABLY HAVE SEVERAL SHELVES (OR AN E-READER) STUFFED WITH COLLEGE TEXTBOOKS. EVEN THOUGH THEY HELPED US LEARN A LOT ABOUT MANY SUBJECTS, ESPECIALLY ENGINEERING, THEY AREN'T A COMPLETE EDUCATION.

"With textbooks, you tend to get a fairly narrow view," said Kim Stelson, a distinguished professor in the College of Science and Engineering at the University of Minnesota.

According to Stelson, who has been at the university since 1981, books about the nature and history of technology can help round out an engineering education.

We've assembled a sample list, and Stelson, who's read most of the books, says they offer a broad view of engineering. "One book I found particularly useful," Stelson said, "is *Structures: Or Why Things Don't Fall Down* by J. E. Gordon. This book helps you apply what you learned in material science and strengths of materials to practical problems. It has a lot of concrete examples and is written with a very humorous tone."

"And Petroski is brilliant," Stelson added, referring to Henry Petroski, a Duke University professor of civil engineering and history who writes about technology in a popular style.

Petroski said that inventions, failures, the history of engineering, and the evolution of technology are the themes that run through most of his books. "These are all subjects that were not covered very explicitly, if at all, in my formal education," Petroski said, "but I feel they are important for understanding the nature of engineering as a practice and a profession."

There is no surprise, then, that Petroski's books figured prominently when we asked six successful early-career engineers what books have informed or inspired them.

But successful engineering careers involve more than technology, so it is also no surprise that their answers are as diverse as their own histories, interests, and goals. They read about business, innovation, management, leadership, even psychology.

On the following pages we present what those six engineers told us about the books that have influenced them and shaped their careers.

JAMES G. SKAKOON is a retired mechanical design engineer and a frequent contributor.

SPENCER BONDHUS

Since earning a B.S.M.E. degree from the University of Minnesota, Spencer Bondhus has been developing new products in the medical device industry. He is named as an inventor on 13 U.S. patents and was recognized by Medtronic with its Star of Excellence Award in 2013.

Throughout my life there have been certain books, especially relating to engineering, that have resonated with me. One, when I had just started to read, was *Harold and the Purple Crayon*. By drawing with his crayon, Harold could create anything—the moon for light, a path to walk on, a picnic lunch—if he could only imagine it. This was my earliest inspiration toward engineering; I wanted to create.

In my teens I started reading poetry, which showed me how structure can exist in places I didn't expect. This exposed the "inside" to me. There is something beautiful about the depth and flow and precision of a poem, how all the pieces fit together. People recognize this artistic quality in poetry, but most don't see it in engineering. When I look at an assembly of parts, I look for the poetry in its construction.

Lately my reading has been mostly what you'd expect for an early-career engineer. One of the main advantages of a book is that it's an individual lesson that allows me to learn at my own pace. I can stop to think, reread, even skip ahead. Two books that come to mind like that are *StrengthsFinder 2.0* by Tom Rath and *Conceptual Blockbusting: A Guide to Better Ideas* by James L. Adams.

StrengthsFinder 2.0 enlightened me to the concept of strengths management. It is OK to have weaknesses, OK to let some of them remain so, and best to focus on strengths. For example, during meetings I often do not speak until I see how my strengths apply to the discussion. This punctuates my comments, making it apparent that I'll say something worthwhile. Learning about strengths management helped me recognize and hone that skill.

Conceptual Blockbusting is a guidebook for the phrase, "Think outside the box." Most people know they should do that, but their thought process stops there. This book defines how. Moreover, it applies to many areas of life.

By incorporating the concepts of *Conceptual Blockbusting* into my thinking, I more easily break assumptions, or "blocks." I can come up with more diverse ideas faster. People practice everything from golf swings to music, but they rarely practice thinking. Practicing to think creatively and flexibly is something *Conceptual Blockbusting* promotes.

Just the fact that I read a book doesn't directly impress others, but had I not read books like *StrengthsFinder 2.0* and *Conceptual Blockbusting*, I would not have some of the valuable skills that make me a better engineer.

ADAM LEEMANS

Adam Leemans was the valedictorian of the United States Military Academy's 2013 graduating class. He was also an NCAA All-American triathlete and captain of the West Point Triathlon Team, which won three national long-course championships. In 2013, ASME selected him as its nominee for the New Faces of Engineering College Edition. He recently completed a master of science degree in energy and sustainability from the University of Southampton in the U.K. Leemans is currently posted in Colorado.

It's implied that Army officers should always be reading something to develop ourselves. Our superiors may ask us what we're reading, and having a good answer sends the right message. And of course, it's useful during any discussion to refer to a book that you've read; it gives you a little more credibility.

The Army provides reading lists for each job area and level. One recommended read is *Getting to Yes* by Roger Fisher and William Ury. I read it when taking part in the West Point Negotiation Project. This program teaches army personnel how to interact with foreign cultures during overseas deployments.

I was a plebe at the time, and I found *Getting to Yes* helpful throughout my West Point education. I applied its ideas during group projects—looking for mutual gain, seeing the other side's point of view, distinguishing between personal relationships and the problem to be solved. This made my groups more likely to come to a consensus rather than just bickering over details.

I decided mid-way through my West Point education to focus on energy, so I read *The Quest* by Daniel Yergin, which gives a broad overview of the field. It's long, so it took a while to get through. We don't have a lot of free time at West Point. The first half describes the history, geography, and world politics of fossil fuels. The rest gives a vision of the future that transitions from the fossil fuel age to an electrical age, largely based on renewables.

As engineers, we don't often think about how what we work on can affect our relationship with the rest of the world. *The Quest* pushed me toward working with alternative and renewable energy technology. These sectors allow us to invest in developments here in the U.S. rather than in some of the riskier overseas fossil fuel ventures.

One book I read in high school, *Present at the Future* by Ira Flatow, ignited my interest in science and engineering. I had become somewhat disillusioned with those subjects, feeling like I was just repeating what had already been done. But this book exposed me to the technologies of the future and I realized that we need engineers and scientists to make it all happen.

CLASSIC BOOKS ABOUT ENGINEERING AND TECHNOLOGY

Browse a bookstore or search Amazon.com for business and management books and you'll see both the classics and current best sellers prominently displayed. But interesting books about engineering and technology are more difficult to find. Here are some worth a closer look.

Conceptual Blockbusting: A Guide to Better Ideas
by James L. Adams.

Flying Buttresses, Entropy, and O-Rings: The World of an Engineer
by James L. Adams.

Engineering and the Mind's Eye
by Eugene S. Ferguson.

Surely You're Joking, Mr. Feynman! (Adventures of a Curious Character)
by Richard P. Feynman.

The Existential Pleasures of Engineering
by Samuel C. Florman.

Structures: Or Why Things Don't Fall Down
by J.E. Gordon.

The New Way Things Work
by David Macaulay.

The Design of Everyday Things (also titled The Psychology of Everyday Things)
by Donald A. Norman.

Invention by Design: How Engineers Get From Thought to Thing
by Henry Petroski.

To Engineer is Human: The Role of Failure in Successful Design
by Henry Petroski.

Zen and the Art of Motorcycle Maintenance: An Inquiry Into Values
by Robert M. Pirsig.

What Engineers Know and How They Know It: Analytical Studies from Aeronautical History
by Walter G. Vincenti.

JILL HERSHMAN

Jill Hershman is a systems engineer at Southern Company's Farley Nuclear Plant. She has been active in both ASME and the Society of Women Engineers, which recognized her with its Outstanding Collegiate Member award in 2011. She graduated with a B.S.M.E. from the University of Alabama, and is pursuing an M.B.A. through the University of Florida.

The majority of what I read is science fiction or historical fiction, often with a technology slant, like Dale Brown's or Tom Clancy's books. But I do read two or three nonfiction titles every year to get other points of view. These include engineering books, "thinking" books, and leadership books. Right now I'm reading *Fearless Leadership: High-Performance Lessons From the Flight Deck* by Carey D. Lohrenz, the Navy's first female F-14 fighter pilot.

One of the "thinking" books is The *Essential Engineer: Why Science Alone Will Not Solve Our Global Problems* by Henry Petroski. This book compares what scientists do with what engineers do. Petroski points out that scientists often get the credit, but engineers do a lot of the work. In part, it's a call to action for engineers to take more credit. I haven't seen this bias directly in my industry. But after reading this book I notice news stories are more often about scientific discoveries than engineering feats. This was my first read by Petroski, but I've put more on my reading list.

Another of the leadership books is *Where Good Ideas Come From: The Natural History of Innovation* by Steven Johnson. I viewed his TED talk, thought it was interesting, and read the book. The premise is that idea generation isn't just a random thought or single event like a eureka moment. Instead, there is a method to it, an organizational scheme, a process. Johnson offers several models of how people get to ideas, innovations, and solutions. I like, for example, the concepts of the adjacent possible (What's the next possible thing we can do?) and exaptation (How can we apply what we're already doing to something else?).

I have always been fascinated with our journeys to space and to the moon. In high school I read *Lost Moon: The Perilous Voyage of Apollo 13* by James Lovell and Jeffrey Kruger. It's a narrative told from the point of view of all the people, including those in mission control, who figured out how to get the Apollo 13 astronauts safely back to Earth. It stresses the importance of not working in a silo—involving people in brainstorming and collaborative teamwork to solve a problem. It spurred my interest in space, and that is what led me to become a mechanical engineer. Some of my college projects were even related to space flight.

I really enjoy what I do. The industry I'm in may not have the cachet of going to the moon or Mars, but my work impacts people day to day—making sure they can turn on their lights, something that everybody needs.

