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No. 01

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TO EXPLOIT THE
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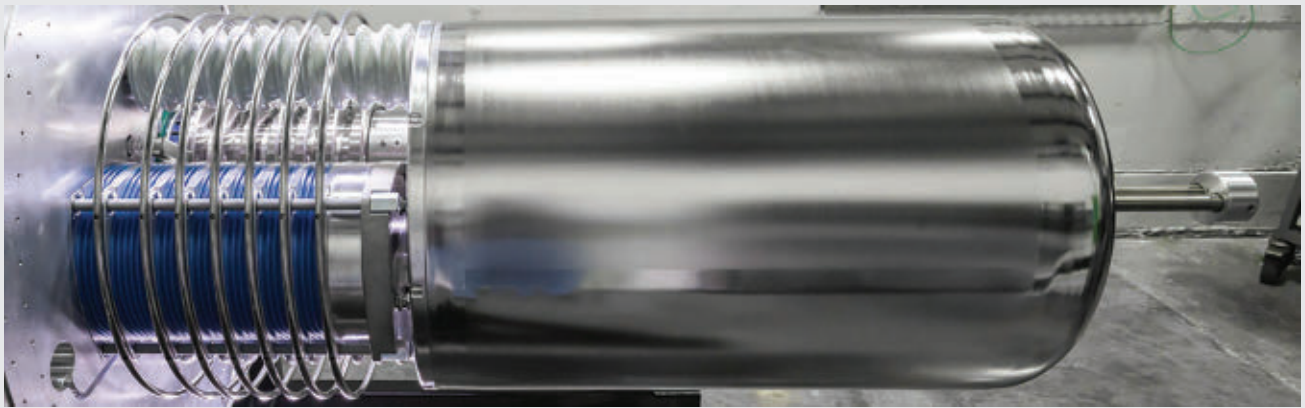
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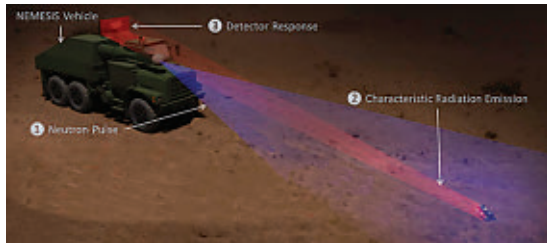




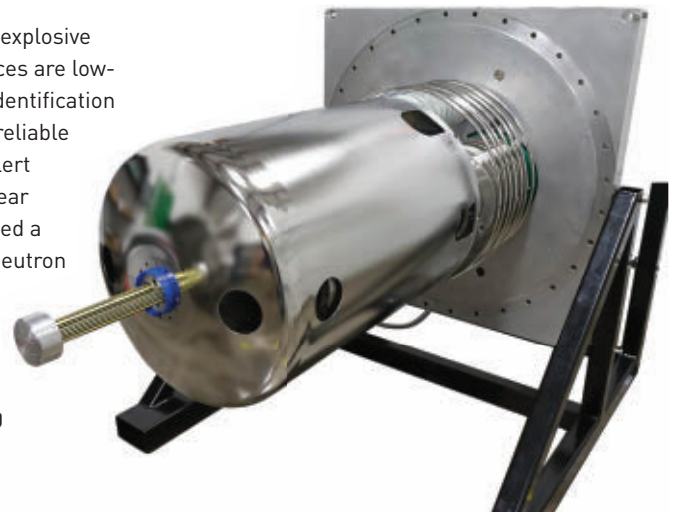
Photos: Phoenix Nuclear Labs

USING NEUTRONS TO DETECT EXPLOSIVE DEVICES

ONE OF THE GREATEST threats to ground troops today is improvised explosive devices, known as IEDs. Methods used for detecting these devices are low-tech, dangerous, and time-consuming, often relying on visual identification or explosives-sniffing dogs. The U.S. military is eager to find a reliable technology that can detect these devices from a distance and alert moving troops before they arrive at the IED location. Now, Phoenix Nuclear



Labs has invented a high-powered neutron generator that can detect improvised explosive devices up to 30 meters away.

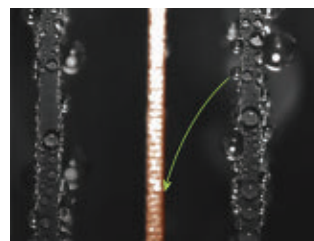


ENGINEERING A CLOSE SHAVE

MEN MAY HATE TO SHAVE, but they love buying gadgets. Advanced engineering has taken the sting out of shaving for the past century.

CHARGING YOUR PHONE WITH JUMPING DROPLETS

RESEARCHERS AT MIT discovered a process that may be the basis for a passive charging device that can power small electronic devices using just humidity in the air.



Nenad Miljkovic and Daniel J. Preston / MIT.

TAKING ADDITIVE MANUFACTURING TO THE MICRO LEVEL

MICROFABRICA HAS DEVELOPED an additive manufacturing process that can mass-produce millimeter-scale metal parts with micron-size features.

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VIDEO: ADVANCES IN SURGICAL ROBOTS

Venkat Krovi, professor of mechanical and aerospace engineering at the University of Buffalo, discusses the current trends and future outlook for surgical robots.



NEW APPS FOR 3-D PRINTING

A roundup of smartphone apps, tablet apps, and web apps for modifying or creating designs for 3-D printing and additive manufacturing.

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They all share one
architecture, determined
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stand, and I shall
move the earth*
—Archimedes



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John G. Falcioni
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THE EMPOWERING ELECTRIC GRID

It's been more than two years since Hurricane Sandy hurled its massive destructive muscle on the Atlantic coast, leaving behind wrecked lives and millions of dollars in damages. By now, most of the damage has been cleaned up, even if the nightmares persist for those whose homes and lives had to be rebuilt.

For those of us who didn't suffer property damage, Sandy made us aware of an electrical grid that *almost* never fails. We had to adapt to a temporary life without television, hot showers, and the other first-world perks we've come to rely on. We lived through seemingly endless days in the dark, and even when things began to get better we had to huddle with strangers at communal tables in coffee shops that had access to the web. And we waited on long lines to get a ration of gasoline to power generators and feed our cars, only to be told when we got to the front of the line that there was no more fuel left.

In this issue we take a deep dive into some of the critical risks to the grid that threaten our accustomed way of life. This month's cover story, "Pandora's Net" is a fascinating article that reviews some of the vulnerabilities in the grid that can be exploited by savvy hackers. "All the stuff we're doing in Western society in regards to cybersecurity is probably ten years or so behind the curve of what the bad guys are doing," a security consultant told Brit-tany Logan, a journalist who spent several months researching this article for us.

In the second article, "Right-Sizing the Grid," physics professor David Newman, says, "There is something about the grid's very size and structure that increases the

risk of cascading failures, where a single event can touch off a chain reaction of failures."

The implications of an electrical grid shutdown are severe. Many of us have lived through blackouts, some of which have stretched into weeks. We've also read in both academic literature and science fiction about doomsday scenarios from the effects of electromagnetic pulses from the sun, or from atomic weapons, or from terrorists, with the potential to take down the grid for much longer periods.

But we mustn't disregard the large portion of the world that has *never* been connected to a grid. In contrast to veterans of Sandy, students in the developing world regularly crowd around transportation hub parking lots to access just enough light from street lamps to do homework, and women often travel far by foot for clean water only to be turned away when the limited supply is exhausted.

To 1.3 billion people in developing countries the path to global development is based on access to energy. The economic and quality-of-life benefits that emerge when poor communities have access to affordable electricity are transformative. Without it, obtaining clean water, refrigeration, and proper sanitation is jeopardized, as is the ability to access the Web and all of the world's knowledge.

This is why the topic of energy poverty shouldn't be ignored in conversations about the electric grid. The threats to our energy infrastructure are serious, as this month's articles detail, but so are the dangers to society if we overlook the people who have no energy infrastructure to rely on.

FEEDBACK

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concerned
about threats
to the electric grid?
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SAVE THE “R” IN R&D

Fundamental research not only improves our understanding of the natural world but forms the foundation for innovative commercial products. If that basic research isn't done in the U.S., then other countries will reap the benefits.

The ultimate goal of research and development is to produce new or improved products. To stay competitive, companies allocate a portion of their resources to R&D. That portion is typically considerable for startup and high-technology firms. For example, the iPhone arguably propelled Apple to become the largest company in the world by market capitalization. Governments also support R&D for such purposes as better crop yield, medical advances, weaponry, space exploration, energy resources, and clean environment.

The “R” in R&D is broadly divided into applied research and basic research. The latter is also called fundamental, pure, or curiosity research. This type of research improves our understanding of the natural world. Curiosity research rarely pays immediate benefits, and therefore is supported mostly by the taxpayers. In the long term, however, fundamental research forms the foundation for applied research and developing commercial products.

As a rule of thumb, if the development of a prototype costs \$100, then applied research costs \$10 and pure research costs a meager \$1. That modest cost comes at a price: pure research does not often transition to a product, and spectacular long-term successes are not the norm. Basic research is a risky business; nevertheless it is one of the better things of which humans are capable.

A distinguishing characteristic of basic research is its occasional

spark to new frontiers unimagined in applied research. Examples abound: instead of developing a better iron lung, a polio vaccine was discovered; a mold that repelled bacteria led to penicillin; molecules' behavior during chemical reactions resulted in the laser; and solving a mathematical riddle metamorphosed into Google. Fundamental research propelled the U.S. to the moon, sequenced the human genome, and produced magnetic resonance imaging.

For 2011, the United States invest-

for the next planting season.

In 2013, the American Society for Biochemistry and Molecular Biology, in cooperation with fifteen partner societies concerned with pure research, issued a report, *Unlimited Potential, Vanishing Opportunity*.

The report surveyed 3,700 scientists from all fifty states. Despite spending far more time writing research proposals, a significant majority of scientists are receiving less federal support than they were a mere three years ago. Eighteen percent of them said they were considering continuing their careers in other countries. Reverse immigration is upon us.

Causes include budget strains to make huge interest payments on

De-investment in long-term fundamental research is shortsighted and outright dangerous to the nation's future prosperity.

ed \$405.3 billion in R&D, more than any other country in the world. But as a percentage of gross domestic product, the U.S. takes sixth place after Israel, South Korea, Japan, Sweden, and Finland.

The situation is more ominous when it comes to the R portion of R&D, particularly the share of basic research. Major events such as World War II, the Cold War, and the energy crisis drove investment in pure research. Today, however, federal expenditures in basic science are 0.82 percent the U.S. economy, the lowest level in over fifty years.

De-investment in long-term fundamental research is shortsighted and outright dangerous to the nation's future health, prosperity, and security. It is tantamount to a farmer eating a good portion of the seeds set aside

the national debt and cover non-discretionary spending, the gridlocked Congress, and a prevailing culture of instant gratification.

The executive and legislative branches of government certainly need to work together to solve today's and tomorrow's problems, and to plant sufficient seeds to feed future generations.

Science and technology will remain the endless frontiers, as long as *Homo sapiens* are on this or some other planet. If American exceptionalism doesn't lead the charge, others are eager to fill the void. **ME**

MOHAMED GAD-EL-HAK is the Inez Caudill Eminent Professor of mechanical and nuclear engineering at Virginia Commonwealth University in Richmond. Contact him at gadelhak@vcu.edu.

NO BATTERY NEEDED

To the Editor: I enjoyed the recent slide rule article (Input Output, September 2014). I went through engineering school during the transition from slide rule to calculator, and could not afford a calculator until my senior year. Not only were significant digits affected, but test times were also significantly reduced because calculators were faster. Taking the EIT test that year, I was surrounded by students with multiple battery packs, extension cords, etc. as failure protection. I think I was the only one who brought his slide rule as a backup to the calculator.

Carey Camp, P.E., Raleigh, N.C.

RECALLING THE GAME CHANGER

To the Editor: In the September issue, one of the authors claims the first scientific/engineering calculator was the Texas Instruments TI-30. That's wrong. The first calcula-

tor that could duplicate all the functions of a slide rule was the Hewlett-Packard HP-35, which was released in 1972.

The TI-30 wasn't introduced until 1976. TI had a four-function calculator on the market before the HP-35, but all it did was arithmetic and square roots.

Wikipedia says, "About twelve HP-35 portable calculators were made as a 'hack' by and for other engineers at HP. It is rumored that the development engineer got carried away and included a full suite of scientific functions to satisfy requests from his co-workers." My hero.

Wikipedia also says that HP sold 100,000 HP-35 calculators the first year.

One of them went to my college roommate, Dave Carter, who received it from his brother-in-law who worked for IBM. He'd loan it to me for exams and it really saved my bacon, especially when calculating convective heat transfer coefficients.

Another friend of mine, an EE major at Bradley University, bought one before buy-

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.

ing his girlfriend an engagement ring. The HP-35 cost \$400, which was a lot in 1972 and about even with a diamond. She got over it; they've been married since 1976.

For one brief, shining moment we lowly engineering students had the drop on the faculty. Mere money would buy us the same computing power they had. No more misplaced decimal points, no more running out of time on tests trying to calculate numerical answers or fighting the log-log scales on a slide rule, and no more trying to get calculations done by the school mainframe, which never was any real-time help anyway.

Ronald Corradin, St. Paul, Minn.



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A GENERATOR IN JUST TWO DIMENSIONS

RESEARCHERS AT COLUMBIA UNIVERSITY AND GEORGIA TECH HAVE DEMONSTRATED THE WORLD'S THINNEST ELECTRIC GENERATOR, A FILM OF MOLYBDENUM DISULFIDE A FEW ATOMS THICK.

The generator has no moving parts. Instead, it is a piezoelectric material that produces current when stretched or compressed. This is the first time anyone has shown the piezoelectric effect in atomically thin films, although the property has been predicted.

The work underscores how materials properties change at the nanoscale, since bulk molybdenum disulfide does not exhibit piezoelectric properties.

Molybdenum disulfide is part of a family of transition metal dichalcogenides. Theorists predicted that they would all have piezoelectric properties when made into atomically thin films. Such films are often called 2-D materials. The best known example of a 2-D film is graphene, which researchers are investigating for electronics uses. Their nanoscale thickness of 2-D films often gives them unusual properties.

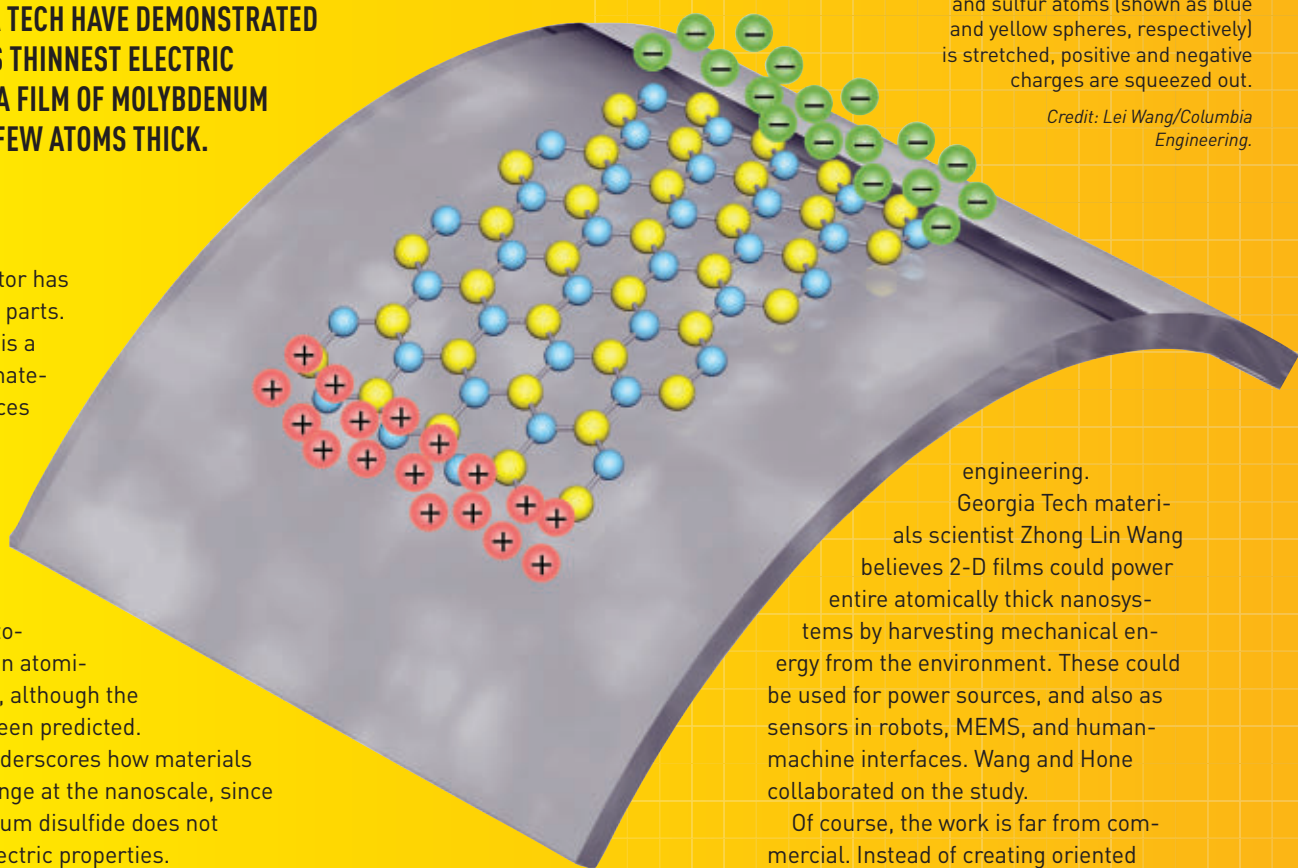
In addition to its ability to generate current, 2-D molybdenum disulfide has other intriguing properties. In bulk, molybdenum disulfide is an opaque and

brittle ceramic. Its 2-D counterpart is optically transparent and very bendable and stretchable. This would enable 2-D films to generate power without cracking or breaking.

"This material—just a single layer of atoms—could be made as a wearable device, perhaps integrated into clothing, to convert energy from your body movement to electricity and power wearable sensors or medical devices, or perhaps supply enough energy to charge your cell phone in your pocket," said James Hone, a Columbia professor of mechanical

As a single layer of molybdenum and sulfur atoms (shown as blue and yellow spheres, respectively) is stretched, positive and negative charges are squeezed out.

Credit: Lei Wang/Columbia Engineering.



engineering. Georgia Tech materials scientist Zhong Lin Wang believes 2-D films could power entire atomically thick nanosystems by harvesting mechanical energy from the environment. These could be used for power sources, and also as sensors in robots, MEMS, and human-machine interfaces. Wang and Hone collaborated on the study.

Of course, the work is far from commercial. Instead of creating oriented films, researchers examined a variety of atomically thin molybdenum disulfide flakes they had created to find the right combination of orientation and properties. They then installed electrodes to measure current. They found that the output voltage actually reversed sign when they changed the direction of the applied strain.

The 2-D film, Hone explained, is "an elegant example of how the world becomes different when the size of material shrinks to the scale of a single atom." **ME**

ALAN S. BROWN

WITH COAL, MORE QUESTIONS THAN ANSWERS

ESTIMATES OF AMERICA'S COAL abundance are based on old numbers. New assessments suggest there's a lot—but we might not be able to mine it.

If there's one thing that energy analysts rely on, it's the availability of American coal. Since the 1970s, politicians and industry advocates have described the United States as "the Saudi Arabia of coal." Statistics seem to justify the sobriquet.

The U.S. coal "resource," which is all the coal in the ground now, totals about 481 billion tons, says the Energy Information Administration, the Department of Energy's one-stop-agency for data collection and analysis. Of that, the "estimated recoverable reserves"—the amount that's available to mine, but not the amount that's economically feasible to mine—total about 258 billion tons.

"The U.S. produces a billion tons of coal a year," said John Hanou, principal of Hanou Energy Consulting in Annapolis. Electricity takes about 82 percent of that. If all the U.S. coal reserves were cleanly burned at today's electricity consumption rates, they could last for 238 years—well into the 23rd century. That's a long span of much-coveted energy independence.

However, growing numbers of skeptics question the long-term dependability of coal. They don't trust the EIA's reserve numbers, which are based on assessments conducted by the U.S. Geological Survey in the 1970s and 1980s. And even if the country has all those available reserves, the skeptics say, industry can't mine it all.

The USGS doesn't necessarily agree—but it acknowledges a need for better numbers. After all, making those assessments is part of the Survey's mission of managing water, biological, energy, and mineral resources. Thus it conducts coal assessments on a nearly ongoing basis.

The latest round of coal resource and reserve assessments began in 2012. Its primary goal is to obtain accurate regional estimates of important coal resources and reserves in all major U.S. coal basins.

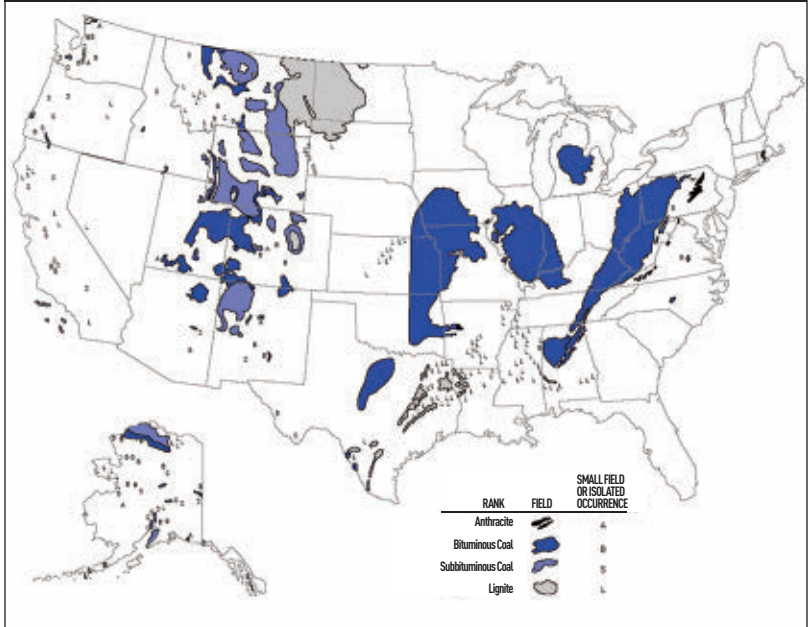
The new assessments began with the Powder River Basin. The geological feature spreads across nearly 19,500 square miles (excluding areas on Native American lands) of northeastern Wyoming and southeastern Montana. It contains the largest deposits of low-sulfur sub-bituminous coal in the world. Most sub-bituminous coal is burned for electricity.

In 2011, the basin's 16 mines produced 462 million tons of coal—about 42 percent of all U.S. coal mined that year. That makes the Powder River Basin the most important coal-producing basin in the U.S.

In the 2012 assessment, the USGS found that the Powder River Basin's cur-

MAJOR COAL BASINS IN THE UNITED STATES

Large coal fields are located in almost every region.



