MECHANICAL
ENGINEERING
THE MAGAZINE OF ASME
No. 02
139
Technology that moves the world

GREEN POWER
FROM COMMON TRASH
New waste-to-energy technology is a clean alternative to landfills.

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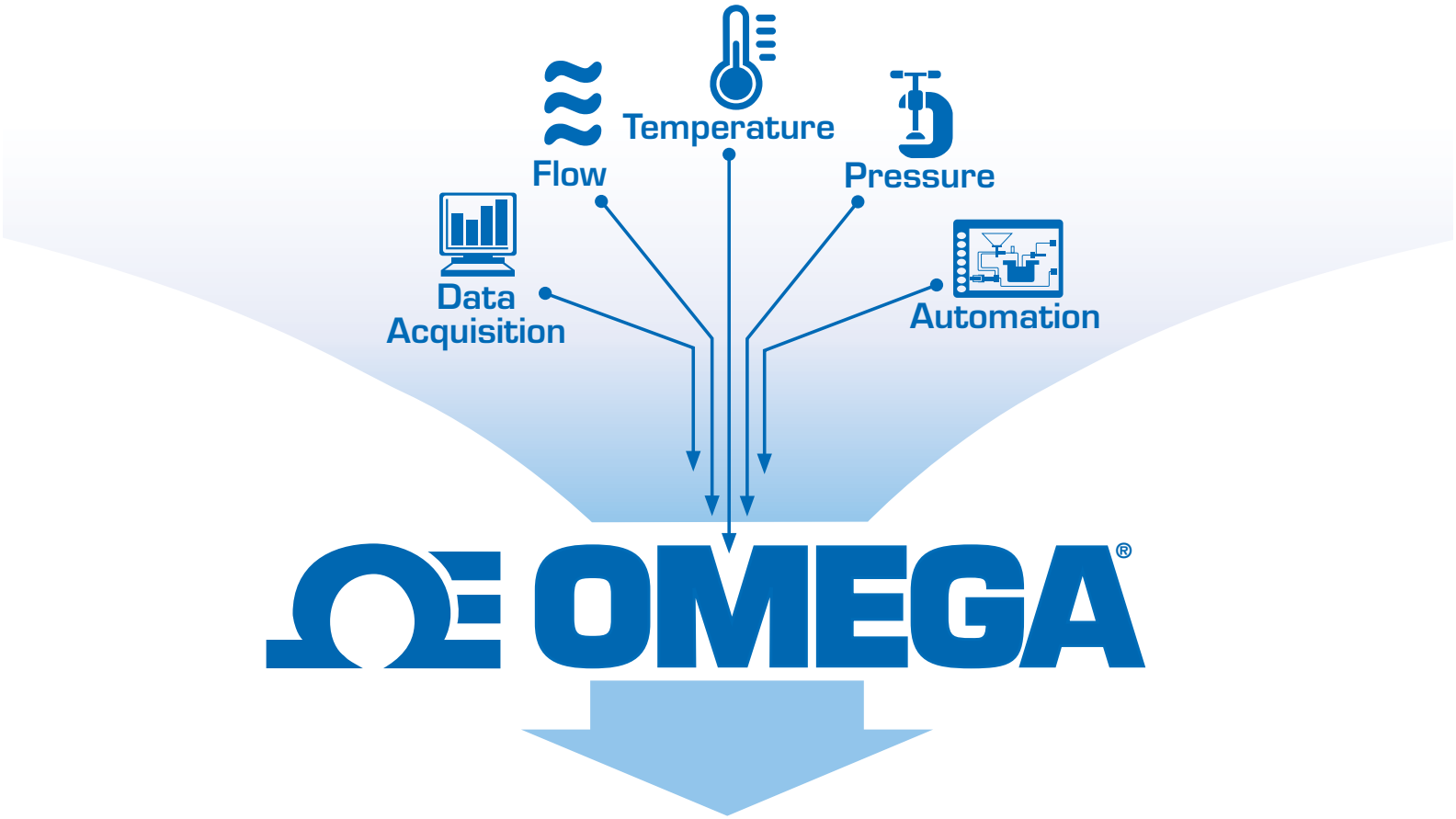

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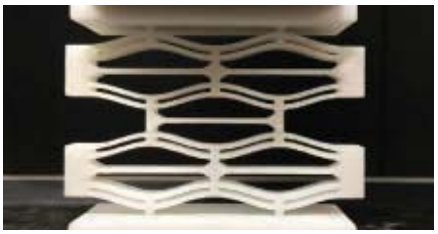
MAKING ELECTRIC MOTORCYCLES GREAT

A **PROUD TREE-HUGGER AND SPEED** junkie with passion for everything engineering, 35-year old Eva Hakansson is officially the world's fastest female motorcycle rider. Hakansson leads her life with two missions in mind: To show that battery-powered electric vehicles are fast and fun and that engineering is a great career choice for women. That first mission led her to design and build KillaJoule, a streamliner electric motorcycle that has been determined to be the world's fastest.

TAKING TRAUMA OUT OF THE BRAIN

Researchers at Tel-Aviv University have shown how the brain activity behind stress and fear can be turned down with biofeedback. Thanks to them, future soldiers may be able to avoid stress-related conditions like PTSD.

For these articles and other content, visit asme.org.



HONEYCOMBS INSPIRE SAFETY DESIGNS

Researchers at the University of Texas at Austin believe the negative stiffness honeycombs they are working on could increase the safety of a wide variety of products, from automobiles to helmets.

SCOTLAND GETS SERIOUS ABOUT TIDAL ENERGY

A number of companies are deploying underwater turbines in Scotland's coastline to convert the energy in tidal currents to electricity that can be connected to the country's power grid.

PODCAST: A SMARTER GRID IS A SAFER GRID

S. Massoud Amin, the father of the smart grid, talks about how the electrical grid remains vulnerable to attack, and how a smart, self-healing grid can protect it.

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HOW IOT IMPROVES DRIVER SAFETY

Yifan Chen, technical lead at Ford Motor Company, discusses how in-vehicle technology is changing the driving experience and what impact IoT will have on driver safety.

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Researchers have developed a human-on-a-chip, on which tissue from seven human organs are grown on a polymer substrate the size of a thumb-size USB computer drive.

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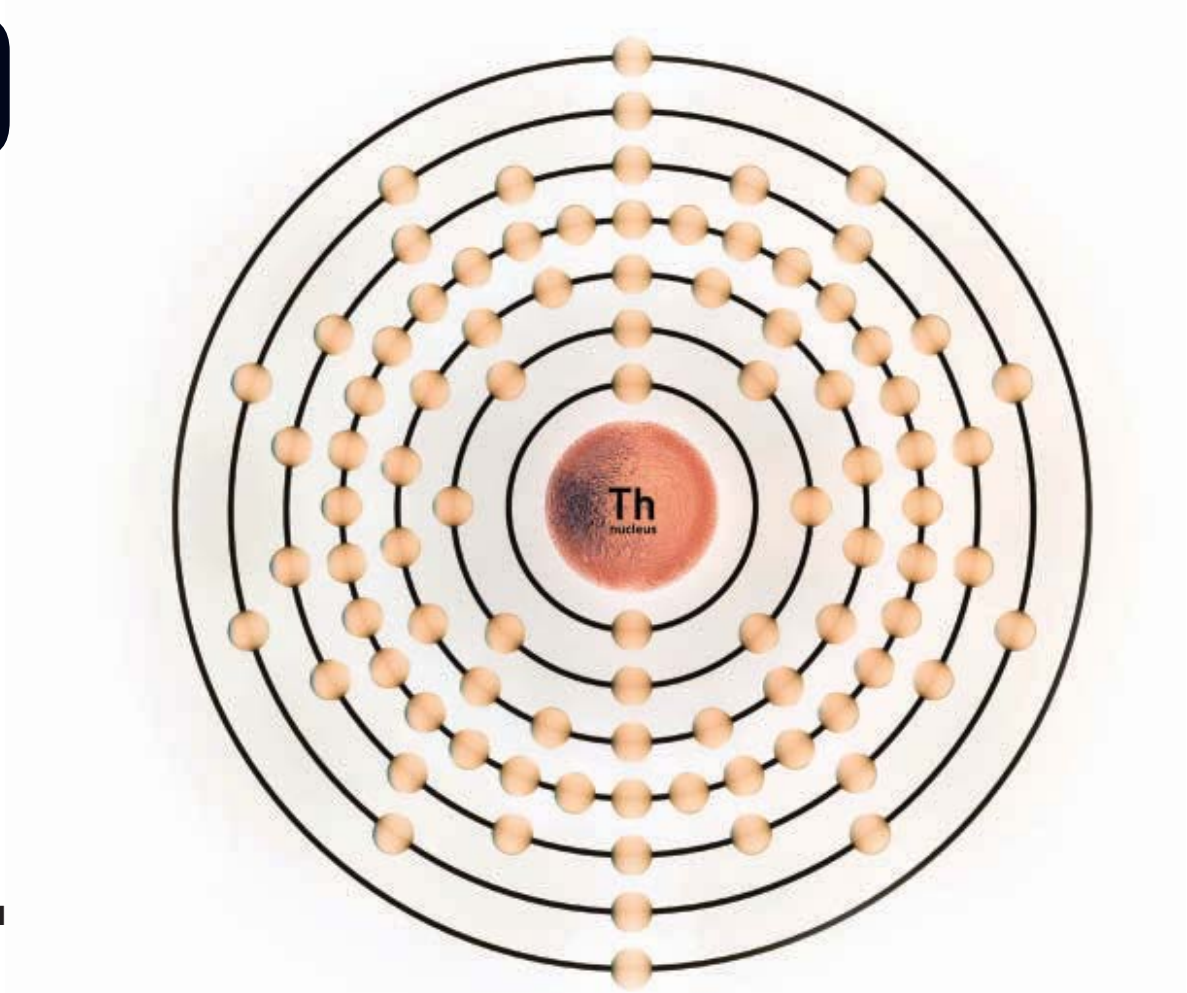

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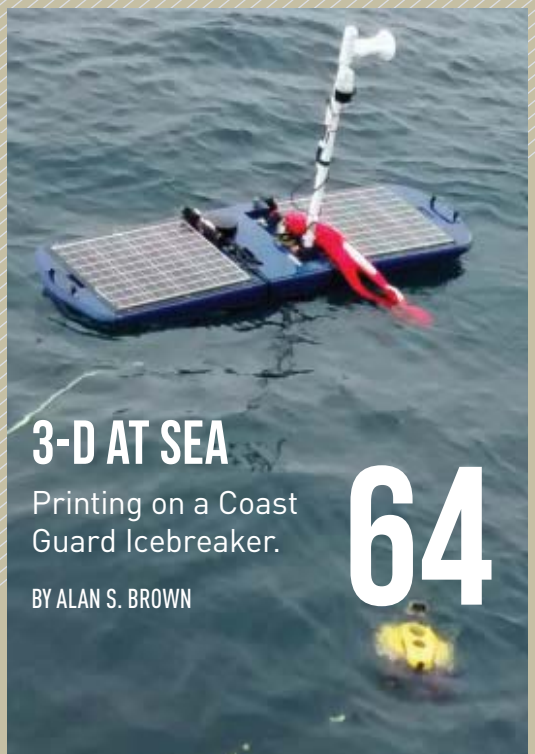
COAL JOBS

Employment in Appalachian coal mines has plummeted. Is it feasible to bring those jobs back?

BY JEFFREY WINTERS



3-D AT SEA

Printing on a Coast Guard Icebreaker.

BY ALAN S. BROWN

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

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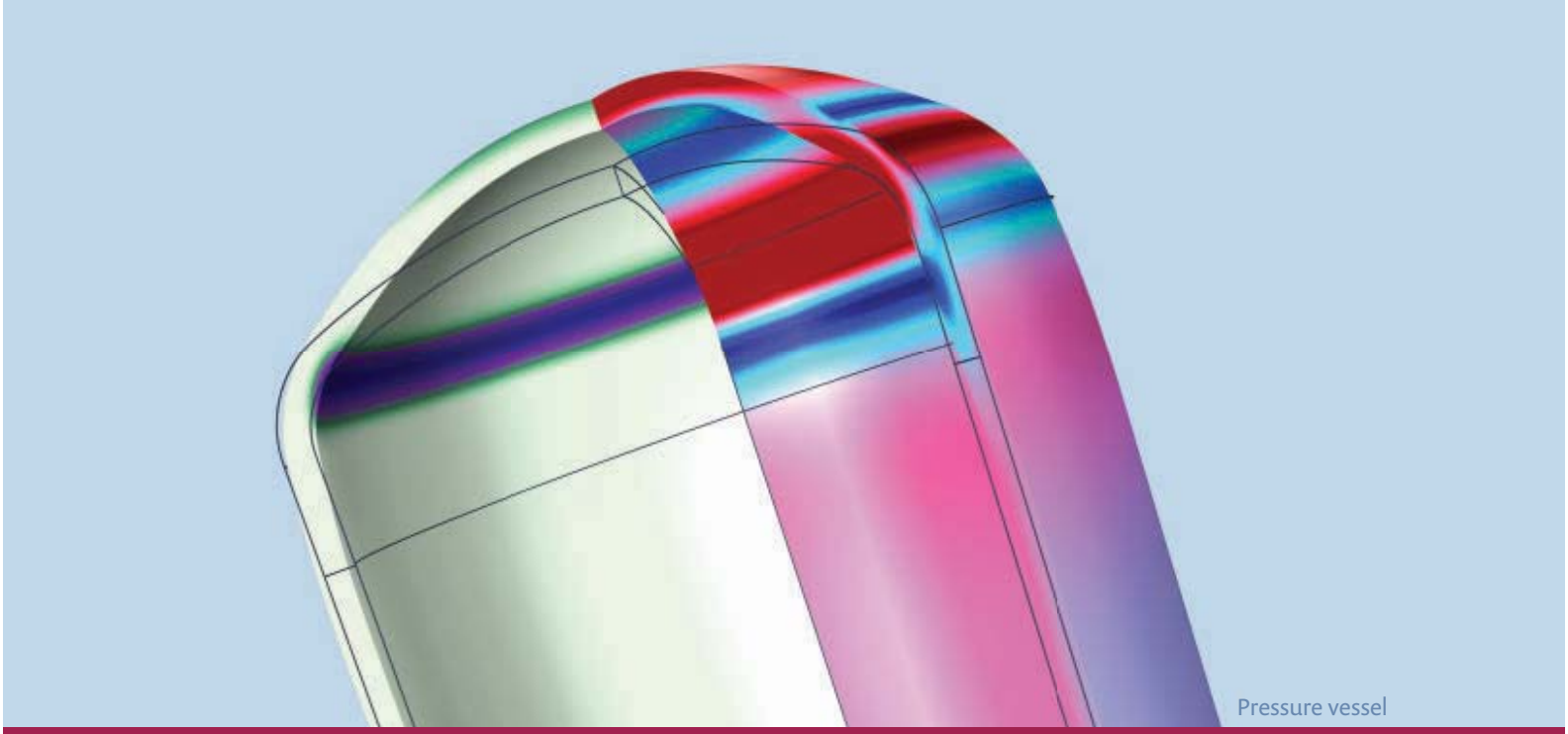

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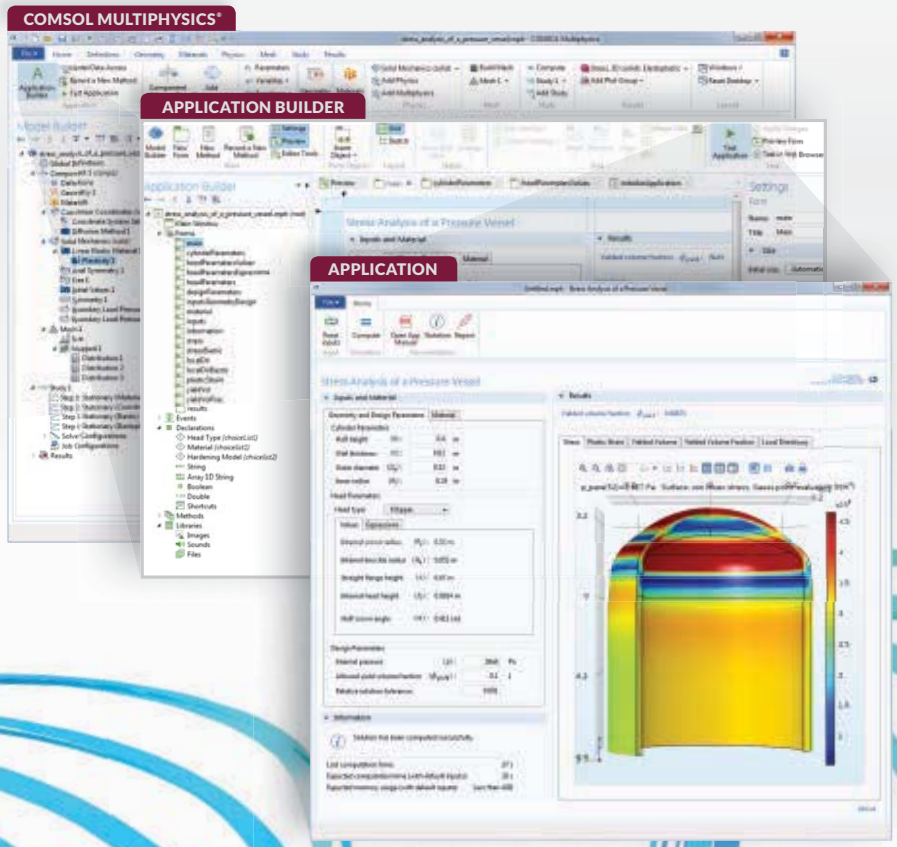

COMSOL

John G. Falcioni
Editor-in-Chief

TRASH ISN'T JUST GARBAGE

What we dump into our trash cans can deliver an endless supply of energy, but it hasn't always been popular to take advantage of it.

Waste-to-energy plants have a controversial history in the United States. The first plant was built in the mid-1970s in Saugus, Mass., and is still active today. But in the 1980s, residents in suburban towns across the United States where trash-to-energy plants were being proposed debated vigorously whether the financial benefits to the municipality outweighed environmental risks.

Even though these waste management facilities were quite different from the trash incinerators commonly used until a few decades earlier, the stigma of those old pollution-emitting burners would not die easily. Add to that the rumors that organized-crime-backed trash haulers were getting into the business and the technology faced a steep hurdle to gain acceptance.

Even today, despite significant technology advances, and rules that qualify some waste-to-energy plants as renewable energy, there is still some skepticism.

But the case in favor of waste-to-energy plants can be compelling. Few make a better argument than John (Bucky) Kitto—an ASME Fellow and a former member of the Board of Governors—and Larry Hiner, who co-authored this month's cover story, "Clean Power from Burning Trash," on page 32. Kitto was the Babcock and Wilcox development manager for the Palm Beach Waste-to-Energy Project they describe and Hiner is the project developer for industrial steam generation at B&W.

The facility generates enough electricity to power 44,000 homes in Palm Beach County, Fla., and reduces the volume of waste to be landfilled by 90 percent. All the while, earning millions of dollars annually from the sale of electric power to the local power company and reclaiming metals left in municipal waste after recycling. From an environmental perspective, the plant helps eliminate the burial of problematic wastes that emit volatile organic compounds and chemicals. Plus the emissions are as low, or lower, than the cleanest gas-fired turbine generators.

It is the "cleanest, most efficient plant of its kind in the world," Kitto and Hiner boast.

Unlike the U.S., where fewer than 80 facilities are in operation, communities in Europe short on landfill space have turned to waste-to-energy plants. Nearly a quarter of all municipal solid waste in Europe is burned in nearly 500 facilities across the continent. Countries with the highest rates of garbage incineration—Denmark, Norway, and Sweden incinerate at least half their waste—also have high rates of recycling and composting of organic materials and food waste.

The Palm Beach Renewable Energy Facility No. 2 is the first greenfield waste-to-energy plant for municipal solid waste built in the United States in two decades. I've yet to visit the facility, but from conversations with Kitto, and photos he showed me that didn't make the final layout, it's clear that this architecturally beautiful plant is nothing like the ones I toured years ago.

But even as the design of this facility is the envy of many modern office buildings, it pales in comparison to a waste-to-energy plant in Copenhagen, Denmark. It features a roof-wide artificial ski slope open to the public. If that doesn't change the perception of incineration plants, then maybe the renewable energy efficiency will. ME

FEEDBACK

Do waste-to-energy plants represent a viable renewable alternative for the U.S.? Email me.

falcionij@asme.org

LETTERS & COMMENTS

SEPTEMBER 2016

Reader Meyer worries that computer-driven cars might crash like old PCs.

« One reader looks ahead to self-driving cars, while another looks back at engineering's progress in diversity.

CORRECTING THE CORRECTIONS

To the Editor: Two of the three letters in the September 2016 issue contain errors.

Akshay Harlalka criticized a previous comment author for including the natural log term in the equation for compression work. But any thermo text book, or indeed some gentle integration, will tell you that work done in (presumably isothermal) compression is indeed proportional to $\log_n(p2/p1)$.

Dennis Hill, following many others, is keen to disprove evolution on the grounds that it contradicts the second law of thermodynamics—or perhaps the other way around. But they are entirely consistent; the Second Law states that any increase in the order of a system must be more than balanced by an increase in the disorder of its environment, generally by the intake of high quality energy and material and the discharge of low quality heat and disordered matter. If this were not the case, complex life could not self-assemble from disordered nutrients.

The natural world shows that evolution works rather well, and many engineers have used evolutionary methods to create optimized solutions to problems.

E.R. Jefferys, *Berkhamsted, U.K.*

BLUE SCREEN OF DEATH

To the Editor: I have some questions about the promise of improved safety of self-driving cars ("Robocars Would Save Human Lives," TechBuzz, September 2016). Tesla wants to eliminate the steering wheel and brake pedal from its vehicles. After all, what is the need for

them, since the car's computer doesn't use those controls?

But who among you has never had your computer crash? Who among you wants to be seated in that car with no steering wheel or brake pedal when its computer crashes and it is headed for the abyss?

When your computer crashes, very likely you will walk away unhurt. When the car's computer crashes, will you walk away at all?

Colton W. Meyer, P.E., *Somerset, Calif.*

PROGRESS IS BEING MADE

To the Editor: The controversy over the April 2016 cover illustrates how easy it is for different groups to arrive at different interpretations of the same work. Maybe it is a question of background and experience.