MAXIM BUDYANSKY

Maxim Budyansky is the chief technology officer and a co-founder of Avitus Orthopaedics, a Connecticut-based medical device start-up. He won first place in ASME's 2010 Old Guard Oral Presentation competition for a talk about his senior design project. His graduate school project team developed an affordable maternal- and newborn-screening kit for the developing world, and won a $10,000 prize in a video competition sponsored by ABC News and the Duke Global Health Institute.

I am an entrepreneur with very little free time, but I still enjoy reading. I like to learn about different ways of thinking as in *The Four Agreements: A Practical Guide to Personal Freedom* by Don Miguel Ruiz and *Become What You Are* by Alan W. Watts. Also self-improvement books like Carnegie's *How to Win Friends and Influence People*. Every human being should read that book.

My master's program in bioengineering innovation and design at Johns Hopkins combined engineering, medicine, and business. I realized then that I enjoyed the business side of developing products. That requires creativity and innovation, too.

One of the program's professors recommended a new book or two for every course. One was *The Innovator's Dilemma* by Clayton M. Christensen. The Hopkins program preaches and preaches about understanding the need. As an engineer, you might think you know what something needs to be, but you're not the user. This book explains how important it is to get things into users' hands as soon as possible.

Another book I read is *Where Good Ideas Come From: The Natural History of Innovation* by Steven Johnson. It presents ideas we don't much think about. Like how important working environments are to innovative thinking and to generating good ideas. And how important timing is. If YouTube had come out ten years earlier, it would have been a massive failure because the Internet and the hardware and software infrastructure just didn't exist.

Creation, in general, is one of my passions, whether it's technology, art, or music. As a kid I had a whole world of LEGOs and was always building something with them. I absolutely love *Invention by Design: How Engineers Get From Thought to Thing* by Henry Petroski. It has accounts of what I think are marvels of creation. The craziest thing is that these are all objects we take for granted, but are really ingenious—the zipper, the aluminum can, the paper clip.

They are so incredible because they're so simple to the user. But simple doesn't mean easy. Simple sometimes is very difficult to develop. You don't even think of these as inventions, and yet so much work went into getting them where they are. Like how much to etch the top of a soda can so it is easy to open, yet won't burst under pressure. Every engineer, and especially every designer, should read this book. It makes you appreciate the world we live in.

TWISHANSH MEHTA

Twishansh Mehta manages supermarket refrigeration operations at Loblaw Cos. Ltd. in Brampton, Ont. He is the 2015 recipient of ASME's Old Guard Early Career Award, which recognizes engineers whose careers have advanced quickly and who have shown leadership in both ASME and community activities. He currently leads ASME's Community Development Team.

I decided to move toward management while I was still an undergraduate. My volunteering and leadership opportunities through ASME played a big part in that because I saw the positive effect those activities could have on others.

I am in graduate school right now, and working as well, so there isn't much time for extra reading. But before I started grad school a friend in a Ph.D. leadership program suggested several books, one being *Good to Great* by Jim Collins. Many of the book's example companies have failed since it was written, so I was skeptical. But when I compared the book's messages to what has worked for me on teams I've led in school, for ASME, and in the workplace, I found that Collins's ideas make sense. Like being humble, for instance. Or dealing with the truth, which sometimes means looking at the negatives. Or staying disciplined without wavering from the goal, which is what I think may have happened to some of those companies.

Another book I read is *Good Leaders Ask Great Questions* by John C. Maxwell. The person who hired me out of school was a vice president who commanded a certain level of respect. I noticed how he always asked questions, especially in meetings.

I'm a shy, introverted guy, and in school I read textbooks and figured

AHMED FARAG

Ahmed Farag is a subsea engineer for BP and works on offshore projects in the Gulf of Mexico. He was president of the student chapter of ASME at Georgia Tech, which has the largest undergraduate mechanical engineering program in the U.S.

A few months ago I reread *To Engineer Is Human: The Role of Failure in Successful Design* by Henry Petroski. I'd first read it in high school as a sophomore or junior when I was figuring out what my career should be.

I had aspirations at the time to become a doctor or surgeon. But both my parents are engineers, so engineering was in my blood. I read this book to learn what engineers do from a perspective different from my parents'. Reading it helped me realize that engineering was the route for me.

Petroski writes that failures are inevitable, and that there are always going to be unforeseen circumstances. But perhaps the best message from *To Engineer Is Human*, at least for this point in my career, is the importance of explaining things in layman's terms to people who might have no knowledge of what you're talking about. For example, Petroski is able to explain the 1981 collapse of the Kansas City Hyatt Regency walkway by using a simple analogy of people hanging on ropes. Being able to effectively communicate like that is crucial.

Another book I like is *Engineering and the Mind's Eye* by Eugene Ferguson, in which he relates engineering to artists. Engineering isn't just a combination of science and mathematics: there's an art to it. I read the book my junior year of college during a course on philosophy. The class was taught by an MIT engineering graduate and former engineer turned professor of philosophy.

This book wasn't assigned for the class, but this professor recommended it to me to show how art can broaden an engineer's thinking. Much as an artist does, engineers need to visualize and replicate their thoughts to get them across to others. Although this book was written before the widespread use of 3-D modeling, the basics are the same, and this book does a good job of showing you how.

We often don't realize the importance of reading something until after we've read it. I'm a subsea wells engineer for BP working on our deep water operations. When I was recruited on the Georgia Tech campus by BP, I knew they'd had the mishap [*Deepwater Horizon*]. But as *To Engineer Is Human* makes clear, accidents are inevitable. So the enthusiasm of the recruiters for their jobs and their company was more important to me. **ME**

out my own answers rather than approach somebody. But when he asked questions, it showed he was thinking and also that he cared. So I started to ask questions, too. This book is a validation of that.

Recently, I read *Quiet: The Power of Introverts in a World That Can't Stop Talking* by Susan Cain. I never thought of my introversion as detrimental. But neither had I considered how extravert-oriented our society is until reading this book, even though a large percentage of us are introverts. *Quiet* says that being an "I" is OK. (Maybe even better.) And we also need better mentorship by introverts to introverts, which is something I try to do.

In my current ASME volunteer role, I am tasked with creating interest and excitement for mechanical engineering. While looking for helpful resources, I found *The Engineering Book: From the Catapult to the Curiosity Rover, 250 Milestones in the History of Engineering* by Marshall Brain. It describes a wealth of engineering marvels arranged chronologically. This book can do wonders for telling stories to younger people about engineers. I wish someone had told me when I was young that so many great achievements throughout history are actually attributable to engineers.

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A SUPPLEMENT TO MECHANICAL ENGINEERING MAGAZINE

GLOBAL Gas Turbine NEWS

Volume 55, No. 2 • May 2016

In this issue

go.asme.org/IGTI
Email: igti@asme.org

Register Today for Turbo Expo 2016

There is still plenty of time to register for this year's Turbo Expo in Seoul, South Korea. Now in its 61st year, ASME Turbo Expo is recognized as the must-attend event for turbomachinery professionals. Whether you are a student, professor, engineer, or other industry professional, we have something for you. The show floor will feature a number of new exhibitors, making this one of our most diverse expos yet. Walk the floor with your complimentary drink and see how they are making an impact in turbomachinery. With the new keynote/plenary format, you will get the chance to attend three panel sessions with high-profile industry leaders – bring your questions. The women in turbomachinery will have a dinner on Tuesday night. Students or early career engineers can network with peers at the mixer on Wednesday night. Since the advance program is online, you can look over the technical sessions and decide now which ones to attend. The sessions explore a variety of new technologies that are paving new ground in the gas turbine industry. See which ones spark your interest. Facility tours that showcase the industry's advancement and progress will be offered throughout the Expo. Bringing a guest? They may like to immerse themselves in Korean culture with a tour of a palace or show. You also can come a day early and attend one of the five pre-conference workshops for a small additional registration fee. See you in Seoul!

2016 Keynote and Plenary Panel Sessions

MONDAY KEYNOTE: ENERGY AND PROPULSION IN THE INFORMATION AGE

Panelists

Eric Gebhardt
Chief Platforms & Operations Officer
Current, powered by GE

Thomas W. Prete
Vice President, Engineering
Pratt & Whitney

Daniela Gentile
CEO
Ansaldo Sviluppo Energia

Moderators

Tim Lieuwen
Professor
Georgia Institute of Technology

William A. Newsom, Jr.
Executive Vice President of Sales & Marketing
Mitsubishi Hitachi Power Systems Americas, Inc.

TUESDAY PLENARY: ASSET OPTIMIZATION AND MONITORING IN THE INFORMATION AGE

Panelists

Maria Sferruzza
Turbomachinery Contractual and Maintenance Services GM
GE Italy

Eisaku Ito
General Manager
Mitsubishi Heavy Industries R&D

Paul Stein
Director, Research & Technology
Rolls-Royce plc

Moderators

James R. Maughan
Technical Director, Aero-Thermal and Mechanical Systems
GE Global Research

James M. Free
Director
NASA John H. Glenn Research Center

WEDNESDAY PLENARY: GAS TURBINE MANUFACTURING IN THE ENERGY AGE

Panelists

Vinod Philip
Chief Technology Officer
Siemens Power and Gas

Akimasa Muyama
Executive Vice President & Head of Turbine Products
Mitsubishi Hitachi Power Systems

Moderators

Richard A. Dennis
Advanced Turbines Technology Manager
U.S. Department of Energy National Energy Technology Laboratory

Karen A. Thole
Department Head of Mechanical and Nuclear Engineering
Professor of Mechanical Engineering
Pennsylvania State University

ASME IGTI Welcomes New Board Members

ASME International Gas Turbine Institute is pleased to announce the appointment of three new board members with terms beginning this July.