Source: U.S. Energy Information Administration/Argonne National Laboratory

rent coal resources total slightly more than one trillion tons. "The economically recoverable base is 162 billion tons," said Robert Milici, a geologist who specialized in coal for the USGS for 20 years and now has emeritus status there. "Out of that 162 billion tons, you can get about 25 billion." That's just 2.5 percent of the original resource or 15 percent of the theoretically recoverable amount—and that's all that is economically feasible to mine today.

Based on more limited assessments conducted in eight coal fields in the late 1990s and 2000s, a 15 percent recovery rate of available reserves would be very good. Only two of the eight coal fields exceeded that rate, and one of those—Gillette—is in the Powder River Basin. The other field—Somerset—is in the Piceance Basin in Colorado, but its assessed available reserves were two orders of magnitude less than Gillette's.

"We've already seen peak coal in Europe," said Greg Croft, a lecturer in the Department of Environmental and Earth Science at Saint Mary's College of California. "In the U.S., production in the East peaked in 1990." Despite prodigious western mine production, "the U.S. has already peaked whether you go by

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"TILTING" LOCK TWISTS OLD CONCEPT

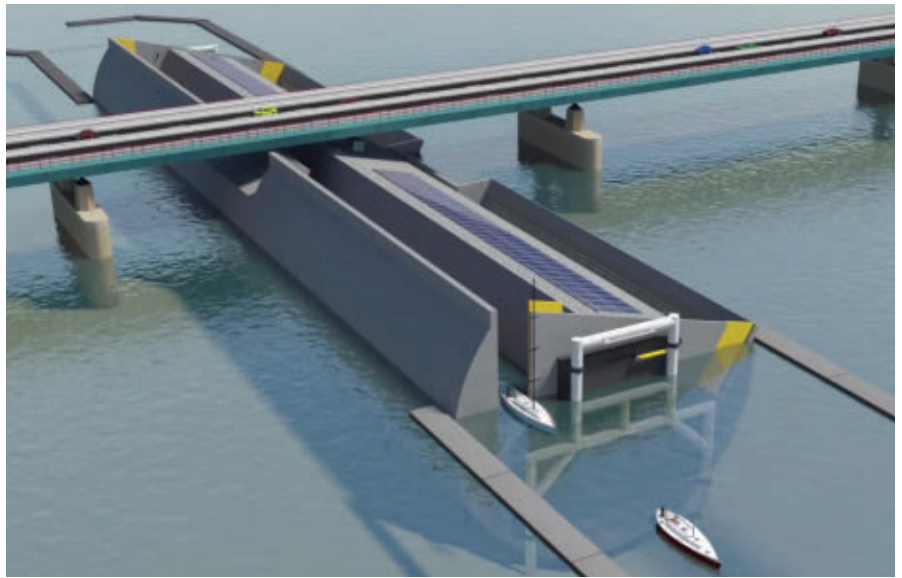
DUTCH ENGINEERS HAVE designed a mobile lock to enable ships to pass beneath bridges without stopping traffic.

Drawbridges, whether they are sliding, lift, bascule, or turning, always produce spectators. While many motorists may very well ooh and ah as the bridge gives way to allow a ship to pass, the resulting gridlock can cause problems on heavily traveled routes as well as on the water, as vessels queue up to pass through the structure.

Now, in a twist on a very old concept, Dutch engineers have designed a mobile tilting lock to allow ships to pass beneath heavily trafficked bridges, reducing the number of openings to keep traffic flowing while moving multiple boats through the crossing. The idea came from Dutch engineer Carolus Poldervaart, a designer with Royal Haskoning DHV in Amersfoort, The Netherlands, who often was caught in a boat waiting for a bridge to open or in a car waiting for one to close.

As envisioned, the tilting lock is a floating structure made of steel in the form of a ship's hull, fitted out with two separate water-filled channels with enough room to hold five vessels at a time. A pontoon separates the channels. Poldervaart sees mostly pleasure vessels such as sailboats or yachts using the structure. When the lock is level, the water surface in both chambers is four meters below the water level of the river.

To let boats enter, the lock tilts up, bringing that side of the lock up to the level of the river.



Once the vessels are within watertight gates, the lock will tilt in the opposite direction to lower the boats by eight meters so they can pass beneath the bridge. When they are past the bridge, the lock tilts up to let them sail out. At this point, there may be vessels in the other channel of the lock passing under the bridge.

Poldervaart says the lock does not pump water and no weight will be displaced. The structure remains in position with tilting being the only movement, and that motion is restricted "to guarantee that the sides of the lock do not touch the mast of the boat," he says.

"THE LOCK IS JUST FLOATING IN WATER AND BECAUSE OF ITS UNDERWATER SHAPE PLUS THE FACT THAT THE CENTER OF GRAVITY IS IN THE CENTER OF THE CIRCULAR HULL SHAPE, IT IS EASY TO TILT."

CAROLUS POLDERVAART, ROYAL HASKONING DHV

Each of the channels is 9 meters wide and 3.5 meters deep. They are not connected. But the channels stay horizontal during tilting. Although that can disturb the center of gravity, the designer says a slight modification of the hull shape above the waterline will handle

the issue. The structure is designed to be 190 meters long and be anchored to the river bottom with two steel "spudpoles," similar to equipment that anchors workboats.

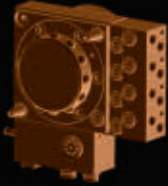
"The lock is just floating in water and because of its underwater shape plus the fact that the center of gravity is in the center of the circular hull shape, it is easy to tilt," Poldervaart says.

Poldervaart says tilting will be powered using hydraulic cylinders mounted about 6 meters above the pivot, between the pontoon and lock. An electric pump powered by solar energy operates the cylinders, as well as lighting and opening and closing the doors of the lock.

Total energy use will be very low. Poldervaart says the lock tilts 32 degrees in three minutes, taking 30 seconds to set the tilting in motion. Energy needs

continued on p.14 »

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Introduction to the tablet: Digital devices for the developing world must withstand dust, heat, moisture, and other environmental challenges.

SEEKING

RELIABLE, WIFI-ENABLED, virtually bomb-proof electronics are needed to connect the world's poorest regions.

Designers of today's electronic devices might not know how hard the developing world can be on hardware.

Connected devices in these places contend with the usual drops, spills, and dunks into puddles that happen all over the world.

But they are also plagued with dust kicked up from unpaved roads, equatorial heat and humidity, unreliable power

continued from page 12 »

TILTING LOCK

are also reduced because the lock is in balance and no water is displaced. In normal weather conditions, the operation uses a scant 0.04 kWh.

Waterway bottoms would be dredged to fit the structure, and changing bottom conditions require the lock be designed to be mobile. When the bottom of the river beneath the lock needs tending to maintain enough depth for operation, the spud poles could be pulled up and the lock moved off site with tugboats.

Depending on size and location, Royal Haskoning estimates a tilting lock will cost about 60 million euros to design and build. Using the existing Haringvlietbrug in the southwestern province of Zeeland, the firm estimates the tilting lock would save 100 million Euros over 25 years in lost

time, wasted fuel and delayed shipments of freight. Haaringvlietbrug carries a major highway across inland waterways with about a 13 meter clearance. Poltevaart says it would pay for itself in 12 years.

The firm says it also could be used as an energy-efficient standard lock with no water lost when moving ships from one level to another, a problem in canal systems dependent on rain water to maintain depth. For new projects, a combination moveable bridge and tilting lock could be more costly than a crossing built high enough to accommodate tall ships but an owner's aesthetic concerns could preclude such a structure. Poltevaart says the firm is conducting "informal talks" with the Dutch Ministry of Works but formal proposals have not yet been offered. **ME**

JOHN KOSOWATZ, ASME.ORG


Personal CNC

Shown here is an articulated humanoid robot leg, built by researchers at the Drexel Autonomous System Lab (DASL) with a Tormach PCNC 1100 milling machine. To read more about this project or to learn about Tormach's affordable CNC mills and accessories, visit www.tormach.com/mem.




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Mills shown here with optional stand, machine arm, LCD monitors, and other accessories.

DURABLE DEVICES

sources, and sometimes a frustrating absence of repair shops.

But that's not all. The list of challenges grows as you talk to more people who use electronic devices in the world's impoverished and hard-to-reach places. To find out what the challenges are, Laura Hosman, assistant professor of political science at the Illinois Institute of Technology in Chicago, teamed with Bruce Baikie, executive director of Inveneo of San Francisco, a not-for-profit organization that offers computing and broadband in the developing world.

Their research project heard from development experts, academics, and regular folk who use these devices in developing areas.

The researchers compiled an overview of their findings into a white paper aimed at designers and manufacturers, *Emerging Markets: Top ICT Hardware Challenges*.

They found that these are the top five challenges for information and communications technology hardware in developing areas, and they outlined how these needs might be addressed:

POWER: Ideally, hardware should require little power, have a long battery life, and not balk at surges or brownouts. It should also charge at 12 volts dc to plug straight into a solar panel.

COST: Should be low, but without sacrificing too much quality.



DURABILITY: These things should be bomb-proof, they said. Devices should withstand

water, humidity, dust, heat, and other abuse. To do that, they might need few to no moving parts.

Screens should be especially tough as they're hard to repair.

TECH SUPPORT: "The best technology

needs no support," the researchers wrote in their paper. Designers should keep in mind that repair shops and spare and parts are scarce.

CONNECTIVITY: WiFi is the preferred method.

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CASE STUDY № 308

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PARTS 1

DAYS 7

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DON'T BE YOUR OWN WORST ENEMY

Instead, reel it in, **work hard**, do more than what is minimally necessary, **and be on time**.

The best advice I can give you about your career is to not be your own worst enemy. Talk about the impossible: you are always your own worst enemy. However, a little self-reflection can keep you from self-destructing.

Let me focus on a few topics which should be apparent to everyone, but obviously are not.

You are your own worst enemy when you overreact to others. This is one of my personal foibles. For example, consider the case where someone is personally attacking you in a meeting, conversation, or e-mail. What often sabotages you with your colleagues and managers is an over-the-top response.

Let's consider a guy named Ron (at least that is what everyone except my wife calls me). Another older faculty member and I were laughing in the hall a while back about my over-the-top responses during my first 10 years or so at the university. As he said, even when the rest of my group disagreed with the other person, they would side against me because of the tsunamic level of my response.

I was born in Heidelberg, Germany, at the hospital where General Patton died (my only remote claim to fame). Trust me, without going into details, growing up and enduring a father who was a former Army sergeant in the 1950s and '60s, means I can bring it when provoked.

The only problem is that you rarely, if ever, need to shock and awe your tormentor and by reflection your other colleagues on the sidelines. The best response, albeit painful and not personally satisfying in the short term, is to let your adversaries hang themselves. Usually they do so with only the slightest nudge. Simply put: Do not be too aggressive with other individuals in personal interaction, but do be aggressive in working on your own tasks.

Most people are frustrated when individuals around them, who they consider to

ity. For these seemingly insignificant time differences, there is half-hour difference between the amounts of time spent on the job by these two individuals per day.

There are two realities to the individual who comes to work late and leaves early. First, when one is habitually late everyone takes note. It is like you are wearing a flashing neon sign that says, "I am incapable of coming to work on time. Think how irresponsible I will be with any assignments."

The second is that this behavioral pat-

THE BEST, THOUGH UNSATISFYING RESPONSE IS TO LET YOUR ADVERSARIES HANG THEMSELVES. USUALLY THEY DO SO WITH ONLY THE SLIGHTEST NUDGE.

be less talented, are more successful in an organization. The most successful professors at my university are the ones most driven and hardest working and thus ultimately the most productive, not the ones who are identified as the most mathematically gifted (the basis for the pecking order for mechanical engineering faculty).

Productivity and contribution come for most individuals, even university faculty, by working hard and submitting work on time, not by being brilliant.

Another major issue is being present. The stated work hours are the minimum hours you are expected to be at work as an engineer. Let us compare two individuals. One arrives at work and is back from lunch 5 minutes early, and leaves 5 minutes after the stated end of the day. The other does the opposite.

Of course, the difference in time may or may not result in a difference in productiv-

tern is never limited to a mere 15 minutes, but extends to hours and days. When there is a period of time when everyone else has to work long and hard on a project, this individual is typically the one who takes off at the time most inconvenient and burdensome for everyone else.

To avoid being your own worst enemy, reel it in, work hard, submit your work on time, be present for more than the minimum amount of time expected, and finally, arrive on time.

You will make mistakes. Despite what some overly paranoid people think, most individuals and organizations expect and are reasonably tolerant of a misstep every so often. They may be out to get me, but I doubt if they are out to get you. **ME**

RONALD A.L. RORRER is the director of motor-sports in the Department of Mechanical Engineering at the University of Colorado Denver.

continued from page 11 »

COAL: MORE QUESTIONS THAN ANSWERS

tons or British thermal units,” Croft said. “Powder River coal yields about two-thirds of the BTUs by weight as Appalachian coal does.”

Hanou—and many others—reject the peak coal theory. “One hundred years ago, we couldn’t mine coal that was 2,000 feet deep, but we can now,” he said. “We didn’t know how to get all the natural gas in shales until the 1990s. Right now, natural gas is relatively inexpensive compared to coal, but when it gets more expensive, we’ll go back to coal.”

Hanou’s argument makes sense. However, it might not apply to coal. “Improved technology for coal is in the realm of possibility, but we don’t mine deeper and thinner coal seams,” Croft said. “There also hasn’t been the same technological development in coal mining as with natural gas. The technologies do exist, but they’re not cost-effective, and they rely on DOE grants.”

Right now, nobody knows how much coal the U.S. actually has or how much the country can economically recover. The forthcoming USGS basin assessments may yield some answers. **ME**

Bridget Mintz Testa is a writer based in Houston and a frequent contributor to *Mechanical Engineering*.

MODERNIZATION FOR 2 OMANI GAS PLANTS

A JOINT VENTURE OF OHL INDUSTRIAL AND SENER HAS BEEN awarded an engineering, procurement, and construction contract to modernize two hydrocarbon plants owned by Petroleum Development Oman LLC.

The plants—Saihi Nihayda Gas Plant and the Saihi Rawl Central Processing Plant—are in the Omani desert, near the city of Qarn Alam, 35 km from one another.

The modernization will allow PDO to increase the recovery of hydrocarbon condensates in natural gas.

This is the first contract in Oman involving OHL Industrial and SENER.

OHL Industrial has a subsidiary, OHL Industrial & Partners LLC, with an office in Abu Dhabi.

SENER also has offices in Abu Dhabi. Its projects in the region include contracts for light rail transportation systems in Abu Dhabi and in Qatar.

The contract includes provisions for Oman’s In-Country Value Development Program, which aims to create more jobs in the oil and gas industry for Oman’s citizens. The contract calls for hiring Omani technicians, for instance, and giving preference to Omani subcontractors.

Petroleum Development Oman has launched a training program to support the In-Country Value initiative. Last October, the company said it would offer technical training to as many as 1,770 of the country’s young men.

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ME: What did you want to do growing up?

H.L.: My father was a flight instructor. At 14, I became a glider pilot, and at 21, the youngest flight instructor in Germany. It financed my education. I became very interested in the physics of what makes an airplane fly or the weather change.

ME: You got your Ph.D. in laser physics in 1980. Why?

H.L.: The laser was invented in the 1960s. When I entered university in the early 1970s, we were fascinated by the future of lasers in medicine or manufacturing. I wanted to be an expert, and wound up at the Max Planck Institute. I thought I would go into teaching. I couldn't image working for money.

ME: So what happened?

H.L.: My advisor said, "There are so many young professors and so much opportunity in the laser industry. If you go there, I think you will be satisfied." He had a friend at Carl Baasel Lasertechnik, and I became employee number 11.

ME: They wanted you to sell, right?

H.L.: I was hired to sell to research labs. This was my home ground. I ran into people who had problems, and I helped solve them. Sometimes, they wanted to buy a component. But when I asked what they wanted to accomplish, it turned out they really needed a different type of system. I achieved my first-year sales goal in my first three months.

ME: What got you interested in 3-D printing?

H.L.: A U.S. company recruited me to start their European business, and I eventually moved to Boston for half a year. While there, I visited some labs developing stereolithography, which used lasers to solidify photopolymers in chemical solutions. I wondered what we could do if we could use real materials, such as metals, ceramics, and engineering polymers.

I started EOS in Germany to pursue that. I found my lead customer in BMW. When you have a startup, you need a customer who is willing to pay for development. We convinced BMW to fund the development of our first stereolithography system, and later our laser sintering technology for plastic and later metal powders.

ME: What were some of challenges in laser sintering powder metals?

H.L.: I nearly gave up on the dream of making non-porous metal parts. We needed high laser intensity. Nothing worked until the introduction of fiber lasers about 10 years ago. All of a sudden, we could make 100 percent dense materials with no porosity.

We also discovered something we did not expect. Melting powders with a laser changed their crystalline structure. It was like laser hardening. We developed the hardest tool steel you could buy. We replaced a titanium part in a racing car powertrain that kept



HANS LANGER BEGAN STUDYING LASERS when they were just emerging from the lab. He founded EOS GmbH Electro Optical Systems in 1989, and pioneered the use of lasers to melt and solidify plastic and metal powders to form complex 3-D structures. Today as chief executive officer of EOS, he is a leading influence in the transformation of 3-D printing as a tool for manufacturing instead of prototyping.

cracking with a stronger laser sintered part.

Suddenly, we had a huge market ahead of us. We had a process that could optimize part design, strength, and material—and offer superior properties.

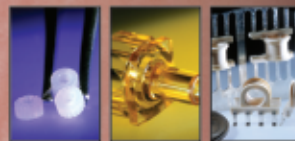
ME: Design is important too, isn't it?

H.L.: Design is the critical factor. For example, cast hip implants weigh 2.25 kilograms. That's heavy enough to destroy the bones around them, and eventually patients must replace their implants. When we design patient-specific optimized implants, they weigh 200 grams and last as long as three standard implants.

There are a very limited number of applications where we are competitive on cost. Instead, companies are using additive manufacturing to take big steps forward by redesigning critical parts that combine technologies and give them an advantage.

ME: Do your customers surprise you?

H.L.: I can't believe what people are doing. Engineers are using advanced polymers, like PEEK, to replace metal for extreme weight reductions. We're moving into the micro world and making parts you can see only with a magnifying glass. Medical researchers are generating parts they could not make conventionally. We have lots of playgrounds to play in, and I am having a lot of fun. **ME**



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The fuselage and wing structures of the Airbus A350 are made primarily of carbon-fiber-reinforced polymer.

AIR LINES

Developments being worked on at two labs could detect and stop structural damage in aircraft and allow planes to be constructed with more fuel-saving composite materials than today's planes.

Engineers Silvestre Pinho and Paul Robinson of Imperial College in London are working on a computer model that can predict how composite materials behave when damaged. The model will make it easier to design lighter, more fuel-efficient aircraft, they said.

Composite materials used in the aerospace industry are comprised of alternating layers of polymers and carbon fibers, Pinho said.

"One key challenge in designing with composites is that while the physical mechanisms leading to damage develop at a tiny scale, models predicting these mechanisms need to be applied to much larger components," said Pinho, who is a professor of mechanics of composites. "Nowhere is this challenge greater than in the aerospace industry."

Composites are proving increasingly popular in the aerospace industry because they're lighter and stronger than metals. How-

ever, the failure mechanisms affecting them are not as well understood, Pinho said, because the industry has several decades more experience using metals.

Aircraft designers have overcompensated for a lack of knowledge of how composites behave by over-reinforcing composite panels, Pinho said.

Developing physically based models and computer codes to predict failure in composites first requires isolating each failure mode through experimentation. Pinho's group has developed several specimen configurations and test methods to carry out such experiments, he said.

Any tiny crack that would spread through the composite material could be predicted using the model, Pinho said. The model could also show in detail how an aircraft's composite wing would behave if it suffered small-scale damage, such as

MODEL AIRPLANES

The Lab: Department of Aeronautics, Imperial College London; Silvestre Pinho, principal investigator; Paul Robinson, co-investigator.

The Objective: A better understanding of failure in fiber-reinforced composites.

The Development: A computer model to show how damage will spread across composite materials, specifically those used in aircraft.

a bird strike, he added. The team's detailed experimental investigations into different failure mechanisms would enable damage to be represented for entire aircraft parts, he said.

The new model will permit manufacturers to make panels that are less bulky while still meeting aviation industry safety margins, Pinho said.

"Up to 8 percent of jet fuel could be saved via weight reduc-

tion," Pinho said.

"Excluding military aircraft, this amounts to about 20 million tons of fuel, 50 million tons of carbon dioxide saved annually."

Aircraft designers using the new computer model will be able to explore the damage tolerance of alternative designs without building as many prototypes or conducting as many physical tests as are currently needed, he added. **ME**

Sandia National Laboratories is now testing structural health sensors that monitor an aircraft's structural integrity as part of the U.S. Federal Aviation Administration's certification process.

"Our activities are proving that the sensors work on particular applications and that it is safe and reliable to use these sensor systems for routine aircraft maintenance," said Dennis Roach, senior scientist in Sandia National Laboratories' Transportation, Safeguards and Surety Program.

Delta Air Lines Inc. and a foreign aircraft manufacturer have partnered with Sandia researchers in two separate programs to install about 100 sensors on their commercial aircraft. These teams worked together to provide the installation procedures for technicians and now oversee monitoring of the in-flight tests.

Center researchers are testing two sensors on flights: comparative vacuum monitoring sensors manufactured by Structural Monitoring Systems of Nedlands, Australia, and piezoelectric sensor arrays produced by Acellent Technologies Inc. in Sunnyvale, Calif.

CVM sensors improve crack detection by monitoring 0.025-inch channels etched by laser into the Teflon sensor. The sensors are then mounted in areas of the aircraft known to experience fatigue; they are bonded to the surface of the structure with an adhesive preparation that seals out the atmosphere, creating a vacuum inside the gallery, Roach said.

When a tiny crack intersects the gallery, the pressure changes, much as the pressure in a vacuum cleaner changes when the hose has a leak. The sensor records the pressure change and alerts inspectors well before the crack becomes a safety issue, he said.



Sandia National Laboratories senior scientist Dennis Roach, center, works inside the cabin of a B737 test bed, installing and acquiring data from structural health monitoring sensors. Sandia mechanical engineers Stephen Neidigk, left, and Tom Rice, right, are also part of the monitoring team.

Image: Randy Montoya

Piezoelectric sensors, made from the compound lead zirconium titanate, or PZT, are strategically distributed in polyimide films that adhere to an airplane's surface to monitor specific regions for damage. The arrays of PZT sensors communicate with one another by transmitting and receiving ultrasonic surface waves. Damage to the aircraft disrupts or changes the signal patterns from the baseline

communication signals and software measures and analyzes any changes and sends an alert to an inspector, Roach said.