I have worked in engineering since 1965 and I realized that you were referring to the stereotype of how women used to be treated in engineering offices and how we have come a long way. Many of us have been working for years to do that with the role of women in engineering and have found how difficult it is to overcome deeply ingrained cultural prejudices.

We have made progress. My class of 1965 at the University of Massachusetts in Amherst included one woman engineer who graduated with her mechanical engineering degree. The entering class at Worcester Polytechnic Institute when I started my Ph.D. work in 1969 included 22 women, 20 more than that of the previous year. I estimate that my statics and stress analysis classes as an adjunct professor at WPI from 2010 to 2015 averaged at least one third women, and their marks equaled or exceeded those of the men in the class.

In 50 years, WPI has gone from a men's technical college to a gender-neutral technological university headed by a woman president, Laurie Leshin, formerly with NASA.

As the son and grandson of Smith College graduates, the father of one girl and two boys, and the grandfather of five girls and one boy—most of whom have demonstrated technical ability—I can only applaud and encourage this progress. To continue this progress, we have to overcome the stereotyping of gender roles which begins before kindergarten. That will take time, patience, and persistence. It will not be achieved overnight.

Charles Innis, ASME Life Member, *Paxton, Mass.*

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.

SHARE A CHARGE

A STARTUP IS TACKLING THE CHALLENGE OF RECHARGING ELECTRIC VEHICLES IN APARTMENT BUILDING GARAGES.

Dedicated charging stations in apartment buildings and other multidwelling units offer a manageable, fast, and convenient way of powering up a growing number of electric vehicles in urban areas.

Sales of electric vehicles—fueled by the highly anticipated launches of the 200-plus-mile range Chevy Bolt and Tesla Model 3—are expected to hit 160,000 in the United States this year, marking a big jump from the estimated 93,000 sold in 2016, according to numbers gathered by Statista.

But sales might be higher if the 43 percent of Americans living in apartment buildings and condos had access to better charging options.

EverCharge hopes to fix that problem with a new type of charging solution that may become more common as EV sales grow. The San Francisco-based startup currently offers an EV smart charging ecosystem aimed at the multidwelling unit, or MDU, market. It includes a charging station and power usage technology that optimizes the allocation of electricity, as well as 24-hour service and support. The company also handles customer billing and reimburses building management for the energy each tenant uses.

Either the EV owner or building management can buy the charging station for about $1,250, while the EV owner is then billed for the monthly electricity charges, said Loren Passmore, EverCharge's chief technology officer.

The key to the system—and what EverCharge considers to be its secret sauce—is the proprietary SmartPower Technology. The SmartPower software recognizes that all EVs plugged in simultaneously don't need to be charged at exactly the same time or draw the same amount of power for a full charge. Instead, the software learns an EV's power usage patterns and capacity, and decides how much power to allocate and when to deliver it.

This approach helps to charge each car as quickly as possible, maximize

the building's electricity capacity, and eliminate the need for expensive infrastructure upgrades, even when the system needs to scale up to accommodate more vehicles.

"We're able to charge a whole lot of vehicles based on usage patterns and the way batteries work," Passmore said, adding that the technology can increase a building's EV charging capacity 10-fold without having to add a new transformer or other equipment. "We can make the best use of whatever power is available in the building."

The system runs on a wireless network, which is not the ideal technology for parking garages built from thick concrete walls and rebar. To optimize the network, EverCharge engineers changed the system's radio frequency, developed a new wireless local area network protocol, and optimized the placement of wireless access points and the use of relay controls. The company also tries to work closely with the same electricians in all its main markets for consistency and quality control. The company recently partnered with Schneider Electric, a global energy management specialist, to drive distribution and sales.

For now, the target markets for MDU EV chargers are in larger cities, such as San Francisco, Los Angeles, and Miami, where EverCharge has installed charging stations in several buildings. Although EVs will continue to draw more power from the grid, that doesn't necessarily mean they have to tax a building's electrical infrastructure.

"We're making more efficient use of the power that's already there," Passmore said. **ME**

JEFF O'HEIR

An ultrasensitive new microphone (left) can detect the low hum of an incoming attack drone up to 1,000 feet away.

A MICROPHONE FOR SENSING TROUBLE

A new breed of highly sensitive microphones can hear sounds too low for people to hear—and could save lives in the process.

The devices can detect the barely audible hum of an approaching attack drone, which could help prevent assaults on power plants, airports, stadiums, and other sensitive locations.

They can also detect the subtle movement of air in a tornado that's just begun to brew.

Today's sensing instruments don't do the best job of picking up the ultralow frequencies given off by an approaching drone or a brewing tornado, said David Wells, executive vice president of Silver Spring, Md.-based SmartSenseCom (SSC), which developed the products.

But about six years ago, SSC licensed passive optical sensing microphone technology from the U.S. Navy, which had developed it in the 1990s to measure underwater sound waves.

Since then, SSC has developed robust, low-power, low-maintenance microphones, typically a little bigger than a AA battery, that can withstand extreme indoor and outdoor environments.

"Our secret sauce is our simplicity," Wells said.

High-performance acoustic measurements are typically made using so-called active mics, which rely on an external power source. But those outside power sources can create unwanted noise and signal interference.

What's more, in the most popular type of active mic, called a condensor mic, one of the two plates of the capacitor is ultrathin and acts as a diaphragm that vibrates as sound waves hit it.

This creates a fluctuating electrical field that serves as the audio signal. But ultralow frequency sound waves often fail to activate the capacitor and generate a signal.

SSC's passive mics eliminate both the need for external power and the capacitor. Instead, they detect sound using an ultrathin mirror that also acts as a diaphragm.

As sound waves cause the mirror to vibrate, LED light shines continued on p.21 »

This vibration-sensing device could help determine if a healing knee is ready for more intense activity.

IF KNEES COULD TALK

By listening to aching joints creak, doctors can tell a lot about how well patients are recovering from knee and ankle injuries.

As a former three-time all-American track star from Stanford, Omer Inan knew that injured and overused joints could get creaky. But could those creaks offer clues to the health of the joints themselves?

Inan, a bioengineering and electrical engineering professor at Georgia Tech, suspected it might. He had previously used vibration sensing to monitor cardiovascular health, and he realized the same method could work on creaky joints. But there was a problem.

"If I measure sounds from 10 different people, the signatures are going to look completely different," Inan said.

IT TURNED OUT THAT THE ACOUSTIC PATTERN OF AN INJURED KNEE IS MUCH DIFFERENT FROM THAT OF A HEALTHY KNEE.

Nevertheless, when the Defense Advanced Research Projects Agency called recently for research proposals on wearable technologies to assist rehabilitation, Inan began thinking about how his sensing work might be applied to joints.

DARPA wants to reduce damage to soldiers' knees and ankles, whether on the battlefield, from marching dozens of miles with heavy backbacks, or crouching in cramped spots for hours. These activities cause musculoskeletal injuries that are among the top reasons for discharge for active-duty service members.

Curious about the sounds he heard and felt in his own body, he started thinking about joint rehabilitation from an engineer's perspective: After something tears in

continued on p. 15 »

THE MANUFACTURING CONUNDRUM: LOCAL OR OUTSOURCED?

The eraser dust has settled, the tablet screen has dimmed, the foam core models are tossed aside on the floor in a coat closet. It's been a creative marathon of product design and prototype testing, and it's time to produce the first run.

Now comes a difficult decision. Where do social businesses in developing countries that sell products to meet basic needs go to make their wares? Do they work with a local manufacturer or even start their own factory in the country where their customers live? Or do they outsource production to China, India, or somewhere else with the proven capacity to do the job well?

"Those two schools of thought compete against one another," said Khanjan Mehta, head of the Humanitarian Engineering and Social Entrepreneurship program at Pennsylvania State University and E4C contributing editor. "From one point of view, local manufacturing for nearby local markets with locally available raw materials can lead to resilient businesses."

But local manufacturing could cost more. For that reason, outsourcing is sometimes necessary to maintain economic sustainability despite the additional transportation and logistics fees, Mehta said. In situations like these, the venture must accept that all development goals cannot be achieved simultaneously.

For example, KickStart treadle pumps and irrigation systems are manufactured in China due to cost restrictions. Similarly, biomedical ventures like ClickMedix face cost and quality control barriers when trying to manufacture locally."

Other experts agree that the decision may come down to the type of product and the quantity of production.

"Go local as much as you can, I would say, because you're not moving huge volumes and you still don't know if your design is great or not," said Yotam Ariel, managing director of Bennu Solar, which establishes supply chains for custom solar products in China.

Inside BURN Manufacturing's factory near Nairobi, Kenya.
Photo by Rob Goodier

"People think it's more expensive to produce locally," Ariel said, "but if you bring in all of the costs of doing it in China, it's not."

It's true that local manufacture is cheaper at low volumes, but it remains cheaper even at high volumes if the product is not difficult to produce, said Eoin Flinn, the former director of BURN Manufacturing in Nairobi, Kenya. Flinn developed the company's stove factory from the ground up.

"For basic manufacturing, it is definitely cheaper in the long run to invest in capital and resources in Africa," Flinn said. "Training local talent in operating equipment and processes makes economic sense and should align with a social enterprise's mission."

On the other hand, the cost of outsourcing includes the profit that a Chinese subcontractor makes, shipping, tariffs, and a slower reaction to the market.

"This logic applies to stamping, molding, assembly—relatively simple manufacturing. Semi-conductors, PCBA, and complex electronics in general make the argument less tenable," Flinn said.

Outsourcing the manufacture to China should be a consideration only when a venture is ready to commit at least USD $100,000 to a single manufacturing plant, Ariel said.

Ultimately, determining a venture's manufacturing goals can help settle the question. Ventures should ask themselves which type of manufacturing will yield the highest quality products, and whether job creation is a priority, Flinn said.

But in the end, the location may not be the most important aspect of the venture. After all, for most social ventures, the primary goal is to provide products that deliver real value to the target market. ME

ROB GOODIER, ENGINEERINGFORCHANGE.ORG

continued from page 12 »

IF KNEES COULD TALK

the knee and is then repaired, there is a mechanical disruption that the body has to resolve over time.

Inan's hypothesis, which he hopes to prove scientifically, is that the sounds come from the natural friction created when internal surfaces rub. He also realized that "addressing it as an engineer could be interesting," he said.

Using the DARPA grant, he and his team outfitted a knee band with microphones and piezoelectric film to measure sounds inside the joint. A graph of the recorded audio much like an electrocardiogram was matched to the joint's range of motion. That let the team see when the knee creaks and pops as the leg extends and bends.

It turned out that the acoustic pattern of an injured knee is much different from that of a healthy knee.

Inan's team is looking to help build simple products based on these findings, such as a knee brace with an embedded microphone to provide doctors with basic information after surgery. Such a device could potentially help doctors to determine whether a recuperating knee is ready to move to more intense activity.

So far Inan has focused on injury rehabilitation, but the technology could be applied to osteoarthritis and other disorders as well, he said. Joints sometimes creak in part because bone surfaces experience minor degradation over time. Sensors should be able to distinct signatures for different types of damage, he said.

"Sounds and vibrations of the body have not been explored as much as other sensing modalities, and I think there is a lot we can learn," Inan said. ME

NANCY S. GIGES is an independent writer. For more articles on bioengineering, go to ASME.org.

"YOU CANNOT EXPECT industry to invest in basic R&D that will pay off in 25 years. The job of companies is to make money, not to create jobs."

— Said Jahanmir, recipient of ASME's Honorary Membership distinction and 2015-2016 ASME Congressional Fellow for Rep. Tim Ryan (D-OH), co-chair of the Congressional Manufacturing Caucus, speaking to ASME's Industry Advisory Board on December 13, 2016.

PEOPLE BEFORE PROFIT

When revenue streams dwindle, **managers must sometimes choose** between people and profit. My company found **a way to do both.**

When profits sink, do you have to lay off valuable staff? That's the terrible question managers sometimes face. It's even harder when some of the staff are personal friends. When you run your own company and have vowed to put people before profits, it's harder still.

All that was staring me in the face in January 2009.

Our company, Device Solutions, which develops and tests Internet of Things technologies, was riding a five-year trend of continuous growth. Then the economy tanked. A series of project cancellations and no new opportunities left me pinching pennies and worrying about making payroll.

For the third time in my career I was faced with the prospect of laying off valued employees, something I had vowed I would never do again.

During my nearly 35 years in engineering and management, I have held senior director positions for large corporations. And twice, when revenue streams slowed, my bosses told me I needed to lay off full teams of engineers.

The second time this happened, the company, which designed cellular phones, chose to give the employees no advance notice. After I learned of these plans, I spent several months torn between keeping the secret and doing the right thing for my employees, who were some of the best engineers in the industry. I had hired many of them personally, knew their families, and knew full well how losing a job would hurt them. For months I lost sleep and lost weight. It was one of the most frustrating, lonely, and sickening periods of my career.

FOR THE THIRD TIME IN MY CAREER I WAS FACED WITH THE PROSPECT OF LAYING OFF VALUED EMPLOYEES, SOMETHING I HAD VOWED I WOULD NEVER DO AGAIN.

By that point, I was completely disillusioned with the way corporations treated their employees.

After some serious soul searching, and many discussions with trusted business colleagues and mentors, in 2003 my friend Chris Lamb and I opened Device Solutions, with an initial focus on product testing and certification. Our goal was not to build a Fortune 500 company or even become multimillionaires, but simply to make a good living, maintain control of our destiny, and spend plenty of time with family. We agreed to grow it sustainably and offer our employees the same level of security and family flexibility that we afforded ourselves.

Chris and I and our third partner, Keith Anderson, gathered the employees to discuss our options. We were completely honest. We explained that the three of us had cut our salaries in half, but that we'd realized that was not enough. We proposed that everyone else go to a four-day work week at 80 percent salary.

I was grateful and relieved when the entire group accepted the proposal and that most of the employees also continued to work a full five-day week, despite the pay cut. Over the next few months, everyone gave 100 percent. Not a single person let us down.

The next year, as our situation improved, we paid everyone for the extra effort they had put in during the difficult period the year before.

Today, business is booming. We now have more than 60 employees who are committed to the belief that putting people before profits is a viable business model.

As for myself, I no longer lose sleep over corporate mergers, acquisitions, and layoffs. I'm squarely focused on meeting new challenges with my team because that is a solution I can live with. ME

BOB WITTER is the CEO of Morrisville, North Carolina-based Device Solutions, which develops technologies for the Internet of Things.

Image: NASA

Q&A DAVID WOLF

DAVID WOLF SPENT MOST OF HIS CAREER at NASA as an engineer and medical doctor—and eventually an astronaut. He spent 168 days in space and made seven space walks. Wolf was NASA Inventor of the Year in 1992 for his work on bioreactors, which made 3-D tissue and organ engineering possible for the first time. He is currently working with the Children's Museum of Indianap-

ME: Did you always want to be an astronaut?
D.W: It was in the back of my mind. My earliest memory is sitting on my uncle's lap in an open cockpit biplane doing aerobatic maneuvers. That's my passion, and I've competed nationally for 30 years.

ME: How did you wind up at NASA?
D.W: I helped develop a high-resolution digital echocardiograph. NASA hired me in 1982 to build a similar machine for the International Space Station for cardiovascular testing.

ME: Was it difficult to build?
D.W: Plenty, yet many of the issues were mundane. For example, we had to rebuild the entire power supply. Air cooling didn't work because there is no convective heat flow in zero gravity. We had to coat exposed metal so a floating coffee spill didn't short it out. When you add up all the changes and science behind them, it's well beyond the typical project.

ME: You became chief engineer for the ISS medical facility. What were your greatest challenges?
D.W: We faced similar technical challenges, but our team of 100 engineers had to test everything all at once. Also, this was the very beginning of the Shuttle program. We had to show we could come in under budget and under time, and I let nothing get in our way.

ME: How did you get involved with the bioreactor?
D.W: We had a design, but when I unwound the math and principles behind it, I realized it had greater potential than NASA realized. I changed the reaction vessel to control sheer forces and particle settling. This, and zero gravity, gave cells the time they needed to organize into organ-like tissues, which became the key to modern tissue engineering on Earth.

ME: As an astronaut, you made seven space walks. What's it like?
D.W: The suits scrub the skin off your body. You come back bruised, fingernails gone, eye problems. I popped an eardrum. Maybe half our spacewalk team wind up in orthopedic surgery.

ME: You were outside the Mir space station when its airlock failed. What happened next?
D.W: The two of us couldn't repressurize the air lock. The emergency checklist was way done. Our suits were dead, and our air and heat came from the umbilical attached to Mir. We had to ditch to a deeper module that was never intended for entry. There was no method to do this. We had to disconnect the umbilical so we could close the hatch once we got inside. That gave only a few minutes to live. Our first breath inside fogged the helmet and we went blind. Adjusting valves to close the hatch was like doing Braille in a space suit.

ME: Did it leave you shaking?
D.W: Now, it does. But our training had simulated dying on the job so much, we were able to focus on working through the problem.

ME: You've retired from NASA. What are you doing now?
D.W: My grandparents used to take me to The Children's Museum of Indianapolis, and I've been working with the museum on a big exhibit that shows what it is like to work on ISS. We want to build children's interest, show how hard work created success, and encourage them to be bigger than they ever thought. That's something I'm passionate about. **ME**

ALAN S. BROWN

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A NEW WAY TO CAPTURE CARBON

Burning hydrogen to make electricity would slash carbon dioxide emissions. But an economical way to scrub CO_2 from hydrogen before it enters the power plant is needed. That requires the right material to capture CO_2, and a new computational technique promises to find it 100 times faster than previous methods.

The materials in question are metal organic frameworks, or MOFs. Structurally, they are crystals that resemble Tinker Toys, with hubs made of metal and rods of organic molecules. Like Tinker Toys, they have an open lattice, or framework. This porosity gives an MOF the size of a grain of salt the surface area of a football field. The right MOF could trap any CO_2 that enters its pores and separate it from the hydrogen fuel. But with millions of potential combinations of hubs and rods to choose from, how can engineers construct the right combination of MOF pore size and chemistry for the job?

The new computational system was developed by a team from Northwestern University, one of the top centers for MOF development. Their research also identified and tested several MOFs that are ideal for capturing CO_2 and could lead to the creation of cleaner hydrogen-burning power plants.

The findings come as industry seeks less expensive carbon-capture technologies to meet clean air goals. Burning hydrogen produces water vapor rather than greenhouse gases, but reforming natural gas into hydrogen releases lots of CO_2.

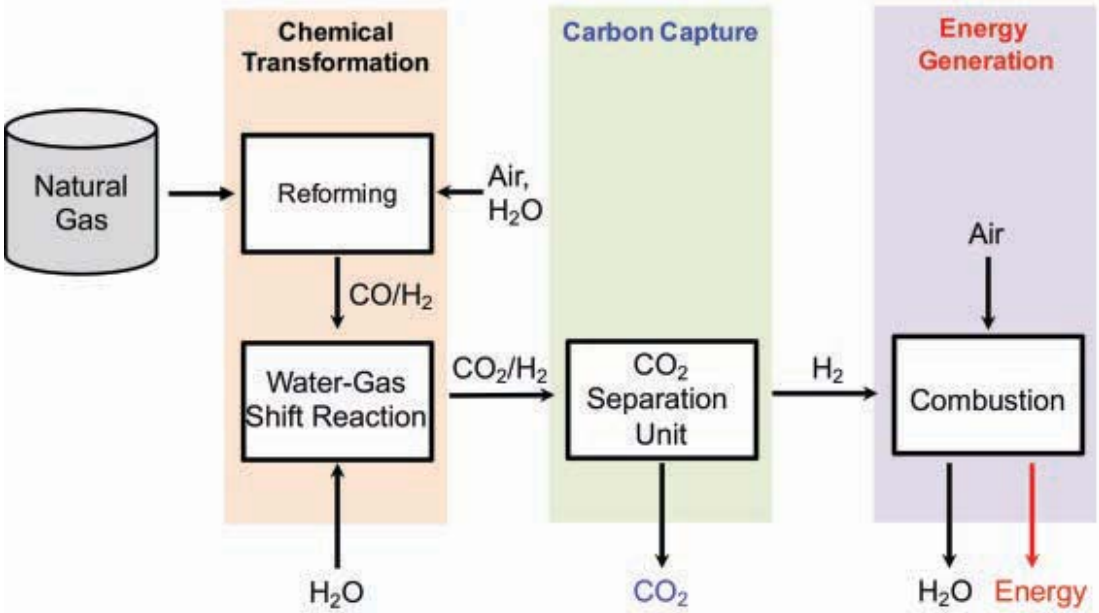
"Our thinking is that over the next few decades the world will continue to burn fossil fuels and will need some type of process to capture the resulting CO_2 before it reaches the atmosphere," said Randall Snurr, a professor of chemical and biological engineering who led the team's research, which was recently published in *Science Advances*.

The Northwestern researchers focused their search on materials for a precombusion carbon capture system—a system that captures the CO_2 before the fuel is burned. This is cheaper and easier than capturing CO_2 after the fossil fuel has been burned, the researchers said. In post-combustion carbon capture, plant operators have to separate a small amount of CO_2 (about 10-15 percent) from a large amount of nitrogen and water vapor. In pre-combustion, operators separate CO_2 from only hydrogen.

To find the best material combinations, the team created and applied a genetic algorithm to a database of more than 50,000 MOFs and crunched the numbers using the university's computer clusters. Genetic algorithms are optimization techniques that mimic natural selection in biology.

The Northwestern team evaluated generations of MOFs, with 100 MOFs in each generation. The MOFs with the best performance survive to create new generations, until the ideal MOF emerges. "It's survival of the fittest," he said.

The genetic algorithm techniques quickly led to high-performing candidates and used only 1 percent of the computing power that previous methods would have required, Snurr said.



In the coming years, the team aims to develop a system that can help the Department of Energy, which supported the research, hit its target of cutting 90 percent of the CO_2 from a power plant's emissions, he said.

"In the old method, we wasted a lot of time calculating properties of structures that might not be very good," he added. "This new method saves you a lot of time and gives you good candidates without having to look at a huge number of materials." ME

JEFF O'HEIR

continued from page 11 »

SENSOR: MICROPHONE

on the mirror, and the vibrating mirror causes the light to oscillate.

The light can then be transmitted via a fiber optic cable up to 3 km (almost 2 miles) to the SmartSenseCom Smart Controller.

From there, it's converted from an optical analog signal to a digital signal that then goes to a laptop or other device for evaluation.

The resulting system can detect frequencies lower than 1 Hz and as high as 200 kHz—a range far greater than the human ear, which can detect sound waves ranging from 20 Hz to 140 kHz.