James R. Maughan was born in Schenectady, N.Y., and is a second-generation GE employee. He received a B.S. from Brigham Young University, and a M.S. and Ph.D. from Purdue University, all in mechanical engineering. He joined GE in 1989 at the Corporate Research Center, in Schenectady, working in the area of low-emissions combustion research, aircraft engines combustion, and gas appliances. He joined GE Energy in 1997 to lead the introduction of low-emissions combustion systems into GE gas turbines, and held subsequent leadership positions in GE's gas turbine, steam turbine and energy services units. He was later global manager of energy-related research at GE's Research Center, general manager of Controls and Power Electronics in Salem, Va., and became general manager of Product and Warranty Service for GE Wind Energy in 2007. He began his current role as technical director of Aero-Thermal and Mechanical Systems in 2013 where he supports all of GE's industrial businesses and leads a global team of researchers in the development of breakthrough technology in combustion, aerodynamics, fluid mechanics, heat transfer, and mechanical systems. Dr. Maughan will be serving a three-year term and will also serve as treasurer.

Timothy C. Lieuwen is a professor in the School of Aerospace Engineering and the executive director of the Strategic Energy Institute at Georgia Tech. Dr. Lieuwen is a top international authority on clean energy, particularly low-emissions combustion. He has authored or edited four books and more than 300 papers. He was appointed by the Secretary of the U.S. Department of Energy to the National Petroleum Counsel, and is editor-in-chief of an American Institute of Aeronautics and Astronautics book series. Dr. Lieuwen has served in leadership positions with IGTI, including the IGTI Board and the Combustion, Fuels, and Emissions technical committee for over 15 years. Dr. Lieuwen is a Fellow of ASME, a Fellow of AIAA, and has been a recipient of the AIAA Lawrence Sperry Award and the ASME Westinghouse Silver Medal. Dr. Lieuwen will be serving a one-year term as the TECC liaison.

Anestis I. Kalfas is an associate professor in Turbomachinery. He teaches at the Laboratory of Fluid Mechanics and Turbomachinery of the Department of Mechanical Engineering at the Aristotle University of Thessaloniki. Dr. Kalfas received his Ph.D. in Turbomachinery aerodynamics from Cranfield University in 1994 and his degree in mechanical engineering from Aristotle University. He worked as a research associate at the Whittle Laboratory, University of Cambridge, and as an aircraft engineer in the Hellenic Air Force. He has been a senior scientist at the Turbomachinery Laboratory of the Swiss Federal Institute of Technology in Zurich since July 2000, where he lectured in Turbomachinery Design. Dr. Kalfas is active in the areas of axial steam and gas turbine aerodynamics, gas turbine performance and power plant optimization, boundary layer transition, and turbulence and novel aerodynamic probe technology. Dr. Kalfas will be serving a three-year term.

ASME IGTI would like to thank the three outgoing board members for their participation and contribution to the organization. Thank you professor Seung Jin Song from Seoul National University, Dr. Allan Volponi from Pratt & Whitney, and Dr. Anthony Sheard from AGS Consulting!

TECHNICAL ARTICLE

GE Power Services Ships First F-class Extended-Life Rotors

By Philip L. Andrew, GE Power

Power Services, a GE Power business, recently shipped from the Greenville, S.C., facility its first two F-class gas turbine life-extended rotors, building upon a foundation of experience gained by executing more than 20 E-class rotor life-extensions (RLEs).

Rotor Life Extension Solution

The GE F-class gas turbine rotor service interval is defined by an envelope of 5,000 factored fired starts (FFS) and 144,000 factored fired hours (FFH) of operation (see GER3620 and TIL 1576). Operation beyond this service interval results in increased risk to the rotor structure. Operators are presented with a choice of two strategies to effectively deal with this increased risk profile: risk-measurement and risk-management.

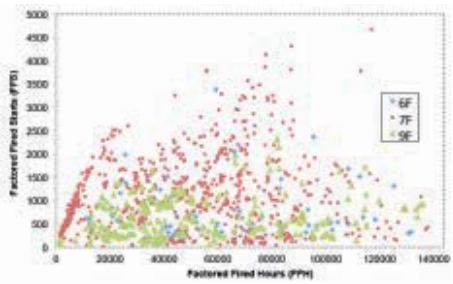


Figure 1. F-Class Rotor Fleet Experience

Risk Measurement

Risk-measurement is characterized by an inspection strategy that varies in scope, from a superficial inspection without disassembly, to a more-rigorous disassembly with full inspection, but in all cases without any replacement of higher-risk components. Upon return to service, this RLE approach is typified by a monitoring regimen wherein degradation of the rotor condition serves as a proxy for risk. Under this approach, some independent service providers (ISPs) offer life-extension advice based on inspecting a single feature only, such as the forward rabbet fillet of the first-stage turbine wheel. Experience has shown that additional features require inspection, but these features that require inspection, including rabbet fillets on wheels other than on stage one, cannot be inspected without a complete rotor disassembly. Requirements for follow-up inspections – such as those that require additional major inspections and rotor swaps – limit risk-measurement strategies based on inspect/repair and re-use. It also forces operators to accept higher risk via exposure to non-inspectable flaws in higher-risk components. In fact, since most critical failure modes are associated with non-inspectable flaws, this is a major limitation of the risk-measurement approach. GE's RLE provides benefits that exceed those provided through a risk-measurement scope.

Risk Management

OEMs possess domain knowledge such as engineering, manufacturing, and material data that enable a more-comprehensive risk management strategy. GE uses a tiered risk-management approach that incorporates a portfolio of three available options: replacement-in-kind, performance upgrades, and life-extension. These can be applied individually or in concert to best suit an operator's specific strategic objectives. Each rotor is uniquely characterized by the combination of its particular configuration and operational history. Based on a thorough analysis of this history, components deemed low-risk are thoroughly inspected and returned to service. Medium-risk components are thoroughly inspected and repaired, to increase their fatigue/creep life. Higher-risk components are replaced during the re-build process, since this is the most important method for providing lower operating risk during extended operation. During reassembly, cold section blade clocking is reset for improved compressor durability, consistent with US patent 8,439,626. GE's F-Class RLE portfolio offering provides for one or two maintenance-interval (MI) extensions on hours, and one MI extension on starts. This is equivalent to as many as 96,000 additional FFH, or up to 2,400 additional FFS, *without requiring any follow-on inspection*, by virtue of the replacement of higher-risk components. Figure 2 demonstrates GE's approach to designing RLEs.

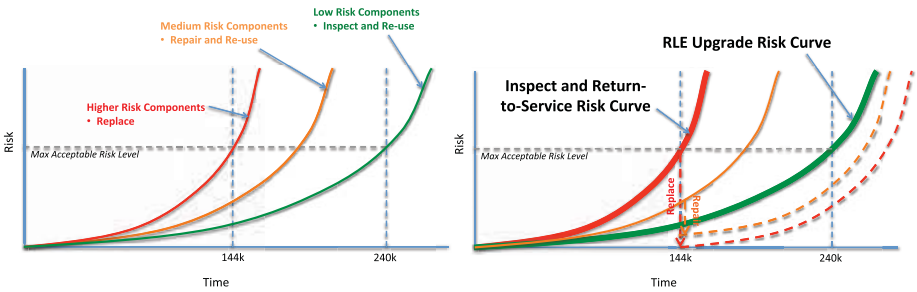


Figure 2. GE's RLE Upgrade Approach

GE's RLE Upgrade Approach

Expanding the value of an RLE upgrade also requires that it is executed at the right point in the rotor's life. As stated above, the medium-risk components can have their fatigue/creep life-extended through a repair process. However, fatigue-damaged areas can increase in size over time, and can exceed repair limits if operated past GER3620 service limits. RLE upgrades should therefore be performed between 96,000 and 144,000 FFH, or 2,500 and 5,000 FFS, in order to ensure that the upgraded rotor can attain an ultimate 240,000 total FFH or 7,400 total FFS.

Inspection Methods

The Greenville service shop has the advantage of collaboration with the new-make manufacturing team to ensure that current assembly/disassembly techniques and tooling are applied. This co-located collaboration has been especially beneficial in the development of the inspection and re-build portion of the life-extension process for the initial F-class rotors. GE applies normal shop methods such as Fluorescent Penetrant and Magnetic Particle Inspection (MPI), and Wheel Bore UT Inspections, augmented by Eddy Current Inspections for selected features. The compressor rotor is analyzed by UT examination for selected wheel bores, combined with MPI. Replicas are taken in certain locations to check surface integrity, in combination with hardness checks. Lessons-learned in Greenville are migrated to satellite service shops located globally.

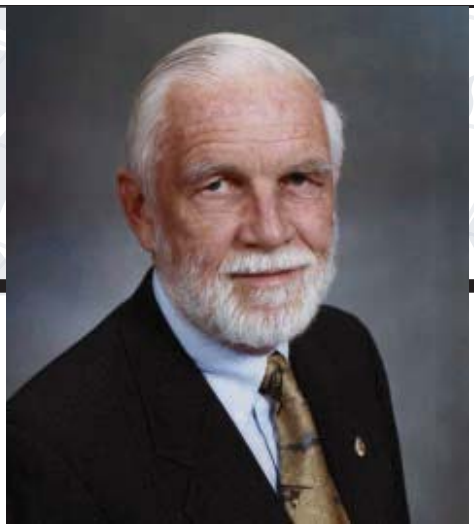
F-class Experience

GE's F-class gas turbine rotor experience began in Greenville in 1988 with the first F-class rotor assemblies and has accrued over the next 30 years with many rotor repairs, part replacements, and re-builds, resulting in company-proprietary tooling designs and processes. In anticipation of an aging F-class fleet, GE engineering and manufacturing have collaborated to offer rotor life-extension services for the F-class. This experiential learning has yielded the development of an effective rotor disassembly sequence, proprietary heating and cooling methods for rotor disassembly, and the evolution of disk-inspection and repair-procedures. Supplementing this manufacturing and design experience is, for a typical F-class gas turbine, an average of more than 10 years of monitoring and diagnostic operational data. This includes transient and steady-state temperature data that have been validated with base-load engine testing to generate boundary conditions for predictions of rotor thermal behavior. GE believes that this understanding of thermal transients is key to assessing rotor life, and that these analyses in support of RLEs form vital inputs in selecting part-replacement and repair strategy. This analytical approach is specific to each unit, as it is a function of that unit's specific configuration and operational history. For the two rotors evaluated to date, there have been no unexpected issues uncovered from the part inspections as compared to analytical predictions.