Work is ongoing on the best spacing and placement for these sensors on aircraft, said Stephen Neidigk, a Sandia mechanical engineer.

The field tests have helped fine tune the sensors, so they can withstand the harsh environment aircraft fly in and the environment aircraft mechanics work in, neither of which is as pristine as the laboratories

where the sensors were initially tested, Neidigk said.

Later this year, Sandia intends to present the flight and laboratory test results to the FAA for approval and certification, Roach said. **ME**

SENSING A STRUCTURAL CHANGE

The Lab: Sandia National Laboratories, Albuquerque, N.M.; Paul Hommert, president.

The Objective: Development of new aircraft technologies.

The Development: Testing of sensors that monitor an aircraft's ongoing structural health, with an eye toward FAA approval for the sensors.

ENGINEERS OF TOMORROW

BY ROBERT M. GATES, PRESIDENT, A.S.M.E., 1944
PRESIDENT, AIR PREHEATER CORPORATION, NEW YORK, N.Y.

The education and re-education of engineers who would be rebuilding the world after an era of war was the subject of the 1944 ASME Presidential Address.



LOOKING BACK

The new challenges of the post-war world were a growing concern when this article appeared in January 1945.

When someone asked Socrates what should be the content of the education of youth, he replied: "That which when men they will do." Our profession covers a wide range of activities, opportunities, responsibilities. It has been called the handmaid of civilization. If that was ever an appropriate term it has become more and more appropriate, for our profession faces great, broader responsibilities than ever in the making of the world of tomorrow. What engineers have to do, what engineering education should fit them to do, needs continually to be rethought and redefined.

Engineers cannot be isolationists, in so far as the traditional branches of the profession are concerned. Even in the very broad and fundamental branch of engineering which our Society represents, few of us in practice can be mechanical engineers alone; we have to learn something of civil, electrical, chemical, and whatever other branches there may be, in order to do intelligently and competently all the jobs that are entrusted to us. Specialize as we will, divide and subdivide our profession as we may for convenience, get way out on the end of a twig of one of the limbs of the engineering tree, the tree is still there to hold together its branches—and most of us at one time or another have to climb around a good deal.

Surveys show that a very large percentage of engineering graduates do not follow the type of engineering in which they specialized at school. The fundamental techniques and disciplines they have

acquired have been more important to them than their early specialized training. Any many regret the time lost by reason of too narrow direction of their school experience.

Many engineers are called upon to assume major responsibilities in industrial management. In the years ahead we may expect that the management of industry will be recruited more rather than less from our profession.

One of the distinguished leaders of our profession, President Wickenden of Case School of Applied Science, has eloquently predicted in his notable address to Canadian engineers, "The Second Mile."

"Engineers will find their way into every field where science needs to be practically applied, cost counted, returns predicted, and work organized systematically. They will be called upon to share the control of disease with physicians, the control of finance with bankers, the beating of risks with underwriters, the organizing of distribution with merchants and purchasing agents, the supplying of food with packers and purveyors, the raising of food with farmers, and the operation of the home with housewives. In few of these new fields, if any, will engineers be self-sufficient; to be useful they must be team workers; and they must be prepared to deal with 'men and their way,' no less than things and their forces.'" ME

DEMOBILIZATION

Within months of Gates's article in *ME* magazine, the war was over, and the U.S. began bringing servicemen home. Code named "Operation Magic Carpet," the effort by the War Shipping Administration began repatriating soldiers from Europe in June 1945, with the operation extended to the Pacific theatre in October after the surrender of Japan. By the time the sealfit operation was ended in September 1946, more than 8 million American military personnel had been returned home.



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Through the development of virtual prototypes of their concepts that capture the dynamics of the system (or systems) early in the design process, machine designers can avoid many of the design issues that often plague them during the integration and prototyping stages.

This Webinar, moderated by Mechanical Engineering Associate Editor Alan Brown, outlines some work being done in applying these techniques in the manufacturing machine and mining equipment industries.

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BY THE NUMBERS: INNOVATION GOES GLOBAL

NOT THAT LONG AGO, any discussion about innovation started with the United States. Other nations were at best also-rans.

This is no longer true. Other governments have recognized a truth the United States embraced years ago, that innovation is a key driver of economic growth. They have embraced innovation strategies designed to spur prosperity and job growth.

This is clearly visible in the *2014 Global Innovation Index*, the latest in a series published annually by Cornell University, The European Institute for Business Administration, and the World Intellectual Property Organization.

GII ranks 143 countries on 81 different indicators. The United States is sixth overall, trailing five European nations and just ahead of Singapore and Hong Kong. While the top 25 countries are all high-income economies, China (ranked 29th) and Malaysia (33rd) could break into the top tier in the very near future.

GII bases its rankings on two sets of factors. The first is inputs. Top performers combine stable, efficient institutions; strong investment in education and research; infrastructure to support innovation (including IT and communications technologies); modern, competitive markets;

and business sophistication, including innovation linkages, knowledge workers, and knowledge absorption.

The second set of factors involves innovation outputs. These include knowledge and technology creation, impact, and diffusion; and creative outputs that embrace intangible assets, and goods and services.

The leaders in both sets of innovation factors vary widely, and offer several surprises. The United States may take pride in its entrepreneurial zeal, but it lags behind United Arab Emirates in joint venture deals; behind Luxembourg in knowledge workers; and behind New Zealand in ease of starting a new business.

The United States, however, continues to attract the world's top talent. "U.S. universities have been exceptionally effective in their quest to engage some of the most prominent people in the world, and have simultaneously created an ecosystem for entrepreneurs who have been able to establish some of the globe's biggest organizations," Chandrajit Banerjee, director general of the Confederation of Indian Industry, wrote in the report.

In fact, *GII* finds that the United States is home to a whopping 75 percent of migrant inventors from low- and middle-income countries. The largest countries of origin are China and India, followed by Russia, Turkey, Iran, Romania, and

TOP-RANKED NATIONS BY KEY INPUTS AND OUTPUTS

INPUTS

Business sophistication

Knowledge workers	Luxembourg
University-industry collaboration	Switzerland
Joint venture deals	United Arab Emirates
International patents	Japan

Institutions

Government effectiveness	Finland
Regulatory quality	Singapore
Ease of startups	New Zealand

Human capital/Research

Per-student spending/GDP per capita	Mozambique
Tertiary engineering/science grads	Thailand
Reading, math & science test scores	China
University quality	United Kingdom

Infrastructure

Use of information technologies	Sweden
Online e-participation	Kazakhstan
Environmental performance	Switzerland
Infrastructure and capital formation/GDP	Mongolia

Market sophistication

Importance of microfinancing	Bolivia
Venture capital deals	Israel

OUTPUTS

Knowledge/Technology Outputs

Scientific & technical article productivity	Iceland
Quality of publications	Germany
Rate of new business creation	Hong Kong, China
Royalty/license receipts	United States
Communications/IT exports	India
High/medium-high-tech manufactures	Ireland

Creative outputs

Resident trademark applications	Paraguay
IT & organization innovation	Estonia
Creative service exports	United Kingdom
Global entertainment/media output	Australia

Mexico.

Relatively few researchers account for a major proportion of overall output, and these innovators are also the most mobile, *GII* notes. In addition to the United States, the United Kingdom, Switzerland, and Singapore are magnets for valued innovators.

Countries are only beginning to address their brain drain

GLOBAL INNOVATION INDEX: THE TOP 10

RANK	COUNTRY	SCORE
1	SWITZERLAND	64.8
2	UNITED KINGDOM	62.4
3	SWEDEN	62.3
4	FINLAND	60.7
5	NETHERLANDS	60.6
6	UNITED STATES OF AMERICA	60.1
7	SINGAPORE	59.2
8	DENMARK	57.5
9	LUXEMBOURG	56.9
10	HONG KONG (CHINA)	56.8

through government policies and economic liberalization. *GII* gives Morocco as an example of a nation that has addressed a brain drain.

China now ranks as high as many high-income economies and outscores most in innovation quality. Yet this year India slipped back 10 places, in part because of challenges it faces in replicating throughout the economy the high standards found in its high-tech cities. Russia showed rapid improvement by rising 13 places to 49th.

Sub-Saharan Africa showed the greatest improvement in 2014. Of its 33 nations, 17 rose in the rankings while only 11 declined.

More surprisingly, this region outpaced all others in "innovation learners." These are nations that perform at least 10 percent higher than peers with similar gross domestic products. This shows "that something is happening

even in the poorest parts of the globe regarding innovation," said the European Institute's executive director, Bruno Lanvin.

The 2014 *Global Innovation Index* report is available at www.globalinnovationindex.org/. **ME**

ALAN S. BROWN

F28

Pandora's Net

**HACKERS HAVE FOUND
VULNERABILITIES
IN THE WAY THE
ELECTRICAL GRID
IS TIED TO THE
INTERNET**

BY BRITTANY
LOGAN

Google we know about. It's a search engine for websites and individual web pages. Shodan, which calls itself "the world's first search engine for Internet-connected devices," promises to do the same thing for the so-called Internet of Things: the devices that are connected to and communicate with the rest of the world. Some of that stuff is small, like ink-jet printers and baby monitors. But other devices that appear on Shodan are part of the world's most critical infrastructure, including parts of the U.S. electrical grid.

That accessibility has been portrayed as a boon to grid operators, who can monitor activity and control various systems remotely. But it also creates opportunities for hackers.

“All the stuff we’re doing in Western society in regards to cybersecurity is probably ten years or so behind the curve of what the bad guys are doing,” said Dan Tentler, founder of the San Diego-based information security consulting firm Atenlabs.

As a penetration tester, consultant, and former information security engineer at Twitter, Tentler knows a thing or two about information technology and cybersecurity. During presentations at the 2014 and 2012 Def Con cybersecurity conferences, he conducted real-time scans on all the connected devices he could find through Internet scans and Shodan. When it comes to securing critical infrastructures online, Tentler said, the lines between control system security and information technology security have blurred.

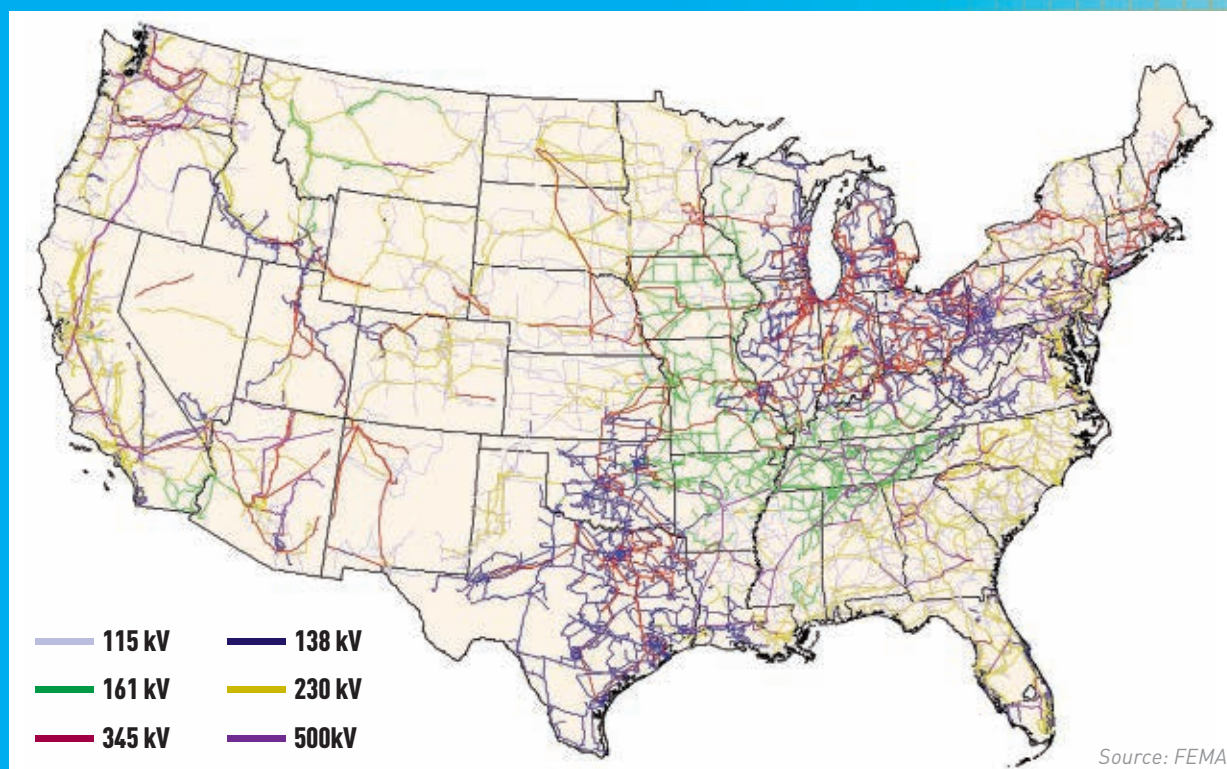
“The trouble is that, up until recently, these systems

weren’t considered IT’s problem,” Tentler said. “Generally speaking, these things ended up online because there was no security oversight of a technical background or nature looking at the concept of taking a giant 12,000 kV diesel generator behind the building and connecting it to the Internet.”

The most vulnerable parts of the electrical grid lie behind locked gates and razor wire-topped fences, but the Internet was not designed with security in mind. That means that operators who work with Internet-connected infrastructure have to play a never-ending game of catch-up with security measures.

Until relatively recently, supervisory control and data acquisition, or SCADA, systems—which are the hardware and software that control and monitor infrastructure and industrial processes—ran on proprietary networks that communicated internally. Password requirements and firewall protections were weak, but that wasn’t considered a security problem since the systems were inaccessible to the outside world.

UNITED STATES TRANSMISSION GRID



Source: FEMA

Ever more connected, the U.S. electricity grid is accessible through the Internet.

When industrial systems moved to public technology like Ethernet and Windows, it enabled companies to save time and money by permitting employees to monitor equipment offsite through field devices. Efficiency was a selling point to customers, who expected quicker service and data collection. But this remote accessibility has a cost.

“These systems are really, really, really vulnerable,” said Joe Weiss, an industrial control systems and cybersecurity expert with more than 35 years of experience. Weiss is a former technical manager of the enterprise infrastructure security and critical infrastructure programs at the Electric Power Research Institute in Palo Alto, Calif.

“In the IT world, their focus is security. In the control systems world, the focus is reliability and safety,” Weiss

to make the centrifuges spin out of control while using previously captured data to trick them and the operator into thinking the system was fine. The worm also hid its files to avoid detection.

The damage caused by the attack destroyed about 20 percent of the centrifuges in the Iranian nuclear program.

Stuxnet may have been launched against an international security target, but the result had a broader, negative impact.

“Prior to Stuxnet, the hacking world really didn’t know or care about the control system world,” Weiss said. “The hacking world was either there for financial gain or reputation. And they didn’t see either of those from the control system world. One of the blowbacks—the unintended consequences—of Stuxnet was all of

a sudden, the control systems world popped up in the hacker’s world.”

Other systems also proved vulnerable to cyber attacks. In 2012, Saudi Aramco became the victim of what was then referred to as the most destructive attack conducted against a business. After being injected through a thumb drive allegedly used by an employee, a computer virus known as Shamoon erased data on servers and wiped clean 30,000-55,000 of Aramco’s hard drives.

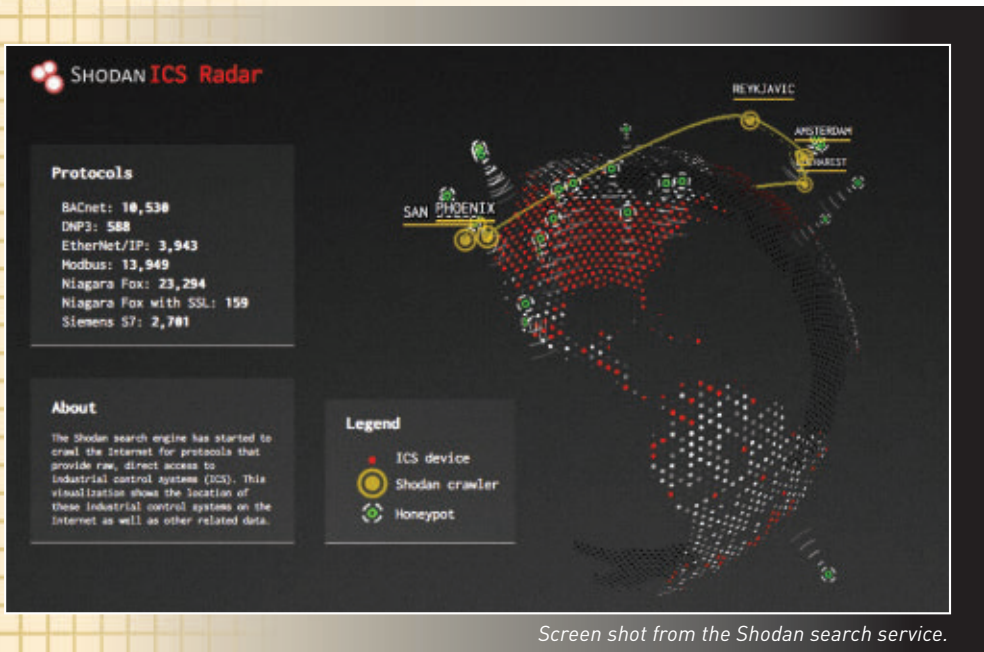
The Shamoon virus contained a kill switch timer that when detonated, spread through Aramco’s hard drives, erased information, and sent data back to the attackers. In addition to infecting computers connected through the Internet, it also corrupted non-connected computers that ran Microsoft Windows, according to a blog run by Eric Byres, a SCADA security expert and

chief technology officer of Tofino Security in Lantzville, British Columbia.

Leon E. Panetta, U.S. Secretary of Defense at the time, expressed his concern about the virus at a Department of Defense press conference later that year.

“It raises tremendous concerns about the potential for the use of that kind of tool when it comes to our power grid, when it comes to our financial systems, when it comes to our government systems,” Panetta said.

In 2014, Symantec, a cybersecurity company, released a report identifying a group of attackers called Dragonfly, who targeted the U.S. and European energy sectors. Using “Trojan horse” software, e-mail campaigns, and remote access tool malware, Dragonfly “managed to compromise a number of strategically important organizations for spying purposes and, if they had used



said. “And the problem is that there are times when they are mutually exclusive.”

REAL-WORLD VULNERABILITY

The potential security weakness of SCADA systems was exposed by a cyber attack against the Natanz uranium enrichment facility in Iran. The plant was the target of a computer worm, called Stuxnet, which was introduced to the site via an infected thumb drive. (The facility itself was isolated from the Internet.) The worm was programmed to search for specific systems pertaining to Iran’s nuclear-enrichment program, including Simatic WinCC (a SCADA system from Siemens written for the Windows operating system) and programmable logic controllers for uranium centrifuges. Once Stuxnet found its target, it essentially used the control systems

the sabotage capabilities open to them, could have caused damage or disruption to energy supplies in affected countries," the report said. Of the top ten countries information was stolen from, only Spain's energy sector was attacked more than the U.S.

To demonstrate that a cyber attack might have a physical consequence as well as a financial one, the U.S. Department of Homeland Security briefed stakeholders on a 2007 test conducted by Idaho National Laboratory. Known as the Aurora Generator Test, it simulated an attack by hackers against a 2.25 MW generator that was connected to a substation. Remote commands caused the 27-ton generator to get out of sync and start to bounce. A video of the test shows bits

flying off the generator and black smoke enveloping the machine. Within minutes, the generator was destroyed.

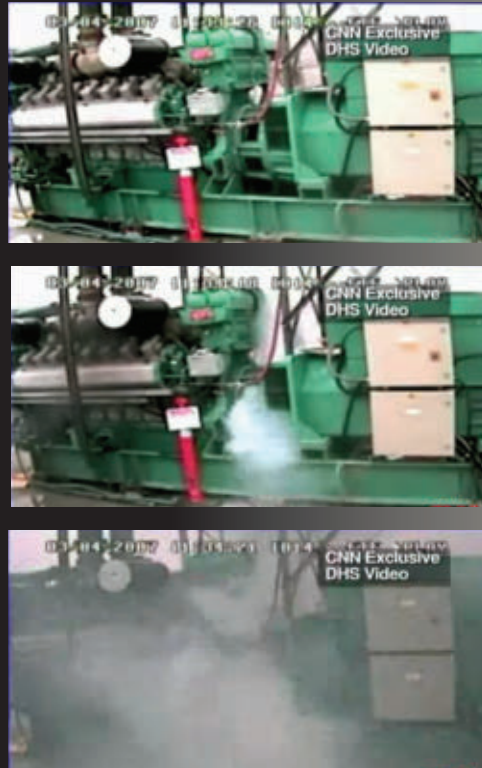
The Aurora test, along with the Shamoon and Stuxnet attacks, provided a glimpse of what a future attack may be able to accomplish against critical infrastructures. The electric grid has always been somewhat open to physical attacks, but now it relies on systems that are vulnerable to cyber warfare that may not be detectable until after the damage has been done.

The Department of Homeland Security's Industrial Control Systems Cyber Emergency Response Team reported responding to 256 incidents in 2013. About three-fifths of them, 59 percent, were in the energy sector. It is a significant increase from 2012, when 198 incidents were reported, of which 41 percent were energy-related.

In 2009, when ICS-CERT was launched, there were nine reported incidents.

One possible motive for the increase in incidents is the potential financial benefit gleaned from information taken by hackers. Another motive may be the potential gain in soft power.

According to Herbert Lin, chief scientist at the Computer Science and Telecommunications Board of the National Research Council and a consulting scholar at Stanford University's Center for International Secu-



Stills from a video of the Aurora Generator Test, a simulated attack by hackers against a 2.25 MW generator that was connected to a substation: (Top) The generator gets out of sync and starts to bounce; (Middle) bits start flying off the generator; (Bottom) black smoke envelops the machine as the generator is destroyed.

rity and Cooperation, soft power can be a serious threat.

One of the benefits of soft power is that it offers the ability to use coercive force and create confusion without using overt means, Lin said. Unlike military power, soft power tends to be less visible and more involved in influence and psychological impact.

In the world of energy, the industrial control systems monitoring the physical processes of machines are less tangible than the actual physical machines they control. But if a person, company, or government were to gain control of a country's physical machines through manipulating their control systems, the hacker could have both influence and power over that system, and over the people and

environments it affects.

The need for cybersecurity makes for some difficult decisions for companies because costs and benefits are hard to calculate and there are no guarantees.

"You can spend every dollar you have on computer security and that can't necessarily be the right thing," said Scott Charney, vice president of trustworthy computing at Microsoft and a former chief of the computer crime and intellectual property section of the U.S. Department of Justice.

Investments in innovation, training, and human resources are still vital to a company's success.

Still, the awareness of grid vulnerabilities may tip the scale toward beefed up security in SCADA and related systems.