What's more, "humidity or temperature doesn't affect our mic because there's no capacitor," Wells said. "That means you can put it in any environment."

Depending on how they're tuned and arrayed, the mics can detect the vibration of drones up to 1,000 feet away.

They can also be customized to detect just about any type of mechanical vibration for a number of applications, including perimeter security, equipment monitoring, and structural dynamics.

"Everything has a vibration and everything has a weight," Wells said. With the right equipment, he added, you can measure almost anything. ME

JEFF O'HEIR

BIG NUMBER

58,495

STRUCTURALLY DEFICIENT BRIDGES IN THE U.S. IN 2016

INFRASTRUCTURE MAY NOW BE a hot topic, but the state of U.S. roads, pipelines, water mains, and inland waterways has been a chronic problem for decades. The American Road & Transportation Builders Association, for instance, reported last year that there were nearly 204 million daily crossings on the 58,495 bridges it determined were structurally deficient and in need of repair. The last time the American Society of Civil Engineers graded the overall infrastructure, it gave out a D+ and estimated a repair bill of $3.6 trillion.

3-D PRINTING NEW BONE

Repairing shattered and diseased bone can be difficult and expensive. Northwestern University engineers hope to change that with a new hyperelastic bone substitute. The material, which is made from a unique combination of materials using a low-temperature 3-D printing process, serves as a scaffold for the regeneration of natural bone.

Researchers designed the system as an alternative to today's most popular bone repair and replacement procedures. One is autografting, where surgeons cut bone from elsewhere in the patient's body and graft it onto the damaged area. A skeleton, though, has only so much available bone, and removing it is a painful process.

Another procedure requires building scaffolds from calcium phosphates—ceramics that are stiffer, more brittle, and more frequently rejected by the immune system. The process can also be time consuming and costly.

Ramille Shah, an assistant professor of materials science and engineering and surgery, wanted to improve bone repair by using new materials and 3-D printing. Her process had to be quick, inexpensive, and convenient.

Shah and her postdoc, Adam Jakus, developed a 3-D-printable ink to form porous and flexible structures that can be pressed into a damaged bone defect.

The ink consists of three components: hydroxyapatite, a form of calcium phosphate that stiffens bones and encourages tissue growth; polycaprolactone, an elastic biodegradable polymer; and a solvent that evaporates immediately when exposed to air.

When the solvent evaporates, it leaves a microstructure of pores and channels, where the patient's cells eventually grow and form natural bone.

"The material induces the body to regenerate its own bone," Shah said, adding that the polymer degrades as natural bone takes over the scaffold. Doctors can add growth factors to the scaffold for the elderly or those with unhealthy bones.

By adjusting the materials, temperature, and 3-D printed architecture, the team discovered they could alter the bone substitute's microstructure to match the strength, flexibility, and functionality of specific bones.

"The material can be bouncy or stiff, depending on the direction it's compressed and how it's 3-D printed," Shah said. "The material had surprising mechanical properties, which gave us a lot of versatility."

Shah's method is still about five years away from clinical trials, but it looked promising in preliminary experiments.

Researchers tested the material by fusing the vertebrae of a rat. After eight weeks, new blood vessels grew and calcified bone formed within the scaffold. The material helped repair a monkey's broken skull, and it also allowed researchers to print a femoral shaft that approached the stiffness and load-bearing capacity of human bone. The shaft supported more than two times the load of existing bone cements and press-fit autografts, the researchers wrote in a paper published by *Science Translational Medicine.*

The whole process is fast. The researchers printed and prepared each animal scaffold in about five hours and an adult mandible in three hours.

It is also convenient. Orthopedic surgeons will be able to stock premade scaffolds and roll, fold, and cut them to fit specific applications. They can x-ray the bone, scan the image, and custom print a scaffold in less than a day. Since the scaffolds are printed at room temperature and take virtually no time to dry, surgeons can insert them as soon as they're printed and sterilized.

The materials are also cheap and readily available, unlike the bone from a person's hip.

"Now that we know there is promise, there are so many different applications in the body this can be used for," Shah said. ME

JEFF O'HEIR

NEW MANUFACTURING INSTITUTES ANNOUNCED

Two new institutes have joined the Manufacturing USA network, also known as the National Network for Manufacturing Innovation, bringing the number of institutes to eleven. One of them, an institute to further biopharmaceutical manufacturing, was the first proposed by industry to address gaps in the existing network.

The $70 million National Institute for Innovation in Manufacturing Biopharmaceuticals, sponsored by the U.S. Department of Commerce, aims to develop new manufacturing methods to spur the biopharmaceutical industry, which develops complex, biologically based pharmaceuticals from living cells.

The $140 million Rapid Advancement in Process Intensification Deployment Institute aims to develop new manufacturing processes in industries such as oil and gas, pulp and paper, and chemicals to increase domestic energy productivity and energy efficiency by 20 percent within five years.

With the establishment of the new institutes, the federal government has now committed more than $700 million toward product development and job creation in advanced manufacturing. Industry, academia, and states have contributed another $1.4 billion to the push.

The network was established in 2013.

"The innovations created [by the biopharmaceutical institute] will make it easier for industry to scale up production and provide the most groundbreaking new therapies to more patients sooner," said U.S. Secretary of Commerce Penny Pritzker said in a press release in December. ME

HEAVY LIFTING DRONES FILL A NICHE

A man stands on the roof of a burning building. The roof is too high for fire ladders to reach, too unstable to land a helicopter, and the building is too dangerous to enter. The man seems stranded and out of luck. But once new generation of unmanned aerial drones come online, he may not be.

New heavy-lifting drones can enter situations too dangerous for men, lift the weight of an adult man and deliver him to the ground safely.

Some of the most advanced new drones, which are being developed by a Latvian company called Aerones, come supercharged with the horsepower of a small car or motorcycle. Aerones first demonstrated the power of its machines in early 2016 in a viral YouTube video showing a big drone dragging a snowboarder along a flat, snowy field. Other videos followed: drones pulling a person over the water on a wakeboard or a surfboard, or down the road on a skateboard.

But the fad—named "best new sport of 2016" by *The Verge* magazine—was never intended to be a sport. Instead, droneboarding was just a fun way to test the lifting capacity of Aerones' high-powered drones, said Janis Putrams, the company's CEO. To carry heavy payloads, Putrams wanted to build a mid-size drone, smaller than a large fixed-wing drone and bigger than a small helicopter drone.

Putrams soon realized that such a drone could assist in firefighting and rescue. "That would be the place where this new technology could prove its worth helping people," he said.

To build a drone that could lift people to safety, Aerones' engineers and computer scientists calculated that it would need 16 motors powered at 1.5 kilowatts each. The latest iteration of the drone named the AX16, weighs a hefty 120 pounds, spans three meters in length, and can carry up to 320 pounds of cargo.

Such a large drone could cause serious damage if it came hurtling to the ground. Rather than make it fully autonomous, the engineers therefore designed it to be manually controlled via remote control. To help people pilot the craft, Aerones did add some automation features, including state-of-the-art microprocessors and laser sensors, to help stabilize the drone in response to wind and air currents.

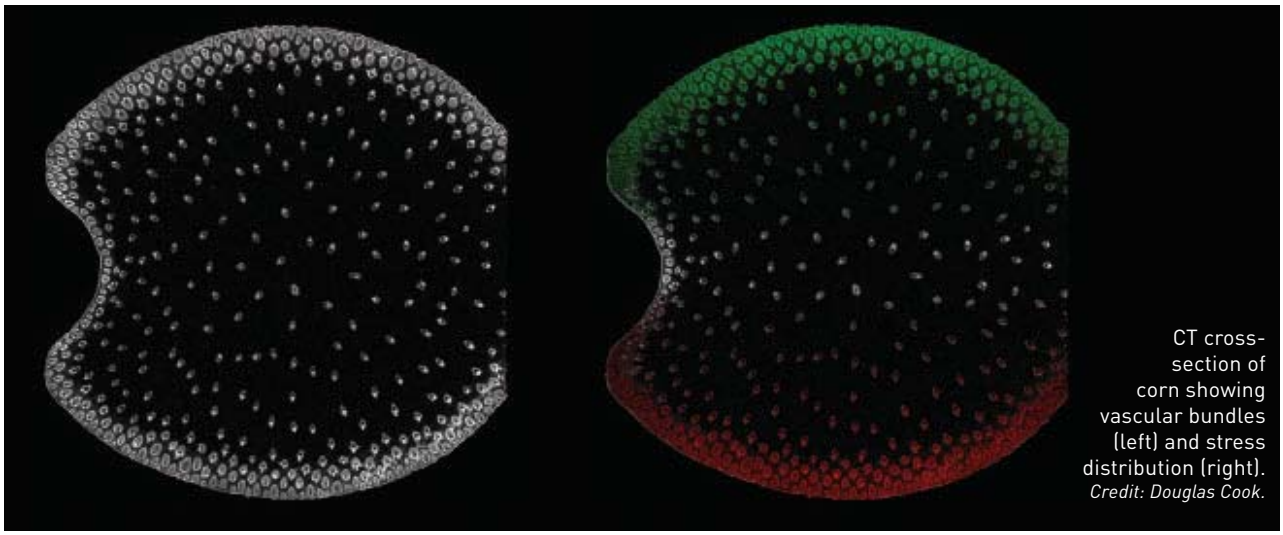
Right now Aerones' AX16 model can carry nearly 176 pounds for about 12 minutes, which is plenty of time for a firefighting rescue mission, and as batteries improve, so will flight time. In tests so far, engineers outfitted the drone with a harness and successfully airlifted a man to safety. They have also has used the drone to a lift a water hose to the height of a five-story building in a simulation of a high-rise blaze.

Aerones' aircraft are not the only heavy-lifting drones that will contend for market share. Freefly Systems, a five-year-old drone startup based outside Seattle, has built heavy-payload drones that can carry 20-pound high-end cameras used in filming for movies and television.

Like the AX16, the ALTA 8 is manually controlled due to safety concerns. And large, heavy-lifting drones won't be self-driving anytime soon, Putrams said. But Alan Yates, a vice president of business development at Freefly, thinks that in time, as automation improves, they will.

Supertough drones could then be key players on first-responder teams, lending a hand in places too dangerous for people to go. ME

MONIQUE BROUILLETTE is a science and technology writer based in Cambridge, Mass.



CT cross-section of corn showing vascular bundles (left) and stress distribution (right). *Credit: Douglas Cook.*

MEASURE FOR MEASURE

YOU CAN'T FIX WHAT YOU CAN'T MEASURE. This month, we look at two labs that are taking some unusual measurements. The first has developed a video strain sensor that is faster, more accurate, and better able to measure large structures like boilers and pressure vessels. The second hopes to save hundreds of millions of dollars by measuring the biomechanics of corn and other crops.

This year, U.S. farmers will plant nearly 400 billion metric tons of corn. Winds and rain will likely knock down about 5 percent of that crop. If geneticists could develop a stronger stalk that saved just 10 percent of those fallen plants, farmers would earn an extra $300 million.

That is the bottom line of the Crop Biomechanics Lab at New York University in Abu Dhabi, where Douglas Cook is probing the mechanical properties of crops to improve harvests.

"Geneticists tell me that they can improve any feature

VISUAL STRAIN

THE LAB Point Semantics, Silver Spring, Md. Christopher Vizas, CEO. John Michopoulos, technical advisor.

OBJECTIVE Develop optical strain measurement systems for monitoring pressure boilers and infrastructure.

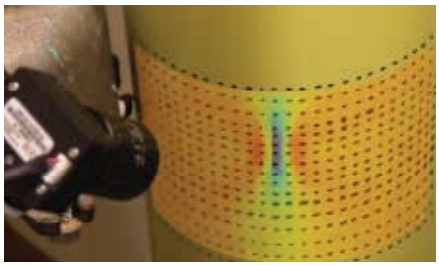
DEVELOPMENT Improved algorithms that support faster, more accurate video strain measurement over large areas.

For more than 30 years, engineers have used digital cameras and software to monitor strain in boilers, pressure vessels, and infrastructure. A new startup, Point Semantics, says it is developing a faster and more accurate way to do this.

Today, the most popular optical technologies rely on random speckles spray painted onto a surface. Cameras image those speckles, assigning them to pixels on a sensor. As strain causes those surfaces to expand and contract, the distance between the speckles changes.

Software captures that motion by running a small virtual window over each section of each image, a few pixels at a time. It maps their location and compares it with prior images to see if there are any changes. These calculations are slow. Also, accuracy suffers when a speckle fills only part of a pixel and the software has to estimate its position.

Point Semantics solves this problem by painting a lose grid of largish dots onto



Point Semantics monitors the center of each dot to measure strain.

Douglas Cook, second from left, with lab research team in South African corn field.
Credit: Douglas Cook

MEASURING CROP BIOMECHANICS

THE LAB Crop Biomechanics Lab, New York University in Abu Dhabi, United Arab Emirates. Douglas Cook, director

OBJECTIVE Pioneering the study of crop biomechanics to improve crop stability and harvests.

DEVELOPMENT Improved understanding of corn and sorghum stability in wind and rainstorms.

of a plant that they can measure accurately," Cook said. "We're trying to help them identify those features and how to measure them."

While biologists have looked at crop stability before, they lacked a deep understanding of mechanics. Cook, with a degree in human biomechanics, hopes to remedy that. His arsenal includes sophisticated piezoelectric sensors, MRI images, and FEA models.

Surprisingly, 90 percent of all corn fails the same way, breaking less than 3 cm above the node where the husk flares off from the stalk. The change in shape causes stresses to concentrate there.

The failure mechanism is harder to pin down. Cook sees tissue failure and buckling. Using piezoelectric transducers, he listens to corn tissue release small amounts of energy as it fractures, but cannot yet say with certainty if tissue damage causes buckling or bucking causes tissue damage.

Once damage begins, however, each augments the other until catastrophic failure.

Cook is also investigating sorghum, a crop that grows 3 to 4 meters tall in dry areas with poor soil. Geneticists want to increase the percentage of tissues that bacteria can break down to make biofuel ethanol. Unfortunately, that weakens the plant and make it more vulnerable to falling.

Cook ran FEA models on both sorghum and corn. He found stability strongly linked to plant shape. In sorghum, for example, a 5 percent increase in stalk diameter will offset a 50 percent reduction in tissue strength.

Ultimately, the lab seeks to provide this type of guidance for geneticists who want to breed better crops. Plant biomechanics is an emerging field, and Cook's lab is one of the first to take on these specialized challenges. ME

a surface. It measures light intensity to find the center of each dot. Instead of trying to calculate the shape and location of irregular speckles, the software simply looks at the movement of the centers from frame to frame.

This reduces computing overhead and errors from partially filled pixels. Point Semantics further simplifies the calculations by measuring only the distance between the center of each dot and its neighbors to compute strain over an entire plane. Adding another camera for a second angle lets it find strain in three dimensions.

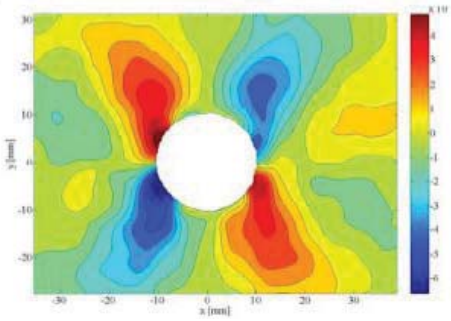
The resulting system is real time fast (30 frames per second compared with less than two for most competitors), according to the company's vice president of development, Brad Pantuck. Its precision is within 40 microstrains, five times better than similar systems, he said.

Engineers could mount their cameras 50 m away from a boiler, dam, or bridge and monitor 75-by-100 m area, including such potential weak spots as welds, junctions, holes, rivets, and edges.

Point Semantics licensed the technology from the U.S. Naval Research Laboratory. NRL's John Michoupolos and Nasos Iliopoulos, who pioneered the technique, serve as technical advisors.

The first commercial products should reach the market in 2017. ME

ALAN S. BROWN



A strain tensor field distribution generated by optical strain sensing.
Credit: Point Semantics

A new type of monitoring system in Denver keeps both light-rail trains and vehicles moving.

TRAIN VERSUS TRAFFIC

When the first steam engines chugged into city limits in the early 19th century, they blocked horse-drawn carts at Main Streets around the globe. Managing conflicts between train and vehicle traffic has been an issue ever since, and as light rail has grown more popular, conflicts between train and traffic flow have grown.

A sophisticated monitoring system near Denver, however, senses how both are moving and makes custom adjustments to traffic-light timing to keep trains on time and vehicles moving.

Transit signal priority (TSP) systems have been a fixture of transit technology for the past two decades in Europe, where they reduce bus and train wait times at intersections.

TSP was introduced later in the U.S., primarily on bus lines. But as cities have grappled with traffic gridlock, transportation manufacturers have worked on developing signaling systems that would lessen the impact of large trains and light rail on road traffic patterns.

A customized TSP system tackles this problem. The system, which went live earlier this year on the new R line of Denver's RTD light rail network, uses Siemens electronic sensors to monitor four inductive magnetic loops at each intersection that do the actual watching of the train traffic.

The loops are laid between the rails and attached to the ties, or embedded in the concrete between the rails in paved track sections. As the train passes over, the metal in the train shifts the magnetic field in the loops. The sensors pick up the shift in the magnetic field and signal a central monitoring system.

Unlike previous TSP systems, Denver's new system massages the timing of individual traffic lights to keep the train running at close to its optimal speed.

"If the sensors indicate the train has to slow, it will, but the goal is to keep it moving and to manage traffic through the intersection lights," says Paul von Fay, deputy project manager for design at RTD.

Kiewit Corporation, which developed the system, bench-tested it for more than six months beginning in February 2016, using computer simulations of a train on its route during rush hour. Engineers worked through various scenarios, figuring out how to handle situations like stalled trains and weather problems. They toiled to make sure the sensors would operate in the cold Colorado winters.

"We had it going pretty well on the simulator, but when you start real-world testing, that's where problems really show up," says von Fay.

By summer, the RTD rolled out tests of the R Line with TSP in effect. The engineering and design staff paced. Cheers were heard throughout the RTD headquarters when the results came back.

"It operated even more efficiently than it did on the simulator," says von Fay. "That's an unusual result. Usually you end up with more things to fix. But we'll take it." ME

JOHN MORELL writes about technology and business from Woodland Hills, Calif.

SHAPES OF THE FUTURE

New software lets engineers take full advantage of additive manufacturing technology.

Engineers working on their next 3-D design project may get help from an unexpected source. Mainstream computer-assisted design software has begun to incorporate automated topology optimization technology. This can rapidly generate parts that look like flowing organic forms found in plants and animals.

Through automated topology optimization, engineers could slash costs by reducing mass and material use without any tradeoff in strength, stiffness, or mechanical performance. This would justify the software's high cost.

Optimization software has been creeping into the mainstream for several years, but many programs don't produce finished designs and are difficult to use in a production setting. That is changing with Siemens PLM Software's latest iteration of its NX CAD/CAM/CAE tools. They will contain Generate, a design optimization tool licensed from Frustum, a Boulder, Colo., startup.

In Generate, engineers design an initial shape and enter constraints, such as loads, weight, vibration, heat transfer, materials, and use scenarios. The software applies multiphysics analysis to the initial design to generate an optimized design. The parts may look nothing like conventionally machined workpieces.

"Look at nature, look at yourself," said Bob Haubrock, Siemens PLM's vice president for product engineering software. "When you look at the output from topology optimization tools, these are not shapes that designers would initially conceive." 3-D printers have no problem printing those shapes.

Siemens PLM's new software will also add a feature called convergent design to help engineers modify optimized designs or models. This feature allows engineers to use different methods of representing shapes—facets, surfaces, and solids—in a single model without having to convert one type of data into another.

For example, scanning and topology optimization produce faceted models. Engineers can add holes, attachments, and supports to these models, using precision techniques such as nonuniform rational basis spline or boundary representation modeling. They once had to convert their faceted models to precision models, but convergent modeling supports these different geometries in the same model, said Aaron Frankel, who heads marketing for Siemens PLM's digital manufacturing solutions.

Frankel calls this a smart model because engineers can use the same model—including all metadata specifications and constraints—from design and engineering through manufacturing without converting or translating data. This greatly reduces data translation issues like misplaced holes and surfaces gaps, though engineers should still verify their models, Frankel said.

Engineers are likely to embrace convergent design quickly. But will they hesitate before accepting the organic designs of topology optimization? Siemens thinks designers of jet, power, and oil and gas turbines will charge ahead, to gain weight reductions that slash fuel costs. Designers of medical devices and production tooling are also interested in optimized parts.

Others may need a learning curve. "They have to have confidence these parts will perform, and simulation and analysis tools will help" Haubrock said. "Over time, they will get used to the computer coming up with ideas that they can work with, and they will see that these parts perform in the real world." ME

ALAN S. BROWN

ARE ENGINEERS UNDERPAID?

RALPH WITHEROW, STEARNS-ROGER MANUFACTURING COMPANY, DENVER, COLO.

In this conclusion to a multipart discussion of engineering salaries, one engineer suggests that a little balance is in order.

On the surface it would appear, based on annual income averages, that the legal and medical professions in most areas receive a greater compensation for equally important services than the engineering profession. Therefore, by this comparison, the engineer is generally underpaid. This situation should, of course, be tempered by local standards with some consideration given to the fact that part of each engineer's compensation is not received in the form of monetary reward but in the form of monumental accomplishment, personal satisfaction, and kindred community spirit.

RELATION TO NATIONAL ECONOMY

However, before a conclusion is reached in this regard, some important factors in connection with our national economy should be considered. "The true test of any system is the ability of that system to defend itself in the marketplace!" And upon this premise we must agree that as a nation we must have the benefit of a world market to absorb our full peacetime production, as we have not yet developed a successful system of economic perpetual motion. In order to have this market and maintain it, we must be competitive in the creation of engineering products. In a rather feeble attempt to meet this requirement we are currying a very dangerous practice. In many cases we are compromising quality for quantity, in a high-class game of "economic Russian roulette." We know our competitors have greatly increased their supply of technical personnel and production facilities in recent years. This has been done without noticeably raising their standard of living. These factors represent a rather serious situation and tell us that if we hope to maintain an economic balance in a highly competitive world market, we are going to have to put our own house in order. The solution to this impending problem seems to be opposed to the general premise of this paper, that engineers are underpaid. The following facts are offered for your consideration and study: For the past ten years we have experienced an ever-increasing spiral of inflation from which individuals have benefited less and less. As you know, labor costs have continued to rise, and material costs have continued to rise as a direct result, but as an end result, the cost of living has reached an all-time high.