Looking Ahead

The first two F-class extended-life rotors shipped from Greenville were completely disassembled, with all components inspected, and repaired or replaced as appropriate. The GE process is based on unit-specific operational experience, validated analysis, and learned-out manufacturing techniques. This process is a differentiator that customers are welcome to observe in Greenville or in other global locations, in preparation for extending the life of their GE E or F-class gas turbine rotor, or any similar rotor technology.

AS THE Turbine TURNS



Gas Turbine Disc Resurrection?

by Lee S. Langston, *Professor Emeritus, Mechanical Engineering, University of Connecticut*

In axial flow gas turbines, discs in the compressor and turbine support and position rings of rotating blades and transmit energy to or from engine shafts. Their rotational speeds and power levels are high, so that each disc, composed of an inner bore, a web and an outer rim, are made of high-strength alloys, carefully manufactured to be as defect free as possible.

Typically records are kept on operation for both aviation and non-aviation engines. Depending on the record keeping system used by government, airlines, OEMs, and users, gas turbine discs are retired before they reach a critical state that might lead to their failure.

Gas turbine lore and legend has it that there are large warehouses storing many of these expensive used discs, particularly those from high usage applications, such as popular single aisle aircraft jet engines, many military jets, and high-sales electric power gas turbines. The thought is that many of these discs, presumably with significant life left, could be resurrected for future use. The means of resurrection might be some reliable reevaluation process (combining a new life law with testing, or a new yet-to-be discovered metallurgical procedure).

Let us look at just how feasible this concept might be. First, let us briefly consider what a disc failure can bring about. Then we can look at the disc life laws and the procedures used to retire them. We will end with an assessment of what is the possibility of their resurrection, i.e. the return of these discs to active service after their "certified" life has ended.

A Turbine Disc Failure

In an earlier column [1], I reported on the inflight turbine disc failure of a Rolls-Royce Trent engine on Qantas Flight QF32 on November 4, 2010. The super jumbo four engine Airbus A380 had just taken off from Singapore, bound for Sydney.

About 6 minutes after takeoff at 7,500 feet altitude over the Indonesian island of Batam, the Trent 900 intermediate pressure turbine disc on engine No. 2 failed, sending engine parts shrapnel through the engine nacelle and the left wing. Passengers saw several perforations take place on the upper surface of the wing above engine No. 2, resulting in one hole as large as 65 by 80 cm. Now powered by three of the four engines, the A380 circled to dump fuel (which was also leaking out of two wing tanks, above the failed engine). The Qantas plane then returned to Singapore, to land without thrust reversers, using emergency pressurized nitrogen to lower landing gear since the hydraulic system had been compromised by the uncontained engine failure. Controls to engine No. 1 had been damaged, so that the pilots were unable to shut it down after landing. Airport firefighters flooded engine No. 1 with foam to shut it down, further increasing the overall damage cost.

Fortunately, all Flight QF32 passengers and crew were safe and uninjured after the uncontained turbine disc failure. We can see that armed with enormous rotational kinetic energy, the disintegrated parts of a failed disc (see Fig. 1) and its blading become dangerous flying projectiles.

Disc Lifing Approaches

Vittal, Hajela, and Joski [2] review current approaches to gas turbine life management. They point out the high reliability and safety of modern gas turbines is largely due to a combination of improved materials, conservative design and maintenance philosophies, and improved life prediction capabilities.

However, there are significant safety and economic concerns involved in the use of life predictions applied to extend disc life. For instance, disc cracking caused by the most common failure modes of low and high cycle fatigue, creep, and manufacturing

defects is difficult to predict, so that statistical methods must also be relied upon.

One probabilistic life management algorithm [2] is the Life-To-First-Crack (LTFC) approach. LTFC is based on the premise that a safe service disc life can be gotten by testing a sample of engine discs in a spin pit.

It is assured that the discs are initially defect free. To get a life standard time, a disc is removed from spin pit operation, at a time just before the appearance of a fatigue-initiated "engineering crack" greater than 0.38mm in length, with a 95% confidence. This leads to a safety procedure whereby aircraft engine turbine discs are being retired at a time when one in 1000 discs has initiated a short fatigue crack of 0.38mm. This implies that over 99.9% of these expensive, high-strength alloy discs are retired before their useful life has been expended. The 1/1000 life limit is a "safe life" approach that is considered conservative [3] and even quite wasteful [2]. (It is a possible supply source for the large warehouses referred to earlier).

An alternate, newer life management algorithm is Retirement For Cause (RFC). RFC [2] allows an aircraft engine disc to be used for the full extent of its safe fatigue life, bypassing the conservatism of the LTFC algorithm. The new safe life is based on fracture mechanics analyses at critical disc locations, the engine service cycle and the inspection/overhaul cycle. A key element in RFC is the ability to predict crack initiation and growth in a probabilistic manner.

These very brief explanations of LTFC and RFC serve to give a flavor of two disc lifing models. These and newer life laws are used by the military, OEMs, government agencies, and gas turbine operators.

Disc Resurrection Prospects

Suppose you are in charge of an MRO (maintenance, repair and overhaul) for an airline company. It has a supply of used turbine discs, stored after removal from service, based on the airline's lifing policy. You know that currently there are no metallurgical procedures to restore their life by removing any residual cracks. Should you drill holes in the used discs, assigning them to scrap, or consider their resurrection in the company's fleet?

If the company has a complete set of operating and service records on the discs and are comfortable with the OEM design criteria used to predict disc service life, you might choose to consider resurrection. Then, should you inspect all the discs for surface distress and cracks, and possibly test one to failure in a spin pit? What is the company's liability if an accident occurs, caused by a failure of an resurrected disc engine?

Figure 1. Recovered R-R Trent 900 intermediate pressure turbine disc segment from Qantas A380 Flight QF32. *(Photo provided by Australian Air Transport Safety Bureau, courtesy of Aviation Week & Space Technology.)*

These are some of the considerations to be made if used discs are to be returned to service after their certified life. Another resurrection path is the question of appropriating used discs to manage safe continued operation from unexpected field damage until new discs become available.

As the reader can see, disc resurrection may be an attractive prospect, but lots of questions need to be answered before gas turbine users, be they military, airlines, or non-aviation, adopt the practice.

1. Please note that a disc failure is a disc failure. The incident I chose here was probably not due to a disc life issue.

References

1. Langston, Lee S., "Gas Turbine Progress through Trouble", *Global Gas Turbine News*, February 2011, p. 51.

2. Vittal, S., Hajela, P., and Joski, A., "Review of Approaches to Gas Turbine Life Management", AIAA 2004-4372, *10th AIAA/ISSMO Multidisciplinary Analysis and Optimization Conference, 30 August - 1 September 2004*, pp. 876-886.

3. Thompson, R.B., and Brasche, L.J.H., "Nondestructive Evaluation", Chapter 13, *Turbine Aerodynamics, Heat Transfer, Materials, and Mechanics*, Shih, T.I-P. and Yang, V. editors, AIAA, 2014, pp. 556-558.

A VIEW FROM THE CHAIR

By Piero Colonna, Chair, ASME IGTI Board

As you know from the March issue of GGTN, a Task Force was formed in order to provide recommendations about the best organizational model, staffing, and volunteer-staff arrangements. The result of the choices cannot be underestimated, even if they are less apparent to the typical volunteer, as they will influence how our community continues on the trajectory of past successes, and even increases its impact and cooperation in today's complex and dynamic world. The outcome of the Task Force activities was presented to the IGTI Board, Tim Graves (director of conferences & events), and Mike Ireland (associate executive director of engineering) by Bobby Grimes (senior vice president, TEC sector) who chaired the Task Force. A healthy and constructive discussion arose, and I trust that I will be able to report on actual positive changes in the next few months.

At the moment I am considering several areas where we could focus our efforts and our resources, though no decision is taken yet about new directions. We will certainly provide continuity with respect to the goals pursued by my predecessor, namely improvements to our Turbo Expo conference in terms of the experience of the attendees, selectivity in the paper review process, and expansion with new technical events and activities both in terms of disciplines and geography. In this respect, once the proper organization is in place, I would like to resume efforts related to organizing a conference on aero engines operation and maintenance in Asia and a conference targeting industrial gas turbines and aero engine users in South America.

As for new ventures, I would like to stimulate cooperation with divisions or groups in other segments, as I see a great potential for cooperation on interdisciplinary topics. Such collaboration would lead to workshops or webinars on specific areas, or to full fledged conferences in case of extensive interest. As an example, I was recently contacted by our Tim Lieuwen in order to discuss opportunities for cooperation at the intersection between advanced manufacturing and gas turbines, together with representatives of the Design, Materials and Manufacturing Segment. Workshops or webinars of course should not be only on cross-fertilization topics, but every IGTI committee should consider it, and I know of some ideas for a webinar on turbine design that have been discussed by the ORC Power Systems committee. ASME webinar facilities are a solid starting point.