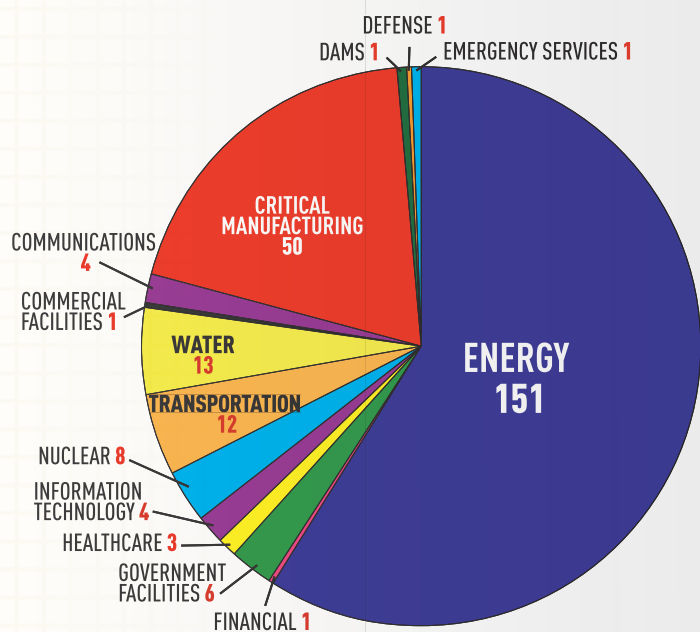
"I think there is a growing consensus, in a good way, that security is about risk management, not risk elimination," Charney said. "You see more and more material in the literature, and more and more discussions where people are practical about the fact that you're not going to get risk to zero. It's about managing risk well."

But preparation doesn't automatically mean execution. Last year Unisys Corp. and the Ponemon Institute in Traverse City, Mich., published results from a study of 599 global IT professionals about security prepared-

UNWANTED ATTENTION: CRITICAL INFRASTRUCTURE

Just what sorts of critical infrastructure are coming under cyber attack? The Department of Homeland Security's Industrial Control Systems-Cyber Emergency Response Team (ICS-CERT) responded to 256 incidents in 2013. Most of these incidents were first detected within the networks of critical infrastructure organizations that operate industrial control systems. The breakdown of the type of infrastructure coming under attack is shown at left—energy infrastructure was by far the most targeted, with 151 incidents, representing 59 percent of the reported attacks. Critical manufacturing facilities were next most likely, targeted by about 20 percent of the attacks.

The ICS-CERT evaluates each reported incident to determine the actual extent to which the systems have been compromised, especially looking for intrusions into the control environment or downloading of sensitive business information. It's estimated that there are many more incidents that go unreported, either because they are not detected or they are being deliberately not reported.



Source: U.S. Dept. of Homeland Security ICS-CERT Monitor, Oct./Nov./Dec. 2013

ness and maturity in critical infrastructure. Among the main findings was that almost “70 percent of companies surveyed that are responsible for the world’s power, water, and other critical functions have reported at least one security breach that led to the loss of confidential information or disruption of operations in the past 12 months.”

The study also found that more than half the respondents lacked confidence that “their organization would be able to upgrade legacy systems to the next improved security state in cost-effective ways without sacrificing mission-critical security.”

Black & Veatch, the global engineering, consulting, and construction company, surveyed 576 electric industry participants last year as part of its annual “Strategic Directions: U.S. Electric Industry” report. Of those surveyed, only 32 percent replied that their security systems were integrated “with proper segmentation, monitoring and redundancies” for infrastructure protection. An additional 48 percent said their systems were not integrated. The rest stated that they did not know.

“I think that it’s fair to say that the cyber vulnerability of critical infrastructure is an unsolved problem at this point,” Lin said. “That doesn’t mean that no one is working on it. It’s just that nobody knows how best to do it at this point.”

FIGHTING A LOSING BATTLE

Within the world of SCADA security, there are so-called white hats, grey hats, and the black hats. White hats are the “good cops,” the cybersecurity experts safeguarding systems through hacking them to find

flaws. Grey hats are hackers who work for a fee and use a combination of tactics. Meanwhile, black hats are those hacking for a malicious or detrimental purpose, and their ranks range from mainstream career hackers to agents of sponsored, terror-related organizations. In this realm, the white hats are fighting a losing battle in both numbers and perception.

“The white hats have had less than stellar luck trying to get large organizations to take security seriously,” Tentler said, explaining that companies tend to view people with information about a system flaw as black hat hackers. That hasn’t stopped Tentler, or his colleagues, whose approach is of the white hats. Tentler’s Atenlabs blog and Twitter account regularly feature posts with security flaws on various systems in the hopes that the companies in charge will fix them.

For his part, Weiss has testified several times to Congress on cybersecurity and control systems. He advises companies, governments, and universities on infrastructure security and attempts to bridge gaps between IT and control system specialists by arranging gatherings to explore problems of cybersecurity and consider solutions.

Others have recommended the energy sector implement back-up and defense-in-depth systems. The concept of a common computer language for SCADA has also been mentioned in the security community, but could come with challenges.

“I think creating a common language for SCADA—like JavaScript—would contribute to improved security,” wrote Chuck Adams, a SCADA security expert and president of Capstone Works Inc., in an e-mail.

Because many SCADA systems are written in a

variety of older, more obscure languages, a common one like JavaScript would enable security experts to search for vulnerabilities and share information. The easier everyone can communicate, the quicker and more likely a system's quirks and flaws can be found and patches issued. (An example of how this could work is to look at how quickly security experts can find and communicate flaws in Microsoft Windows products.)

"But with the disparate systems in place and the long lived nature of many of these systems, it would potentially take decades for enough adoption to significantly mitigate some of the security threats to the existing systems," Adams said.

More formal efforts are also taking place. The International Society of Automation, which has a global membership of 30,000 automation professionals, has released a series of international standards for industrial automation and control systems security.

In 2013, President Obama issued an executive order on improving critical infrastructure cybersecurity. As part of that order, he assigned the National Institute of Standards and Technology the task of developing a cybersecurity framework with standards and practices to address cyber risks. In early 2014, NIST released its report including voluntary guidelines for improving security and managing risks for critical infrastructure companies. In addition, the U.S. Department of Energy released "Cybersecurity Procurement Language for Energy Delivery Systems" to provide guidance on cybersecurity protections specific to the energy sector.

"There is not a single solution," said Black & Veatch's report of tackling cybersecurity issues in the electric industry. "But with an approach that addresses the physical elements of cybersecurity and the cyber elements of physical asset security, organizations will be better equipped and educated to manage the full spectrum of dangers."

Black & Veatch also made a point to note that respondents ranked cybersecurity as one of the top five electric industry issues. As recently as 2012, cybersecurity wasn't even listed in the top ten.

ACCESSIBLE TO ANYONE

There are steps that companies can take to beef up their cyber security. Requiring strong passwords and login credentials for SCADA systems are among the im-

mediate, fundamental ways to improve security.

Following best practices, such as those described in the Security Benchmarks program of the Center for Internet Security, can help minimize vulnerabilities in IT systems.

Disconnecting any unnecessary network connections and restricting personnel access to only essential programs will limit unwanted access to SCADA systems through backdoor networks. Also useful: employing an offensive strategy of working together with respected white hats who can search for weaknesses ("penetration tests") the way hackers would.

Increased awareness is important, but protecting the electrical grid from cyber threats requires doing more. The Internet has an ingrained culture of security as a secondary concern. That same approach can no longer be applied to cybersecurity in critical infrastructures. SCADA and other industrial control systems previously isolated from the public are now potentially accessible to anyone with an Internet

The National Supervisory Control and Data Acquisition Test Bed at Sandia National Laboratories in Albuquerque is tasked with finding and addressing critical security vulnerabilities in the energy sector.



connection.

The option to return to the way things were pre-World Wide Web no longer exists. The economy demands speed and automation on levels unheard of by previous generations.

The only direction left is towards resiliency and better technology and safeguards. [ME](#)

BRITTANY LOGAN is a freelance writer based in Paris.

RIGHT-SIZING THE GRID

The electric grid is prone to massive outages. Would downsizing improve its performance?

BY DAVID NEWMAN

We often talk about banks as being “too big to fail.” But what if the very size of the financial system not only made individual failures inevitable, but made massive failures more likely?

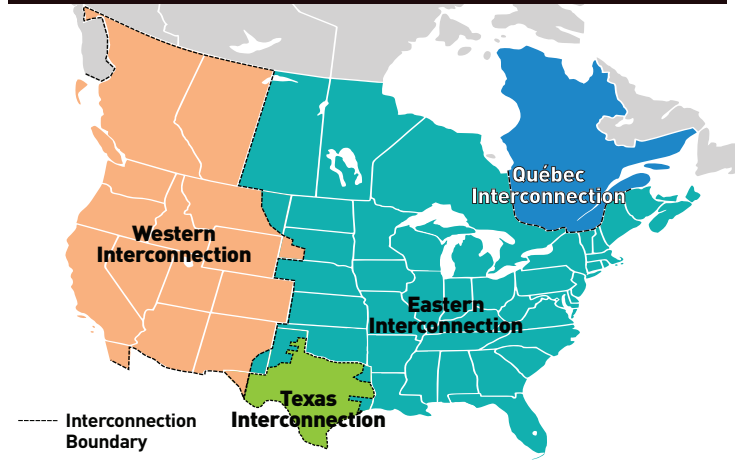
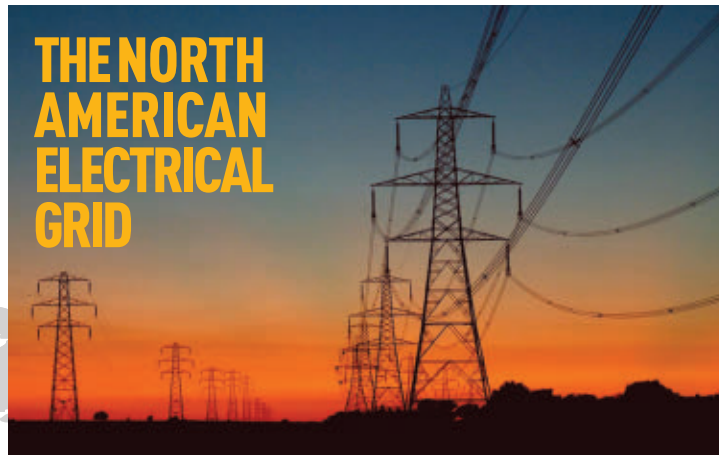
That is exactly what my colleagues and I believe is happening with the electrical grid. There is something about the grid’s very size and structure that increases the risk of cascading

failures, where a single event can touch off a chain reaction of failures.

It happened in 2003, when a power line touched an overgrown tree branch. It short-circuited. Software failed to warn operators of the problem. Within minutes, outages had spread to four states. Ultimately, 55 million people in eight states and Canada were left in the dark. Most got power back within a day or two, but others had to wait weeks.

Night falls on New York City during the 2003 regional blackout.

THE NORTH AMERICAN ELECTRICAL GRID



Source: North American Electric Reliability Corporation

Such massive blackouts are rare. Yet they are extremely costly and disruptive. Recovery takes much longer than smaller events. Because of their size and duration, massive blackouts represent the largest economic risk posed by grid failure.

For the past 15 years, my colleagues—Benjamin Carreras, a principal scientist at the physics and systems consulting firm BACV Solutions in Oak Ridge, Tenn., and Ian Dobson, an electrical engineer at Iowa State University in Ames—and I have been analyzing blackout data.

We have found that large blackouts occur more frequently than you might think. More surprisingly, some engineering responses to outages may actually increase the likelihood of larger, more devastating blackouts.

To understand why, we believe engineers must stop looking at the electrical grid solely as an aggregation of components. Instead, they must also view the grid as an entity whose very size and complexity make it behave differently from other types of systems.

A systems perspective can help us explain why large blackouts are inevitable and why they occur more frequently than we might expect. It also enables us to consider new ways to reduce risk by restructuring the grid. And it lets us ask whether the same mechanisms that make the electrical grid prone to massive failure exist in other large, complex infrastructure systems.

SAND PILES AND GRIDS

To understand grid behavior, let's start with a sandpile or, better yet, a mound of rice. Dribble grains onto it and each new grain will subtly alter the position of the grains around it. The mound will grow taller and steeper—

and more unstable.

Once it gets to a certain point, adding just one more grain dislodges some of the surrounding grains. They, in turn, cause other grains to tumble. This chain reaction creates an avalanche that carries away large slabs of the pile.

The mound now has a broader base, but it is still driven by the same dynamic. If we keep dribbling grains onto it, it will grow higher and steeper, and eventually collapse again.

This is an example of something complexity

theorists call self-organized criticality. In this type of system, the critical point is the position where system properties change abruptly. As long as we keep dribbling sand or rice onto the pile, it will automatically organize itself near that critical point every time. And every time, it will come tumbling down.

The power grid also tends to organize itself near the critical point. The long-term drivers in this case are economic pressures and engineering responses to failure.

On one hand, demand for electricity keeps rising about 2 percent every year. To keep up, power companies build new generators, transmission lines, substations, and other components. At the same time, those companies want to maximize profits, so they run their infrastructure near capacity. This pushes the system ever closer to the critical point.

Most of the time, the system works remarkably well. But perhaps, during a heat wave, when every office and home air conditioner is running flat out, grid capacity utilization edges closer to the brink.

Then something happens. A branch might ground out a transmission line (as one did in 2003). A squirrel may short-circuit a trans-



former (which happened more than 50 times this past summer). Or maybe a generator has to take an unscheduled outage.

In large, complex systems like the grid, repeated disruptions are a certainty. Most of the time, even when the grid is operating close to capacity, it adjusts gracefully to these events. But sometimes, simply because of the random fluctuation of demand and current, it cannot.

So a small part of the grid goes down. Operators compensate by rerouting additional power over other transmission lines to make up for the loss. But if those lines are running close to capacity, thanks to random fluctuations in demand, shifting additional current onto them trips their circuit breakers and shuts them down. As the grid tries to compensate, more lines shut down. Failure cascades through the system, causing a massive blackout.

Blind economic forces drove the grid closer to its critical point. Random variations in demand maxed out capacity. Then, one day, someone dropped that last grain of sand, and it all came crashing down.

FAT TAILS

Ben Carreras and I first began to model sand piles at Oak Ridge National Laboratory 20 years ago. We were not looking at the electrical grid then. Instead, we wanted to understand nuclear fusion.

To achieve fusion, we need to contain a hot, dense plasma confined by a magnetic field. Like a sand pile, the system contains the plasma near the critical state until random fluctuations trigger a cascade of events that sends a burst of energy through the field.

That's when we saw a report on a blackout caused by cascading failures. I contacted Ian Dobson, who, as an electrical engineer, could better judge the similarities



small blackouts are far more likely than large ones. As the number of transmission lines affected by an outage grows in number, the likelihood of the outage falls exponentially—up until about 10 lines.

For blackouts of 10 lines or more, the exponential rate of decline flattens out. Rather than a waterfall-shaped curve, we get something that looks like the tail of a Jurassic sauropod. Instead of an exponential drop, we get a slower decline based on a power law. This is a characteristic of complex systems near their critical point. Researchers

found similar patterns when they analyzed blackout data from China, New Zealand, Norway, and Sweden.

The exponential drop-off in small and moderate-size outages makes sense.

Every so often, a small section of the grid fails. Each failure begins as an isolated incident in one component. The likelihood of this is small, but significant, like the likelihood of flipping a coin and getting all heads several times in a row.

For the outage to spread, a second component must go down. For example, if operators reroute power through another transmission line to make up for the outage, that line can usually handle it. But if that line has a weak link or is running too close to capacity because of random variations in current, it might shut down too. It is like flip-

EFFORTS TO MITIGATE SMALL DISRUPTIONS MAY ACTUALLY INCREASE THE FREQUENCY OF LARGER DISRUPTIONS. THIS APPEARS COUNTERINTUITIVE, BUT IT IS A CHARACTERISTIC OF MANY COMPLEX SYSTEMS.

between the two paradigms. Together, the three of us created a simple sand pile-like model to see if we could explain blackouts.

First, we analyzed 1984-1998 power blackout data from the North American Electric Reliability Corp. We wanted to see if it showed the characteristic signatures of a complex system near its critical point.

The first thing that jumped out from the data is that



Small events, such as power line short circuits caused by unpruned trees, squirrels, or other animals can have a catastrophic effect on the wider regional grid.

Photo: Robert Lawton

ping our coin again and getting all heads. It can happen, but it is less likely. In fact, it is exponentially less likely.

Yet large blackouts are more common than this initial dropoff in probability would suggest. Why? We think this is because the grid, like our rising sand pile, moves closer to its critical point as it grows. This is a function of size, and we see it very clearly in the data.

To test this thesis, we built a model of the Western United States electrical grid. We did not try to model the grid realistically or predict actual blackouts. Instead, we wanted to see how it would evolve over time.

To do this, we greatly simplified our model. We included only the transmission grid and ignored distribution within towns and cities. We use a dc loadflow model and eliminated transformers. We simplified transmission lines, generators, load variations, and nodes (where the power goes).

The model followed rules that reflected the actual grid. For example, we increased power demand at a constant rate, about 2 percent per year, and let daily loads fluctuate randomly (within parameters consistent with variations in the real system). To meet rising demand, we built more generators and upgraded transmission lines.

We used our NERC data to determine the probability of outages. When they occurred, we modeled the engineering response to failures. For example, we used the

same type of linear programming methods that utilities use to redispatch generators and shed load to prevent blackouts. In some cases this worked; in others it did not. After “virtual” blackouts, we upgraded failed transmission lines to carry more power, just as utilities do following real outages.

We validated our results against NERC data from the Western U.S. grid. Our model’s basic dynamics and statistics showed excellent agreement with the NERC data.

Then we did something we could not do in real life: We let the model run for hundreds of virtual years and watched how the grid evolved. This is especially important when investigating massive blackouts. Because these events occur so infrequently, we needed to let the model run for prolonged periods to get enough examples to analyze statistically.

BLACKOUTS

Some interesting patterns emerged. As our initial analysis of NERC data showed, massive blackouts occur more often than we might expect. We believe this is due to the grid’s self-organized criticality.

More surprisingly, long-term engineering efforts to prevent failures usually fail to reduce the likelihood of large blackouts. In fact, they can often make the problem worse.

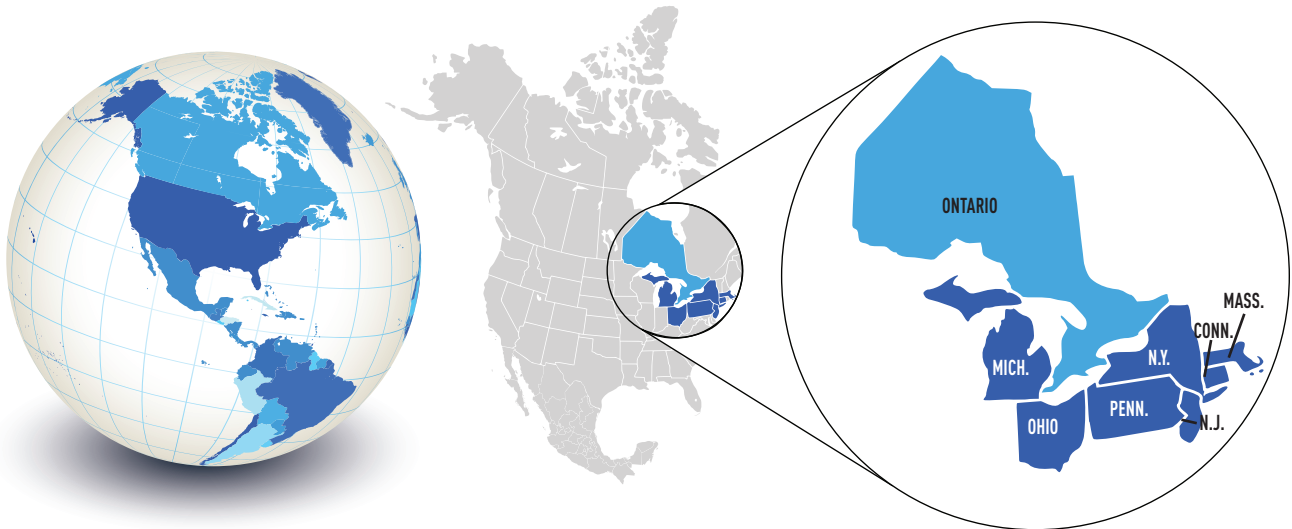
This seems counterintuitive. Upgrading generators, transmission lines, and other components seems like it should improve grid stability. Yet these upgrades do not address the factors that push the system to the edge of criticality.

That is because the forces shaping the grid—rising demand and the push for profits—are part of society and not part of the grid itself. Improving components may move the system to a new dynamic equilibrium, but that equilibrium will still move towards the critical point every single time.

We can see this clearly in our rice mound. Grid improvements are like wetting the rice to increase its stickiness. It lets us build the mound higher and steeper. Yet it does not change the fundamental structure of the pile. Eventually, the mound will grow too high and too steep and collapse, just as it did before.

Similarly, upgrading grid components lets the system carry more power, but does nothing to address the fundamental push-pull among demand, profits, and engineering responses to failure that push the system towards its critical point.

Efforts to mitigate small disruptions may actually increase the frequency of larger disruptions. This also appears counterintuitive, but it is a characteristic of many



2003 NORTHEAST BLACKOUT: TIMELINE OF EVENTS

The blackout that hit the Northeast United States and the Canadian province of Ontario struck without warning on August 14, 2003.

According to a report by the New York Independent System Operator (NYISO), which runs the electrical grid in New York state, the power system was operating normally: almost all the transmission lines were in operation and there was a 3,000 MW surplus in generating capacity.

A series of events began in the late afternoon, following the shorting out of a high-voltage power line in northeast Ohio:

■ Beginning at around 4:06 p.m., a sustained power surge north toward Cleveland overloads three 138 kV lines.

■ Minutes later, NYISO noted a larger power swing—approximately 700 MW—out to Ontario, as well as a coincident swing of similar propor-

tion from the PJM grid operating system in the Mid-Atlantic region into the NYISO.

■ Starting at 4:10, transmission lines trip out, first in Michigan and then in Ohio. The eastward flow of power around the south shore of Lake Erie and into New York is blocked. Cut off from demand, generating stations go offline, creating a huge power deficit. To compensate, power surges in from the east, overloading power plants in New York, Ontario, and elsewhere, which then go offline as a protective measure.

Within minutes, a cascading failure disconnects various parts of the interconnected grid. The NYISO system, for instance, separated into two electrical islands and western New York separated from the Ontario system.

The grid instability took more than 250 power plants offline. More than 80 percent of those

plants went offline after the grid separations occurred, most due to the action of automatic protective controls. For instance, severe frequency oscillations in the grid caused large nuclear and combined cycle units to trip off. Some of the fossil generation tripped by relay protection, and in other cases operators took the units off-line because they were becoming thermally unstable.