LOOKING BACK

The relative value of engineers to society was a hot topic when this article was published in February 1957.

COST OF LIVING

Just how well paid (or underpaid) were mechanical engineers in 1957? According to the article, the mean income for a 50-year-old ASME member was at $15,100. Standard consumer price index adjustments peg that at $128,000 in 2017. But not all prices have shifted the same way. Ads in the Greencastle, Ind., *Daily Banner* from February 1957 list a Hoover vacuum cleaner for $69.95, a five-piece chrome dinette set on sale for $129.57, sirloin steak for 49 cents a pound, a girdle for $7.50, and a two-door Buick sedan with a radio, heater, and white sidewall tires for $2,595.83. They don't make them like that anymore.

Newspaper ad from 1957
Credit: The Daily Banner

INCREASING STANDARD OF LIVING

In many respects, we resemble the children of Babylon building a tower far out in space whose proportions are exceeding the wildest imagination of its founders. As you well know, we have just witnessed the inception of another round of increases which will affect people at every level one way or another. In short, we are going to build our tower somewhat higher but we are not going to fortify its foundation with a stable national economy. As engineers, every one of you knows better than that. Our ever-increasing standard of living is very quietly pricing us out of a world market. This high standard of living amounts to a veneer of convenience to which we have become accustomed and which we have accepted as a necessity, but we must not continue to pursue the dictates of our personal wishes and desires while ignoring our national economy. With these exceptions we have established that, by and large, engineers are underpaid. We have also agreed that engineers' compensations are many and diversified. ME

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ASME SETTING THE STANDARD

The American Society of Mechanical Engineers® (ASME®)

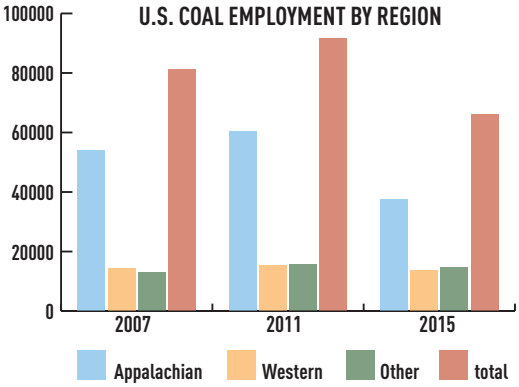
BY THE NUMBERS: CAN COAL COME BACK?

Appalachian mines have been shedding employees for decades. There may be no feasible policy for putting those miners back to work.

The Appalachian coal miner was a focal point of last fall's election. One candidate touted a plan to provide benefits and development funds for hard-hit mining communities. Her opponent promised to restore all the old coal mining jobs. The simplicity of that second message is one reason why Donald J. Trump is now president of the United States.

Trump's message was easy to understand, but is it practical?

It's true that coal mining employment in the U.S. has been in free fall. According to data from the U.S. Bureau of Labor Statistics, total coal mining employment was 52,900 in July 2016, the most recent date for which numbers are available. Just ten years before, there were 78,000 workers in coal mining. (The most recent peak in coal mining employment was in January 2012, with 89,500 jobs; in 1985, there were 177,900 mining jobs.)



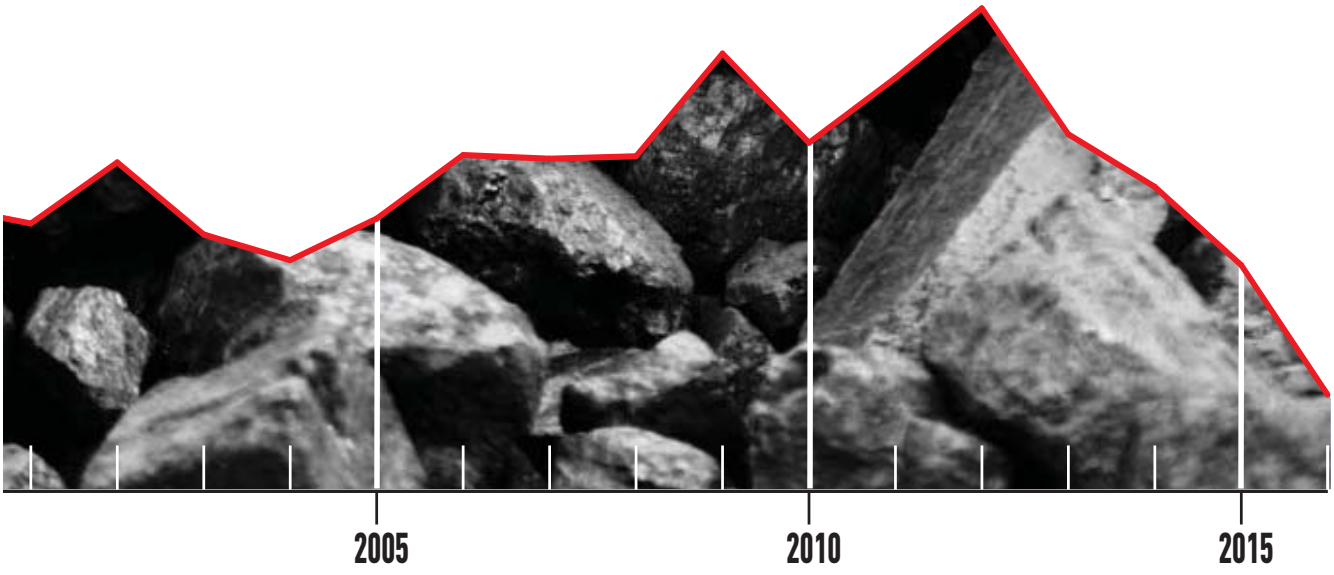
Nearly 23,000 Appalachia miners, or about 38 percent of that workforce, lost their jobs between 2011 and 2015.

Many people look at this steep decline and chalk it up to some sort of "War on Coal." But scrapping regulations on power-plant emissions or even shuttering wind farms wouldn't make that much of a difference. All the wind, solar, and biomass-fired power generation on the grid—which according to the Energy Information Administration accounted for 295 million MWh in 2015—doesn't equal as much as half the decline in coal power since 2006. Even switching all that renewable power back to coal, which hardly seems feasible, might not bring back mining jobs to Appalachia. The EIA's *Annual Coal Report,* published last fall, shows that coal from surface mines in Wyoming and Montana sells for a fraction of that from underground mines in West Virginia and Pennsylvania, and Western coal mines are almost seven times more productive than Appalachian mines.

Given the flat demand for electricity in the United States and the sharp increase in natural gas power plants, it is likely impossible to bring back coal-mining jobs to Appalachia without taking jobs from elsewhere. For instance, in Germany, where the rise in wind and solar power mirrors the surge of gas-fueled power in the U.S., coal power has kept much of its share of electric generation. But German coal power's health has come at the expense of that county's nuclear industry, which according to the German Federal Statistical Office has fallen from 167 million MWh of electricity production in 2006 to only 92 million MWh in 2015.

In theory, scaling back U.S. nuclear power by the same magnitude and making up the difference with coal could put some Pennsylvania coal miners back to work. But not only would the cost to the nuclear industry be catastrophic, it still wouldn't fully restore the coal fields to their one-time health. The promise to bring back the old coal-mining jobs is one no leader can hope to redeem. ME

JEFFREY WINTERS



CLEAN POWER FROM BURNING TRASH

America's first new waste-to-energy plant in two decades is a source of renewable energy and reduces greenhouse gas emissions.

BY JOHN B. KITTO, JR. AND LARRY A. HINER

For the past 20 years, municipalities have had few choices for disposing of solid waste. If landfills were nearing capacity, cities were usually forced to spend millions of dollars to design, permit, and build a new one—despite issues with odor, greenhouse gas emissions, and pollution.

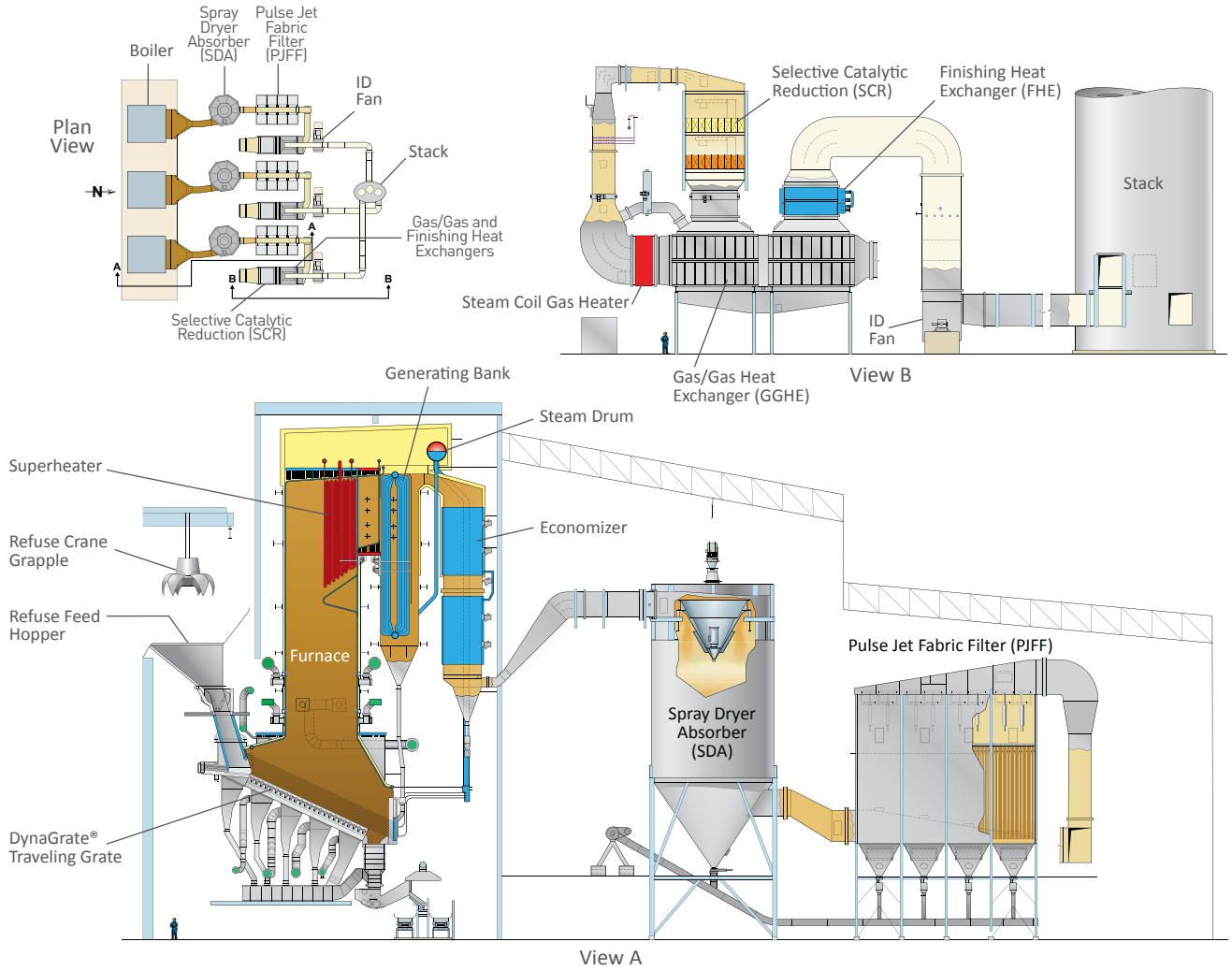
That changed in July 2015, when the Solid Waste Authority of Palm Beach County, Fla., began operating Palm Beach Renewable Energy Facility No. 2. It is the first greenfield waste-to-energy plant for municipal solid waste built in the United States in two decades. With combustion and air pollution equipment designed and supplied by The Babcock & Wilcox Co. (B&W), the new facility addresses the pollution and cost issues that stopped municipalities from building waste-to-energy plants for two decades. This is a technology that can change how local governments approach solid waste management, renewable energy, and sustainability.

Based on data from month-long acceptance tests, the Palm Beach facility ranks as the cleanest, most efficient plant of its kind in the world. It generates enough electricity to power 44,000 homes while reducing the volume of waste to be landfilled by 90 percent—enough to extend the lifespan of Palm Beach County's landfill by up to 30 years.

Like existing waste-to-energy facilities, the new plant earns millions of dollars annually from selling electrical power to the local power company and reclaiming metals left in municipal waste after recycling. Unlike previous facilities, it competes head to head with landfilling on total cost alone.

This waste-to-energy plant also comes with significant environmental benefits. It eliminates the burial of problematic wastes that routinely emit tons of volatile organic compounds and problematic chemicals. The emissions from Palm Beach County's new waste-to-energy facility are as low as or lower than the cleanest gas-fired turbine generators.

In fact, this waste-to-energy plant slashes the total net release of greenhouse gases to zero or below in several



The plan view (top left) shows a top-down layout of Palm Beach Renewable Energy Facility No. 2. View A shows the boiler section and absorption system. View B shows the remainder of the pollution control section.

ways. First, waste-to-energy plants emit less net carbon dioxide than fossil fuel plants that use gas, oil, or coal. This is because more than 60 percent of municipal solid waste consists of food, agricultural waste, paper, wood, and other types of biomass. EPA classifies biomass as a renewable resource that adds no net carbon dioxide to the ecosystem.

Second, if the food, paper, and wood in municipal solid waste were landfilled, it would decompose and emit methane. Eliminating emissions of methane—a greenhouse gas 28 to 36 times more powerful than carbon dioxide, according to the EPA—more than offsets any release of carbon dioxide from the facility. This transforms waste-to-energy into a better way to reduce greenhouse gases than landfilling alone.

The advanced technology that makes this plant's achievements possible represents two decades of progress in hundreds of waste-to-energy plants built in Europe and Asia. Babcock & Wilcox designed many of them. It brings together the best global technologies to set a new standard in economics and emissions reduction that could make it part of long-term renewable energy and sustainability strategy.

Boiler

Each day, the new Palm Beach waste-to-energy plant burns up to 3,000 tons of municipal solid waste created by Palm Beach County's 1.4 million residents. The facility cost $674 million, or $224,700 per ton of daily capacity, to construct. On an inflation-adjusted basis, this is less than similar, less clean, plants built 20 years ago. It processes waste for about $25 per ton, roughly as much as burying the waste in

Palm Beach County's landfill.

A number of technical advances make these economics possible. They include an innovative grate system on which to burn waste and an advanced emissions control system. The plant's modularized design saved construction time and costs, while its integrated design maximized energy recovery and minimized water use.

A good example of that integration is the facility's use of water. The facility gets its water from a variety of sources. Between 5 and 15 percent comes from rain, and 25 to 35 percent from non-potable industrial water. The remaining 60 percent is recycled from water used in the cooling tower of an older waste-to-energy facility next door. In the past, this plant's water was injected into a deep well for disposal.

The facility also saves water by using an air-cooled (rather than a water-cooled) heat exchanger to condense steam after it exits the turbine, so it can be returned as condensate to the power cycle.

Through recycle and reuse, the new facility actually lowers the amount of water that both facilities need to inject into deep underground wells. The result is water discharge for the new facility that is better than net zero—less that what the older facility discharged alone.

The Palm Beach waste-to-energy facility consists of two central elements: the boiler and the emissions control systems.

The boiler system uses three 1000-ton-per-day boilers to power a 95 MW turbine generator. It also features several advanced technologies used for the first time in the United States. This starts with the crane loading area. The plant collects waste in a football-field-sized pit that's 40 feet deep. Operators use two of the facility's three 16-ton cranes to mix the waste so it will burn more uniformly in the boiler. The cranes generate electricity when braking and can run autonomously at night to feed the boilers.

The cranes deliver the waste to a hopper, where hydraulic rams push it onto an inclined grate that runs under the furnace. Grates are often maintenance trouble spots because their holes plug up. B&W Volund's DynaGrate combustion system solves this problem by using grate bars (with air gaps between them) that rotate back and forth 60 degrees to mix and move the waste down its length. Operators can control the grate speed and air flow in each of the grate's eight modular sections. This enables them to control the burn very precisely, while reducing carbon monoxide combustion products and unburned carbon in the ash.

The emissions from Palm Beach County's new waste-to-energy facility are as low as or lower than the cleanest gas-fired turbine generators.

Despite Palm Beach County's extensive curbside recycling, metals remain in the waste. These are captured in the bottom ash. After cooling, the ash goes to a rotating drum magnetic separator, where large electromagnets remove iron and steel. The remaining ash then goes through an eddy current separator to recover aluminum and other non-ferrous metals from the ash.

On average, the facility has recovered 2,000 tons of steel and iron and 100 tons of aluminum per month. The remaining ash is mixed with lime to stabilize the ash so it is safe for landfilling. In Europe, this material is used in construction materials and as aggregate for roadbeds. This type of recycling is being evaluated in Palm Beach as well.

Emissions

Meanwhile, the waste burned on the grate has undergone partial combustion. This produces carbon monoxide and nitrogen oxides (CO and NOx). As the products of combustion, or flue gas, move up through the furnace, they pass by an overfire air system, which injects the balance of the combustion air into the gas. This effectively completes combustion and converts NOx into nitrogen and oxygen (N_2 and O_2) and turns CO into carbon dioxide (CO_2). Maintaining gas temperatures above 1800 F for 2 seconds or more also destroys organic compounds, including dioxins and furans.

The hot flue gas then passes through the boiler components that turn water into superheated steam. This steam powers the turbine generator and then goes to an air-cooled heat exchanger, where it condenses into water and returns to

The boiler building, seen from the emissions control section.

Waste-to-energy plants produce less net carbon dioxide emissions than any of the fossil fuel plants using gas, oil or coal.

the power cycle.

The flue gas exiting the boiler has cooled enough to enter the emissions control system. The first step involves spraying activated carbon particles into the flue gas to absorb mercury vapor and any residual dioxins and furans not destroyed in the furnace.

The flue gas then moves to a piece of machinery called the spray dryer absorber, where a spray of lime slurry absorbs sulfur dioxide, hydrogen chloride, and hydrogen fluoride, air pollutants found in the flue gas.

The flue gas then moves into a bag house containing a small forest of six-inch-diameter fluoropolymer membrane-coated bags. As the flue gas passes through the bags, it deposits entrained ash, spent activated carbon and lime, and any other particulate on the outside of the bags in a filter cake deposit. The cleaned flue gas then passes up through the center of the bag.

Unreacted lime and carbon in the filter cake continue to scrub pollutants from the gases that pass through the bags. To prevent the cake from building up, a pulse of pressurized air periodically shakes the bag and knocks it off. This ash is recovered and mixed with bottom ash from the furnace for disposal.

The last emissions step converts any remaining NOx into nitrogen gas and water vapor through selective catalytic reduction, or SCR. This involves mixing ammonia into flue gas and flowing the mixture over a catalyst. The Palm Beach facility is the first U.S. waste-to-energy plant to use this catalyst technology.

Unfortunately, the flue gas exits the bag house at around 280 F. It must reach 450 F before passing over the SCR catalyst. The facility does this by reheating the gas by recapturing some of the heat from the hot flue gas exiting the SCR reactor and adding a small amount of boiler drum steam to provide the additional energy to reach 450 F. This additional heat input from the boiler drum is then recaptured into the deaerator water system—integrating the emissions control system into the power cycle to maximize energy efficiency.

Performance

Palm Beach Renewable Energy Facility No. 2 was designed to generate power, recover metals, and reduce waste volumes and pollution. The only way to justify its cost and complexity is to assess how well it accomplishes these goals. The plant's initial 30-day acceptance test in 2015 demonstrated that it is the cleanest and most efficient waste-to-energy plant of its kind in the world today.

During the month-long acceptance tests to validate plant operations, the facility easily met its guaranteed capacity of 3,000 tons per day of post-recycled municipal solid waste without interruption. The plant was also guaranteed to generate 625 kWh per ton of waste, the highest ever in a waste-to-energy plant using an air-cooled condenser. It exceeded that target by 6 to 8 percent.

The facility also exceeded its guaranteed metals recovery

rates. It recovered 97.2 percent of all ferrous metal in the waste (versus a 90 percent guarantee) and 88.6 percent of non-ferrous metal (compared with an 85 percent guarantee).

Primary air pollutants, such as nitrogen oxides and sulfur oxides, were not only below those required by the new plant's emissions permit, but were as good or better than those of the best gas turbines.

Waste-to-energy plants have special emissions requirements. They must strictly curtail the release of dioxins, furans, and trace mercury, cadmium, and lead. The new plant's permit sets emission limits measured in millionths and billionths of a gram per dry standard cubic meter of gas.

Test results showed that the facility's emissions are, at their maximum, an order of magnitude lower than those limits. This makes it the best in class of any waste-to-energy plant in the world.

The advanced technology that makes this plant's achievements possible represents two decades of progress in hundreds of waste-to-energy plants built in Europe and Asia.

To put these results into perspective, before the 1980s, scientists did not understand the environmental risks of dioxins and furans. As a result, waste-to-energy plants were allowed to discharge the equivalent of more than 10,000 nanograms per dry standard cubic meter. Palm Beach facility's measured emissions are four orders of magnitude lower, a 99.996 percent reduction.

The emissions control building, before the exterior siding was added.

As noted earlier, municipal solid waste buried in landfills emits methane, a powerful greenhouse gas. In 2007, a study that used an EPA evaluation methodology determined that collecting methane from landfills and then flaring or burning it for power would reduce emissions dramatically when compared with landfilling alone. Yet about 30 percent of a landfill's methane still escapes into the atmosphere.

According to the same study, waste-to-energy plants produce lower net greenhouse gas emissions than any landfilling option. Not only do they displace fossil fuels to produce electricity, but they effectively eliminate methane landfill emissions by burning the biodegradable landfill waste that forms methane. According to the EPA, this reduces net greenhouse gas emissions by 1 ton for every 1 ton of municipal solid waste burned. The Palm Beach plant achieves similar results.

In addition, the plant also recovers more than 95 percent of the metals left in post-combustion bottom ash. This reduces the CO_2 emissions that would have been generated by processing virgin ore to make those metals.

Despite its superior environmental performance, no municipality can afford to build a waste-to-energy plant unless it can compete head-to-head economically with landfilling. As previously noted, Palm Beach County's new facility has demonstrated this by processing waste for $25 per ton, about the same as the county's landfill.

The Solid Waste Authority earns millions of dollars per year by selling electricity back to the local power company (without a premium) and by selling recovered metals. In addition, the new plant saves money by reducing landfill volume by 90 percent. This extends the life of the existing landfill and avoids expensive permitting and construction of a new one.