Two ideas that I am entertaining and that I would like to discuss soon with the board are 1) the possibility of awarding grants for mini-sabbaticals either of academics in companies, or vice versa; and 2) the establishment of a global competition dealing with a technological challenge with inspiring principles (see, for example, the World Solar Challenge, http://www.worldsolarchallenge.org).

As a side note, I would like to bring your attention on an opportunity that not many of us are aware of: if you are an ASME member, and have selected IGTI (Code #22) in your membership form, you are entitled to a one-year subscription to either the ASME *Journal of Turbomachinery* or the ASME *Journal of Engineering for Gas Turbines & Power* for only $85.00 USD (application form at https://community.asme.org/international_gas_turbine_institute_igti/w/wiki/4042.journals.aspx)

In conclusion, I am happy to report that our first Turbo Expo conference in Asia is on track to become a success, with a number of high quality papers, technical sessions, and tutorials that will be roughly comparable to that of recent editions, if not greater. The number of applications to our recently streamlined Young Engineer Turbo Expo Participation Award (YETEP) has substantially increased to 86 (66 in 2015, 24 in 2014, 22 in 2013). We will confer up to 20 YETEP awards and up to 40 IGTI SAC travel subsidies to students who actively contributed to the growth of committees.

I very much look forward to meeting you all at Turbo Expo 2016 in Seoul!

ASME IGTI Awards & Scholarships

2016-2017 IGTI STUDENT SCHOLARSHIP
The deadline to submit an application is June 15, 2016. In the 2016-2017 school year up to 20 scholarships at $2,000 (USD) each will be awarded to qualifying students registered at an accredited university (either in the U.S. or elsewhere).

2017 DILIP R. BALLAL EARLY CAREER AWARD
Nominations for the 2017 award are due to igtiawards@asme.org by August 1, 2016. The Early Career Award is intended to honor individuals who have outstanding accomplishments during the beginning of their careers. The recipient of the Early Career Award will be honored at Turbo Expo 2017.

For more detailed information on these opportunities, please visit:
https://community.asme.org/international_gas_turbine_institute_igti/w/wiki/4029.honors-and-awards.aspx

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SPRING 2016

ASME TRAINING COURSES FOR ENGINEERS AND TECHNICAL PROFESSIONALS

MAY 2016 – ATLANTA, GEORGIA USA

PD475	The Engineering Manager: Engaging Today's Workforce	23-24 May
PD539	Bolted Joints and Gasket Behavior	23-24 May
PD027	Heating, Ventilating and Air-Conditioning Systems: Sizing and Design	23-25 May
PD077	Failure Prevention, Repair and Life Extension of Piping, Vessels and Tanks ASME STANDARDS COURSE	23-25 May
PD389	Nondestructive Examination - Applying ASME Code Requirements (BPV Code, Section V) ASME STANDARDS COURSE	23-25 May
PD442	BPV Code, Section VIII, Division 1: Design and Fabrication of Pressure Vessels ASME STANDARDS COURSE / TOP SELLER	23-25 May
PD513	TRIZ: The Theory of Inventive Problem Solving	23-25 May
PD685	The Engineering Manager: Engaging Today's Workforce and Strategic Thinking Combo Course *(combines PD475 and PD676)* SAVE UP TO $450!	23-25 May
PD720	Layout of Process Piping Systems	23-25 May
PD763	Centrifugal Pumps: Testing, Design and Analysis	23-25 May
PD014	ASME B31.3 Process Piping Design ASME STANDARDS COURSE / TOP SELLER	23-26 May
PD184	BPV Code, Section III, Division 1: Rules for Construction of Nuclear Facility Components ASME STANDARDS COURSE / TOP SELLER	23-26 May
PD359	Practical Welding Technology	23-26 May
PD657	HVAC Systems and Chiller Performance Combo Course *(combines PD027 and PD387)* SAVE UP TO $440!	23-26 May
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PD581	B31.3 Process Piping Design, Materials, Fabrication, Examination and Testing Combo Course *(combines PD014 and PD457)* SAVE UP TO $575! ASME STANDARDS COURSE / TOP SELLER	23-27 May
PD601	Bolting Combo Course *(combines PD539, PD386 and PD577)* SAVE UP TO $1,275!	23-27 May
PD686	Layout of Process Piping Systems and Optimization of Plant Layouts Utilizing 3D CAD/CAE Systems Combo Course *(combines PD720 and PD721)* SAVE UP TO $650!	23-27 May
PD386	Design of Bolted Flange Joints	25 May
PD676	Strategic Thinking	25 May
PD766	Post Weld Heat Treatments in ASME Codes	25-26 May
PD190	BPV Code, Section IX: Welding, Brazing and Fusing Qualifications ASME STANDARDS COURSE	25-27 May
PD387	Understanding Chiller Performance, Operation and Economics	26 May
PD382	How to Predict Thermal-Hydraulic Loads on Pressure Vessels and Piping	26-27 May
PD441	Inspections, Repairs and Alterations of Pressure Equipment ASME STANDARDS COURSE	26-27 May
PD577	Bolted Joint Assembly Principles Per PCC-1-2013 ASME STANDARDS COURSE	26-27 May
PD606	NQA-1 Requirements for Computer Software Used in Nuclear Facilities ASME STANDARDS COURSE	26-27 May
PD673	Design and Selection of Heat Exchangers	26-27 May
PD721	Plant Design Project Management and Design Using 3D CAD/CAE Laser Scanning Technology	26-27 May
PD457	B31.3 Process Piping Materials Fabrication, Examination and Testing ASME STANDARDS COURSE / TOP SELLER	27 May

Visit: go.asme.org/atlanta7

JUNE 2016 – HOUSTON, TEXAS USA

PD115	The Gas Turbine: Principles and Applications	6-7 Jun
PD570	Geometric Dimensioning and Tolerancing Fundamentals 1 ASME STANDARDS COURSE	6-7 Jun
PD706	Inline Inspections for Pipelines	6-7 Jun
PD395	API 579-1/ASME FFS-1 Fitness-for-Service	6-8 Jun
PD410	Detail Engineering of Piping Systems	6-8 Jun
PD615	BPV Code, Section III, Division 1: Class 1, 2 & 3 Piping Design ASME STANDARDS COURSE	6-8 Jun
PD619	Risk and Reliability Strategies for Optimizing Performance	6-8 Jun
PD763	Centrifugal Pumps: Testing, Design and Analysis	6-8 Jun
PD765	Gas Turbine Engines – Controlling Pollutants	6-8 Jun
PD448	BPV Code, Section VIII, Division 2: Pressure Vessels ASME STANDARDS COURSE	6-9 Jun
PD603	GD&T Combo Course *(combines PD570 and PD561)* SAVE UP TO $825!	6-9 Jun
PD432	Turbo Machinery Dynamics: Design and Operation	6-10 Jun
PD665	BPV Code, Section I: Power Boilers ASME STANDARDS COURSE	6-10 Jun
PD561	Geometric Tolerancing Applications and Tolerance Stacks	8-9 Jun
PD583	Pressure Relief Devices: Design, Sizing, Construction, Inspection and Maintenance ASME STANDARDS COURSE	8-10 Jun
PD673	Design and Selection of Heat Exchangers	9-10 Jun

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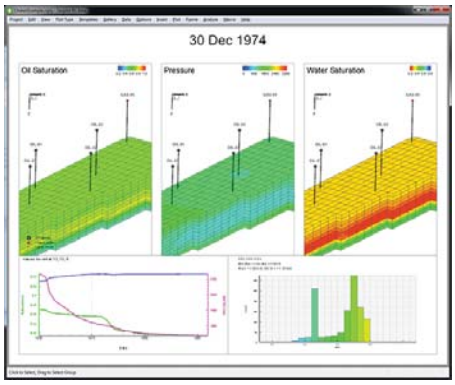


RESERVOIR MANAGEMENT

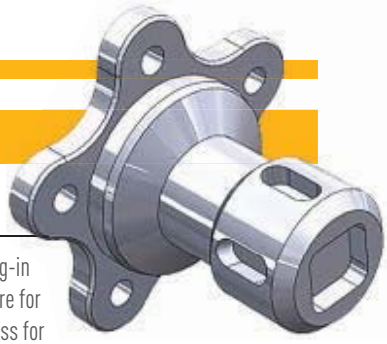
TECPLOT, BELLEVUE, WASH.

Tecplot RS is designed to help users manage and analyze oil and gas reservoir simulation data. The software's publisher says its newest version, 2015 Release 2, features enhanced plotting and analysis capabilities. For instance, the multi-variable quick XY plots feature enables users to look at the time history of grid variables for user-selected cells. Those quantitative plots also have been enhanced to display lines for multiple grid variables and to compare multiple grid solutions in one plot. The goal, the company says, is for engineers to determine the potential profitability of petroleum reservoirs via simple-to-understand data visualization.

SUBMISSIONS

Submit electronic files of new products and images by e-mail to **memag@asme.org**. Use subject line "New Products." *ME* does not test or endorse the products described here.

AUTOMATED MACHINING



BOBCAD-CAM, INC., CLEARWATER, FLA.

BobCAM for SolidWorks operates as a plug-in product for the SolidWorks design software for use in automating the programming process for mill, router, laser, plasma, waterjet, lathe, mill turn, and wire EDM CNC machines. The latest release, Version 5, offers two new add-on modules: Mill Turn, a CAM programming product, and BobART, an artistic CAD application. The Mill Turn module supports nearly all types of mill turn machines, including machines with y-axis capabilities and multi-axis machines that include a milling spindle. The BobART add-on can be used for engraving logos, creating raised or sunken text, or even sculpting and creating artistic models. Other new features include improvements to surfacing toolpaths and hole-making capabilities.

HEAT TRACING

PENTAIR, MENLO PARK, CALIF.