The blackout left an estimated 10 million people in Ontario and 45 million people in eight U.S. states without power.

Parts of the affected region had power restored by that evening. Other areas—including New York City—saw the lights go back on the next day.

Still other areas didn't have full power until August 16, and electricity was limited in many parts of Ontario for days afterward.

One estimate put the total cost of the 2003 blackout at \$6 billion. The event contributed to at least 11 deaths.

Source: New York Independent System Operator: Blackout August 14, 2003 Final Report; Wikipedia

complex systems.

Complexity theorists have studied how this works in several systems, including forest fires. Suppressing small forest fires seems like a good way to keep them from growing into large fires. True, sending out fire crews to put out small blazes initially lowers the number of small and large fires significantly.

Yet fires are part of the natural forest ecosystem. Extinguishing them changes the forest in unexpected ways. Without periodic fires, trees grow denser and there are more dead trees on the ground. These serve as fuel for the next fire. Sometimes, a crew does not spot smoke early, or cannot respond to all the fires started by lightning storms. With more fuel, these fires spread rapidly. While big fires are rare, they are still more frequent—and more destructive—than they would have been if smaller fires had

thinned the forest naturally.

So, how does this play out in the grid? We considered different mitigation strategies. First, we adjusted the model so that no blackouts occurred until a minimum number of lines overloaded. This was our way of representing operator actions to resolve overloads by redistributing power. When we did this and ran our simulations, we found this actually increased the number of large events over time.

We also upgraded the emergency ratings of our virtual transmission lines so they could carry more power to increase component reliability. This reduced the number of small blackouts, but increased the number of large blackouts.

Finally, we increased generator capacity. If the excess power was large enough, it reduced blackouts—but only

if we upgraded the transmission lines to carry additional power. Otherwise, additional capacity alone results in fewer but larger blackouts.

FINDING THE SWEET SPOT

If the grid is prone to massive blackouts and improving its components actually makes the problems worse, how can we reduce risk and improve reliability?

We discovered a clue in “On Being the Right Size,” an essay written in 1928 by famed biologist J.B.S. Haldane. In it, Haldane surveyed the link between an animal’s size and its biological systems. An insect, for example, gets all the oxygen it needs through diffusion, while larger mammals need a complex circulatory system to supply interior cells.

The essay struck a chord. After all, the grid, like animals, evolved over time in ways that were not pre-engineered. Perhaps, like animals, the grid had a “right” size that allowed it to thrive while minimizing risk.

North America’s power grid grew to its present size to give operators more resources to deal with power supply, demand fluctuations, and potential outages. We certainly want to preserve that flexibility.

At the same time, the grid’s size and self-organized criticality makes it highly susceptible to cascading failures. While it does a good job of preventing small outages, its very success appears to make massive blackouts more likely.

To see if there was a “right” size that gave us flexibility without more risk, we modeled grids of different sizes. We compared the behavior of 200-, 400-, 800-, and 1,600-node grids with systems of the same size built from unconnected 100-node modules.

We found that smaller 200- and 400-node systems behaved similarly to even smaller systems made up of 100-node modules. The number of blackouts dropped exponentially with the size of the outage, and none of the networks had fat tails.

The 800- and 1,600-node networks behaved very dif-

ferently. They had the resources to prevent small and medium-size blackouts, and had fewer of them than same-size modular systems. On the other hand, the larger networks had fat tails and much greater likelihoods of large blackouts than in the modular networks.

Our own analysis (using our simplified grid model) shows that a grid with 500 to 700 nodes might be the sweet spot for a grid. It is large enough to let us suppress many small and medium-size outages, yet small enough to avoid the increased probability of massive blackouts.

Utilities may not find this suggestion palatable. On one hand, it reduces the likelihood of massive blackouts that last days or even weeks and that pose the greatest risk to society. Yet such massive outages happen only rarely.

On the other hand, dividing the grid into independent modules would produce more small and medium-size blackouts. While these events are quickly remedied,

they would occur frequently enough to notice and draw complaints from utility customers. It would also make the grid less efficient for operators.

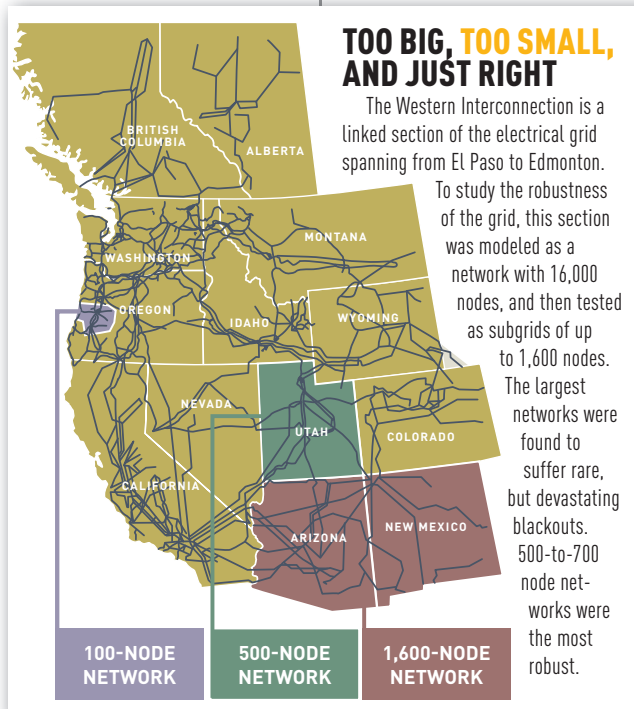
Still, we think this is a promising avenue of research. If we start thinking of the grid as a self-organizing system that will always move towards the critical point, we may find better ways to balance stability and risk. There may better ways to share resources and secure smaller electrical networks without endangering the entire system.

We also think our research into self-organizing criticality has broad implications for other types of infrastructure.

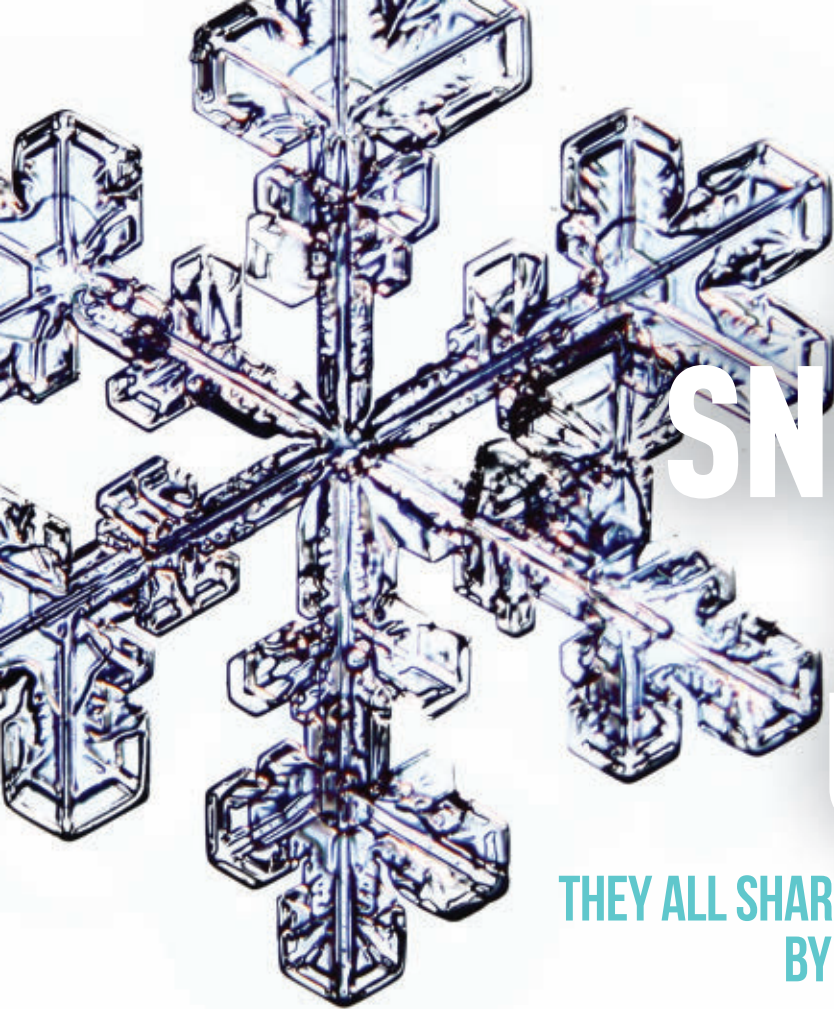
Many are driven by the same

economic forces. They might include our vast and tightly interconnected financial, air transportation, communications, and Internet systems.

By acknowledging that failure is inevitable and rethinking acceptable risk, perhaps we can reduce the cost to society when things do go wrong. **ME**



DAVID NEWMAN is a professor of physics and director of the Center for Complex Systems Studies at the University of Alaska Fairbanks.



EVERY SNOWFLAKE IS **NOT** UNIQUE

THEY ALL SHARE ONE ARCHITECTURE, DETERMINED
BY THE WAY HEAT FLOWS.

BY ADRIAN BEJAN

People like to say that every snowflake is unique. On the level of execution and fine detail, that may or may not be true. After all, who has seen every snowflake?

It is certain, however, that every snowflake conforms to only one architecture: a flat star with six fishbones connected at the center. What's more, that structure is predictable provided that we recognize the underlying principle: first, that something flows, in this case heat, and, second, that the natural tendency of all flows is to evolve into architectures that provide easier access. It's another example of the constructal law.

Here is how to predict the shape and structure of the

snowflake. In the beginning, there is cold humid air, below 0 °C. Then, all of a sudden, around a tiny speck of dust, ice forms and grows as a spherical bead. Counterintuitively, the bead is warmer than everything else around it, and heat flows away from it in all directions. What heat? The latent heat of solidification, which is released by the water vapor that becomes solid at the bead surface.

There comes a critical time when the spherical bead is no longer an efficient architecture for dissipating heat. The principle calls for design change, toward faster heat release and solidification. The growth of ice morphs abruptly into a ball continued in one plane by needles. Because of the configuration of the water molecule, the needles grow in six directions. The flat star transfers heat to the surroundings



more easily than a spherical bead with the same diameter.

Incidentally, why does the snowflake grow in one plane, as a flat star? Because needles in one plane grow faster (with more access to cold air) than needles growing in all directions.

There comes a second critical moment when the tip of every needle feels the same as the original bead. Each tip would generate six new needles, except that only the three that point forward can grow. One needle cannot grow backward because that place is occupied by the mother needle; and the two backward side needles cannot grow either, because the air in the interstices (between two mother needles) is no longer cold.

This stepwise evolutionary design continues as long as the new forward-pointing needles find cold air that serves as a sink for the heat released by their growth.

To give credit to the view that every snowflake is unique, the actual configuration depends on many secondary effects, which are of random origin. Very cold air makes needles that are sharp and fast growing (fluffy snow). Cold air just under 0°C makes fat needles; the snowflake falls like a leaf; it bumps into and sticks to its neighbors, and the wind damages all the snowflakes in random ways due to air turbulence.

In spite of the obvious diversity, the human mind records the snowflake design

in the same simple way that the mind predicts the design from principle. Snowflake-themed art—from Christmas ornaments to patterned sweaters—all show a consistent design that is predicted by constructal law. Artists do not talk to each other while making their objects; they draw from the organization in nature, and such is life.

The snowflake story has many equivalents throughout nature, animate and inanimate. Every river basin is not unique. The river basin has a rule of construction and a principle: four tributaries to a larger channel, predicted from the constructal law. Every sprinter is not unique. The runner has a rule of construction and a principle: the speed is a multiple of the body mass raised to the power $1/6$, predicted from the constructal law. Next time you hear

that every snowflake is unique, think about its principle, the constructal law.

ADRIAN BEJAN is the J. A. Jones Distinguished Professor of mechanical engineering at Duke University.

To know more:

A. Bejan, *Advanced Engineering Thermodynamics*, 3rd ed., Wiley, Hoboken, 2006, pp. 779-782.

A. Bejan, S. Lorente, B. S. Yilbas, and A. Z. Sahin, "Why solidification has an S-shaped history," *Nature Scientific Reports*, Vol. 3, 2013, 1711; DOI: 10.1038/srep01711 (2013).

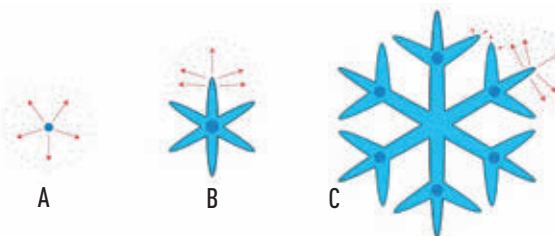
A. Bejan and J. P. Zane, *Design in Nature: How the Constructal Law Governs Evolution in Biology, Physics, Technology, and Social Organization*, Doubleday, New York, 2012.

The 9th Constructal Law & Second Law Conference will be held in Parma Italy, on 18-19 May 2015: www.clc2015.eu.



Snowflakes formed at just below 0°C will stick together, producing heavy "wet" snow. While great for building snowmen and making snow angels, it also causes damage to tree branches and electrical power lines.

Photo: Share Alike 3.0 via Wikimedia Commons



The ice architecture morphs stepwise toward easier heat flow from the solid to the surrounding cold air, in this particular sequence, predictably: (A) spherical bead, (B) flat star with six arms, and (C) arms with second-generation arms that look like forward-pointing branches.

2014 ARTICLE INDEX

THE FOLLOWING IS A LIST OF FEATURE ARTICLES THAT APPEARED IN *MECHANICAL ENGINEERING* IN 2014.

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Cold Start, Dead Sensor

Electrostatic discharge from oil can destroy sensitive and crucial engine components.

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ABRAMS, MICHAEL

Power Lines

For decades researchers have searched for a material to make cheap but powerful artificial muscles. They've found it in a tackle box.

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ALAPAN, YUNUS, ISMAIL SAYIN, AND UMUT ATAKAN GURKAN

Making the Smallest Medical Devices

As engineers seek to manufacture nanoscale products for medical applications, several paths look promising.

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ASME NUCLEAR CODES AND STANDARDS

A Group Effort That Grew

As the industry's needs expanded, so did the scope of ASME's nuclear codes and standards.

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BERNSEN, SIDNEY, BRYAN ERLER, DANA K. MORTON, AND OWEN HEDDEN

The Code Builders

The first nuclear power plants required the largest pressure vessels ever built at that time. To ensure they would be safe required a new section of the ASME Boiler and Pressure Vessel Code.

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Nanotechnology for the Brain

Ever smaller-scale tools seek to unravel that complex mystery in our heads.

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Iconic Design

We asked six leading industrial designers to tell us which products inspired them. The breadth of their choices was unexpected.

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Seeing the Light

How pluck, luck, and perseverance helped Rochester's optics industry get its groove back.

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What Really Matters in STEM Education

Everyone knows that "STEM" stands for "science, technology, engineering, and mathematics." That may be the only thing about it that people agree on.

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Maximum Zero

Homes and office buildings that produce as much energy as they consume are becoming an affordable reality.

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Engineers in the Distance

Online learning opens a path from the technical to the technological.

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HUTCHINSON, HARRY

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A small country is amassing a brain trust to compensate for resources that nature didn't provide.

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Robot See, Robot Do

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Calculators Before the CPU

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KOSOWATZ, JOHN

Spinning Liquid Gold

Advanced drilling and production techniques have given the United States more natural gas than its markets can handle. Converting that bounty into liquefied natural gas promises to transform the U.S. gas industry into a global energy power.

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LANGSTON, LEE S.

Whisper + Roar

As the gas turbine industry progresses, raw power isn't the only important metric.

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LEISHEAR, ROBERT A.

From Water Hammer to Ignition

The spark that ignited Three Mile Island burst from a safety valve.

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The X Prize Foundation wants engineers and doctors to build a functional tricorder—a science-fiction medical scanner. The surprise is that many of the technologies they need to do it are already here.

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The Tesla Phenomenon

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Houston is more closely identified with space than any other American city. For all that, the city has never been the launch site for a spacecraft.

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The new wolves of Wall Street may be computer algorithms that run in packs.

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PD359	Practical Welding Technology	2-5 Feb
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PD632	Design in Codes, Standards and Regulations for Nuclear Power Plant Construction ASME CODE COURSE	2-5 Feb
PD644	Advanced Design and Construction of Nuclear Facility Components Per BPV Code, Section III ASME CODE COURSE	2-5 Feb
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PD445	B31 Piping Fabrication and Examination ASME CODE COURSE	5-6 Feb

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PD714	BPV Code, Section VIII, Division 2: Pressure Vessels	9-11 Feb
PD720	Layout of Process Piping Systems NEW!	9-11 Feb
PD643	B31.3 Process Piping Code ASME CODE COURSE TOP SELLER	9-12 Feb
PD443	BPV Code, Section VIII, Division 1 Combo Course ASME CODE COURSE SAVE UP TO €800!	9-13 Feb
PD686	Layout of Process Piping Systems and Optimisation of Plant Layouts Utilising 3D CAD/CAE Systems Combo Course NEW! SAVE UP TO €750!	9-13 Feb
PD441	Inspections, Repairs and Alterations of Pressure Equipment ASME CODE COURSE TOP SELLER	12-13 Feb
PD577	Bolted Joint Assembly Principles Per PCC-1-2013 ASME CODE COURSE	12-13 Feb
PD721	Optimisation of Plant Layouts Utilising 3D CAD/CAE Systems NEW!	12-13 Feb

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FEBRUARY 2015 – DUBAI, UNITED ARAB EMIRATES

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FEBRUARY 2015 – ABU DHABI, UNITED ARAB EMIRATES

PD673	Design and Selection of Heat Exchangers	15-17 Feb
PD723	B31.4 and B31.8, Liquids and Gas Pipelines	15-18 Feb
PD642	ASME B31.1 Power Piping Code	15-19 Feb
PD726	API 579-1/ASME FFS-1 Fitness-for-Service	15-19 Feb

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MARCH 2015 – HOUSTON, TEXAS USA

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PD570	Geometric Dimensioning and Tolerancing Fundamentals 1	2-3 Mar
PD583	Pressure Relief Devices: Design, Sizing, Construction, Inspection and Maintenance ASME CODE COURSE	2-3 Mar
PD190	BPV Code, Section IX: Welding, Brazing and Fusing Qualifications ASME CODE COURSE	2-4 Mar
PD268	Fracture Mechanics Approach to Life Predictions	2-4 Mar
PD349	Design and Applications of Centrifugal Pumps	2-4 Mar
PD370	B31.8 Gas Transmission and Distribution Piping Systems	2-4 Mar
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PD027	Heating, Ventilating and Air-Conditioning Systems: Sizing and Design	3-5 Mar
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PD606	NQA-1 Requirements for Computer Software Used in Nuclear Facilities ASME CODE COURSE	5-6 Mar
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PD531	Leadership and Organizational Management	16-17 Mar
PD539	Bolted Joints and Gasket Behavior	16-17 Mar
PD077	Failure Prevention, Repair and Life Extension of Piping, Vessels and Tanks ASME CODE COURSE	16-18 Mar
PD395	API 579-1/ASME FFS-1 Fitness-for-Service	16-18 Mar
PD618	Root Cause Analysis Fundamentals	16-18 Mar
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PD184	BPV Code, Section III, Division 1: Rules for Construction of Nuclear Facility Components ASME CODE COURSE	16-19 Mar
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PD676	Strategic Thinking	18 Mar
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This article was originally published in the October 2014 issue. Due to a printing error, the full article did not appear in print editions.

SOLAR ENERGY WAS ONCE VIEWED AS PIE IN THE SKY.

Photovoltaic cells might be suitable for running pocket calculators or communications satellites, but they could not compete with electricity from conventional power plants.

BUT RECENT ADVANCES in the production of photovoltaic panels have driven down the cost of solar power. Estimates for the levelized cost of electricity from PV range from 10 to 30 cents per kWh. And though this is still higher than the cost of generation from a newly built coal-fired thermal power station, solar power could be the cheapest electricity available in some areas within a few years, according to data from the Energy Information Agency.

Solar energy supplanting coal in producing electricity would be a milestone, but it would scarcely be the end of fossil fuel. Of the nearly 80 quadrillion Btu of oil, gas, and coal that the U.S. consumes each year, only 25 quads—about 31 percent—are used to generate electricity.

Carbon-based fuels are critical to many sectors, such as transportation. Even if electric vehicles become common, it seems unlikely that airplanes will ever be battery powered. Process heat is another important application for fossil

FOSSIL FUELS HAVE A NUMBER OF INDUSTRIAL USES BEYOND ENERGY



fuel combustion, and most industrial hydrogen is produced via the cracking of natural gas.

Solar energy is usually considered in terms of making electricity, but it also has the potential to supplant fossil fuels in the production of liquid fuels, and in driving endothermic industrial processes. Solar thermochemical processes are feasible, and a solar power concentration process that harnesses sunlight's infrared energy is the best suited technology for making solar fuels a reality.



While electricity has myriad uses, there are many industrial processes that rely on heat to drive them. The production of lime, a crucial step for making concrete, requires heating crushed limestone to around 1,000 °C. Many industries, from papermaking to food processing, require heat to dry their products, and the chemical industry relies on heat

to drive many reactions.

Process heat is used to produce valuable materials used in other parts of the industrial chain. Hydrogen, which is often derived from the endothermic steam reforming of natural gas, is used to produce crucial commodities such as methanol and ammonia, and is used extensively in the petroleum industry to upgrade crude oil through various hydrotreating processes.

While it's convenient to use fossil fuel combustion to provide this process heat, it's not without drawbacks. Steam reforming natural gas, for instance, emits approximately 11.9 kg of carbon dioxide equivalent for every kilogram of hydrogen produced. The calcination of limestone to make lime results in carbon emissions directly, but nearly an equivalent amount results from fossil fuel combustion to drive the reaction.