Finally, the facility's design is highly modularized and integrated. Certainly, its cost, $674 million in 2012 dollars, sounds impressive. Yet, on an inflation-adjusted basis, it cost less to build than the less efficient and less environmentally sound waste-to-energy plants built 20 years ago.

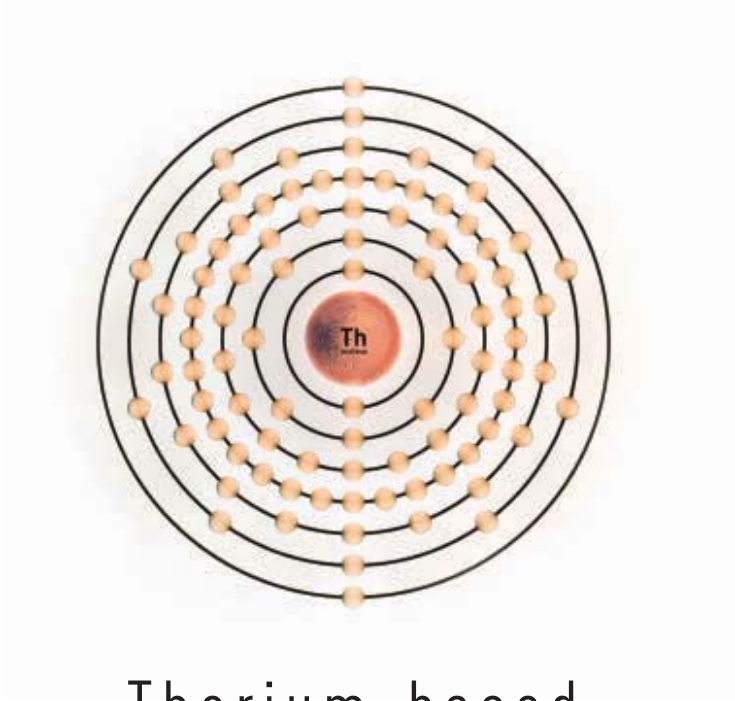
Waste-to-energy plants cannot compete everywhere. Many municipalities can dispose of solid waste for less than $25 per ton. But in many parts of Florida, as well as urban areas such as New York City, Chicago and Cleveland, landfill costs may reach $40 to $50 per ton. Waste-to-energy plants give municipalities facing rising landfill costs an economically and environmentally sound alternative to consider. **ME**

JOHN B. KITTO, JR. PE is an ASME Fellow and was the development manager for the Palm Beach Waste-to-Energy Project for Babcock & Wilcox in Barberton, Ohio.

LARRY A. HINER is project developer for industrial steam generation (including waste-to-energy) with Babcock & Wilcox in Barberton, Ohio.

For more information, "World-Class Technology for Newest Waste-to-Energy Plant in the United States – Palm Beach Renewable Energy Facility No. 2," presented to the Renewable Energy World International Conference, Orlando, Fla., in December 2016.

THUNDER
ON THE HORIZON



Thorium-based

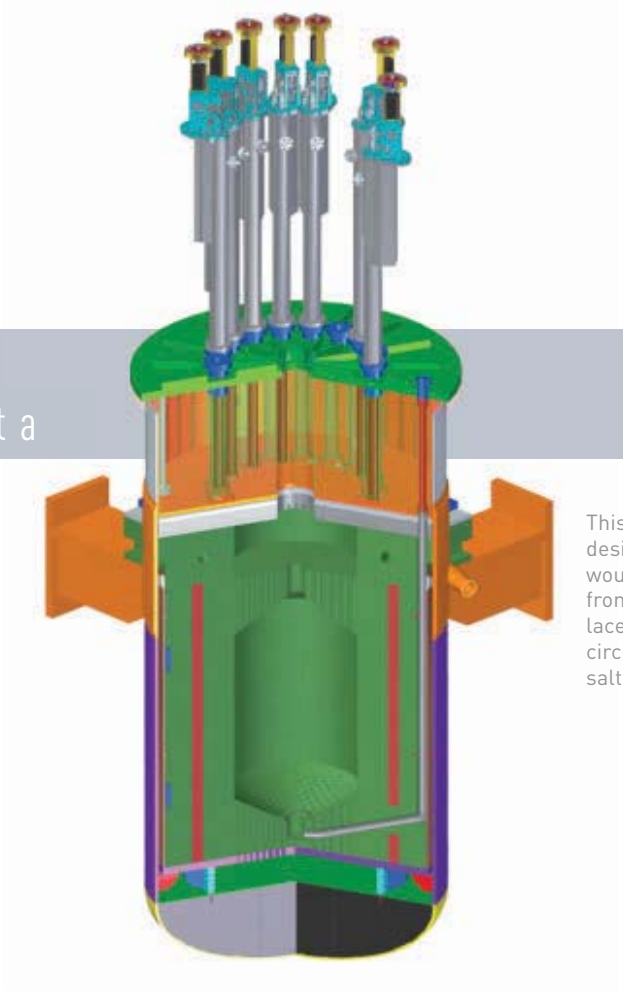
breeder reactors

could begin

a new era

of nuclear power.

By Bridget Mintz Testa



This Chinese-designed reactor would remove heat from its thorium-laced fuel pellets by circulating molten salt.

The Nuclear Renaissance was all the rage 15 or 20 years ago. The idea was that a little boost from the U.S. government would kickstart the industry past its post-Three Mile Island, post-Chernobyl doldrums. Long-planned units would be completed and a new generation of reactors would be built.

It says something about the state of the renaissance, then, that one of the more intriguing plans for advancing nuclear power includes a step where a barge is towed to Indonesia.

"Indonesia has agreed to install these power plants," said physicist Robert Hargraves of ThorCon, a Florida-based nuclear-power startup. "Indonesia is the world's fourth largest country in terms of population, and it wants to have an option not to use coal."

The ThorCon reactor concept has a lot of innovative features—for one, it is borrowing some construction techniques from the world of shipbuilding—but it also has something in common with several reactors that are in various stages of planning: It will be breeding some of its own fuel by irradiating thorium.

The nuclear industry has been built up to now on uranium, the heaviest naturally occurring element. When one of its isotopes, uranium-235, absorbs a neutron, the nucleus breaks apart and releases energy plus a couple of extra neutrons to sustain a chain reaction. Unfortunately, U-235 is relatively rare—it makes up one out of every 139 uranium atoms—so raw uranium requires enrichment to become fuel for nuclear power.

Thorium is about three times more abundant than uranium, and all of it—not just one rare isotope—can be used to create a fuel source for nuclear reactors. And that is why companies and governments from China and India to Norway are developing thorium reactors.

But harnessing thorium will require a new fuel breeding cycle and perfecting some reactor designs that have never left the experimental stage. Though the interest is strong, the stumbling blocks are very real.

A not-so-rare breed

Thorium is not fissile. Unlike atoms of uranium-235, when a thorium atom (almost all thorium is isotope 232, with 90 protons and 142 neutrons in its nucleus) captures a neutron inside a reactor core, it does not spontaneously split apart and produce energy. Indeed, it does not do anything at first except become a new isotope—Th-233. Changing the number of neutrons doesn't change the chemistry of an atom; changing the number of protons does.

But Th-233 isn't stable; its half-life is only 22 minutes. Quickly, one of its neutrons decays spontaneously into a proton to become an atom of protactinium. Pa-233 is also unstable. After an average of four weeks, another neutron decays, and the former

This equipment tested the ability of molten salts to circulate through a reactor to a heat exchanger and back. That work is crucial for optimizing the design of a molten salt reactor.

thorium atom becomes an atom of uranium-233. U-233 isn't as stable as U-235—the isotope isn't found in nature—but it is fissile and can be used to sustain a nuclear chain reaction and produce energy.

When enthusiasts talk about thorium reactors, then, what they are describing is a power plant that breeds its own fuel on the fly within the core of the reactor. Since thorium is more abundant than uranium and can be turned into fuel without the enrichment process needed to concentrate U-235, advocates believe the thorium fuel cycle could be cheaper and more sustainable than the uranium cycle.

Another, ironic, plus is that U-233 is more dangerous to handle, which makes it harder to turn into nuclear bombs. The isotope is radioactive enough to fry the circuitry that controls the bombs, ruling it out as a candidate for nuclear weapons.

Advocates believe the thorium fuel cycle could be more sustainable than the uranium cycle.

For countries such as India, thorium's advantages make it worth the development costs. India already has the world's only operating uranium-233 reactor, and large thorium reserves. According to the Bhabha Atomic Research Center (BARC) in Mumbai, which leads India's nuclear energy program, "The currently known Indian thorium reserves amount to 358,000 GWe-yr of electrical energy and can easily meet energy requirements during the next century and beyond."

"India doesn't possess enough natural uranium to provide the required energy for its masses," said Ganapati Myneni, a physicist at Jefferson Lab in Virginia who has been working closely with physicists at BARC. "Additionally, it is also very short on fossil fuels."

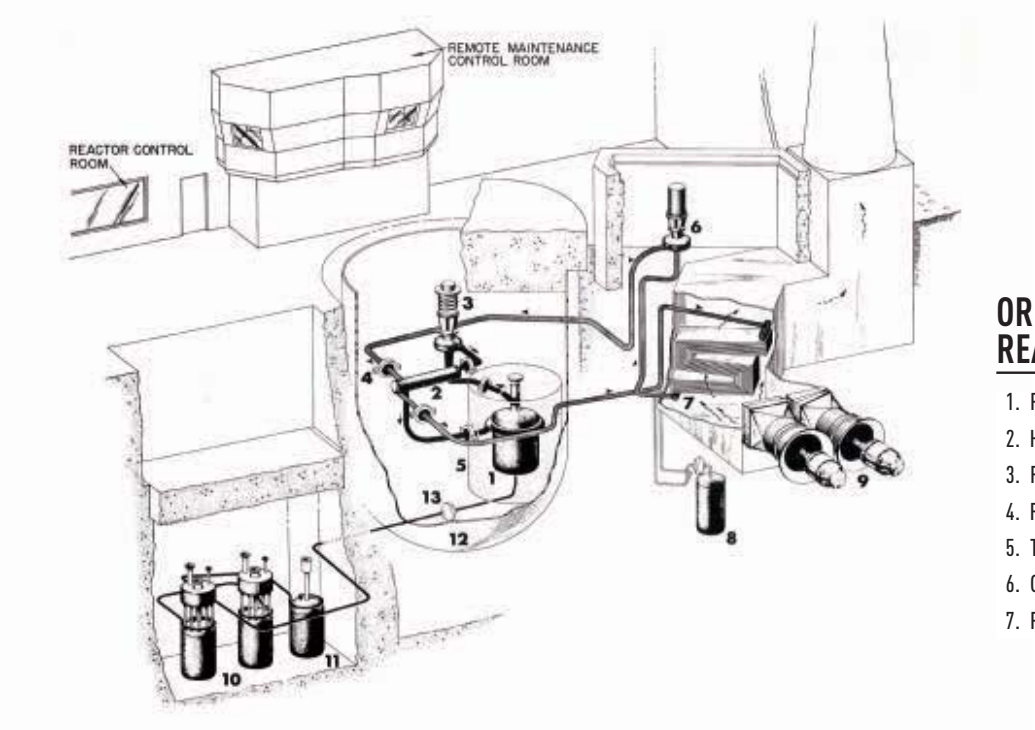
India has a multistage breeder reactor program on the drawing boards, and the country is looking at thorium as part of it.

At the moment, the fuel program is using a more conventional cycle, looking to take plutonium separated from spent nuclear fuel to power a 500 MWe fast breeder reactor; a blanket of non-enriched uranium will capture neutrons and transmute into more plutonium. That 500 MWe reactor is currently under construction and near completion at Kalpakkam. After some delays, the reactor is expected to begin operations by March 2017.

The plan, however, is to swap the uranium blanket with thorium, and use the bred U-233 as the fuel.

"The U-233/Th-232-based breeder reactors are under development in India today and will serve as the mainstay of the final thorium-utilization stage of the Indian nuclear program," according to BARC.

Those reactors will come at the end of a 40-year development program that just started. Other countries can't wait that long.



ORNL'S MOLTEN-SALT REACTOR EXPERIMENT

1. Reactor vessel
2. Heat exchanger
3. Fuel pump
4. Freeze flange
5. Thermal shield
6. Coolant pump
7. Radiator
8. Coolant drain tank
9. Fans
10. Drain tanks
11. Flush tanks
12. Containment vessel
13. Freeze valve

"China needs all the clean energy it can get, and they need it fast," said Andreas Norlin, the Geneva-based publisher of the Thorium Energy Report, which tracks and documents global activities in thorium-based nuclear power.

The Chinese Academy of Science program, run through the Shanghai Institute of Applied Physics, or SINAP, is pursuing a couple of technological options. One is based on the pebble-bed reactor concept tested in Germany, with particles of solid thorium mixed with uranium particles to provide a neutron boost. Unlike previous pebble-bed designs that were cooled with helium gas, this reactor is to be cooled with molten salt which would carry the energy to heat exchangers.

The other option is to build a reactor that dissolves the fuel directly into the circulating salts. The salt would be pumped through the reactor core, where the atoms would fission, and then to a heat exchanger and back to the core.

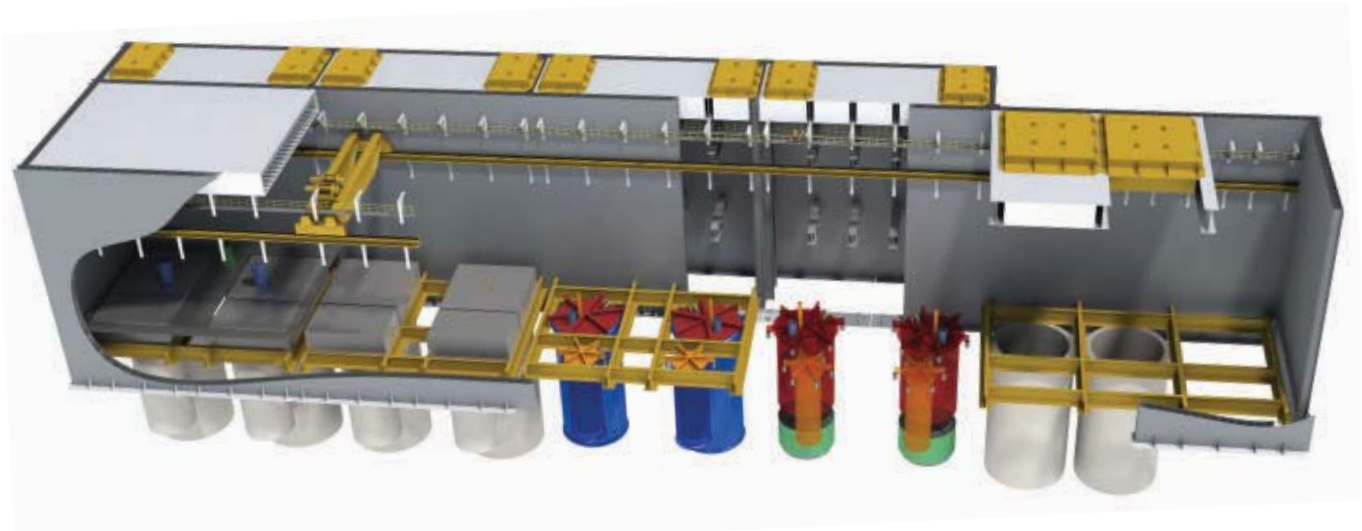
This sort of fluoride salt-cooled molten salt reactor was demonstrated at Oak Ridge National Laboratory in Tennessee in the 1960s as part of a program to make nuclear-powered bombers, and SINAP is cooperating with ORNL to develop the technology further, said David Holcomb, an Oak Ridge physicist.

ORNL will "work together on fundamental research supporting salt-cooled reactors," Holcomb said, though there won't be any joint work on fuel development.

"An example task that ORNL staff members are performing for SINAP is to develop the capability to calibrate liquid salt flowmeters," Holcomb said. The two labs will also be modifying Oak Ridge's reactor modeling and simulation software to better replicate the physics of a salt-cooled pebble-bed reactor.

In spite of the short track record, dissolving the thorium in the salt provides an advantage in processing the material as it transforms into uranium fuel. (Some concepts call for removing the protactinium from the reactor and setting it aside until it decays, since the element has a tendency to snag neutrons and become non-fissile.) Also, the fission decay products can be chemically removed from the fluid without having to pull out the thorium or uranium. The hope is that virtually all the thorium can be converted to fuel and all the uranium can be "burned." By contrast, in conventional solid-fuel reactors less than 7 percent of the total uranium atoms are burned, either directly or via transformation of U-238 to fissile plutonium.

A fluoride salt-cooled molten salt reactor was demonstrated in the 1960s as part of a program to make nuclear-powered bombers.



This cutaway shows the nuclear island of a ThorCon power plant. The plant is desiged to be built in a shipyard-like assembly line.

Image: ThorCon.

By 2020, China plans to have both types of thorium-fueled reactors in operation, according to Norlin. By 2025, those demonstration reactors will be scaled up in size. By 2030, China plans to commercialize both reactor types.

China's top technological challenge in meeting that schedule, Norlin said, is the "need to verify their technology and materials in a realistic environment to prove that everything works before they start building a reactor based on a 'new' technology."

Security blanket

Molten-salt thorium reactors are getting attention in the West, too. Flibe Energy, headquartered in Huntsville, Ala., plans to build a liquid fluoride thorium reactor, or LFTR, based in part on Oak Ridge's original experimental molten salt reactor. The company's name is a nod toward the chemical make-up of the molten salt: fluoride, lithium, and beryllium.

"A huge amount of the design of the LFTR comes from the Oak Ridge work," said Flibe's founder, nuclear engineer Kirk Sorensen, who said he hoped to have a first reactor online in about ten years.

Flibe Energy's LFTR will keep the thorium in its own blanket salt separate from the fuel-laden salt that runs through the reactor core. The bred uranium will be systematically removed from the blanket and injected into the fuel salt.

One improvement over the original Oak Ridge design is in the heat exchanger. The plan is to heat carbon dioxide to run through a gas turbine rather than make steam. Using a gas turbine allows the reactor to run at a higher temperature, Sorensen said, increasing the efficiency of the process to about 45 percent.

"Most reactors use steam turbines. A LFTR uses gas turbines because they have better efficiencies," Sorensen said. "The greater efficiency is due to the higher temperatures—that's the general rule. This reactor operates at 600 °C versus the 300 °C of today's reactors," Sorensen said.

ThorCon's reactor design is also based on the Oak Ridge MSR. But instead of a separate salt blanket for breeding fuel, the ThorCon will have a single, messy fluid cycling through the reactor.

"The fuel salt contains fissile material—U-235, U-233, and Pu-239—that fissions to make heat," ThorCon's Robert Hargraves said. "The fuel salt also contains fertile Th-232 that absorbs neutrons to make U-233, and U-238 that makes Pu-239. The fission process generates enough neutrons to continue the chain reaction and also convert some of the fertile elements to fissile ones, but not enough to continue the process indefinitely."

Since the breeding rate isn't as fast as the burn rate, small amounts of low-enriched uranium will be added as needed.

The reactor could be run solely on uranium, of course. But Hargraves said the addition of thorium to the fluid salt helps reduce uranium consumption. In Hargraves' estimation, half the power will come from burning U-235, while a quarter will come from breeding U-238 into plutonium, and the rest will result from breeding thorium into U-233.

"With improvements," Hargraves said, "future ThorCons will burn less uranium and convert more thorium."

The addition of thorium to the fluid salt helps reduce uranium consumption.

Another unconventional aspect of the ThorCon stems from the background of its principle engineer. Jack Devanney has a degree in naval architecture, and to speed the reactors into production, he wants to bring the experience of building supertankers to the design and construction of nuclear reactors.

"In building supertankers, they complete the design as they complete the specs," Hargraves said. "Once you complete the specs, you present them to likely bidders and get bids inhand. At that point, we will know what these things will cost. ThorCon is a liquid fuel reactor with tanks, pumps, valves—the same components as in a supertanker."

The company will contract with shipbuilders to build a test reactor on a barge, and then begin shaking it down.

"We will use external electric power to raise temperatures," Hargraves said. "We will load salts that melt, and we will check out the performance of heat transfers, pumps, valves, and so on. Lots of tests will get done before we put in fissile fuel. In this phase, we will find all the errors in the design."

Once those design errors are corrected, a steam turbine and an electric generator will be installed. These elements comprise half the cost of a nuclear power plant, according to Hargraves.

Then the plan is to tow the barge to Indonesia.

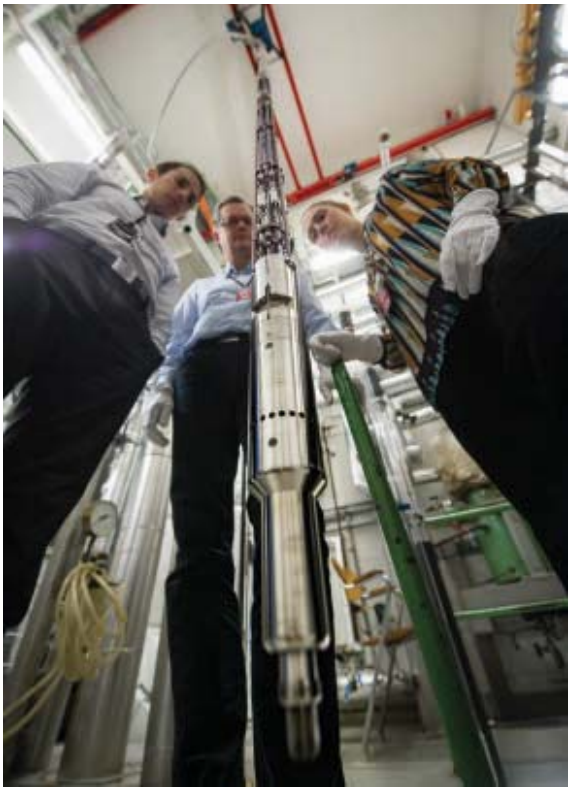
"We will need a year to turn it on, slowly bringing it up to the fission level and test," Hargraves said. "We will work alongside the regulators and incrementally address issues that arise. All the nuclear experience in the world is with light water reactors. So we will work beside the regulators and learn together how to safely operate this kind of power plant."

Thought for fuel

It would be a shame if nuclear power from an element called "thorium" didn't involve a Scandinavian effort. Fortunately, Oslo-based Thor Energy is testing thorium-based fuels in the experimental Halden reactor in Norway, with an eye toward the conventional, light-water reactor market.