Raychem Trace-It 1.1 is an add-on to the Autodesk Revit platform that enables users to easily incorporate heat-tracing content into their building information modeling simulations. The add-on is available for free download. Trace-It 1.1 offers a more accurate bill of materials for a wider and more complex range of pipe networks than the original version, the company says, which should simplify project planning and installations to reduce raw materials. The software also enables engineers to change the graphical placement of controls and connectors for visual space planning, and the upgrade allows users to open customized specifications, create a Revit schedule, or place critical Revit families into their project.

Energy Sources and Processing

ASME ESP

FROM THE ENERGY SOURCES AND PROCESSING SEGMENT TEAM LEADER – MAY 2016

> "You will meet fellow mechanical engineers who have a passion for sharing their experiences and passing on their sage knowledge of the oil and gas industry. You will, in fact, be establishing a professional network that will prove its value over and over again."

As ASME embraces its new organizational structure, the Energy Sources and Processing (ESP) Segment continues to engage and reach out to other ASME groups that share common content focused on energy sources and designing products, materials, systems, and services for the energy sources and processing industries. The Petroleum; the Pipeline Systems; Ocean, Offshore, and Arctic Engineering; and Pressure Vessels and Piping divisions are the first four chartered divisions/groups in the ESP. As ESP moves into its second year, it is focused on top technologies that enable ASME to be the go-to organization for innovation and establishing standards in mechanical engineering in petroleum, natural gas, petrochemicals, coal, shale, LNG, pipelines, processing plants and pressure vessels.

This comes at one of the most challenging and opportune times when most of the upstream industry is faced with sets of challenges outside the technical scope. As a 20-year veteran of the oil and gas industry, I can say the one thing that has remained constant in my career has been ASME. With a focus on energy, global impact and workforce development, ASME has provided me and many others with opportunities to contribute to our industry. This has been in the form of technical activities and the development of students and early career engineers.

When I was an early career engineer, leaders in the Petroleum Division encouraged me to apply for the ASME Leadership Development Intern position (now ECLIPSE). The experiences I gained helped me develop skills for my employer and as a technical leader within ASME. Volunteering in ASME, in many ways, was tantamount to interviewing for employment or my next promotion. The engineers, scientists and society leaders (both staff and volunteers) that you'll work with on conferences and student and professional development will remember you when there is a gap to be filled at their employer or a leadership role within ASME.

If you are an engineering student, become a segment volunteer. The ESP segment welcomes you. You will meet fellow mechanical engineers who have a passion for sharing their experiences and passing on their sage knowledge of the oil and gas industry. You will, in fact, be establishing a professional network that will prove its value over and over again. If you are a young professional, continue your education and take advantage of your experiences to give back in both the technical events and content segments, as well as other

Continued next page

ASME ESP

"I encourage all members to remain engaged with ASME, the Energy Sources and Processing segment and our four divisions. Now is the time to find out what ASME can do for you and with you."

sectors such as the student and early career development sectors.

For all long-term members of our professional society, we encourage you to share your passion for improvement. There is nothing so rewarding as mentoring and encouraging new talent and watching enthusiasm blossom into innovation and achievement. Our professional society has a legacy of multigenerational, multidiscipline inclusiveness that is reflected in worldwide interest in our conferences, events and training initiatives. There is no better way to give back than to collaborate, share and develop skills and knowledge across all engineering disciplines worldwide through these technical conferences.

This coming year alone ESP's divisions will be deeply involved in OTC Asia in Kuala Lumpur; OTC in Houston, Texas; the International Conference of Ocean, Offshore and Arctic Engineering (OMAE) in Busan, Korea; the ASME 2016 Pressure Vessels and Pipeline (PVP) Conference in Vancouver, B.C., Canada; the Unconventional Resources Technology Conference (URTeC) in San Antonio, Texas; the International Pipeline Conference (IPC) in Calgary, Alberta, Canada; and the OTC Arctic Technology conference (ATC) in St. John's, Newfoundland and Labrador, Canada.

Even more exciting, we are launching a new lecture series framed for Asset Integrity Management. The series kicks off in May, addressing "Oil & Gas Infrastructure with UAVs (unmanned aerial vehicles)." Future lectures are planned to explore the 2011 Fukushima Japan Nuclear Failure, HPHT impact on integrity management, validation and verification best practices, and guidelines for Pressure Boundary Bolted Flange Joint Assemblies.

In the next few pages, you'll learn just how our society recognizes unparalleled level of mechanical engineering innovation and achievement, year after year. The awards honor mechanical engineering achievement by all levels of participants — from august industry leaders to early career professionals —and are bestowed on a truly international stage at the annual Offshore Technology Conference in Houston.

In closing, I encourage all members to remain engaged with ASME, the Energy Sources and Processing segment and our four divisions. Now is the time to find out what ASME can do for you and with you.

For more information on ESP student and early career professional development opportunities, please contact KiezerJ@asme.org. For more information on all ESP technical content and activities contact bellj2@asme.org ■

Jennifer Bell
Energy Sources and Processing Segment Leadership Team - Leader
May 2016

ASME ESP

2016 ASME AWARDS

Recognizing Talent, Honoring the Best

Each year, ASME recognizes the top mechanical engineering talent and achievements in the energy industry. These awards, distributed at the Offshore Technology Conference in Houston every May, honor outstanding performance, groundbreaking ideas and cutting-edge development — and represent the future of both the mechanical engineering profession and the energy industry. At time of publication, only the Keith Thayer and Silver Patent awards had been announced for 2016. All honorees will be officially recognized at the ASME OTC awards reception held Monday, May 2, at NRG Stadium in Houston.

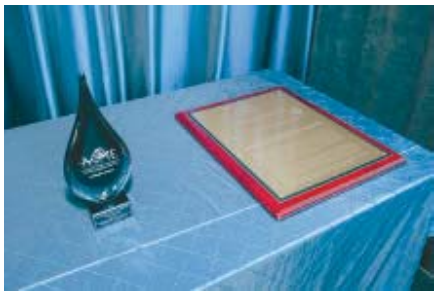
GEOCA MECHANICAL ENGINEERING ACHIEVEMENT AWARD (Oil Drop)

Established in 1965 as an extraordinary award for distinguished and meritorious achievement or service in the field of petroleum mechanical engineering, this award is named after Karl Geoca the former chair of the Petroleum Division and former member of the ASME Board of Governors. This awards honors experienced applicants who have made significant contributions to the field of mechanical engineering. One ME recipient per year is chosen.

Past Recipients:

2015 Blake Deberry, DRIL-QUIP, INC.
2014 Jean-Francois Saint-Marcoux, Subsea 7 (retired)
2013 Benton F. Baugh PE, PhD., Radoil
2012 RJ (Bob) Brown, RJ Brown Deepwater, a Technip company

WOELFEL BEST MECHANICAL ENGINEERING ACHIEVEMENT AWARD (BMEA)



The BMEA is presented to a company or organization for outstanding petroleum mechanical engineering achievement displayed at the Offshore Technology Conference. Each year, one achievement award plus four awards of merit are bestowed. Congratulations to the 2015 BMEA Winner!

2015 Achievement	Versabar for Versacutter
2014 Achievement	Baker Hughes for Harpoon Cut and Pull
2014 Innovation	FMC Technologies for Offshore Loading Arm Footless (OLAF)
2013 Achievement	Managed Pressure Operations (Aker Solutions) for Riser Safety System (RSS)
2012 Achievement	Baker Hughes for the MaxCOR Large-Diameter Rotary Sidewall Coring Service

LUBINSKI BEST PAPER AWARD

Each year, the Petroleum Division honors the best petroleum mechanical engineering paper presented at OTC. Named in honor of Arthur Lubinski, the founder of the ASME Study Committee for the Exchange of Offshore Information, which led to the formation of OTC, the award honors high standards of quality in the papers presented at OTC. Mr. Lubinski received the Petroleum Division award for his work in 1968.

Continued next page

LUBINSKI BEST PAPER AWARD

Continued

2015 Winning Paper:

OTC 25643 *Next Generation HPHT Subsea Wellhead Systems Design Challenges and Opportunities*

Author: Jim Kaculi

2014 Winning Paper:

OTC 25403 *Subsea Wellhead and Riser Fatigue Monitoring in a Strong Surface and Submerged Current Environment*

Authors: Scot McNeil, Puneet Agarwal, Dan Kluk, Kenneth Bhalla, Ron Young, Steve Burman, Stergios Liapis, Saurabh Jain, Vikas Jhingran, Stephen Hodges, Early Denison

2013 Winning Paper:

OTC 23943 *Design Guideline Strategies for HPHT Equipment*

Authors: H. Brian Skeels, Kwok Lun Lee, Anand Venkatesh FMC Technologies

2012 Winning Paper:

OTC 23223 *Compact Separation Technologies and their Applicability for Subsea Field Development in Deepwater*

Authors: A. Hannisdal, R.Westra, M. R Akdim, A. Bymaster, E. Grave, D.Teng

SILVER PATENT AWARD

Patents are a major achievement in the career path of a petroleum mechanical engineer. ASME's Petroleum Division seeks to encourage and recognize engineers holding multiple patents. The division honors an ASME Petroleum Division member who has received at least 25 U.S. patents with the Silver Patent Award.

2016 Recipient: Chris Bartlett, FMC Technologies

Past Recipients:

2014 Colby Ross, Halliburton

2012 Tom Bailey, Weatherford

KEITH THAYER EXCEPTIONAL EARLY CAREER ENGINEER AWARD

Named after Keith Thayer, ASME past President and Petroleum Division past Chair, this award is presented in recognition of outstanding achievement, dedication, effort and performance by an early career professional. The Keith Thayer Exceptional Early Career Engineer Award was established in 2007.