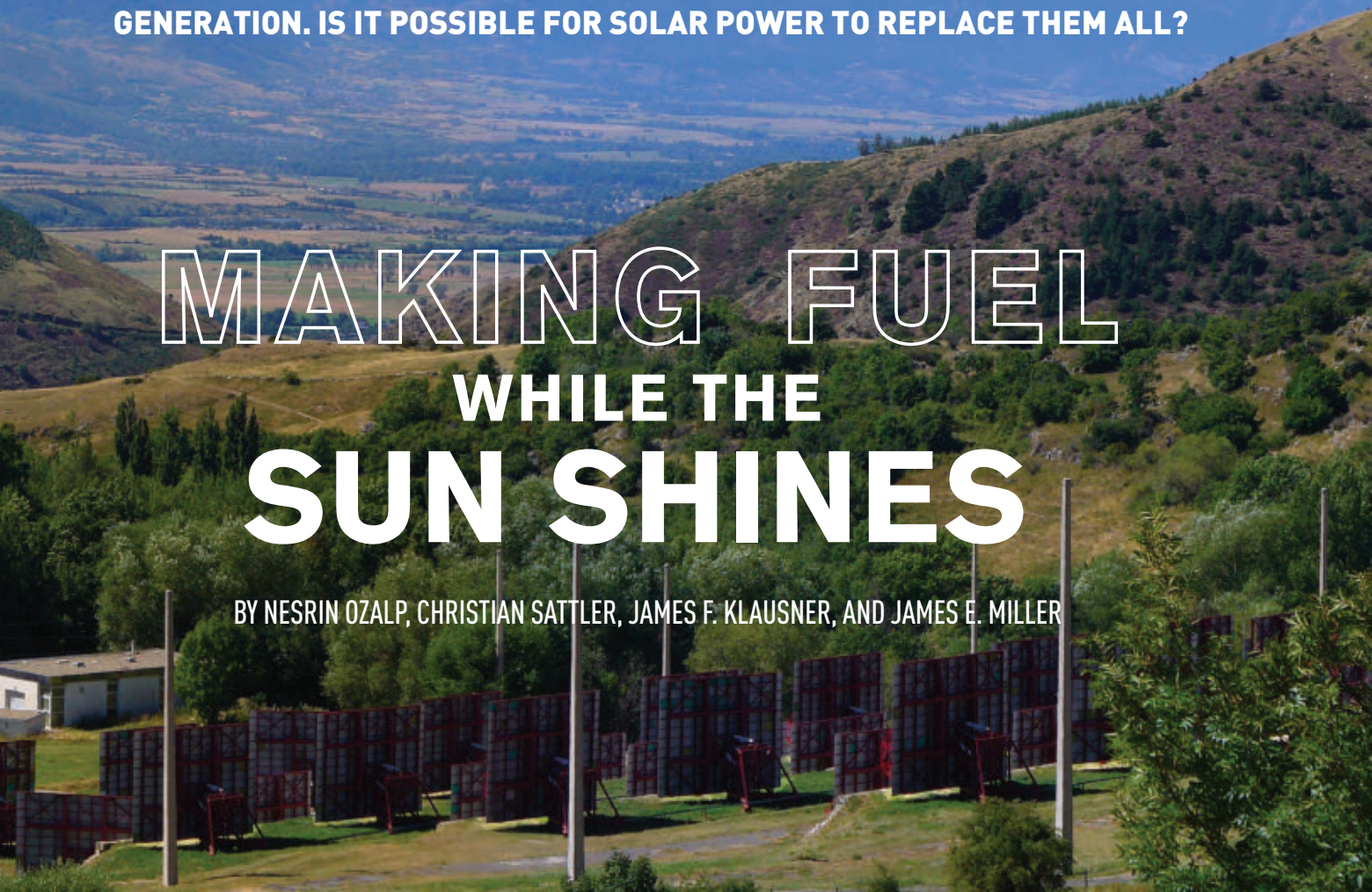
Other sources of heat are available. Nuclear reactors, for instance, can be designed to supply process heat. Given the many challenges of building reactors, however, nuclear power may be better reserved for other uses such as generating electricity.

Another readily available heat source is solar en-

GENERATION. IS IT POSSIBLE FOR SOLAR POWER TO REPLACE THEM ALL?

MAKING FUEL WHILE THE SUN SHINES

BY NESRIN OZALP, CHRISTIAN SATTLER, JAMES F. KLAUSNER, AND JAMES E. MILLER



ergy. The sun provides an average of around 1,000 watts per square meter of power during daylight hours, which by itself provides enough for some low-temperature processes such as food drying. (Some tomatoes are marketed as “sun-dried” for good reason.) Small reflectors have enabled solar-powered water heaters to be economical for domestic use.

To obtain the temperatures needed for large industrial processes, however, large arrays of mirrors are necessary. These arrays collect the sunlight falling on many square meters or even hectares and reflect it on receivers that heat up. A concentration factor of 500 to 1,000 can yield a temperature at the receiver well over 700 °C. A solar furnace in Odeillo, France, for instance, focuses light from about 2,000 square meters of mirrored surface onto a spot 60 cm across to produce temperatures in excess of 3,200 °C—easily hot enough to vaporize iron or nickel.

Vaporizing iron may have limited practical uses, but many industrial processes can be driven by heat from a large solar concentrator. Several research teams—including some that we have participated in—have shown the practicality of making hydrogen from water splitting via solar thermal reactions. In the most basic framework, steam flows over a high temperature metallic substrate, and as steam oxidizes the metal, hydrogen is released. Concentrated solar energy is then used to reduce the metal so that the cyclical steam oxidation can be repeated.

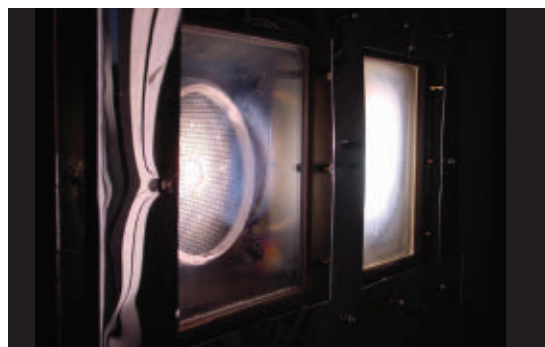
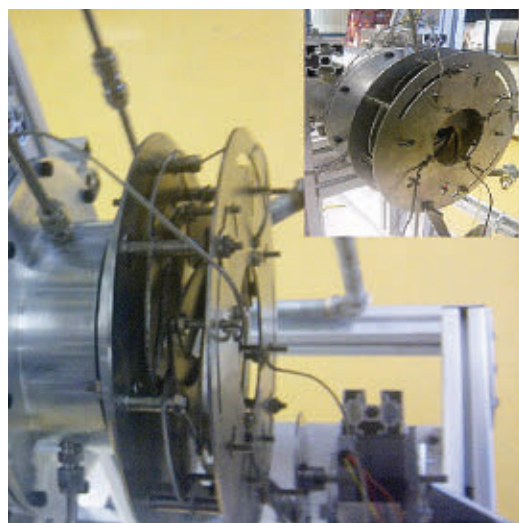
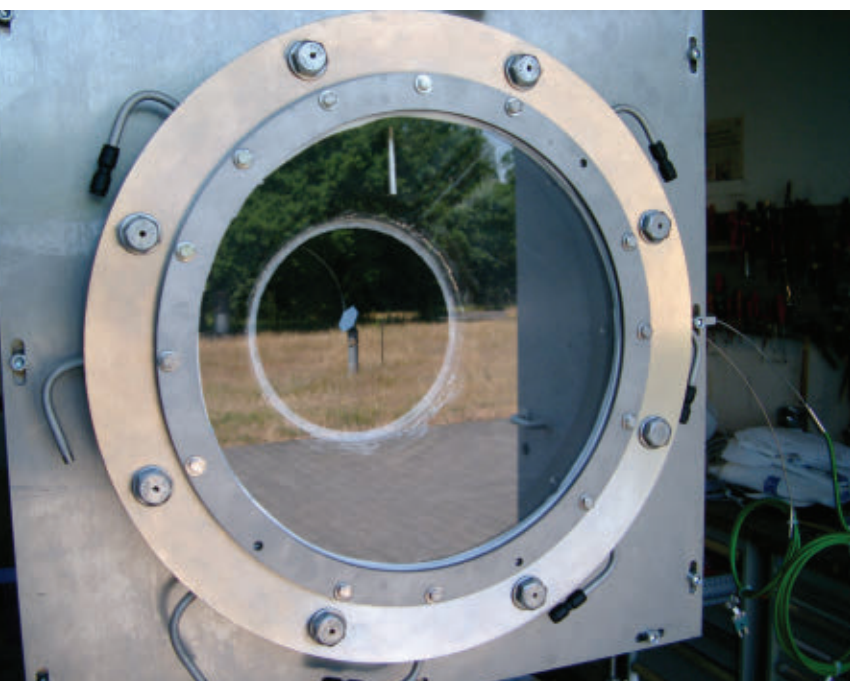
Such processes could entirely eliminate the emissions of carbon dioxide associated with fuel combustion. Other groups are working to use solar heat to crack methane for hydrogen production, which would produce fewer carbon and other hazardous emissions than current

industrial practices.

One route to making hydrogen from natural gas via solar thermochemical processes produces carbon black instead of carbon dioxide as a byproduct. Carbon black is the most important technical carbon product after metallurgical coke. An important additive for rubbers, inks, batteries, and several polymers, it is also used in power generation, soil amendment, and environmental remediation. This method of hydrogen production could potentially provide the double benefit of being both CO₂-free and cost-effective, with the production of marketable carbon products defraying the expense of hydrogen. It is also possible to produce carbon nanotubes from natural gas by tuning the cracking process conditions.

Another area in which solar commodity production may have advantages over traditional industrial practice is in the separation of pure metal and oxygen from metal oxides found naturally in many ore deposits. For example, the use of solar thermochemistry to produce metallic magnesium from magnesium oxide appears to be quite promising. Advanced aluminum-magnesium alloys are essential in keeping vehicles, such as the new Ford F150

Solar reactors up close: A single-chamber reactor (below) for thermochemical reduction of metals; a two-chamber reactor at the German Aerospace Center (lower right) for producing hydrogen; an iris mechanism (top right) for controlling incoming thermal power.





Facilities such as the Mont-Louis Solar Furnace (above) and the Odeillo Solar Furnace (right and on the opening pages) concentrate sunlight to conduct thermochemical experiments.

production model, as lightweight as possible.

Solar thermochemistry could potentially have the biggest impact in the production of hydrogen-derived fuels which would be capable of replacing those derived from fossil fuels. Hydrogen can be used directly as a fuel, and advances in fuel cell technology may one day make it an attractive substitute for gasoline or diesel. But it is also possible to use solar heat to drive processes to create fuels that are compatible with the existing hydrocarbon infrastructure.

For example, methanol is readily produced via the catalytic reaction of hydrogen with carbon dioxide. This process has been commercialized with renewable hydrogen and recovered CO_2 by Carbon Recycling International.

Alternatively, solar thermochemical processes can produce carbon monoxide from carbon dioxide and hydrogen from water, or both can be produced from the solar steam reformation of methane, and the resulting gas mixture can be used to produce more conventional liquid fuels via the Fischer-Tropsch process. (That process is used today to make synthetic fuels, but the heat to drive the reactions comes from the combustion of a portion of the fossil fuel feedstocks.) Solar thermochemistry could plausibly produce a significant fraction of the world's transportation fuels in the long-term, as technological advancements continue increasing efficiencies and driving down costs.

IN SPITE OF THEIR APPEAL, solar thermochemical processes have the same drawback that direct solar power has: the transient and diurnal nature of sunshine. Fossil fuel-powered process heat provides the sort of constant temperatures and continuous operation that simplify industrial processes and controls. Fluctuations of available solar radiation—over the course of a day, across different types of weather, and from season to season—present considerable challenges for potential solar-thermal systems. Although there are economically affordable and com-

SOLAR FUELS CAN PROVIDE A STABLE AND STRATEGICALLY IMPORTANT ENERGY RESOURCE; SOME MAY CONSIDER THEM TO BE THE IDEAL SOLUTION FOR SUSTAINABLE ENERGY INDEPENDENCE.



mercially available solutions to some of those problems, substantial research and development are still required.

One common approach to dealing with fluctuations of solar energy is storing a fraction of the solar radiation as thermal energy. This can be done at a scale that manages short-term, transient variability such as the passing of a cloud or, if more energy is stored, to allow continued production for several hours after sunset. High temperature sensible heat storage in ceramic powders would enable such a process.

Several non-storage solutions can control the power and temperature of endothermic processes rendered through concentrated solar energy approaches that reduce peak power. These include the partial focusing/defocusing of the sun-tracking mirrors and the use of shuttering devices that can block a fraction of the sunlight entering the receiver. Varying the mass flow rate according to the incident solar flux is another widely used technique to maintain semi-constant temperature inside a reactor.

It would be best not to simply waste the solar power. The heliostat array can account for up to 60 percent of the capital costs of a solar thermal facility; so if possible, facilities should be designed to make full use of the light falling on the mirrors.

One promising approach to obtain semi-constant temperatures inside a solar reactor is an iris-like aperture mechanism that adjusts

the area of the opening through which solar energy enters the reaction chamber. The mechanism can dynamically increase or decrease the aperture as the solar flux changes. Such a mechanism has the potential to stabilize internal reactor operating conditions by minimizing radiation losses through the aperture and by responding to the fluctuations in solar flux by regulating the aperture area.

The optimum aperture size depends on the magnitude of direct normal insolation. For a particular time of the day, depending on the magnitude of direct normal insolation, there exists an optimum aperture size that can maintain the desired level of temperature inside the reactor. The power intercepted by the aperture as a function of its diameter can be calculated using the mean concentration ratio of the paraboloidal concentrator and the normal beam insolation.

An aperture size of 4 cm, for instance, intercepts a maximum of about 5.5 kW for a peak noon-time normal beam insolation of 981 W/m²; in the morning and evening, when the insolation drops to 200 W/m² the same aperture size intercepts only 1.12 kW—a reduction of a factor of 5. To compensate, the aperture could open up to let in more radiation in the morning and evening, or conversely could iris down at mid-day so as to have a constant flux all day.

In order to compensate this dramatic change in power intercepted from morning to evening, a variable aperture might be used where the optimum size is set according to the incoming power level. Such a mechanism would conveniently work for smaller concentrating devices, such as solar furnaces.

When coupled with an energy recovery system that absorbs the sunlight that doesn't pass through the aperture, such a mechanism could make full use of the installed capacity of the heliostats irrespective of fluctuating solar radiation. For commercial solar

tower installations, however, the proper control of the heliostat field will be more economical.

WHILE TECHNICAL CHALLENGES CAN BE MET, the factors that will ultimately determine whether solar fuels and commodities gain widespread acceptance are mostly economic. That's not the same as pure cost considerations: In markets where cheaper competitors are available, it's possible for a technology to gain an economic advantage if it meets other goals.

For solar fuels, one key benefit is the security of supply. Unlike fossil fuels, which are subject to depletion and to wide swings in prices due to the international nature of their markets, solar radiation will be available indefinitely and therefore is not dependent on economic and political changes. This means solar fuels can provide a stable and strategically important energy resource; some may consider them to be the ideal solution for sustainable energy independence.

Another strong case for solar-driven endothermic processes to supplement or even replace (over time) fossil-fueled endothermic processes concerns health. In many urban areas around the world, air pollution due to the combustion of carbon fuel is a major issue. Cleaner burning fuels from solar thermochemical processing would likely be welcomed in many places, especially China, which has notoriously opaque air.

One way in which air quality has been improved over the past century is the gradual replacement of carbon with hydrogen in commonly used fuels. Coal, which is mostly carbon by weight, was supplanted by oil and gasoline, mixtures that contain around twice as many hydrogen atoms as carbons, and then by methane, which has a hydrogen-to-carbon ratio of 4 to 1.

A solar fuel process to produce a syngas could increase the hydrogen ratio to around 6 to 1, or even remove the carbon component entirely if pure hydrogen was the final product. The benefit for society in the reduction

To Learn More

The following publications discuss many of the topics covered in this article.

M. Roeb and C. Sattler, "Isothermal water splitting," *Science*, 341, 470–471 (2013).

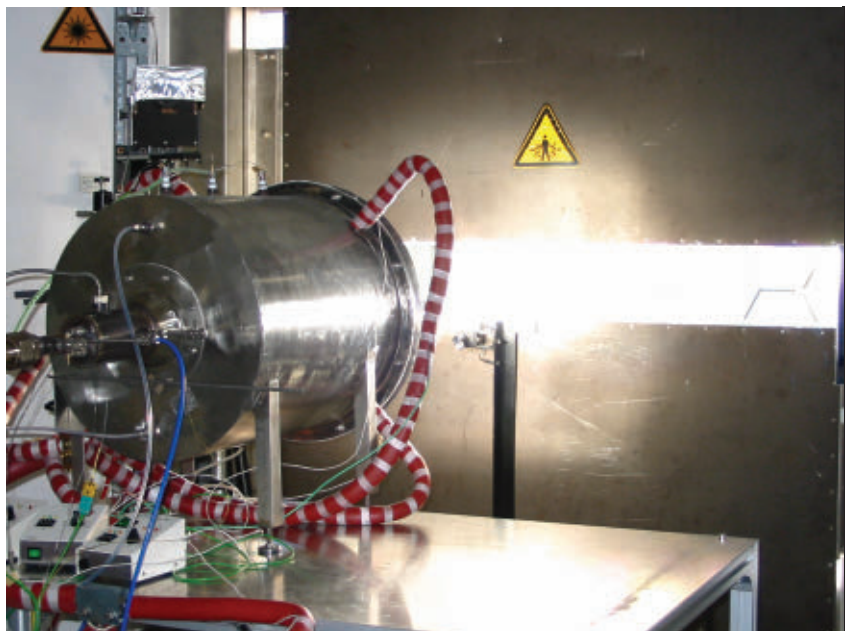
A. Singh, F. Al-Raqom, J. Klausner, J. Petrasch, "Production of hydrogen via an iron/iron oxide looping cycle: Thermodynamic modeling and experimental validation," *International Journal of Hydrogen Energy*, 37, 7442–7450 (2012).

E.B. Stechel and J.E. Miller, "Re-energizing CO₂ to fuels with the sun: Issues of efficiency, scale, and economics," *Journal of CO₂ Utilization*, 1, 28–36 (2013).

N. Ozalp, A. Toyama, D. Jayakrishna, R. Rowshan, and Y. Al-Hamidi, "Effect of camera-like aperture in quest for maintaining quasi-constant radiation inside a solar reactor," *ASME Journal of Mechanical Design*, 133, 021002–021008 (2011).

R.E. Bird and R.L. Hulstrom, "Simplified Clear Sky Model for Direct and Diffuse Insolation on Horizontal Surfaces," Technical Report No. SERI/TR-642-761, Golden, Colo. (1981).

S. Usman and N. Ozalp, "Numerical and optical analysis of solar power level adaptable solar reactor," *Heat Transfer Engineering*, 35(16/17), 1405–1417 (2014).



or elimination of carbon pollution, both in terms of local health effects and global climate issues, may more than outweigh the price differential between solar fuels and the existing fossil fuels.

Solar fuels can also perform in places where electrical power is difficult or impossible to tap. Battery-powered airplanes may be impractical, but in the 1980s, when the oil crises of the 1970s were still a fresh memory, researchers demonstrated the practicality of hydrogen-fueled aircraft. It would take an effort to create a hydrogen-powered air fleet because the existing infrastructure would take decades to replace, but converting aviation to clean fuels would be a major step toward reducing global air pollution. In the meantime carbon-based solar fuels for aeronautic applications could be produced using the Fischer-Tropsch process.

Although much work still needs to be accomplished to make solar fuels and commodities readily and easily available, research into solar thermal processes has been marked by rapid progress in recent years, with interest in the field steadily growing.

ASME has a major role in making the technology viable. This article is a follow up to the Heat Transfer Division-sponsored panel, "Clean energy as a building mark of this millennium," held at ASME IMECE in November 2013. ASME journals, such as the *Journal of Solar Energy Engineering* and the *Journal of Heat Transfer*, among many others, have recently published groundbreaking research advancing the field.

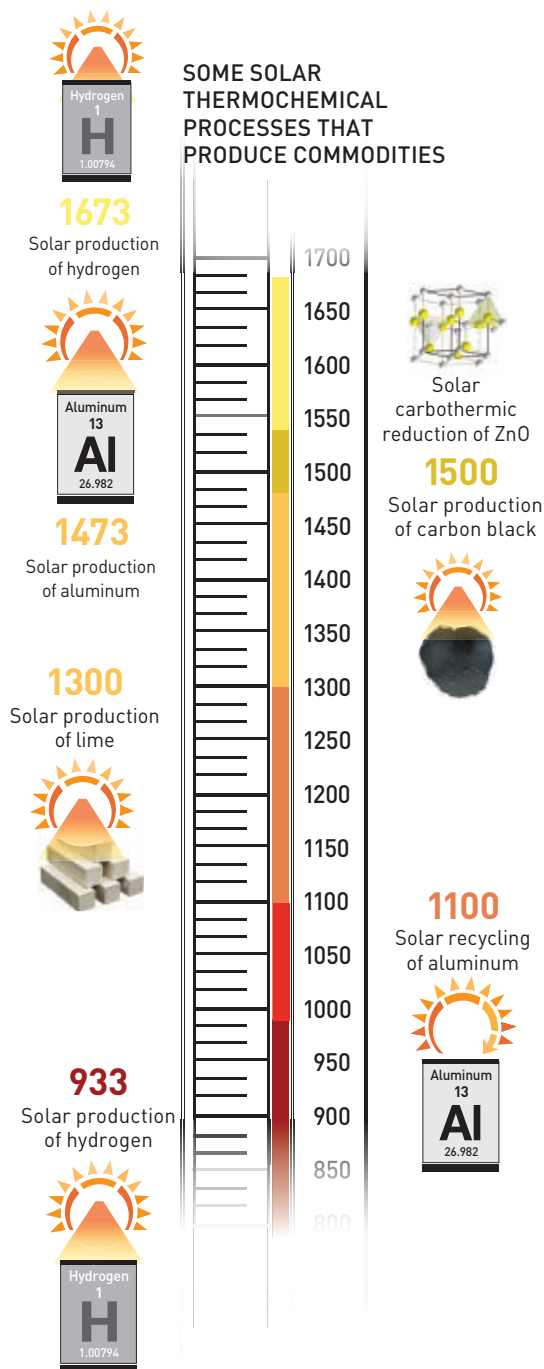
The first law of thermodynamics states that energy cannot be created. But if mechanical engineers apply themselves to optimizing processes to make thermochemically derived solar fuels and commodities viable, it will be the next best thing. They will have transformed a ubiquitous but diffuse resource into the backbone of a clean and green economic future. **ME**

NESRIN OZALP is an associate professor of mechanical engineering at the Katholieke Universiteit Leuven in Belgium. **CHRISTIAN SATTLER** is head of solar chemical engineering at the German Aerospace Center in Cologne. **JAMES F. KLAUSNER** is Ebaugh Professor of mechanical engineering at the University of Florida in Gainesville and an ARPA-E program director. **JAMES E. MILLER** is a chemical engineer in the Advanced Materials Laboratory at the Sandia National Laboratories in Albuquerque.



At left, a thermochemical reactor splitting water to make hydrogen. Above, a high-temperature solar reactor producing fuel.

SOME SOLAR THERMOCHEMICAL PROCESSES THAT PRODUCE COMMODITIES



Various thermochemical processes can be driven by the heat obtained via concentrated solar power. Because some reactions are possible through different chemical pathways, there may be more than one temperature at which a commodity material can be produced. (All temperatures in Kelvin.)