"Thor Energy is developing two different families of thorium-based fuels with both U-235 and Pu-239 as the fissile driver material," said Lise Chatwin Olsen, vice president of business development for the company.

The first group of U-235-based fuels will also include thorium, and the company describes this family as a "thorium-additive" fuel. It will either be added to traditional uranium fuel or serve as an alternative to it.



Researchers at Thor Energy in Norway examine a thorium fuel rig prior to inserting it in a reactor for irradiation testing.

Image: Thor Energy.

The second family of fuels is a plutonium-plus-thorium mix (thorium MOX). It will replace traditional uranium fuel or uranium-plutonium mixes known as U-MOX.

All tests of these alternative fuels, conducted since 2013 in the Halden reactor, have the same objective: the "qualification of new thorium-based fuels for use in existing reactors," Olsen said.

"We have seen that the fuel behaves as expected with thorium fuel having lower temperatures, better heat conductivity, better power output, higher conversion ratios, reduced use of neutron poisons (which absorb neutrons) and less long-lived waste," Olsen said. "This would mean higher safety margins or higher power output from the reactor when using thorium fuel compared with traditional uranium-based fuels."

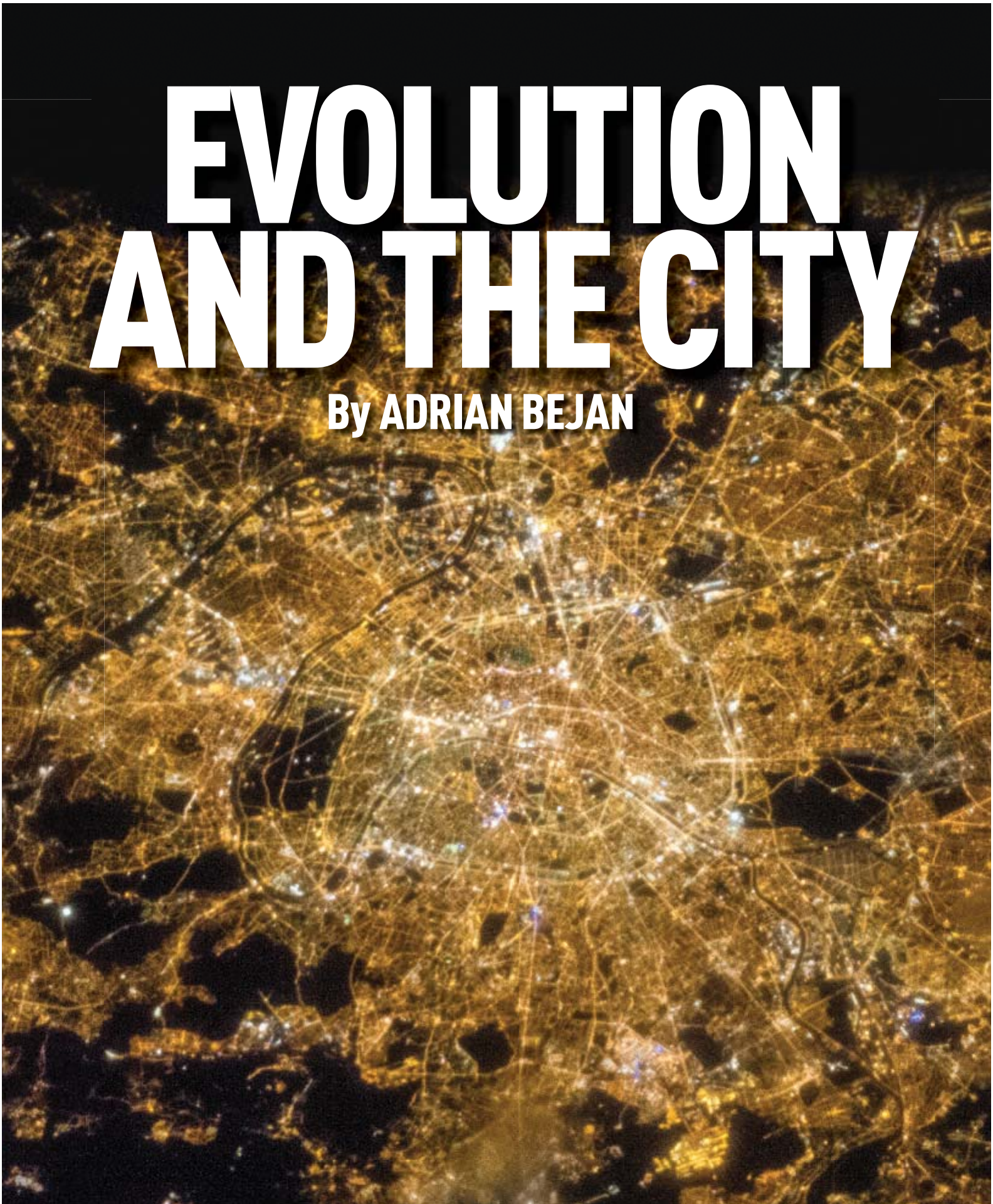
It's impossible to guess which approach to the thorium fuel cycle—if any—will help the nuclear power industry regain its promise from just a few years ago. Does the industry just need a better fuel, or radical new reactor designs?

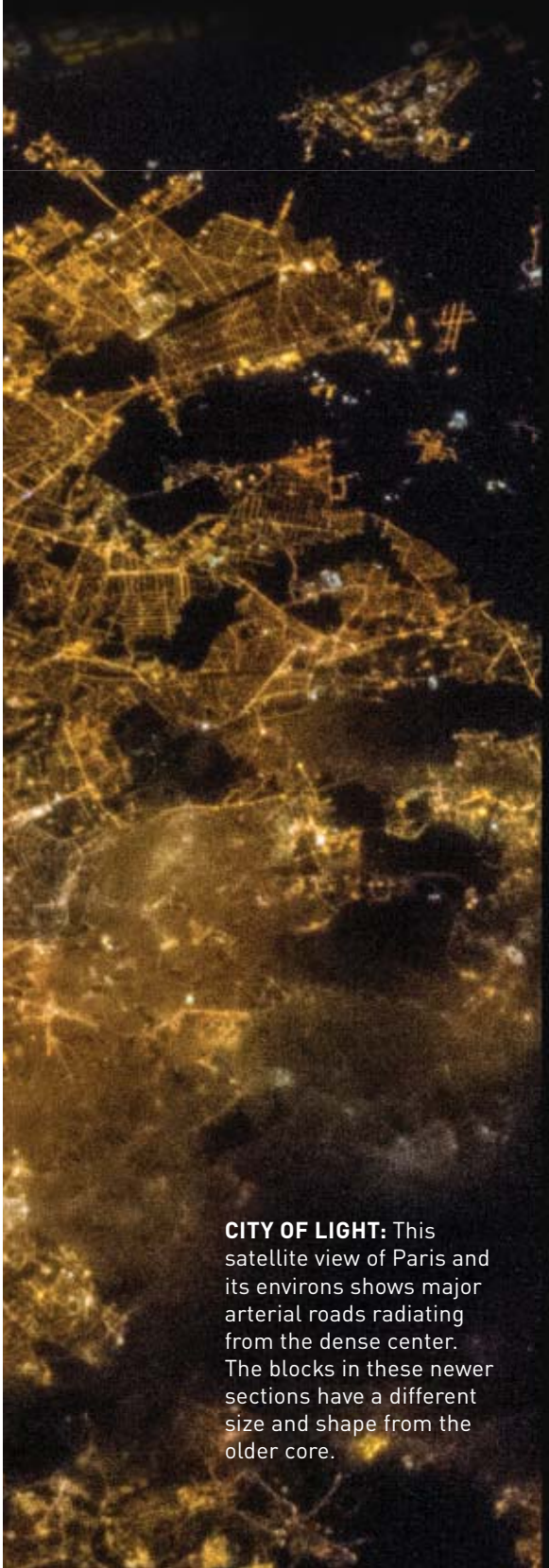
Whatever the answer is, the interest in thorium suggests that it's going to take an unconventional approach to lead to the much anticipated Nuclear Renaissance. **ME**

BRIDGET MINTZ TESTA is a contributing writer based in Houston.

EVOLUTION AND THE CITY

By ADRIAN BEJAN





CITY OF LIGHT: This satellite view of Paris and its environs shows major arterial roads radiating from the dense center. The blocks in these newer sections have a different size and shape from the older core.

A lot of care and attention is paid to urban planning, but the evolution of human settlements happens naturally because it is governed by a law of physics.

The Occupy Movement, which saw protesters seize public squares all over the world, was intended to highlight wealth inequality and lack of freedom. But it provided an unintended lesson on the design of cities: Access is the future of urban design.

That was evident to observers who compared Occupy Wall Street in New York and Occupy Central in Hong Kong. The squatters in New York brought a wide section of the city around its Financial District to a standstill in 2011, and that gridlock produced strong resentment from residents and businesses. The reason for the standstill was the interrupted flow of pedestrian and auto traffic in downtown New York, which is mainly on a horizontal plane at street level. For all its skyscrapers and subways, much of New York is two-dimensional.

OCCUPY CENTRAL: Pedestrian bridges and underpasses in the business district of Hong Kong enable workers to bypass even large protests.

When I visited Hong Kong during the height of the Occupy Central movement, I saw that the protesters squatting there did not stop the pedestrian and auto traffic because that city's central business district is "vascularized" in three dimensions, with overpasses, underpasses, and loops everywhere for pedestrians and vehicles. Compared to New York, access for inhabitants and businesses in Hong Kong was not impaired. While the protesters were forced out of Zuccotti Park in New York after eight weeks, Occupy Central was tolerated for ten months.

It makes sense that the next step in urban design should be to add dimensions. Cities metamorphose as they grow. They exhibit the phenomenon of vascularization on a grand scale. Avenues, one-way loops, overpasses, underpasses, beltways, and subways are new channels that join the old channels to ease the movement of the growing urban population. Paths occur where people walk freely, not the other way around. People disobey when forced to follow a rigid path that is not of their own choosing.

The occurrence of channels and vasculatures is not a new phenomenon. Its first manifestation was the dirt path between a few homes in a village, with peasants and oxen walking on it. Paths were joined by alleys, streets, and avenues. Crooked streets once traced by farm laborers and animals became straighter and wider.

This evolution is as old as civilization. Even the city grid that many associate with Manhattan dates back to the cities designed by Hippodamus of Miletus in the 5th Century BCE. In evolution, what works is kept.

This raises many questions about the arrangement of streets in the city. Why are the large few and the small many? Why does hierarchy happen? Why is a large street connected to only a handful of smaller streets that are oriented sideways? Why does the city traffic design change discretely, in stepwise fashion, and not continuously? Why is the city block shaped like a block? You can find the answers in physics.

Man, ox, carriage, and car

The city is a living, flowing system. It morphs freely as it flows, which is how it derives its lasting power, its life. And we can analyze the organization of a city in terms of how well it enables humans to move from any point to the whole area.

Consider the simplest type of human settlement, one with a single point of prominence such as a central market or harbor surrounded by houses scattered across the landscape. The quickest route to each house from that central point is a straight line. In the most primitive settlement, footpaths radiated outward from the center of the hamlet. This radial pattern of access paths survives today, especially in perfectly flat or sparsely populated rural areas.

In time, the design of movement changed. The ancient market became a larger village with a constellation of almost equidistant tiny villages and farms. The radial length in any such "wheel" was set in antiquity by the distance that the pedestrian and the ox could cover in a few hours, so that the round-trip to the mill or the marketplace could be made during daylight. The order of magnitude of that distance was 10 km, and that's what we see on today's maps.

Horse-drawn carriages eventually disrupted that radial pattern. Humans then had two modes of travel—walking and riding in a carriage—each with a characteristic speed. Because it was impossible for every person to drive a carriage in a straight line to every possible point on the area, trips were divided between the two modes. There was a walking leg, a riding leg, and another walking leg.

In accordance with Constructal Law, the natural way to assemble and connect a road and street network is to ensure that travel time is reduced at every turn and with every change in the flow design. As a result, for a typical trip the time spent traveling slowly is roughly equal to the time spent travelling fast. Of course, that means that the distance covered by fast travel is much greater than the ground covered at slow speed. Imagine a typical commute by automobile: It begins with a slow drive over surface streets, then high-speed travel on long-distance freeways, and then slower speeds as the car exits the highway and moves across surface streets to the final destination.

This principle—slow travel over a shorter distance, fast travel over a greater distance—applies to all travel time, whether it's in the city, on

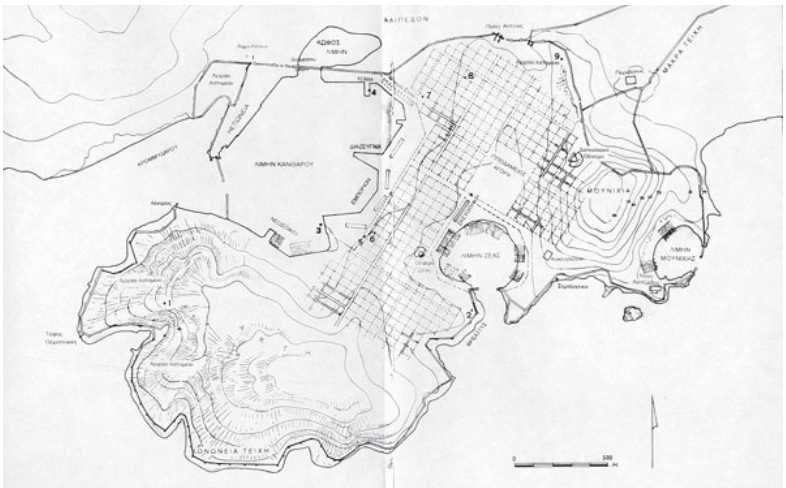
Even the grid associated with Manhattan dates back to the cities designed by Hippodamus of Miletus in the 5th Century BCE.

a highway , or through the air. It's a basic law of physics, and is used to describe how light refracts as it enters and exits glass. Light travels the fastest and most efficient path, not simply the shortest.

The ancient center of an old city such as Rome has small, square blocks with short streets, which serve as a reminder of the vehicles of antiquity, the ox pulling the cart and the horse pulling the carriage. There is a sharp contrast between the ancient center and the newer neighborhoods that emerged during the automobile era. The latter have longer streets, slender city blocks, and more homes per street.

In a city, the smallest scale time balance is between walking from the house to the car and then driving on the small (short, slow) street. At the next length scale, the balance is between riding on small streets and riding on avenues (long, fast), then on to even larger scales: larger avenues and highways. From the highways, the flow design of the city links to intercity train and air travel that includes short and long flights.

Physics applies to human life as well as inanimate movement and flow. We seek the fastest and most efficient path, not simply the shortest. That aspect determines the movement of every individual as he



PIRAEUS: The original plan for Piraeus, the seaport of Athens, was drawn up by Hippodamus of Miletus in the 5th Century BCE. That plan (above) featured a street grid made up of largely identical square blocks. After the city's destruction, Piraeus was rebuilt in the 19th Century following a grid (left) of longer rectangles suitable for faster travel by carriage and tram as well as by foot.

moves through the three-dimensional space of the city, and explains the often baroque shapes the cityscape takes on.

Predicting the suburb

Not all of the vascular features in the city are shaped like blocks. Some are shaped like veins, like the tunnels under a city center or beneath the harbor between Kowloon and Hong Kong Island. Even more stunning are the circular highways around a city, for example, Le Périphérique in Paris and the Beltway in Washington, D.C. All of these features of city evolution owe their existence to the need for easy access of movement.

The construction of a beltway becomes attractive when it is quicker to skirt the margin of the city at highway speed than it is to drive a straight line through it.

Travel time depends on the factors of urban design—one-way streets, stop lights, safety-minded speed limits, and the inevitable congestion—as well as the ability of highway engineering to accommodate higher speeds and greater vehicle capacity. As technology improves to allow faster highway speeds (or congestion on existing roads degrades those speeds), a new and larger beltway farther from the city center may be even more attractive than the first, inner beltway. If we knew the effect on travel times of beltway routes of differing distances from the city center, we could use this evolutionary principle to determine not only the size and location of the new beltway, but also when it should be built.

What's more, across the new neighborhoods sandwiched between the inner and outer beltways, the speed will be greater than in the city center, because new neighborhoods have longer blocks and wider streets. This evolutionary aspect is due to the change in vehicle technology, which means a change in speed.

Constructal Law, then, not only describes the natural tendency that

If we knew the effect on travel times of beltway routes of differing distances from the city center, we could determine not only the size and location of the new beltway, but also when it should be built.

RING ROADS: When travel directly through the center of a city becomes slow due to congestion, engineers devise ring roads such as the one in Shanghai (right). The optimal location for a ring road is based on travel time through the congested center as well as the anticipated speed along the beltway. As those ring roads fill up, new beltways are needed. Houston, Texas, is now in the process of designing and building its fourth ring road (above).

MEDIEVAL TO MODERN: The old center of York, England, (far left) is comprised of small, irregular blocks bisected by alleys, or "snickelways," surrounding the ancient cathedral. Districts built in the 19th century (middle) feature longer blocks with more row houses facing each block. York's modern suburbs (right) have even larger blocks and are designed for access by automobile. (All photos are on the same scale.)

shapes the city grid, it also predicts the emergence and the form of the suburb.

Why is this important to know? If we can anticipate the urban features that emerge naturally from the need for greater access, we can plan ahead and design with confidence the features that not only serve the population, but do so with staying power. It is much more economical to build a new road in the right place and at the right time than to build several roads that are only partway successful. Predicting the future and constructing changes based on a proven scientific principle is much faster and more economical than trial and error.

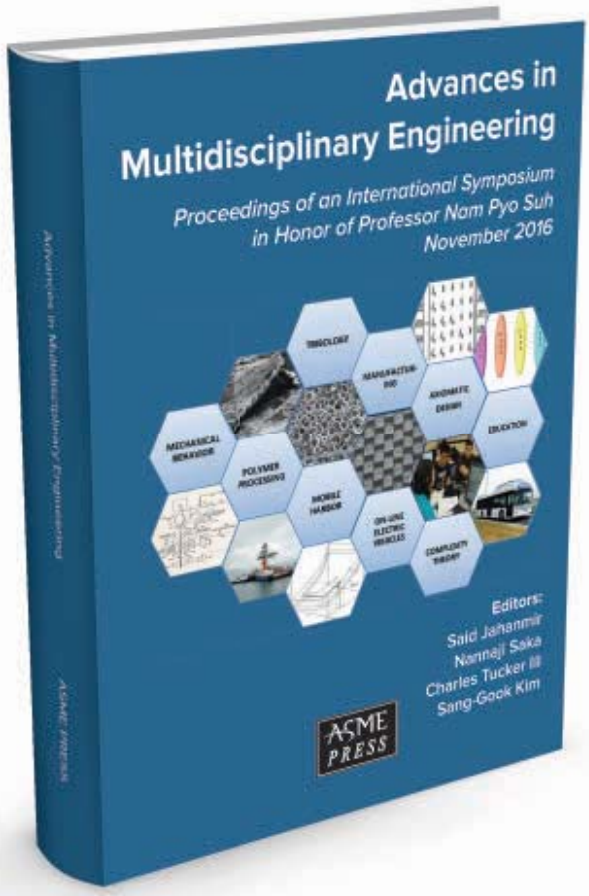
Here, in the evolution of the city, we see how useful the science—and the physics—of evolution is. With the physics of evolution we predict the future.

Thanks to modern technology, urban design expands not only outward, into suburbs, and inward, toward dense city centers, but also vertically. A building or a subway station is a three-dimensional living space with two aspect ratios, the floor shape and the profile shape—that is, the number of floors. In the best-designed modern urban settings, this three-dimensional thinking about the flow of people extends to complex public spaces, which is why Hong Kong could function during Occupy Central while Occupy Wall Street strangled New York's Financial District.

The city is a live flow system with freely changing architecture, many small streets, few large streets, and beltways. We, the people, are what flows. The morphing design strikes us with natural hierarchy, at every level and in every flow: pedestrian movement, traffic, freight, and emergency evacuation.

The changing city opens our eyes to the physics of evolution—and the physics of life. **ME**

ADRIAN BEJAN is the J.A. Jones Distinguished Professor of Mechanical Engineering at Duke University in Durham, N.C. This article was adapted from his recent book, *The Physics of Life: The Evolution of Everything,* published by St. Martin's Press.



FEATURED

ADVANCES IN MULTIDISCIPLINARY ENGINEERING

SAID JAHANMIR, NANNAJI SAKA, CHARLES TUCKER, AND SANG-GOOK KIM, EDITORS

ASME Press Books,
Two Park Avenue, New York, NY 10016-5990. 2016.

Innovative solutions to large-scale, complex engineering problems are no longer confined to a particular discipline of science or engineering. Multidisciplinary engineering, which draws upon concepts from many subfields, often in an iterative process, has become a popular approach to finding optimal solutions to some of technology's thorniest problems. The papers and abstracts collected in this volume were first presented as part of an international symposium held to honor Nam Pyo Suh, the longtime Massachusetts Institute of Technology professor who helped engineering bridge disciplinary barriers during his 50-year career. Among the topics covered in the book are cutting tools and machining, polymer processing, mechanical behavior of materials, friction and wear, prefabricated housing, the milling of aluminum alloys, on-line electric vehicles, and the use of Lego Mindstorms robots in engineering education.

500 PAGES. $300; ASME MEMBERS, $100. ISBN: 978-0-7918-6108-0.

CLIMATE CHANGE AND THE FUTURE OF SUSTAINABILITY

Muyiwa Adaramola, editor
Apple Academic Press, 9 Spinnaker Way, Waretown, NJ 08758. 2016.

Many policy makers look to renewable resources as a way to provide energy in a carbon-constrained future. But many of those renewable resources are liable to be degraded by the most severe impacts of climate change. Long droughts, for instance, will dry up the water needed to power hydroelectric dams, and changing weather patterns driven by long-term climate change could disrupt photovoltaic panels. Muyiwa Adaramola, a professor in renewable energy at the Norwegian University of Life Science, assembled a diverse a set of experts to write on those issues and others, with an eye toward providing an accurate picture of how renewable energy sources will perform in the years ahead.