2016 Recipient: Hieu Tran, Universal Pegasus

Past Recipients:

2013 Vicki Blocker Risinger, FMC

2012 Jason Strouse, WGIM ■

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ASME ESP

Since 1880...

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- Enabling inspired collaboration, knowledge sharing and skill development across all engineering disciplines, all around the world
- Promoting the vital role of the engineer in society
- Helping to make the world a safer and better place

The Energy Sources & Processing Segment

ESP Divisions include Petroleum; Pipeline Systems; Ocean, Offshore & Arctic Engineering and Pressure Vessels and Piping.

The Energy Sources and Processing Segment focuses on developing and delivering technical content that is vital for industries involved with petroleum, natural gas, petrochemicals, coal, shale, LNG, renewables, pipelines and processing plants.

For more information about any ESP activities contact
houstonasmeoffice@asme.org

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1-800-THE-ASME

The American Society of Mechanical Engineers (ASME)

ASME ESP

Energy Sources & Processing Conferences and Events

TECHNICAL CONFERENCES

2016

International Offshore Pipeline Lunch and Learns Quarterly 2016, Houston, Texas

Offshore Technology Conference 2016, Houston, Texas, **May 2-5**

International Conference of Ocean, Offshore and Arctic Engineering 2016, Busan, Korea, **June 19-24**

2016 ASME Power and Energy Conference & Exhibition, Charlotte, N.C., **June 26-30**

ASME 2016 Pressure Vessels and Pipeline Conference, Vancouver, British Columbia, Canada, **July 17-21**

Unconventional Resources Technology Conference (URTeC), San Antonio, Texas, **August 1-3**

International Pipeline Conference, Calgary, Alberta, Canada, **September 26-30**

Arctic Technology Conference, St. John's Newfoundland and Labrador, **October 24-26**

2017

International Offshore Pipeline Lunch and Learns Quarterly 2017, Houston, Texas

India Oil & Gas Pipeline Conference 2017, Mumbai, India, **February**

International Pipeline Geotechnical Conference 2017, Lima, Peru, **July**

Rio Pipeline Conference 2017, Rio de Janeiro, Brazil, **Fall**

OTC Brasil 2017, Rio de Janeiro, Brazil, **Fall**

2018

OTC Asia, Kuala Lumpur, Malaysia

Attention Early Career Engineers:

The ASME Petroleum Division Early Career Committee will enhance your career path! The group provides opportunities for career growth and development through networking at both formal and informal events outside of the regular workplace.

Qualifications: 10 years or less industry experience

ASME- Early Career Committee leaders:
Co-Chairs: Kyle Richter and Madeleine Kopp
Members: Hana Ego, Glen De la Santos, Rigo Lopez, Kashan Qazi, Andrea Spring

Contact Javanni Kiezer, KiezerJ@asme.org for more information.

NETWORKING EVENTS

Annual ASME OTC Golf Tournament
Houston, Texas
April 30, 2016 – held annually the Saturday before OTC

Early Career Mixers
Houston, Texas

Annual ASME Sporting Clays Tournament
Houston, Texas
October 7, 2016

COLLET CHUCK

LEXAIR, LEXINGTON, KY.

The new 16C wrench-operated collet chuck from Lexair features an integral A2-5 nose to accommodate standard 16C collets up to 1.625 in., bolt-on closing rings, ID mandrels, and a universal flat back design. It is concentrically adjustable for accuracy. For use on hybrid CNC/manual teach lathes, the chucks can also be used with a variety of lathes, mills, grinders, indexers, and other rotating spindle equipment. The 16C collet is operated via a t-handle chuck wrench and does not require draw bars or cylinders.

OPEN WINCH CRANE

KONECRANES, SPRINGFIELD, OHIO.

Konecranes added a round of new features to its SMARTON open winch cranes. The new elements are designed to help operators achieve faster load handling with less risk of damage to the load, crane, and surrounding area. The features are enabled by an infrared camera mounted on the crane; the camera monitors LED sensors located on the hook block. Hook centering automatically eliminates side pull and load swing, and snag prevention constantly monitors the rope angle and slows down the movement of the bridge if the rope reaches a pre-set angle. A system to control sway stabilizes load movements in trolley traverse and/or bridge travel directions.

SUBMISSIONS

Submit electronic files of new products and images by e-mail to **memag@asme.org**. Use subject line "New Products." *ME* does not test or endorse the products described here.

APPLICATION ENGINEER (CONVEYOR TECHNOLOGIES), TKIS (USA), Greenwood Village, CO. Req. BA (or foreign equiv) in Mech. Engg + 3 yrs exp engg conveyor systms/components. Travel to S. America & Germany. Resume to E. Thomason, HR, Ref 141549, 6400 S. Fiddler's Green Cir., #700, Greenwood Village, CO 80111.

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The U.S. Army Research Office (ARO) located in Research Triangle Park, Durham, North Carolina, is seeking a visionary scientist or engineer to be the Director of Engineering Sciences. ARO's mission represents the most long-range Army view of research for changes in future capabilities, with system applications typically 20 or more years away. ARO competitively selects and funds basic research proposals from educational institutions, nonprofit organizations, and private industry. In this position, the incumbent will serve as the Army's senior scientific professional for the conduct of that extramural research in the engineering sciences to include the fields of electronics, mechanical sciences and materials science. In the conduct of program planning, development and execution, the Director will consult with other eminent scientists and executive level officials throughout the Army and other DOD agencies, other Federal agencies, the world's leading research universities and other educational institutions, and private industry.

He/she will develop and manage extramural basic research programs to create new fundamental scientific and engineering discoveries and advances that take into account current Army technology deficiencies and potential impact on future requirements. The incumbent's actions, recommendations and decisions strongly influence the direction of the Department of the Army's research programs and basic research policies, have an immediate impact on the scope of research activities at the national level, and a long-range impact on the scientific community in general. The preferred education level for this position is a Ph.D. or equivalent in a relevant engineering or closely aligned scientific discipline, with experience in managing Ph.D. engineers and scientists, including managing other supervisors and administrative staff. The minimum qualifications are based on federal qualification standards for series 0801, 1301, or 1520, and are http://www.opm.gov/qualifications. This is a temporary employment opportunity (federal appointment or temporary promotion will be for five years). Further information about ARO and the Army's extramural research focus can be found at **http://www.arl.army.mil/www/default.cfm?page=214. Salary: $145,273-170,400** depending on qualifications and experience. Department of the Army is an Equal Opportunity Employer.

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d. Dates of employment (Month/Year-Month/Year) for each work experience listed that qualify you for the position.
e. Education (Degree Type; Major field/Discipline; institution, and year granted)
f. Contact information (email address and telephone number)
g. Names of three references (must include names, positions, and email/telephone contact information)
h. (optional) cover letter, one page maximum
DO NOT INCLUDE SOCIAL SECURITY NUMBER, DATE/PLACE OF BIRTH, OR PERSONAL ADDRESS ON YOUR RESUME.
Point of Contact is Wanda Wilson, ARO Admin Officer at (919) 549-4296, or wanda.e.wilson.civ@mail.mil

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e. Education (Degree Type; Major field/Discipline; institution, and year granted)
f. Contact information (email address and telephone number)
g. Names of three references (must include names, positions, and email/telephone contact information)
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ENERGY TECHNOLOGY A FOCUS OF ENGINEERING MEETING IN CUBA

The opening of relations with Cuba may present an opportunity for engineers who want to discuss trends in the profession. The National Union of Architects and Engineers of Cuba will hold its 4th International Engineering Convention in June, and UNAICC is encouraging members of engineering societies throughout the world to take part.

To be held June 23 to 25 at the Plaza Convention Center America in Varadero, the conference is focused on the theme, "Current Engineering Trends and Challenges."

In particular, the organizing committee is asking engineers to submit abstracts for a special forum, titled "Forum III: The Engineer's Role in the Energy Matrix." Papers to be presented during the energy forum may address a variety of topics, including renewable energy, hybridization and storage; energy management systems and processes; conventional and alternative fuels; energy for transportation; energy integration for distributed and autonomous systems; international, regional and local regulatory agencies and financial guidelines and incentives; and bioclimatic architecture.

The forum is intended to provide a venue for publicizing advanced energy technologies with entrepreneurial interests.

The conference will also feature three other forums, addressing sustainability and environmental engineering challenges, professional development for early career engineers, and empowering the woman engineer.

In addition, the event will include several roundtable sessions discussing such topics as construction technology research; hydraulic engineering for water management; and mechanical, electrical, and industrial engineering connected to new technology.

Engineers who are interested in presenting a technical paper at the conference should submit an abstract to the meeting's organizers by May 10. For more information on the International Convention of Engineering in Cuba, or to submit an abstract, visit www.ciiccuba.com (a Spanish-language website) or contact Antonio Ferras Valcárcel, Forum III coordinator, by e-mail at simei@unaicc.co.cu. ME

FOUR PROJECTS WIN EED EDUCATION AWARDS

The ASME Environmental Engineering Division selected four proposals for its first annual Education Support Program Awards. The $5,000 awards go to students, educators, and EED members who propose interesting ways to impact environmental education in their communities.

The program, which can fund a maximum of five proposals a year for a maximum of $25,000, is designed to help foster the impact of environmental engineering and education in communities around the world and enable people to identify and solve environmental problems.

The Awards Committee, which is comprised of ASME volunteers from the EED Executive Committee, reviewed the proposals from around the world. The winners included both engineers and non-engineers.