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The new faculty member will complement and advance existing research Centers, for example the NSF IUCRC Smart Vehicle Concepts Center, the OSU Center for Automotive Research, the Gear and Power Transmission Research Laboratory, and the OSU Institute for Materials Research, while creating synergy in one or more areas of strategic interest to the department and college such as advanced manufacturing, energy and environment, materials for a sustainable world, and data analytics.

Qualifications:

Candidates must have, by the start date, an earned doctoral degree in mechanical engineering or a closely related field. The new faculty member will be expected to teach core undergraduate and graduate courses in the Dynamic Systems Technical Area (for instance system dynamics, vibrations, acoustics, nonlinear dynamics, experimental methods, and smart materials and structures), develop new graduate courses in his/her research area, develop and sustain active sponsored research programs, and provide intellectual leadership in his/her research field. The anticipated start date is fall 2015. Screening of applicants will begin immediately and continue until the position is filled. Interested candidates should upload a complete curriculum vitae, statements of research and teaching goals, and the names, addresses, and e-mail addresses of four references. The website link is http://www.mecheng.osu.edu/faculty_positions/.

To build a diverse workforce, Ohio State encourages applications from individuals with disabilities, minorities, veterans, and women. Ohio State is an EEO/AA Employer. Columbus is a thriving metropolitan community, and the University is responsive to the needs of dual career couples. For more information about the Department of Mechanical and Aerospace Engineering at OSU, please visit <http://mae.osu.edu/>.



UNIVERSITY OF CENTRAL FLORIDA
MECHANICAL AND AEROSPACE ENGINEERING

Assistant/Associate Professor in Mechanical and Aerospace Engineering

In collaboration with the Townes Laser Institute and the College of Optics and Photonics, the Mechanical and Aerospace Engineering (MAE) Department of the College of Engineering and Computer Science (CECS), are establishing a new initiative in advanced manufacturing technologies.

As part of this initiative, the MAE Department is recruiting a tenure-track/tenured faculty member who can successfully build strong research and educational programs in sensors and advanced laser-based manufacturing technologies, establish new manufacturing facilities, and strengthen partnerships with relevant industries. Faculty associated with this initiative will benefit from the recently formed \$250M International Consortium for Advanced Manufacturing Research (ICAMR) in Osceola County to develop innovative manufacturing of sensors and other high-tech products.

The Townes Laser Institute, housed in the College of Optics and Photonics, is one of the nation's premier academic research centers in advanced laser technologies and their applications. Its mission is to advance laser technologies that will impact applications in manufacturing, medicine and defense.

Interested persons with questions about the positions may contact the Search Committee Chair, Dr. Ranganathan Kumar, Associate Dean for Research, at Ranganathan.Kumar@ucf.edu. For more information about the department, we invite all interested parties to visit MAE's website at www.mae.ucf.edu. Candidates must submit all documents on-line to <http://www.jobswithucf.com:80/postings/40092>. Review of applications will begin immediately and continue until the positions are filled.

UCF is an equal opportunity, affirmative action employer and encourages the candidacies of women, members of racial and ethnic minorities, and persons with disabilities. All searches and documents are subject to the Sunshine and public records laws of the State of Florida.

POSITIONS OPEN

ASSISTANT PROFESSOR – Two Positions (9-month, tenure-track, start date Aug. 22, 2015). **DEPARTMENT OF MECHANICAL ENGINEERING, SOUTH DAKOTA STATE UNIVERSITY.** Teach courses and conduct research in one of the following fields: (1) machine design/solid mechanics, (2) dynamic systems/controls/robotics. For a full list of qualifications and application process, visit <https://yourfuture.sdbor.edu>. Position is open until filled with full consideration given to applications received by January 1, 2015. For questions on the electronic employment process, contact SDSU Human Resources at (605) 688-4128. SDSU is an AA/EEO employer.

THE MECHANICAL ENGINEERING DEPARTMENT AT SOUTHERN POLYTECHNIC STATE UNIVERSITY in Marietta, Georgia is accepting applications for a **DEPARTMENT CHAIR POSITION**. Please see <https://employment.spsu.edu/postings/3078> for complete details and how to apply. SPSU is committed to affirmative action, equal opportunity, and the diversity of its workforce.

THE SCHOOL OF ENGINEERING AT THE UNIVERSITY OF CALIFORNIA MERCED invites applications for a **TENURE OR TENURE-TRACK FACULTY POSITION IN MECHANICAL ENGINEERING**. A s - sistant, Associate or Full Professor in Thermal Fluids: Candidates with proven expertise in the engineering aspects of thermal sciences and fluid flow together with strong application interests to energy technologies are especially encouraged to apply. Specific areas of interest include but are not limited to: combustion, reacting flows, turbulence, chemical reactions, radiation, and heat and mass transfer in multiphase media. For more informa-

POSITIONS OPEN

tion or to apply, visit <https://aprecruit.ucmerced.edu/apply/JPF00158>. AA/EEO.

BRADLEY UNIVERSITY CATERPILLAR COLLEGE OF ENGINEERING & TECHNOLOGY DEPARTMENT OF MECHANICAL ENGINEERING The Department of Mechanical Engineering at Bradley University is accepting applications for a **TENURE-TRACK POSITION AT THE ASSISTANT OR ASSOCIATE PROFESSOR LEVEL AND TWO NON-TENURE TRACK FULL TIME TEMPORARY INSTRUCTOR POSITIONS** starting August 2015. Applicants for the tenure track position should have an earned Ph.D. in mechanical engineering by the start date. Preference will be given to candidates in the general area of thermal systems, with strong experimental background, proficiency with digital instrumentation, and data acquisition. Applicants for the instructor positions should have at least a MS degree in mechanical engineering or a related field, and significant teaching and/or industrial experience in one of the traditional areas of mechanical engineering; controls, design, thermo-fluids, instrumentation, or kinematics. Review of applications will begin Dec 15, 2014. Additional information about the positions may be found at www.bradley.edu/offices/business/humanresources/opportunities/faculty

THE UNIVERSITY OF MISSISSIPPI'S DEPARTMENT OF MECHANICAL ENGINEERING is seeking to fill a **TENURE-TRACK ASSISTANT PROFESSOR** position in Computational Solid/Structural Mechanics to start in August 2015. Candidates should have proven expertise in the multiscale modeling of structural, heterogeneous materials, and/or energy systems that are complementary and synergistic with ex-

POSITIONS OPEN

isting research areas in the School. The computational mechanics topics include but are not limited to: micro/meso-scale solid mechanics, mechanics of biological systems, and mechanics of materials for energy applications. The successful candidate is expected to make a significant contribution to the School's research activities and to build a strong, externally funded research program. The candidate should also have a marked interest in, and demonstrated talent for, teaching in both the undergraduate and graduate programs. The candidate is expected to foster a balanced program of research and instruction that integrates the perspectives of computational mechanics, structural dynamics, and materials science. The candidate is also expected to develop strong collaborative research in the area of computational mechanics with faculty performing experimental research in blast response of composite materials, multiscale modeling of biological materials, and energy harvesting systems. Interested candidates should submit a CV with a cover letter by December 31, 2014. The letter should discuss research plans, laboratory requirements, and teaching interests. Candidates should hold a Ph.D. from a reputed institute and demonstrate potential for outstanding research and a commitment to teaching. For more information and to apply, visit <https://jobs.olemiss.edu> Only applicants who apply online will be considered. Review of applications will begin immediately and continue until an adequate applicant pool is established. The University of Mississippi provides equal opportunity in education and employment for all qualified persons without regard to race, color, religion, national origin, sex, age, sexual orientation, genetic information, physical or mental disability, or veteran status.



The College of Engineering seeks several outstanding engineering experts to join their faculty to teach in their professional MS programs. Recently, the college has seen exponential growth with research initiatives (8 federally-funded research centers) and with enrollment in their Professional Masters programs (more than tripled over the last 5 years). Successful candidates will continue to launch the COE to even greater prominence in the field of Engineering education and professional preparation.

The main responsibilities for this position include developing course content, preparing highly engaging academic activities, advising students; collaborating to identify and hire part-time instructors, and serving at the department, university, and profession levels. Expertise of successful hires will focus on one of the Professional MS Program area and will have the ability to teach courses that support the other programs. This position requires active scholarship, with particular interest in educational, instructional, and industry-inspired research.

This position is highly collaborative with other faculty in the growing Professional MS group and with the cooperative education faculty.

Interdisciplinary Professional Master of Science Programs:

- Computer Systems Engineering
- Energy Systems
- Engineering Management
- Information Systems
- Sustainable Building Systems
- Telecommunications Systems Management

For more information and to apply, please visit: www.coe.neu.edu/transform



FACULTY POSITION IN MECHANICAL ENGINEERING (Assistant Professor of Instruction)

The Department of Mechanical Engineering (ME) at the University of Delaware invites applications for a full time non-tenure track Assistant Professor of Instruction faculty position.

Responsibilities will include teaching and curriculum development related to all aspects of the undergraduate mechanical engineering program; for example, teaching engineering fundamentals courses, teaching design - ranging from freshman to senior level courses, mentoring undergraduate students, and developing new courses in target areas such as mechatronics and industrial design.

The ME Department offers a Bachelor of Mechanical Engineering (BME) degree accredited by the Engineering Accreditation Commission of ABET. The BME Program is designed to produce graduates with a strong foundation in engineering fundamentals enabling them to lead a successful career in industry or government and/or obtain an advanced degree and to contribute to engineering knowledge, the profession, and the community. Curricular details can be found at <http://www.me.udel.edu>.

Applicants should hold a Ph.D. in mechanical engineering, or closely related field. Successful candidates are expected to have demonstrated excellence in teaching and curricular development in mechanical engineering, with particular interest in mechatronics and industrial design. Industrial experience in mechanical engineering design will be viewed favorably.

To apply, applicants should send a curriculum vitae, a statement of teaching interests and achievements, and a list of at least four references to <http://apply.interfolio.com/27090>. Full consideration is guaranteed for applications received before December 31st, 2014. However, the search will continue until the position is filled.

Equal Employment Opportunity

The University of Delaware is an Equal Opportunity Employer which encourages applications from minority group members, women, individuals with a disability and veterans. The University's Notice of Non-Discrimination can be found at <http://www.udel.edu/aboutus/legalnotices.html>. Employment offers will be conditioned upon successful completion of a criminal background check. A conviction will not necessarily exclude you from employment.





THE CHINESE UNIVERSITY OF HONG KONG

Applications are invited for:-

Department of Mechanical and Automation Engineering

(1) Professor

(Ref. 1415/103(495)/2)

Applications are invited for a Professorship in the undergraduate energy engineering programme launched in fall 2012, which is targeted to become full-fledged in four years' time. Further information about the Department is available at <http://www.mae.cuhk.edu.hk>. Applicants should have (i) a doctoral degree in a relevant engineering or scientific discipline related to energy technologies in the areas of renewable, environmental, power grid, and building automation and control; and (ii) recognized leadership in the academic discipline. The appointee will (a) teach and conduct research in his/her expert areas; (b) concurrently serve as the Programme Director; and (c) lead the development and promotion of the programme, staff recruitment and fostering of partnership with industries. Appointment will normally be made on contract basis for two to three years initially commencing August 2015 or earlier, which, subject to mutual agreement, may lead to longer-term appointment or substantiation later. Outstanding candidates with substantial experience for Professor rank may be considered for substantive appointment forthwith. Applications will be accepted until the post is filled.

(2) Professors / Associate Professors / Assistant Professors

(Ref. 1415/104(495)/2)

The Department is seeking excellent candidates to fill the above faculty positions in the following areas:

- Energy technologies, including energy management, smart metering and smart grid;
- Environmental engineering, including building automation and control, smart/green building; and
- Robotics and manufacturing, including 3D printing and CAD.

Applicants should have (i) a PhD degree; and (ii) a proven track record or demonstrating potential for teaching and research excellence. The appointees will (a) teach undergraduate and postgraduate courses; (b) develop an externally funded research programme; and (c) supervise postgraduate students. Appointments will normally be made on contract basis for up to three years initially commencing August 2015, which, subject to mutual agreement, may lead to longer-term appointment or substantiation later. Outstanding candidates with substantial experience for Professor rank may be considered for substantive appointment forthwith. Applications will be accepted until the posts are filled. Further information about the Department is available at <http://www.mae.cuhk.edu.hk>.

Salary and Fringe Benefits

Salary will be highly competitive, commensurate with qualifications and experience. The University offers a comprehensive fringe benefit package, including medical care, plus a contract-end gratuity for appointments of two years or longer, and housing benefits for eligible appointees. Further information about the University and the general terms of service for appointments is available at <http://www.per.cuhk.edu.hk>. The terms mentioned herein are for reference only and are subject to revision by the University.

Application Procedure

For post (1): Please send full resume, a cover letter describing how the applicant can bring significant value to the programme, and contact information of three professional referees, to the Dean, Faculty of Engineering by e-mail to energy-pd@erg.cuhk.edu.hk. The University reserves the right to fill the post by invitation. Review of applications begins immediately and will continue until the post is filled.

For post (2): Please send full resume, copies of academic credentials, publication list with abstracts of selected published papers, details of courses taught and evaluation results (if available), a research plan, a teaching statement, together with names, addresses and fax numbers/e-mail addresses of three to five referees to whom the applicants' consent has been given for their providing references (unless otherwise specified), to the Dean, Faculty of Engineering by e-mail to recruit@erg.cuhk.edu.hk.

The Personal Information Collection Statement will be provided upon request. Please quote the reference number and mark 'Application – Confidential' on cover.



COLUMBIA ENGINEERING
The Fu Foundation School of Engineering and Applied Science

Faculty Position in Fluid Mechanics in the Department of Mechanical Engineering

Columbia Engineering is pleased to invite applications for a faculty position in the Department of Mechanical Engineering at Columbia University in the City of New York. Applications at the assistant professor, and in exceptional cases, at the associate professor and full professor levels, will be considered.

Applications are specifically sought in the broad area of the mechanics of fluids, including such areas as microfluidics, complex fluid rheology, reacting flows, physiological fluid mechanics, among others. Candidates must have a Ph.D. or its professional equivalent by the starting date of the appointment. Applicants for this position at the Assistant Professor and Associate Professor without tenure must demonstrate the potential to do pioneering research and to teach effectively. Applicants for this position at the tenured level (Associate or Full Professor) must have a demonstrated record of outstanding research accomplishments, excellent teaching credentials and established leadership in the field.

The successful candidate is expected to contribute to the advancement of their field and the department by developing an original and leading externally funded research program, and contributing to the undergraduate and graduate educational mission of the Department. Columbia fosters multidisciplinary research and encourages collaborations with academic departments and units across Columbia University. The Department is especially interested in qualified candidates who can contribute, through their research, teaching, and/or service, to the diversity and excellence of the academic community.

For additional information and to apply, please see: <http://engineering.columbia.edu/faculty-job-opportunities>. Applications should be submitted electronically and include the following: curriculum-vitae including a publication list, a description of research accomplishments, a statement of research and teaching interests and plans, contact information for three experts who can provide letters of recommendation, and up to three pre/reprints of scholarly work. All applications received by **December 31, 2014** will receive full consideration.

Applicants can consult www.me.columbia.edu for more information about the department.

Apply for this position:

academicjobs.columbia.edu/applicants/Central?quickFind=59998

Columbia is an affirmative action/equal opportunity employer with a strong commitment to the quality of faculty life.



THE OHIO STATE UNIVERSITY
COLLEGE OF ENGINEERING

Two Faculty Positions - Assistant Professors of Practice
Department of Mechanical and Aerospace Engineering

Academic Field(s): Mechanical Engineering or related field with expertise in (i) the design of mechanical and thermal/fluid systems or (ii) experiment design, measurement systems, instrumentation, and dynamic systems.

Job Descriptions: The Department of Mechanical and Aerospace Engineering seeks two full time Assistant Professors of Practice. The positions are non-tenure track, and offer renewable multi-year contracts. The positions' primary responsibilities are for the teaching and ongoing development of (i) the Capstone Design course sequence or (ii) the Capstone Laboratory course, both senior level courses in the Mechanical Engineering Undergraduate Program.

The Capstone Design course duties include instruction and leading of exercises in design methodology; project management; overview of computational and solid modeling for use in engineering analysis; technical communications; ethics and professionalism; and overseeing, advising and evaluating group design/build/test projects. Continual development of either in-house or industrially sponsored projects for the course is also expected.

The Capstone Laboratory course builds upon prior laboratory background of undergraduates, and integrates thermofluid and mechanical system concepts with a focus on problem solving using a combination of experimental and analytical/computational methods. The instructor will be responsible on an ongoing basis for course development, preparing and delivering lectures, preparing and grading examinations, and training Graduate Teaching Associates (GTAs), for assigned laboratory courses. Course development will include design and construction of new experiments, preparing budgets for the laboratory activity, and developing instructions for GTAs.

Both positions would also have broader responsibilities involving other undergraduate courses as needed such as engineering mechanics, machine design, and junior laboratory courses; developing curriculum; preparing lecture materials for presentation; developing projects, exams, quizzes, and homework assignments; advising M.S. and undergraduate research; holding office hours; and other committee duties as assigned.

Interested candidates must have a doctorate in Mechanical Engineering or a closely related field and three or more years of experience in either (i) design and analysis experience with mechanical and thermal/fluid systems in an academic, industrial, or research institution setting, or (ii) laboratory experience in an academic or research institution or equivalent industrial experience. Expertise is sought in the broad range of the undergraduate mechanical engineering curriculum, complemented by a strong background in either (i) engineering design and analysis with experience in teaching design, or (ii) experiment design, measurement systems, and dynamic systems. Candidates must have excellent communication skills for both positions and must also demonstrate an ability to develop and plan (i) student projects and interact with industry sponsors of projects or (ii) laboratory experiments. Prior experience in mentoring students and instructing undergraduates in the classroom is desirable. Successful candidates will also have a strong interest in serving as the primary thesis adviser for MS students, as well as collaborating in research with other faculty members as appropriate.

The anticipated start date for both positions is May 2015. Screening of applicants will begin immediately, and will continue until the positions are filled. Interested candidates should upload complete curriculum vitae, 1-2 page statement of research interests and goals, and 2-3 page statement of teaching interests and goals, and names and postal/email addresses of three references electronically at http://www.mecheng.osu.edu/faculty_positions. Please upload the material for only one of the two positions advertised.

The Ohio State University is an equal opportunity employer. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, sexual orientation or identity, national origin, disability status, or protected veteran status. Columbus is a thriving metropolitan community, and the University is responsive to the needs of dual career couples.

POSITIONS OPEN

NANJING TECH UNIVERSITY FACULTY POSITIONS in College of Mechanical and Power Engineering. This announcement invites applications for **TENURE-TRACK FACULTY POSITIONS** in: Mechanical Engineering, New Energy Science and Engineering, Welding Technology and Engineering, Mechanical Design Manufacturing and Automation, Vehicle Engineering, Process Equipment and Control Engineering. Required Qualifications: Ph.D. in Mechanical Engineering or a closely related field is required. Initial appointments are at the assistant professor level. Exceptionally qualified candidates at the associate or full professor level may also be considered. Rank and salary are commensurate with experience and accomplishments. Candidates should send application to chunlei-shao@njtech.edu.cn. A CV, list of publications, statements of research and teaching plans are required. Applications received before December 31, 2015 will be guaranteed full consideration. Additional information is available at <http://www.njtech.edu.cn>.

FACULTY POSITION IN MECHANICAL ENGINEERING, UNIVERSITY OF SOUTH CAROLINA The University of South Carolina, Department of Mechanical Engineering, is accepting applications for tenure track positions at the Assistant and Associate Professor levels. Preference will be given to candidates in one of the following areas: (a) thermo-fluids, (b) materials and/or (c) mechanics of materials, (please see <http://www.me.sc.edu/employmentopportunities.html> for details). However, highly qualified candidates from all areas of Mechanical Engineering will be considered. Applicants must possess a Ph.D. in Mechanical Engineering or a closely related field. Applications should be submitted by email to odonnemc@cec.sc.edu, in the form of a single PDF document, containing: 1) vitae, 2) statement of research plans, 3) statement of teaching interests, and 4) contact information for three references. The selection process will begin on January 15, 2015 and will continue until the positions are filled. The University of South Carolina is an Equal Opportunity/ Affirmative Action Employer. Minorities and women are encouraged to apply.



Assistant or Associate Professor in Mechanical and Materials Engineering: Building Science Focus

The Department of Mechanical and Materials Engineering at Portland State University seeks a highly qualified candidate to fill a tenure track position at the level of Assistant/ Associate Professor with research and teaching interests in the area of Building Science. Applicants must have a Ph.D. in a relevant science or engineering discipline. Specific areas of interest include but are not limited to indoor air quality, building-environment interactions, sensors for building science applications, and building controls. Applicants with interests in related areas such as smart buildings, innovative materials for high performance buildings, and building energy efficiency are also encouraged to apply.

The successful applicant is expected to develop a funded research program, mentor graduate students, and participate in department and university-wide collaborations and initiatives. The successful applicant will also teach courses at both the undergraduate and graduate level on topics related to their areas of expertise. This may include courses in Thermodynamics, Heat Transfer, and Fluid Dynamics as well as specialty courses in Building Science.

Compensation is competitive and commensurate with experience, with an excellent benefits package including 95% premium paid healthcare; a generous retirement package; and reduced tuition rates for employee, spouse or dependent at any of the Oregon University System schools.

Applications must be submitted online, at <https://jobs.hrc.pdx.edu/> for position #D95051. Applications must include cover letters, curriculum vita, teaching and research agendas and at least three references. Application review will begin on/after January 1, 2015 and continue until the position is filled. Non U.S. residents must state their visa status.

Portland State University is an Affirmative Action, Equal Opportunity institution and welcomes applications from diverse candidates and candidates who support diversity.



STRATEGIC HIRING POSITION – NANOTECHNOLOGY AND MICROSYSTEMS ENGINEERING FOR SYNTHETIC BIOLOGY

CONCORDIA UNIVERSITY,
MONTREAL, CANADA

The Faculty of Engineering and Computer Science is seeking excellent tenure-track candidates at the Assistant or Associate Professor ranks in the area of Nanotechnology and Microsystems Engineering for Synthetic Biology. This successful applicant will become a member of one of the following departments, depending on their background: Electrical and Computer Engineering, or Mechanical and Industrial Engineering. Applicants must possess expertise and research interests in an area of research and scholarship of benefit to synthetic biology such as, but not limited to:

- Nanotechnology & microsystems for synthetic biology
- Synthetic biology for nanotechnology
- Cellular and sub-cellular level engineering of living organisms
- Micro and nano devices & methods for synthetic biology applications

Applicants must hold a Ph.D. degree in a relevant engineering discipline and must be qualified to become a registered engineer in Canada. The language of instruction at Concordia is English; however, knowledge of French is an asset. The new appointee will become a member of Concordia's Centre for Applied Synthetic Biology (casb.concordia.ca) situated at the Centre for Structural and Functional Genomics and is expected to collaborate with their colleagues in Engineering and Biology on cross-disciplinary research programs and projects. Detailed applications should include: a CV, teaching and research statements, and names of three referees, and shall be accepted in electronic form (PDF) until positions are filled. Applications should be sent to Christopher W. Trueman, Associate Dean for Academic Affairs, at christ.trueman@concordia.ca. Further details on these positions are available at www.ens.concordia.ca.