358 PAGES. $159.95. ISBN: 978-1-7718-8431-0.

XCOR: DEVELOPING THE NEXT GENERATION SPACEPLANE

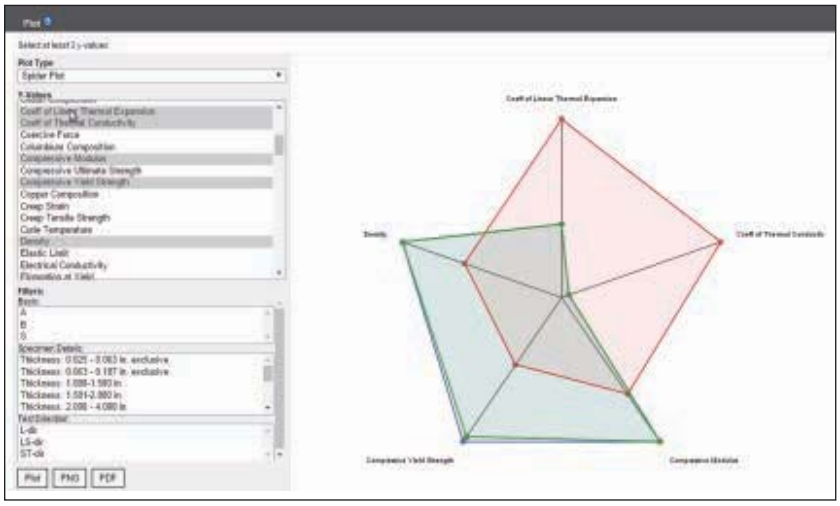
Erik Seedhouse
Springer International Publishing AG, Picassoplatz 4, 4052 Basel, Switzerland. 2016.

Erik Seedhouse examines XCOR Aerospace, the Mojave, Calif.-based developer of the two-seater Lynx spaceplane. The company quietly developed and built 13 different rocket engines over the past 15 years and has flown two of its own manned rocket-powered aircraft. Seedhouse chronicles the development of rocket propulsion, avionics, simulation, and ground support operations that have led to an aircraft that could launch from a conventional airfield and fly to the so-called edge of space several times a day. "The Lynx has been in the works for years, but XCOR, unlike some companies, prefer to let their deeds do the talking," Seedhouse writes. "No bold pronouncements of when revenue flights will start from this company."

213 PAGES. $24.99. ISBN: 978-3-319-26110-2.

MATERIALS LIFECYCLE MANAGEMENT

MSC SOFTWARE CORP, NEWPORT BEACH, CALIF.



MATERIALCENTER 2016, THE MATERIALS lifecycle management system, is intended to enable direct integration into CAE applications and address complex engineering challenges such as those encountered in the aerospace, automotive, and material sectors. The application allows users to export material data directly into solvers like MSC Nastran, Marc, Abaqus, and ANSYS. By giving users additional control over range and interpolation of properties, that feature enables the extraction of the most relevant information from large material data sets. The company says that structural analysts and engineers can now more easily search for and retrieve CAE model data due to new plug-ins for Abaqus/CAE and ANSYS/Mechanical APDL software tools.

MULTIPHYSICS

PRECISE SIMULATION LTD, KOWLOON, HONG KONG S.A.R.

FEATool is designed to be an easy-to-use finite elements method multiphysics simulation toolbox for Matlab and GNU Octave. Release 1.5 now provides features such as external function calls for equation and boundary coefficients, which enable the user to write his own Matlab m-script coefficient functions and call them directly from the FEATool GUI. Also, the implicit 3-D geometry CAD engine has been redesigned to take geometrical features into account, and graphical user interface support for grid conversion and smoothing allows convenient conversion between triangular, quadrilateral, tetrahedral, and hexahedral grid cells.

METROLOGY

BUILDIT SOFTWARE & SOLUTIONS, MONTRÉAL.

BuildIT 2016.5, an update to the 3-D metrology software, adds new automation functionality, additions to its geometric dimensioning and tolerancing capabilities, and a number of large point cloud handling and meshing features. The application is intended to provide quick and easy dimensional inspection of manufactured parts and assemblies for tool building, assembly, alignment, process automation, quality control, and reverse engineering. Other key features include CAD-to-part inspection and the generation of extensive customizable reports. The application can interface in real time with a variety of probing and scanning measurement devices from all major hardware vendors, including Faro, Leica, Romer, API, Creaform, Nikon, and Kreon, and can read 3-D CAD files in either native or neutral formats.

WORKFLOW MANAGEMENT

MATEREALITY, ITHACA, N.Y.

Matereality Software for Materials is intended to give manufacturing enterprises the means to build a centralized, secure knowledge core to store properties, CAE material files, and specifications for any kind of material. The latest release, version 10, provides enhanced material parameter conversion support for LS-DYNA and Altair RADIOSS software. LS-DYNA MAT_089 and MAT_019 support includes graphical drag-and-drop capability to tune and extrapolate plasticity curves as well as rate-dependency parts of these models. A CAE modeler module is part of support for the RADIOSS explicit solver's Law 36. The new release also provides text editing capabilities for documentation of the test methods used for property measurement. Those test methods are displayed alongside properties and data certificates, so that engineers have all the information related to a piece of data readily available.

CLOUD-BASED DESIGN

SIEMENS PLM, ORLANDO, FLA.

Siemens' Solid Edge ST9 is designed to provide easy access to the full capabilities of Solid Edge with cloud-based licensing, user preferences, and collaboration tools. New migration tools build on the existing toolset for importing CAD data, allowing the associativity between SolidWorks models and drawings to be migrated to Solid Edge. In addition, the new built-in data management capabilities enable users to index their CAD models, while the new migration tools allow the rapid conversion of legacy design data from virtually any CAD system. Solid Edge ST9 also adds data storage options via cloud-enabled vaulting so users can store and share design data in a controlled manner with external suppliers and customers, using popular

software like Dropbox, OneDrive software, Google Drive online storage service, and Box. The option to work offline is still available.

BUILDING INFORMATION

ALLPLAN, MUNICH.

Allplan 2017, a building information management application for architects and engineers, is intended to promote interdisciplinary collaboration via integration with bim+, an open, cloud-based BIM platform. That platform enables model data from Allplan and other OpenBIM solutions to be merged, viewed, analyzed, and shared. If a situation is unclear, or if planning mistakes have been made, the visual check or the bim+ collision control will allow errors to be identified at an early stage. Individual design specialists see these errors as "collisions" during the automatic comparison of the models. The issues can now be directly assigned as tasks to the relevant design specialist.

IoT MANAGEMENT

GLOBERANGER, RICHARDSON, TEXAS.

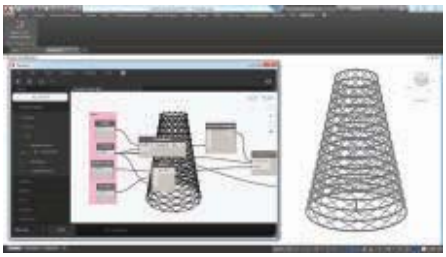
The iMotion IoT Edgeware Platform is intended to provide device and data management for RFID, sensors, and other devices. The application connects a wide variety of edge devices, then processes, correlates, and reacts to edge data in real time, as part of managing an Internet of Things-enabled system. The latest release of the iMotion Platform, iMotion 7.0, adds features for developers, support for the MQTT protocol, greater scalability, and support for .NET 4.6. iMotion 7.0 can integrate complex Edge solutions with Amazon Web Services, Microsoft Azure IoT, GE Predix, and IBM Watson.

PIPELINE INTEGRITY

CREAFORM, LEVIS, QUÉBEC.

Pipecheck 3.3 is the latest release of the NDT pipeline integrity assessment application designed to detect and characterize internal and external pipe defects, such as corrosion and mechanical damage. New features include an ability to make more precise dent calculations that replicate repeatable and user-independent field measurements, and a strain-based assessment approach that uses advanced strain calculations along the pipe. The intention is that users will be able to more effectively interpret results, thereby facilitating decision making with respect to the repair actions to take. Pipecheck 3.3 can also automatically distinguish and identify clusters from anomalies, thereby helping operators pinpoint critical issues on a pipeline.

STRUCTURAL STEEL DETAILING



AUTODESK, NEW YORK.

Advance Steel 2017.1 is an update to Autodesk's structural steel detailing application. The product is designed to enable users to move quickly from steel design to steel detailing and fabrication. The release improves interoperability with enhanced IFC 2×3 export capabilities and makes drawings easier to read with background mask capability behind dimension and label texts. Users can also check steel connection design with latest AISC codes, to help validate steel connections against the latest standards. Other features found in the new release are the ability to edit XRef and Block in-place feature available for referenced Advance Steel DWG files, improvements to the polygonal beam behavior for cuts, and the inclusion of bolt weights within a BOM to get a more accurate assembly weight.

PEDESTRIAN SIMULATION

VECTORWORKS, COLUMBIA, MD.

Developed by A&A Co., Ltd., the Vectorworks distributor in Japan, in partnership with Waseda University and Takenaka Corporation, SimTread 2.4 can aid in analyzing an array of crowd control needs, anything from the flow of people as they slowly meander through an art museum to determining the evacuation route for a capacity crowd at a football stadium. Among the new features in version 2.4 is a way to display reports to clients using a color-coded map on top of a floor plan, which helps to identify potential egress bottlenecks. A visual reporting feature called "Plot Travel Time" will determine the time it takes for each individual occupant to evacuate from a building model, displaying a circle over each occupant's starting position, color-coded to indicate how long it took each individual to evacuate.

FIRE SAFETY

HILTI, PLANO, TEXAS.

Hilti Button for Firestop is a firestop automation application that integrates with building information model software platforms. Hilti Button automates the firestop product and UL system selection process, eliminating the tedious and time-consuming manual task of placing hundreds of firestop objects in BIM. Hilti Button automatically detects penetrations in fire-related construction and populates the appropriate firestop products and UL systems directly into BIM to save time, increase efficiency and reduce costs. By seamlessly integrating with the Autodesk ecosystem around Navisworks Manage, AutoCAD, Fabrication CADmep, and Revit, Hilti Button automates the firestop selection process on a project. Using attributes in the BIM model for clash detection, Hilti Button identifies penetrations going through fire rated barriers that need to be firestopped. That information from clash detection is then pulled into Firestop Manager, reducing the number of hours spent on the jobsite and in the office.

HVAC SIZING

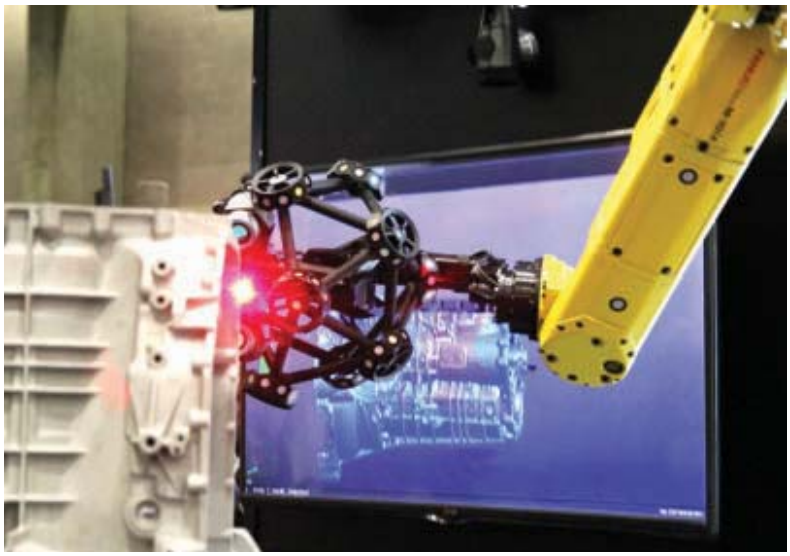
SEMCO, COLUMBIA, MO.

ExpressSelect FV is a product selection software module now offered by SemCo, the maker of HVAC equipment. ExpressSelect FV is designed specifically for the FV Series of outdoor air heat recovery and pre-conditioner systems used in hospitals, hotels, office buildings, schools and other commercial facility HVAC designs. It is accessed via a web browser and operates from the cloud. After signing in with the company website, users input project data and then the application calculates HVAC demand based on AHRI standards. Consulting engineers, contractors, and manufacturer's representatives can then view a selection of fresh air ventilator heat-recovery systems that fit the customer's need. Completed and unfinished submittals are stored and backed up on a cloud-based server, which means the information can be accessed or printed from any Internet-connected device.

AUTOMATED INSPECTION

CREAFORM, LÉVIS, QUÉBEC.

THE NEW VERSION OF CREAFORM'S MetraSCAN 3D R-Series is designed to be more rugged than previous releases and features improved cycle times to further support industrial production control. With built-in seven laser crosses, the system can now pick up to 480,000 measurements per second on complex surfaces with reflectivity. The MetraSCAN 3D R-Series also features new glass-protected positioning targets that can withstand harsh environmental conditions and ensure overall improved durability in shop-floor environments, such as airborne dust or dirt, that could impact product lifecycle and require unnecessary and repetitive calibrations.



LINEAR ACTUATORS

KOLLMORGEN, RADFORD, VA.

The ERD series of stainless steel linear actuators combine the AKMH series servo motors with ball-screw driven transmissions as IP69K-rated packages. Designed for use with Kollmorgen's AKD or AKD-N series centralized and decentralized servo drives, the ERD actuators use a single cable for both power and feedback. A choice of encoder feedback includes digital resolver SFD3 and Hiperface DSL. The 316 stainless steel, housed AKMH series servo motor has a torque derating of under 20 percent. The ERD has a thrust force of up to 20 kN with feed speeds to over 1 m/s over a stroke length of up to 600 mm. For compact installation the actuator screw section diameter ranges from 42 to 132 mm across the four frame-sizes. The actuator is intended for precision positioning tasks for lifting units, closing or feed axes, or machine format adjustments in the food, produce, or pharmaceutical industries.

SPRAY NOZZLE

EXAIR, CINCINNATI.

Exair's new 1/2 NPT large external mix spray nozzles atomize fluids up to 303 gal. per hour. They can be used on liquids with a viscosity up to 800 cP and are available in a narrow angle flat fan pattern. The stainless steel construction of the nozzles is intended to add durability and corrosion resistance. Internal mix and siphon fed atomizing nozzles are also available, as well as patented no-drip versions of all atomizing nozzles.

COMPACT LINEAR POSITIONER

PHYSIK INSTRUMENTE, AUBURN, MASS.

The Q-545 is a new compact linear stage, just 45 mm wide, that according to its manufacturer combines high positioning accuracy with higher force and velocity than many conventional inertia drives. Stick-slip drive motors, lacking gears, are powered by the natural difference in the static and dynamic friction coefficients found between two surfaces. That enables the stages to be more compact, reliable, and cost efficient. With holding force of 8 N and maximum velocity of 10 mm per second, the self-clamping motor design provides long-term power-off position-hold capabilities without the need for a brake. A high resolution option with integral linear position encoder providing 1 nm resolution is available, as are nonmagnetic versions and an ultra-high-vacuum version for pressures of 10-9 hPa.

WATERJET CUTTING

JET EDGE, ST. MICHAEL, MINN.

Designed especially for high-volume water-only waterjet cutting applications, Jet Edge Waterjet Shuttle Systems are intended for industrial use and hold a linear positional accuracy of +/- 0.001 in. per axis over 12 in. as well as +/- 0.001 in. bi-directional repeatability. Moving elements are supported on THK linear ways, precision ball screws are directly coupled to servomotors, and XY mechanical components are protected by a lip seal system. The system is available in a high rail gantry format supporting up to 12 cutting heads or a mid-rail gantry format supporting up to four cutting heads.

HELICAL GEARBOX

AUTOMATIONDIRECT, CUMMING, GA.

The IronHorse line of motor products now includes helical gearboxes. Designed for use with 1 hp to 20 hp electric motors, the gearboxes reduce output speed while increasing torque, and feature C-face, TC-face inputs, and inline outputs. They are available in five frame sizes ranging from 56C up to 254/6TC with six nominal ratios of 5:1 to 60:1. Constructed of FC-20 cast iron one-piece housings, the IronHorse gearboxes feature a carbon steel shaft protected with shaft sleeves, as well as heat-treated and ground high-strength steel gears. Manufactured in an ISO9001-certified plant, the gearboxes may be mounted in most directions, and the universally interchangeable compact design ensures easy OEM replacement.

PERMANENT MAGNET MOTOR

NOVATORQUE, FREMONT, CALIF.

NovaTorque has introduced 600 RPM versions of its PremiumPlus+ electronically commutated permanent magnet motors. They are currently available from 0.75 hp to 3 hp, and are produced in standard NEMA frame sizes for easy substitution. The company says that these motors have losses around half as great as similar products, and will reduce overall energy use by between 4 and 20 percent, depending on operating speeds, with the largest percentage savings at partial rated speed. The company says the motors are well suited for applications such as directly driving larger diameter fans at low speeds because it eliminates the efficiency losses associated with belts and pulleys.

LOAD CELL

HARDY PROCESS SOLUTIONS, SAN DIEGO.

Hardy has released a new line of footed load cells with height-adjustable rubber feet. Two members of the new line feature a threaded captive load pin design: HI SBHC14, with a 500-to-5,000 lb. capacity, and the smaller HI HBB01, with a 22-to-1,100 lb. capacity. According to the company, captive load pin designs not only provide a high degree of structural integrity but also make them flexible for a wide variety of installations. The third new load cell, HI SBHF14, has a 500-to-5,000 lb. capacity and a blind hole, rocker pin design intended to help prevent unwanted mechanical binding or torsional forces from affecting load cell performance. Footed load cells are used for platform scales, tank weighing, hoppers, and conveyor systems.

INFRARED THERMOMETER

LUMASENSE TECHNOLOGIES, FRANKFURT AM MAIN, GERMANY.

The IMPAC IGAR 6 Advanced infrared thermometer is a digital, compact pyrometer designed for non-contact temperature measurement in ranges between 100 to 2000 °C. In addition to one-color and two-color modes, the IGAR 6 Advanced features a "switchover" technology, known as Smart Mode, to enable the pyrometer to measure temperature in one-color mode at temperatures between 100 and 250 °C, and then transition to two-color mode to provide the advantages of measurements in ratio mode at temperatures between 280 to 2000 °C. Like other pyrometers in the series, the IGAR 6 Advanced offers sighting options such as through-lens-sighting, laser targeting, and TV module. The pyrometer can be connected to a PC through an RS485-to-USB connection.

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.

FLEXIBLE SHAFT MACHINE

SUHNER, BRUGG, SWITZERLAND.

Suhner has introduced the Rotomax flexible shaft machine, a unit with interchangeable hand pieces that allow a user to perform a wide variety of machining operations with a single machine. By changing the hand piece, the Rotomax may operate as an angle grinder, straight grinder, drum polisher, belt sander, tube polisher, or die grinder. The combination of an industrial grade motor and solid-state electronic control ensure constant speed and torque during any application. Up to 4.7 hp of power is available, and shaft speed is electronically controlled, with speeds from 500 to 15,000 RPM available at the touch of a button. The Rotomax can be hung for overhead use or may operate on a stand or trolley. The machine may be suitable for applications in industrial steel fabrication, polishing operations, appliance manufacturing, and fabricating stainless steel.

ELECTRIC MOTOR ENCODER

LEINE & LINDE, SCHAUMBURG, ILL.

The MRI 2850 is a bearing-less encoder for high horsepower electric motor applications using vector control. The MRI 2850 offers able outputs and robust line drivers with a unique code-wheel securing mechanism, and its lightweight aluminum enclosure reduces the effort for installation and is coated to prevent corrosion. Designed for mounting on a NEMA standard 8.5-in. C-Face, the sensor technology provides extremely compliant tolerances. One or two independent read-heads can be provided, each with any resolution between 1 and 16383 PPR. The IP67-protected read-heads include power and status LEDs so proper mounting and operation can be visually determined at any time. The magnetic code-wheel on the MRI 2850 supports shaft sizes from 1" to 4" without the need for a stub shaft. The magnetic material is permanently covered with a stainless steel shield so that damage from mechanical contact is eliminated.

LEVEL SENSOR

HAYWARD FLOW CONTROL, CLEMMONS, N.C.

The new CPVC HLS series level sensor line is not affected by foaming, waves, or head space vapors. With a complete CPVC housing and construction, the HLS is ideal for corrosive fluids and environments where metals cannot perform, such as chlorination systems, aquatic and animal life support systems, and chemical storage, transfer, and processing. The HLS level sensor measures hydrostatic pressure and converts the reading to an analog 4-20 mA signal, which can be displayed on a wide range of indicating transmitters or taken directly into a PLC. PFA-coated cable, in standard 30 and 49 foot lengths, offers superior chemical compatibility, and the large ceramic diaphragm ensures accuracy and repeatability.

RESOURCEFILE

- Instrumentation & Control
- Power Transmission & Motion Control
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- Materials & Assembly
- Engineering Tools
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A bimonthly listing of the industry's latest technical literature and product information available FREE to *Mechanical Engineering* readers.

STANDARDS

ASME STANDARDS & CERTIFICATION
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If you are looking for information regarding an ASME code or standard committee, conformity assessment program, training program, staff contact, or schedule of meetings:

PLEASE VISIT OUR WEBSITE: WWW.ASME.ORG/CODES

COMMITTEE LISTING: For a listing of ASME Codes and Standards Development Committees and their charters, visit the Standards and Certification website at http://cstools.asme.org/charters.cfm.

CONFORMITY ASSESSMENT: For a listing and description of ASME Conformity Assessment programs (accreditation, product certification, and personnel certification), visit the Certifications webpage at go.asme.org/certification.

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STAFF CONTACTS: To obtain the ASME staff contact information for a Codes and Standards Development Committee or a Conformity Assessment program, visit the Codes and Standards website at http://cstools.asme.org/staff.

SCHEDULE OF MEETINGS: Meetings of Codes and Standards Development Committees are held periodically to consider the development of new standards and the maintenance of existing standards. To search for scheduled meetings of Codes and Standards Development Committees, by date or by keyword, visit the Standards and Certification website at http://calendar.asme.org/home. cfm?CategoryID=4.

PUBLIC REVIEW DRAFTS

An important element of ASME's accredited standards development procedures is the requirement that all proposed standards actions (new codes and standards, revisions to existing codes and standards, and reaffirmations of existing codes and standards) be made available for public review and comment. The proposed standards actions currently available for public review are announced on ASME's website, located at http://cstools.asme.org/csconnect/PublicReviewpage.cfm.