The four winning proposals are:

- **Michael S. Czahor** and **Austin Herrema** of the Wind Energy Student Organization, Iowa State University in Ames, for "Wind Energy Student Organization"
- **Megan Fuller** of Philadelphia University for "Lab Component for Sustainability Course"
- **Michael Lazere** of Marshalltown High School in Iowa and **Mark Mba Wright** of Iowa State University for "Using Interactive iPython Simulations to Model Life Cycle Analysis of Ethanol Production"
- **David A. Roke** and and **Theresa Cutright** of the University of Akron for "High School Student Laboratory Education Module: Use of Abundant Waste Materials in Concrete Mix Design"

For more information on the EED Education Support Program, please contact Martin Edelson, Education Support Committee Chair, by e-mail at mcedelson@gmail.com or Arnold Feldman, EED Chair, at jjdsenv@att.net. ME

ASME LAUNCHES PROGRAM FOR BOLTING SPECIALISTS

ASME has begun a new training program, the ASME Bolting Specialist Qualification Program, which is specifically developed to enhance a bolter's ability to safely and effectively assemble and disassemble pressurized joints.

Preventing gasket leaks in these types of joints is one of the single most effective ways to improve safety and shorten turnaround times during shutdowns. The key to achieving these improvements is enhancing the bolter's understanding of both the functions and limits of bolts, gaskets, and flanges.

"While welders have long had the training they need to prevent leaks, bolters now have the formal training they need," said **Michael Ireland**, associate executive director, Engineering. "ASME's new qualification program was developed by a group of bolting industry experts—with over 193 collective years' of bolting experience—whose prime motivation is preventing bolted flange connection gasket leaks and who recognize the need for this training program."

The ASME Bolting Specialist Qualification Program will help participants understand and demonstrate the principles and practices of safe bolted joint assembly as outlined in Appendix A of ASME PCC-1: Guidelines for Pressure Boundary Bolted Flange Joint Assembly.

It consists of four online modules and a one-day hands-on training session. Candidates will receive the ASME Certificate for the Qualified Bolting Specialist upon the successful completion of the online courses, the online final examination, and the hands-on training.

While the program is intended to enhance participants' familiarization with the general principles and best practices of bolted joint assembly, it is not a certification program. The determination of an individual's competency remains the responsibility of his or her employer.

For more information about the new ASME Bolting Specialist Qualification Program, visit http://go.asme.org/boltingspecialist. ME

NOMINEES SELECTED FOR THE NEW FACES OF ENGINEERING PROGRAM

DiscoverE has selected six ASME members and student members as finalists in the 2016 New Faces of Engineering program, which annually highlights the contributions early career engineers and engineering students are making to the profession and to society.

The New Faces of Engineering-Professional category recognizes the accomplishments of practicing engineers up to the age of 30. The selected ASME members are: **Bryony DuPont**, an assistant professor of mechanical engineering at Oregon State University in Corvallis; **Dylon Rockwell**, an airframe design and integration engineer at the Boeing Company in Ridley, Pa.; and **Yi Zheng**, is an assistant professor at the University of Rhode Island in Kingston.

The New Faces-College Edition program highlights the achievements of third-, fourth- and fifth-year engineering students. The ASME student members who were nominated are: **Drew Haxton** of Daniel Webster College in Nashua, N.H.; **Nicholas Russell** of Tennessee Technological University in Cookeville; and **Jacob Steinmetz** of Iowa State University in Ames.

The finalists from ASME and the other societies participating in this year's DiscoverE New Faces of Engineering program were announced during Engineers Week in February.

To learn more about the finalists from each participating organization, visit http://discovere.org/our-programs/awards-and-recognition. ME

SPECIAL ISSUE OF JBE FEATURES GRAND CHALLENGE COMPETITION

A new special issue of the ASME *Journal of Biomechanical Engineering*, published in February 2016, features a series of papers from the sixth and final Grand Challenge Competition to Predict In Vivo Knee Loads.

The competition, which launched in 2010, provided researchers with the opportunity to predict in vivo knee contact forces, as measured by instrumented knee replacements, using musculoskeletal modeling methods but without having access to the experimental contact force measurements.

The five previous competitions were held during the annual ASME Summer Bioengineering Conference. The shift to a journal-based competition eliminated the time and financial constraints associated with traveling to a conference and made it easier for researchers from around the world to participate. Those steps encouraged broader participation.

The special issue features papers from the four teams that completed this year's competition, including the competition's winning research paper, "Intra-Articular Knee Contact Force Estimation During Walking Using Force-Reaction Elements and Subject-Specific Joint Model," by Yihwan Jun, Cong-Bo Phan, and Seungbum Koo from Chung-Ang University in Korea.

The competition was organized by B.J. Fregly at the University of Florida in Gainsville, Darryl D'Lima at Shiley Center for Orthopedic Research and Education at Scripps Clinic in San Diego, and Thor Besier at the University of Auckland in New Zealand. It was funded by the National Institute of Biomedical Imaging and Bioengineering at the National Institutes of Health.

For more information on this special issue of the *Journal of Biomechanical Engineering*, visit http://biomechanical.asmedigitalcollection.asme.org/issue.aspx?journalid=114&issueid=934913. ME

GOLF LESSONS

Last February, Rajat Mittal and Neda Yaghoobian set out to help the best golfers in the world overcome what many consider the sport's toughest hole: the 12th at Augusta National. They spent months developing precise trajectory models, detailed representations of the plant canopy, and complex fluid dynamics equations, then crunched all the numbers on a supercomputer.

Now Mittal, an aerodynamics expert and mechanical engineering professor at the Johns Hopkins University Whiting School of Engineering, is ready to share some invaluable advice with legions of duffers: "It's simple. Don't even think about it—just go out there and hit the ball. Don't overanalyze the game."

The computer model may not keep the average amateur out of the rough, but it could yield electronic devices, apps, or online programs for professional golfers, equipment makers, and golf-course architects that predict the impact wind patterns and tree canopies have on different objects. It could also be used to make wind farms and other forms of energy generation more efficient.

In 2012, Mittal, a recreational golfer, read an article in *Golf Digest* that illustrated how the swirling winds around the 12th hole at Augusta National—home of the Masters Tournament—continue to vex the world's greatest golfers. Most golf experts attribute the unpredictable wind conditions to tall trees around the 155-yard, par-3 hole. Mittal thought a more rigorous analysis would show if they were right.

Rajat Mittal (left) and Neda Yaghoobian simulated golf ball trajectories on Augusta National's notorious 12th hole (above). *Will Kirk/Johns Hopkins University*

Last year, Yaghoobian, a visiting scholar in Mittal's lab who focuses on urban energy, microclimate, and flow research, used a trajectory model based on Newton's second law of motion (net force equals mass times acceleration), the Navier-Stokes fluid dynamics equation to model airflow, several years' worth of local weather and wind conditions; and details of local tree canopies culled from Google Maps and Google Earth. Supercomputers took 48 hours to crunch the data and create the final simulation.

The resulting system confirmed that the tree canopy at Augusta National's treacherous 12th hole caused the swirling winds. It also revealed that winds from the northwest, southwest, and west create more troublesome eddies and turbulence than wind from other directions, and headwinds cause more unpredictability than tailwinds.

Although professional golfers aren't allowed to use devices or apps in a tournament, they can use the model in advance of a game to help determine the club, swing, and shot direction they'd choose for a particular hole.

The research also answered a question that's been nagging Mittal ever since he picked up a club.

"I always wondered how effective it is to throw a tuft of grass in the air," he said. "It provides very little useful information, at least on this hole." ME

JEFF O'HEIR

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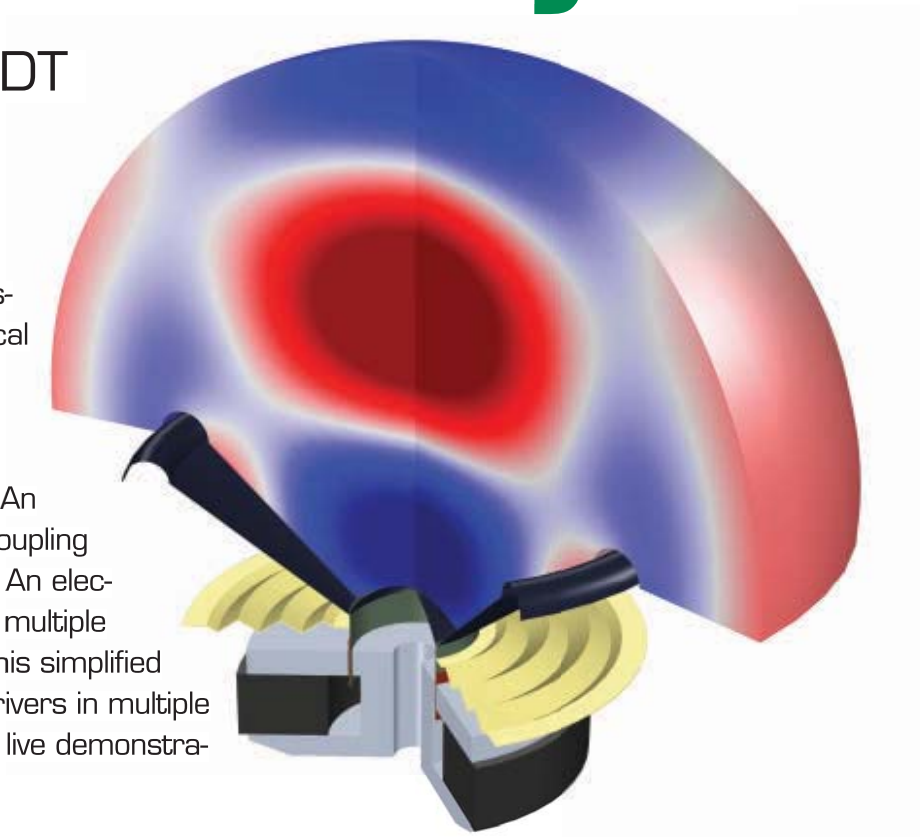

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