The website announcements will provide information on the scope of the proposed standards action, the price of a standard when being proposed for reaffirmation or withdrawal, the deadline for submittal of comments, and the ASME staff contact to whom any comments should be provided. Some proposed standards actions may be available directly from the website; hard copies of any proposed standards action (excluding BPV) may be obtained from:

MAYRA SANTIAGO, Secretary A
ASME Standards & Certification
Two Park Ave., M/S 6-2A
New York, NY 10016
e-mail: ansibox@asme.org

ASME maintains approximately 500 codes and standards. A general categorization of the subject matter addressed by ASME codes and standards is as follows:

Authorized Inspections
Automotive
Bioprocessing Equipment
Boilers
Certification & Accreditation
Chains
Controls for Boilers
Conveyors
Cranes & Hoists
Cutting, Hand, & Machine Tools
Dimensions
Elevators & Escalators
Energy Assessment
Energy Storage
Engineering Drawings, Terminology, & Graphic Symbols
Fasteners
Fitness-For-Service
Gauges/Gaging
Geometric Dimensioning & Tolerancing (GD&T)
High-Pressure Vessels Systems
Keys and Keyseats
Limits & Fits
Materials
Measurement of Fluid Flow in Closed Conduits
Metal Products Sizes
Metric System
Metrology & Calibration of Instruments
Nondestructive Evaluation/ Examination
Nuclear
Performance Test Codes
Personnel Certification
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Post Construction of Pressure Equipment & Piping
Power Plant Reliability, Availability & Performance
Powered Platforms
Pressure Vessels
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Rail Transportation
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Risk Analysis
Screw Threads
Steel Stacks
Surface Quality
Turbines
Valves, Fittings, Flanges, Gaskets
Verification & Validation
Water Efficiency for Plants
Welding, Brazing & Fusing

The ASME Standards & Certification section is published as submitted to Mechanical Engineering magazine by ASME's Standards & Certification Department.

Department of Mechanical Engineering Faculty Positions

The Department of Mechanical Engineering at Virginia Tech invites applications for two open faculty positions in the general areas listed below. One is a tenure-track or tenured position located in Blacksburg, VA to be filled at the Assistant, Associate, or Full Professor level, the other is a non-tenure track collegiate faculty position located at National Capital Region (NCR) in suburban Washington DC area. Exceptional candidates will be considered for named professorships.

Virginia Tech is committed to diversity and seeks a broad spectrum of candidates including women, minorities, and people with disabilities. Virginia Tech is a recipient of the National Science Foundation ADVANCE Institutional Transformation Award to increase the participation of women in academic science and engineering careers (www.advance.vt.edu).

1. Robotics and Autonomous systems (open rank in Blacksburg, VA): Areas include perception, sensor systems, robotics and autonomous systems, intelligent systems, signal processing and estimation, and other related areas. We are looking for a senior leader in the area of perception which can develop a strong internationally recognized sponsored research program and continue to develop a group in this specialty for the Virginia Tech's Destination Areas (below). Job number TR0160179. Search Chair: Prof. Saied Taheri (staheri@vt.edu).

This position is part of a large cluster hire of faculty across the university for VT's newly developed Destination Areas. VT's Destination Areas represent difficult problems of present and future national and global importance for which VT is investing resources to build and support world-class groups of faculty that transcend our disciplinary strengths. This position will serve the Destination Area in "Intelligent Infrastructure for Human Centered Communities" which aims to design, develop, and understand social, technical, economic, cultural, political, and information paradigms to support sustained and adaptive human societies. Other related Destination Areas which this position could serve are "Data Analytics", "Decision Sciences and Integrated Security", and "Adaptive Brain and Behavior."

Applicants must hold a doctoral degree in mechanical or electrical engineering or a closely related discipline. We are seeking highly qualified candidates committed to a career in research and teaching. The successful candidates will be responsible for mentoring graduate and undergraduate students, teaching courses at the graduate and undergraduate levels, and developing a strong externally sponsored research program. Candidates should apply online at www.jobs.vt.edu to the appropriate posting number given above. Applicants should submit a cover letter, a curriculum vitae including a list of published journal articles and other scholarship activities, a brief statement on teaching preferences, a one-page research statement, and the names of five references that the search committee may contact. Review of applications will begin on **February 15, 2017** and will continue until the position is filled.

2. Design, Materials and Manufacturing (collegiate faculty, non-tenure track position): Areas include computational solid mechanics, multi-scale modeling of materials, design methodology, design optimization, materials design, computer-aided design, and modeling and simulation of advanced manufacturing processes. This position will be part of the newly expanding graduate program in the National Capital Region (NCR) in suburban Washington DC area. Job number **TR0160177**. Search Chair: Prof. Mehdi Ahmadian (ahmadian@vt.edu)].

This position is part of a large cluster hire of faculty across university for VT's newly developed Destination Areas. VT's Destination Areas represent difficult problems of present and future national and global importance for which VT is investing resources to build and support world-class groups of faculty that transcend our disciplinary strengths. These positions will serve the Destination Area in "Data Analytics and Decision Sciences." (http://provost.vt.edu/destination-areas/da-data.html). Although candidates with expertise in all sub-themes of this Destination Area are encouraged to apply, we are particularly interested in candidates with expertise in Infrastructure Analytics: Data as it relates to and revolutionizes the way we interact with the natural and the built environment.

VT's National Capital Region (NCR) operations is continually expanding in the Washington, D.C. metropolitan area and currently offers more than 45 graduate degree and certificate programs. Approximately 1,000 students are enrolled in master's degree and 300 students in Ph.D. programs in the region. The university's Northern Virginia Center (NVC) in Falls Church, and its buildings in Old Town Alexandria and Arlington, are all easily accessible by Metro. Many online courses are also available. The VT's College of Engineering at NCR currently offers graduate degrees in computer science, and electrical and computer engineering, civil and environmental engineering, and industrial and systems engineering. The ME department has offered nuclear engineering graduate program but now is expanding its offerings at NCR, envisioning a rapidly growing graduate program. With this new position, and our existing faculty at NCR, a total of five ME faculty will serve our NCR graduate program by next year, while also supported by the faculty from our main campus in Blacksburg, VA program by next year, while also supported by the faculty from our main campus in Blacksburg, VA.

Applicants must hold a doctoral degree in engineering or a closely related discipline. We are seeking highly qualified candidates committed to a career in teaching and research. The successful candidates will be responsible for mentoring primarily the graduate students at the NCR and some undergraduate students, teaching courses at the graduate and undergraduate levels in both regular classrooms and long-distance settings, and developing a research program, although the primary mission of this position is teaching. Candidates should apply online at www.jobs.vt.edu to the appropriate posting number given above. Applicants should submit a cover letter, a curriculum vitae including a list of published journal articles and other scholarship activities, a brief statement on teaching preferences, a one-page research statement, and the names of five references that the search committee may contact. Review of applications for all positions will begin on **February 15, 2017** and will continue until the position is filled.

The Department of Mechanical Engineering (http://www.me.vt.edu/), which includes a Nuclear Engineering Program, has 61 faculty, research expenditures of over $16M, and a current enrollment of 340 graduate students with 180 students at doctoral level, and over 1100 undergraduate students. The Department is ranked 13th and 16th out of all mechanical engineering departments in the nation in undergraduate and graduate education, respectively, by the 2017 U.S. News and World Report. The Department includes several research centers, and its faculty members are engaged in diverse multidisciplinary research activities. The mechanical engineering faculty also benefit from a number of university-wide institutes such as the Institute for Critical Technology and Applied Science (ICTAS), the Biocomplexity Institute, Virginia Tech Transportation Institute (VTTI), College level centers such as the Rolls-Royce and the Commonwealth of Virginia Center for Aerospace Propulsion Systems (CCAPS), the recently established Rolls-Royce University Technology Center (UTC) in advanced systems diagnostics, the Virginia Center for Autonomous Systems (VaCAS), and state level industry-academic research centers such as the Commonwealth Center for Aerospace Propulsion Systems (CCAPS) and the Commonwealth Center for Advanced Manufacturing (CCAM).

1865 THE UNIVERSITY OF MAINE

Tenure-Track Assistant/Associate Professor: Materials Science and Engineering

Mechanical Engineering Department College of Engineering, University of Maine

The Mechanical Engineering Department at the University of Maine invites applications for the position of tenure-track Assistant or Associate Professor. A background in materials science and engineering is required, with a demonstrated track record in research and a strong commitment to teaching. Applications are invited in all areas of materials science and engineering, particularly those that complement current research activities in computational and experimental solid mechanics, renewable energy, aerospace engineering, ocean engineering, biomechanics/biomedical engineering, and geomechanics/geophysics. The successful candidate is expected to develop a strong externally funded research program, and teach undergraduate and graduate courses in engineering materials, mechanical behavior of materials, engineering mechanics, and related areas. Applications, including cover letter, full curriculum vita, statements of teaching and research interests, and contact information for at least three potential references should be sent to the Department of Human Resources via https://umaine.hiretouch.com. Review of applications will begin Feb. 13, 2017. The expected start date is September 2017. Salary and benefits are competitive and dependent on qualifications. A B.S. and Ph.D. in Mechanical Engineering or a closely related field is required at time of appointment. Underrepresented minorities and women are strongly encouraged to apply.

The University of Maine is an EEO/AA employer. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, national origin, sexual orientation, age, disability, protected veteran status, or any other characteristic protected by law.

1865 THE UNIVERSITY OF MAINE

Tenure-Track Assistant/Associate Professor: Dynamics and Control of Mechanical Systems

Mechanical Engineering Department College of Engineering, University of Maine

The Mechanical Engineering Department at the University of Maine invites applications for the position of tenure-track Assistant or Associate Professor. The candidate must have a background in dynamics and control systems with a demonstrated track record in research and a strong commitment to teaching. Applications are invited in all areas of dynamics and controls, particularly those that complement current research activities in renewable energy, aerospace engineering, ocean engineering, robotics, and biomechanics/biomedical engineering. The successful candidate is expected to develop a strong externally funded research program, teach undergraduate and graduate courses in control systems, dynamics and related areas, and contribute to the capstone effort in his or her area of expertise. Applications, including cover letter, full curriculum vita, statements of teaching and research interests, and contact information for at least three potential references should be sent to the Department of Human Resources via https://umaine.hiretouch.com. Review of applications will begin Feb. 13, 2017. Expected start date is September 2017. Salary and benefits are competitive and dependent on qualifications. A B.S. and Ph.D. in Mechanical Engineering or closely related field is required at time of appointment. Underrepresented minorities and women are strongly encouraged to apply.

The University of Maine is an EEO/AA employer. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, national origin, sexual orientation, age, disability, protected veteran status, or any other characteristic protected by law.

POSITIONSOPEN

THE DEPARTMENT OF MECHANICAL ENGINEERING at the **AMERICAN UNIVERSITY OF BEIRUT** invites applicants for two faculty positions at the **ASSISTANT PROFESSOR LEVEL** beginning Fall 2017 in the areas of dynamics/vibration and materials engineering. All applicants from broad experimental, analytical, or computational modeling research interests are invited to apply.

The successful candidate must 1) Have a PhD degree in mechanical engineering or in a closely related field, preferably with postdoctoral or industrial experience. The bachelor's degree must have been earned in mechanical engineering 2) Be able to conduct strong research programs in mechanical design 3) Demonstrate a record of independent research and publications.

The successful candidate is expected to teach graduate and undergraduate courses in mechanical engineering, participate in program development, and be active in research. The candidate is expected to take an active role in developing research initiatives leading to external funding and publications in internationally recognized journals, and should have the ability to work in a team-oriented environment.

Applications will be reviewed as received and the process will continue until the position is filled (tentative starting date is Sept. 2017). Salary is commensurate with education and experience. Applicants should submit 1) A complete resume 2) A statement that articulates the applicant's teaching and research interests 3) Names and addresses of at least three referees.

The complete application should be sent via email in PDF format or air mail to: Dean of Engineering and Architecture (email:fea@aub.edu.lb), Faculty of Engineering and Architecture, the American University of Beirut, P.O. Box 11-0236, Riad El-Solh, Beirut 1107-2020, Lebanon. Information on the Faculty of Engineering and Architecture at AUB can be found at www.aub.edu.lb/fea/.

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POSITIONSOPEN

THE COLLEGE OF ENGINEERING at **NEW MEXICO STATE UNIVERSITY (NMSU)** invites applications for **TWO TENURE-TRACK FACULTY POSITIONS** at the rank of **ASSISTANT PROFESSOR** in the **MECHANICAL AND AEROSPACE ENGINEERING DEPARTMENT** starting Fall 2017. The successful candidates must have an earned Ph. D., or equivalent, in Mechanical or Aerospace Engineering or a closely related field. Particular expertise is sought in the areas of un-manned systems, robotics, and autonomy. Duties for the positions include teaching at both the undergraduate and graduate levels in the discipline, developing an externally-funded research program with peer-reviewed dissemination of results, and providing services to the university and the profession. In addition to a competitive salary, NMSU also offers group medical and hospital insurance, group life insurance, long-term disability insurance, state educational retirement, workers' compensation, sick leave, annual leave and unemployment compensation, and opportunities for educational advancement. Applicants should e-mail application packages to Search Committee Chair, facultysearch-2016-mech@mae.nmsu.edu. All the application documents should be assembled into a single PDF file that includes a cover letter, a current vita, a statement of teaching and research and the names and contact information of at least three references. Candidates selected as finalists will be required to provide unofficial transcripts from the highest degree granting institution. Review of applications will start February 15, 2017. Applications received after this date may be considered until the positions are filled. NMSU is an equal opportunity/affirmative action employer. All offers of employment, oral or written, are contingent upon verification of credentials, individual's eligibility for employment in the United States and other information required by federal law, state law, and NMSU policies and procedures, and may include completion of a criminal history check.

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BRAVE NEW ROAD

Self-driving cars will change society in all sorts of unexpected ways

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ROE SPEECH HAILS CHANGES

ASME President Keith Roe discussed the Society's new strategic path during his speech at the President's Luncheon during the ASME International Mechanical Engineering Congress and Exposition in November.

"We are witnessing a transformation of our Society as it reshapes itself to meet today's challenges," Roe said. "The changes we see around us affect almost every aspect of our lives."

Roe went on to highlight the difference between ordinary transition and the kind of game-changing transformation the Society is experiencing.

"A transition will draw you a map to an expected destination, but a transformation puts you on a less clear path to a new, exciting destination," Roe said. "A transition can lead to major shifts to a new set of opportunities; a transformation brings entirely new perspectives and a vision of a unified whole with limitless possibilities. In the end, transition tries to find a way through the chaos; transformation brings order to chaos."

Roe also reviewed the key steps ASME has taken in the past year to ensure its future relevance, including the selection of five technologies that will be the focus of forthcoming programs and products and the formation of four new Society task forces to support ASME's strategic plan.

Roe laid out some of the key activities the Society has undertaken in recent months to pave the way for this ground-breaking transformation, beginning with the Board of Governors' decision more than a year ago to approve a new technology-focused strategy for the future that is intended to establish ASME as the go-to organization—or "global technology hub," as Roe called it—for critical mechanical engineering technologies.

The basis of the new strategy, which Roe said was intended to take ASME "from good to great," was the selection of five technologies the Society would focus on when developing its portfolio of programs and products in the future.

The five chosen technologies—manufacturing, clean energy, bioengineering, pressure technology, and robotics—were approved by the Board of Governors in June after being identified by ASME staff and the newly formed Technology Advisory Panel from an original list of more than 2,000 individual technologies.

In addition to the five focus technologies, ASME identified eight enabling technologies that it considered highly important to innovation and the expansion of the Society: the Internet of Things, big data analytics, sustainability, artificial intelligence, cybersecurity, materials, nanotechnology, and design engineering.

Roe also discussed the launching of four new Presidential and Sector Management Committee task forces that were formed to support the Society's new strategy: the Task Force on Group Engagement and Alignment, chaired by Rick Marboe, vice president of the Technical Events and Content Sector; the Task Force for Increasing Industry Leadership Engagement in ASME, chaired by Stacey Swisher Harnetty, former Board of Governors member; the Task Force for Increasing Engagement of Student, Early Career and Digital Mechanical Engineers in ASME, chaired by ASME Past President Terry Shoup; and the Task Force on Strategy and Planning, chaired by John Goossen, Board of Governors member.

"When 100 years from now the 22nd century leadership looks back at us, let them celebrate how we embraced a radically new vision of the future," Roe said. ME

SANDALOW KEYNOTE HIGHLIGHTS ENERGY CHALLENGES

David Sandalow of Columbia University's Center on Global Energy Policy, described worldwide energy and technology challenges during his keynote address to the ASME International Mechanical Engineering Congress and Exposition in Phoenix.

Sandalow highlighted changes in China and India as part of a general trend he called "the transformation of emerging economies." Over the past 30 years, for instance, China has risen to economic prominence as a leader in manufacturing and construction, evolving from a country where more than 90 percent of its population lived on less than $1.25 per day to one where fewer than 10 percent now exist at that level of poverty.

"All of this comes at a cost," said Sandalow, who held senior positions at the U.S. Department of Energy, including acting Under Secretary of Energy and Assistant Secretary for Policy and International Affairs before joining Columbia University. "The air pollution in China is absolutely horrific." Chinese citizens, Sandalow added, are as aware of pollution forecasts as Americans are of the weather.

Another development Sandalow expects will have considerable consequences for society will be the transformation of the U.S. energy policy following the election of Donald Trump as President of the United States. While Trump does not have the long track record of a traditional politician, Sandalow said there was a "reasonable amount of certainty" regarding a few components of Trump's energy plan.

A key feature of the plan, for instance, is expected to be a "fossil fuels first" philosophy, which would most likely lead to federal lands and waters being opened up to drilling and result in the lifting of the moratorium on coal mining on federal lands. "That seems to be a fairly consistent theme that he has talked about when he talks about energy," Sandalow said.

During a question period at the end of his talk, Sandalow appealed to the engineers in the audience to become engaged in the policy-making process.

"You are problem solvers," he said. **ME**

ARCHIMEDES SCREW PUMP REDESIGNATED AS AN ASME LANDMARK

The wind-powered Archimedes Screw Pump of the San Francisco Bay, an invention that enabled local production of salt in the San Francisco area, was recently redesignated as an ASME landmark at a ceremony in Hayward, Calif.

The Archimedes pump was originally designated as a Historic Mechanical Engineering Landmark by ASME in 1984.

The redesignation, supported by the ASME San Francisco Section, coincided with the screw pump's relocation to a site roughly three-quarters of a mile from the Hayward Shoreline Interpretive Center.

The pump in Hayward is one of the oldest surviving examples of the wind-driven Archimedes Screw Pump in the United States. The device was originally designed and built by Andrew Oliver in the 1870s. It was used for more than a century for harvesting salt from San Francisco Bay. **ME**

NINE ENGINEERING INNOVATORS HONORED

The professional achievements of nine distinguished engineers—including J.N. Reddy of Texas A&M University, James Duderstadt of the University of Michigan, and Helen L. Reed of Texas A&M University—were recognized by ASME at this year's Honors Assembly. The ceremony, which was held Nov. 13 during the ASME International Mechanical Engineering Congress and Exposition in Phoenix, was co-hosted by ASME President Keith Roe and Krishna Gupta, chair of the Committee on Honors.

Reddy, an ASME Fellow, received the ASME Medal for his contributions to applied mechanics through the development of shear deformation plate and shell finite elements for the accurate determination of interlaminar stresses in composite structures, which have had a major impact on engineering education and practice.

Duderstadt was presented the ASME Ralph Coats Roe Medal, which recognizes an outstanding contribution toward a better public understanding and appreciation of the engineer's worth to contemporary society. Duderstadt was honored for his significant contributions to the engineering profession and society through research, teaching, public policy, and service activities.

Reed received the ASME Kate Gleason Award for lifetime achievement in the fundamental understanding and control of boundary layer transition for high-efficiency aerospace vehicles, and in pioneering small satellite design and implementation. The award recognizes women engineers who are either highly successful entrepreneurs in a field of engineering or who have had a lifetime of achievement in the engineering profession.

Also recognized at the Honors Assembly were: Evangelos Trifon Laskaris, who won the Nancy DeLoye Fitzroy and Roland V. Fitzroy Medal; Bernard E. Hrubala, who received the ASME Melvin R. Green Codes and Standards Medal; Lijie Grace Zhang, winner of the Society's Sia Nemat-Nasser Early Career Award; and three recipient of Honorary Memberships—Christina H. Amon, Ashwani Gupta, and Shiv G. Kapoor. **ME**

It may look like a blob, but it's actually a shoe insert for a tall sailor (left). A 3-D printed shield protects this robot's camera lens (below).

WHERE NO 3-D PRINTER HAS GONE BEFORE

It takes a lot to stop Ronald Adrezin. When the Coast Guard turned down his proposal for a 3-D-printing project for the International Space Station, Adrezin, a mechanical engineering professor at the U.S. Coast Guard Academy in New London, Conn., opted for the next best alternative. He shipped out on an icebreaker.

Icebreakers spend weeks and months at sea. If something breaks, it stays broken until the ship returns to port. It was as close to the remoteness of space as he was likely to get.

Adrezin believed that 3-D printing offered a fast and flexible fix for unexpected problems in isolated environments, but he needed to prove it. Think of it as a quest for the 21st Century equivalent of duct tape and WD-40.

Adrezin spent three weeks aboard the USS *Healy*, a 450-foot-long icebreaker that also conducted research in the Arctic Ocean. The *Healy* carried a crew of 80, plus 50 scientists and associated buoys, drones, robots, and instruments. Armed with a consumer-grade MakerBot Replicator 3-D printer, Adrezin went looking for trouble.

He deliberately placed the printer where things could go wrong—in the Science Lounge. Temperatures plummeted every time the door to the deck opened. In choppy seas, the room rocked like a New York subway car. If the MakerBot could make it there, it could make it anywhere.

After a few days at sea, the ship's only dishwasher broke. The problem was a hinged float akin to a toilet bowl float. Printing a new float was easy enough, but the MakerBot used polylactic acid, which melted in hot water. A protective silicone coating resolved the problem.

After that, word spread. Sailors and scientists began buttonholing Adrezin. One request came from a very tall sailor who had to spread his feet apart to stand under the ship's low overheads. His arches were killing him.

Adrezin modeled the man's foot in SolidWorks and printed an insert that exactly matched his instep. "But when the sailor stood on it, it went completely flat," Adrezin said. Exaggerating the insert's features worked better, and when heat and perspiration dissolved the PLA, Adrezin simply printed a replacement.

Other projects followed: a camera lens shield, a toggle switch for a depth finder, a fixture to hold inflatable boat tillers. He even fixed the ship's microphone stand.

Adrezin hopes to ship out with a printer that can produce structural composite parts. His vision: a 3-D printer on every ship. If somebody has a problem, they can print what they need right on the spot." ME

ALAN S. BROWN

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