All qualified candidates are encouraged to apply; however, Canadians and Permanent Residents will be given priority. Concordia is strongly committed to employment equity within its community, and to recruiting a diverse faculty and staff. The University encourages applications from all qualified candidates, including women, members of visible minorities, Aboriginal persons, members of sexual minorities, persons with disabilities, and others who may contribute to diversification.

CONCORDIA.CA



Department of Mechanical Engineering Faculty Positions

The Department of Mechanical Engineering at Virginia Tech invites applications for four faculty positions: one in the area of Mechanical Systems and three in the area of Fluid Dynamics and Thermal Sciences. These positions will be at Assistant, Associate, or Full Professor levels. Exceptional candidates will be considered for named professorships.

The successful candidate for the Mechanical Systems position will have expertise in fields related to robotics, dynamics and control, mechatronics, machine learning, human-machine interaction, bio-robotics and medical robotics, robotic exoskeletons, or other emerging applications of robotics or autonomous systems.

The Fluid Dynamics and Thermal Sciences positions are targeted towards (1) Experimental combustion science and technology in novel propulsion and energy applications; (2) Fundamental and applied experimental fluid dynamics using advanced measurement techniques in emerging applications such as, but not limited to, energy harvesting, biological and bio-inspired systems; (3) Experimental or computational multiphase flow and heat transfer at the micro-nano scales in emerging energy and thermal management systems. Applicants in other emerging areas such as data analytics and uncertainty quantification in fluid-thermal engineered systems are also encouraged to apply.

Blacksburg is located in the Blue Ridge Mountains and is widely recognized by national rankings as a vibrant and desirable community with affordable living, world-class outdoor recreation, an active arts community, and a diverse international population. The Department of Mechanical Engineering which includes a Nuclear Engineering Program, has over 50 faculty, research expenditures in excess of \$17M, and a current enrollment of over 170 doctoral, 130 masters, and over 1200 undergraduate students. The Department is ranked 16th and 17th out of all mechanical engineering departments in the nation in undergraduate and graduate education, respectively, by the 2014 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), 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, and the Virginia Center for Autonomous Systems (VaCAS, www.unmanned.vt.edu).

Applicants must hold a doctoral degree in engineering or a closely related discipline. We are seeking highly qualified candidates committed to a career in research and teaching. The successful candidate will be responsible for mentoring graduate and undergraduate students, teaching courses at the undergraduate and graduate levels, and developing an internationally recognized research program. Candidates should apply online at www.jobs.vt.edu to posting number TR0140100 for the Mechanical Systems position and to posting number TR0140101 for the Fluid Dynamics and Thermal Sciences positions. For the Fluid Dynamics and Thermal Science positions please indicate the research area you would like to be considered for in your cover letter. Applicants should submit a cover letter, a curriculum vitae including a list of published journal articles, a one-page research statement, a brief statement on teaching preferences, and the names of five references that the search committee may contact. Review of applications for all positions will begin on December 10, 2014 and will continue until the positions are filled.

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).

For assistance submitting the application please contact Ms. Brandy McCoy (brandy07@vt.edu), (540) 231-6661. General inquiries about the positions should be addressed to the search committee chairs: Prof. Andrew Kurdila (kurdila@vt.edu) for Mechanical Systems and Prof. Francine Battaglia (fbattaglia@vt.edu) for Fluid Dynamics and Thermal Sciences



Faculty Positions Mechanical Engineering

The Physical Sciences and Engineering (PSE) Division at King Abdullah University of Science and Technology (KAUST) (<http://pse.kaust.edu.sa>) invites qualified applicants to apply for faculty positions at all ranks (Assistant, Associate and Full Professor) in the Mechanical Engineering program.

KAUST offers superb research facilities which include the Supercomputing Core lab, generous assured research funding and internationally competitive salaries. The science produced in the PSE focuses on the understanding, modeling and manipulating matter at all scales (nano, meso and macroscopic levels), in all forms (bulk, thin films, divided colloids, fluid flows, the earth as a system, etc.). The knowledge produced serves to help design and engineering cutting-edge materials, technologies and systems.

The Mechanical Engineering program at KAUST has 11 full-time faculty members. Their research focuses on the following areas: Combustion and energy, fluid mechanics, materials and solid mechanics and dynamics and control. <http://me.kaust.edu.sa>

Priorities will be given to candidates with research interest in areas that may enhance and complement KAUST's research centers and clusters. These areas include, but are not limited to:

- Combustion: Advance optical diagnostics for high pressure flames, spray and emissions; new concepts in combustion assisted by plasmas and electric fields, including pre- and post-combustion applications; and advanced internal combustion engine experiments. The faculty members will also be affiliated with the Clean Combustion Research Center: <http://ccrc.kaust.edu.sa>

- Solid mechanics: Experimental and high-performance computing research applicable to very low scale mechanical testing, micromechanics, dynamic behavior of materials, multi-physics behavior, soft materials, molecular mechanics/dynamics, reduced models, inverse problems and materials for energy.
- Dynamics and control: Nonlinear control, stochastic phenomena, vibrations, with preferred applications in sensing, MEMS/NEMS, energy harvesting and bio-inspired devices.
- Fluid mechanics: experimental and/or computational research in fluid flows of relevance to environment or petroleum industry, such as flow in porous media, multi-phase flow, turbulence, and dynamics of complex liquids.

Applicants should have a proven track record to establish a high-impact research program and should have a commitment to high-quality teaching at the graduate level.

To learn more about the PSE Division and to complete the online application form, visit <http://apprkr.com/546587>

Application requirements include the following:

- Updated curriculum vitae with full list of publications
- Statement of research
- Statement of teaching
- Contact details of at least four potential referees

Applications received by January 31, 2015 will receive full consideration. Positions will remain open until filled.

www.kaust.edu.sa





Department Chair and Richard C. Hill Professor of Mechanical Engineering, University of Maine

The Mechanical Engineering Department, University of Maine, Orono, Maine, invites applications for the position of Chair of the department and Richard C. Hill Professor of Mechanical Engineering. The department offers B.S. (ABET accredited), M.S., and Ph.D. degrees in Mechanical Engineering and has 13 full-time regular faculty, approximately 400 undergraduate students and over 30 graduate students. In addition to traditional mechanical engineering focuses, undergraduates can choose concentrations or minors in aerospace engineering, robotics, renewable energy, and ocean and marine engineering. The department has a robust research program with several faculty members engaged in interdisciplinary research in the Advanced Manufacturing Center; Advanced Structures and Composites Center; Laboratory for Surface Science and Technology; Marine Sciences; and Earth and Climate Sciences.

Qualified applicants for the position are expected to bring outstanding leadership and administrative skills to the department, have a strong record of research performance, articulate a vision for growing the research enterprise in the department, and have the ability to build strong relationships with academic departments and research centers across campus as well as external constituencies including potential students, alumni, and corporations. Applicants must be committed to quality undergraduate and graduate education. A Ph.D. in mechanical engineering or a closely related discipline, and credentials commensurate with appointment as a full professor with tenure in the department are required.

Applicants should include a current resume, a statement of professional interests and vision, and the names, affiliations, and contact information (including e-mail addresses) of at least three references. Applications should be submitted to the Department of Human Resources via <https://umaine.hiretouch.com>. Review of applications will begin January 1, 2015 and continue until the position is filled.

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.

**UNIVERSITY OF ILLINOIS AT CHICAGO
DEPT. OF MECHANICAL & INDUSTRIAL ENGINEERING
FACULTY POSITION • MECHANICAL ENGINEERING**

The Department of Mechanical and Industrial Engineering at the University of Illinois at Chicago invites applications for tenure-track faculty positions in various areas of Mechanical Engineering. Individuals will also be considered at associate or full professor rank if they possess outstanding qualifications commensurate with the rank. Successful applicants are required to have an earned PhD in Mechanical Engineering or a related field, and are expected to develop and maintain an active, externally-funded research program as well as teach courses at both the undergraduate and graduate levels. The Department offers BS, MS, and PhD degrees in Mechanical Engineering, and Industrial Engineering and Operations Research, and currently has an undergraduate enrollment of about 640 and a graduate enrollment of about 200. More information about the Department can be found at <http://www.mie.uic.edu>. Applicants are required to send a letter of application indicating their qualifications, an up-to-date CV including the names and contact information of three references, and separate one-page statements outlining their future teaching and research plans. For fullest consideration, applications must be submitted online at <https://jobs.uic.edu/job-board/job-details?jobID=43717> by January 2, 2015. Applications will be accepted until the positions are filled. Expected starting date is August 2015.

The University of Illinois at Chicago is an affirmative action, equal opportunity employer, dedicated to the goal of building a culturally diverse and pluralistic faculty and staff committed to teaching and working in a multicultural environment. We strongly encourage applications from women, minorities, individuals with disabilities and covered veterans.

EMBRY-RIDDLE
Aeronautical University.

Tenture Track Assistant/Associate Professor of Aerospace and Mechanical Engineering)

The College of Engineering at Embry-Riddle Aeronautical University (ERAU) in Prescott, Arizona, invites applications for a tenure-track position in our Aerospace and Mechanical Engineering Department. This position is anticipated to be available with a potential start date no later than the first week of August, 2015, at the Assistant/Associate Professor level. The department is particularly interested in interviewing candidates with proficiency in computer aided design, aerospace propulsion, energy and thermal sciences, and robotics; however, candidates with expertise in other areas will be considered as well.

The faculty of the Embry-Riddle Aeronautical University College of Engineering are housed in a modern academic complex, which is adjacent to wind tunnel, propulsion, robotics, and mechatronics laboratories and facilities. The College of Engineering faculty also make extensive use of the Aerospace Experimentation and Fabrication (AXFAB) laboratory complex. This complex includes a modern machine shop with two (2) fabrication suites, a space systems laboratory, a structural dynamics laboratory, a rapid prototyping laboratory, a material science laboratory, a mechanical testing laboratory, a structures and instrumentation laboratory, two (2) dedicated faculty research laboratories, and two (2) small classrooms. All of these facilities feature state-of-the-art equipment for both student and faculty use.

Embry-Riddle Aeronautical University is dedicated to building a culturally diverse faculty and staff. We strongly encourage women, minorities, and members of under-represented groups to apply for this position. Embry-Riddle Aeronautical University is an Equal Opportunity Employer.

Apply here https://ebs.erau.edu/OA_HTML/OA.jsp?page=/oracle/apps/irc/candidateSelfService/webui/VisVacDispPG&OAHP=IRC_EXT_SITE_VISITOR_APPPL&OASF=IRC_VIS_VAC_DISPLAY&akRegionApplicationId=821&transactionId=895868219&retainAM=N&addBreadCrumb=RP&p_svid=59212&p_spid=1451927&oapc=6&oas=nB09drT0J2UY0MoiI5FTrg



Faculty Position in Robotics and Automation

The Department of Mechanical and Aerospace Engineering at The Ohio State University invites applications from outstanding individuals for a tenure track faculty position with primary focus on Robotics and Automation. The anticipated start date is August 2015, but the search will continue until the position is filled.

This search will consider faculty candidates having interest and expertise to develop a strong research program in a promising area or areas of robotics, including, but not limited to, (a) control, planning, and integration; (b) bio-inspired design with novel mechanisms and materials; (c) robot perception and sensing; and (d) human robot interaction, that support application areas such as manufacturing automation, reconfigurable manufacturing systems, healthcare and medical robots, service robots, soft robots, and micro robots. Whereas candidates are primarily sought at the assistant professor level, exceptionally qualified applicants at the associate professor level may be considered.

Qualifications:

An earned doctorate in mechanical engineering or an appropriate related field is required. We seek candidates having demonstrated the ability to conduct research at the highest level, and had a record of or the promise for, outstanding teaching and supervision of students. The successful candidate will be expected to attract funding to develop and sustain active sponsored research programs, teach core undergraduate and/or graduate courses, and develop new graduate courses related to their research expertise. Screening of applicants will begin immediately and continue until the position is filled. Interested candidates should upload complete curriculum vitae, separate 2-3 page statements of research and teaching goals, and the names and postal/email addresses of four references electronically at http://www.mecheng.osu.edu/faculty_positions.

The Ohio State University is an affirmative/equal opportunity employer. Women, minorities, and people with disabilities are encouraged to apply and build a diverse workplace. Columbus is a thriving metropolitan community, and the University is responsive to the needs of dual career couples.



College of Engineering

**Department Chair,
Department of Mechanical Engineering,
University of Kentucky**

The University of Kentucky (UK) invites applications and nominations for the position of Chair of the Department of Mechanical Engineering--the largest department in UK's College of Engineering. Mechanical Engineering's 28 tenured and tenure-track faculty educate over 1,000 undergraduate students and 90 graduate students, and conduct a wide array of fundamental and applied research in areas such as thermal-fluids, control and dynamic systems, manufacturing, mechanics, acoustics, aerospace, and design. ME has numerous federally supported programs and four applied research centers that partner with industry. A majority of ME's undergraduate students engage in hands-on design-build experiences from solar car to small satellites, co-ops, and internships. Mechanical Engineering offers undergraduate degree programs on UK's main campus in Lexington and across Kentucky through two extended campus programs. ME is centrally located on the campus of Kentucky's land-grant research university in the welcoming and culturally rich community of Lexington. Co-located colleges, including Medicine and Agriculture, enable multi-disciplinary research in an environment energized by campus-wide construction and UK's upcoming 150-year anniversary. The search committee seeks candidates for the rank of full professor with a distinguished record of achievement and internationally recognized for their research excellence, scholarship, and academic leadership. Further details about the ME Department and the position can be found at www.engr.uky.edu/me/departments-chair-search. The desired start date is July 1, 2015, or as soon as possible thereafter. Applications will be accepted until the position is filled. Apply at <http://ukjobs.uky.edu/postings/41777>. Nominations for this position are also encouraged. Nominations should be in the form of a letter detailing the accomplishments of the nominee. Nominations and questions regarding the position of Department Chair should be addressed to the chair of the search committee: Prof. Suzanne Weaver Smith, email: me-chairsearch@uky.edu. *The University of Kentucky is an equal opportunity employer and encourages applications from minorities and women.*

Assistant/Associate Professor of Mechanical Engineering



The Pennsylvania State University, the Altoona College invites applications for a tenure-track position in Mechanical Engineering. The successful candidate will teach courses in engineering and engineering technology. Possible course topics include computer-aided design, engineering mechanics, manufacturing materials and processes, machine design, mechanical drives, measurement and instrumentation, control systems, capstone design, fluid mechanics, and thermodynamics. At least three years of industrial experience or its equivalent is preferred.

Located in the beautiful Allegheny Mountains of central Pennsylvania, Penn State Altoona is a largely residential campus of 4000 students offering 22 baccalaureate degree programs and the first two years of 180 Penn State baccalaureate degrees.

The position requires a Ph.D. in mechanical engineering or related field, and is a tenure-track appointment at the level of assistant professor or a rank commensurate with qualifications beginning Fall 2015. Applicants should present a record of evidence and potential effectiveness in teaching, research, and service.

For more information, please go to <http://apptrkr.com/528874> (Job # 53962).

CAMPUS SECURITY CRIME STATISTICS: For more about safety at Penn State, and to review the Annual Security Report which contains information about crime statistics and other safety and security matters, please go to <http://www.police.psu.edu/clery/>, which will also provide you with detail on how to request a hard copy of the Annual Security Report.

Penn State is an equal opportunity, affirmative action employer, and is committed to providing employment opportunities to minorities, women, veterans, disabled individuals, and other protected groups.



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Faculty Position in the "Sensors and Systems" in the Department of Mechanical Engineering

Columbia Engineering is pleased to invite applications for faculty positions in the Department of Mechanical Engineering at Columbia University in the City of New York City. Applications at the assistant professor, and in exceptional cases, at the associate professor and full professor levels, will be considered.

Applications are specifically sought in the interdisciplinary area related to the fabrication of unique sensors with transduction principles coupled to mechanical response especially at small length scales, and deployment of such sensors into large scale monitoring systems with big data processing. Candidates must have a Ph.D. or its professional equivalent by the starting date of the appointment. Applicants for this position at the Assistant Professor and Associate Professors without tenure must demonstrate the potential to do pioneering research and to teach effectively. Applicants for this position at the tenured level (Associate or Full Professor) must have a demonstrated record of outstanding research accomplishments, excellent teaching credentials and established leadership in the field.

The successful candidate is expected to contribute to the advancement of their field and the department by developing an original and leading externally funded research program, and contributing to the undergraduate and graduate educational mission of the Department. Columbia fosters multidisciplinary research and encourages collaborations with academic departments and units across Columbia University. This position particularly seeks candidates whose research focus intersects with the field of data sciences and can take full advantage of the Institute for Data Science and Engineering at Columbia. The Department is especially interested in qualified candidates who can contribute, through their research, teaching, and/or service, to the diversity and excellence of the academic community.

For additional information and to apply, please see: <http://engineering.columbia.edu/faculty-job-opportunities>. Applications should be submitted electronically and include the following: curriculum-vitae including a publication list, a description of research accomplishments, a statement of research and teaching interests and plans, contact information for three experts who can provide letters of recommendation, and up to three pre/reprints of scholarly work. All applications received by December 31, 2014 will receive full consideration.

Applicants can consult www.me.columbia.edu for more information about the department.

Apply for this position:
academicjobs.columbia.edu/applicants/Central?quickFind=59999

Columbia is an affirmative action/equal opportunity employer with a strong commitment to the quality of faculty life.



Faculty Positions in Advanced Manufacturing

The Department of Industrial and Manufacturing Systems Engineering invites applications and nominations for two positions: (1) tenure-track associate professor or assistant professor and (2) visiting assistant professor. Candidates for these positions must have an earned doctorate in industrial engineering, mechanical engineering, or a closely related field. Industrial experience and professional registry are highly desirable. The successful candidate will lead funded research endeavors that complement or extend the current strengths of the department, with preference given to the areas of advanced manufacturing technologies and processes, product innovation, sustainable manufacturing operations, and similar areas. The successful candidate will demonstrate commitment to teaching at the graduate and undergraduate levels. For more senior applicants, an outstanding reputation in the field of specialty is a primary requirement. The starting date will be January 2015 for the visiting position and August 2015 for the tenure-track position. Salary will be commensurate with qualifications.

The Department of Industrial and Manufacturing Systems Engineering has a tradition of excellence in research and education. The department offers an ABET-accredited B.S.I.E.; master's degrees in Industrial Engineering, Operations Research, and Engineering Management (including distance education options); and a Ph.D. in Industrial Engineering. The department has 11 faculty members, 240 undergraduate students and 106 graduate students. Faculty members conduct research in advanced manufacturing, logistics, operations research, health care systems, human factors, and statistical quality control. Research expenditures exceeded four million in FY 2013 from diverse sources including NSF, U.S. and Kansas Departments of Transportation, a Veterans Engineering Resource Center, and private organizations.

Applicants should submit a cover letter, curriculum vitae, a one-page statement of research vision, a one-page statement of teaching interests, and contact information for at least three professional references to iesearch@ksu.edu. Questions may be directed to Dr. Shuting Lei, search committee chair, at lei@ksu.edu. For additional information, please visit <http://www.imse.ksu.edu/about/employment/>.

Screening will begin February 1, 2015 for the tenure track faculty position, November 17, 2014 for the visiting faculty position, and will continue until the position is filled.

Kansas State University is an Equal Opportunity Employer of individuals with disabilities and protected veterans. Kansas State University actively seeks diversity among its employees. Background check required.

DEPARTMENT CHAIR MECHANICAL ENGINEERING

Michigan State University invites nominations and applications for the position of **Chair of the Department of Mechanical Engineering** in the College of Engineering, with a starting date of August 16, 2015.

The Mechanical Engineering faculty has built strong interdisciplinary research and educational programs on a foundation of core mechanical engineering disciplines and provides a first-class education while engaging in research at the frontiers of knowledge. The Chair of the Department of Mechanical Engineering will promote the development of this departmental vision of academic leadership and excellence, and will represent the Department to the academic community, industry, and government. The Chair will actively work with faculty in the Department and across the University to identify and pursue innovations in research, education, and service. This individual will lead the Department and the College in strategic planning in the above context. The Chair is also responsible for promoting cultural diversity throughout the University.

The Department has 37 faculty members with a strong commitment to research, teaching, and service. Annual research expenditures exceed \$10M. Research strengths are in the areas of experimental and computational thermal sciences and fluid mechanics, automotive engines and turbomachinery, manufacturing, solid mechanics and composites, biomechanics and bioengineering, dynamic systems and controls and micro-nano engineering. The Department is home to the Energy and Automotive Research Laboratories and affiliations with other centers within the College including the Composite Vehicle Research Center, the Composite Materials and Structures Center, the Fraunhofer USA Center for Coatings, the High Performance Computing Center, and the Biomedical Imaging Research Center. The current enrollment is approximately 150 full-time graduate students and 565 undergraduate students (juniors and seniors). The Department is committed to develop and maintain state-of-the-art facilities and instrumentation in support of its key research foci. For additional information about the ME Department, the College of Engineering or MSU, see: www.egr.msu.edu/me/

MSU enjoys a park-like campus with outlying research facilities and natural areas. The campus is adjacent to the city of East Lansing and the capital city of Lansing. The Lansing metropolitan area has a diverse population of approximately 450,000. Local communities have excellent school systems and place a high value on education. Michigan State University is pro-active in exploring opportunities for employment for dual career couples, both inside and outside the University. Information about MSU's dual career support can be found at miwin.msu.edu/. Information about WorkLife at MSU and the College of Engineering can be found at www.egr.msu.edu/WE.

Candidates must be qualified to receive an appointment at the rank of Professor in the Department and be experienced in attracting research funding from diverse sources. Evidence of scientific and organizational leadership and educational innovation is essential. A demonstrated track record of outstanding administrative effectiveness is preferred.

Interested individuals should submit an application for this position through: jobs.msu.edu and refer to position #0442. Applicants must submit a detailed resume, a cover letter summarizing qualifications and leadership approach, and the names and contact information for five references. Applications will be reviewed on a continuing basis until the position is filled. For full consideration, applications should be received before February 1, 2015. Nominations or questions are welcome by contacting the search committee chair through email at ME-CHAIR-Search@egr.msu.edu

MICHIGAN STATE UNIVERSITY

MSU is committed to achieving excellence through cultural diversity. The University actively encourages applications and/or nominations of women, persons of color, veterans and persons with disabilities.

MSU is an Affirmative Action, Equal Opportunity Employer.

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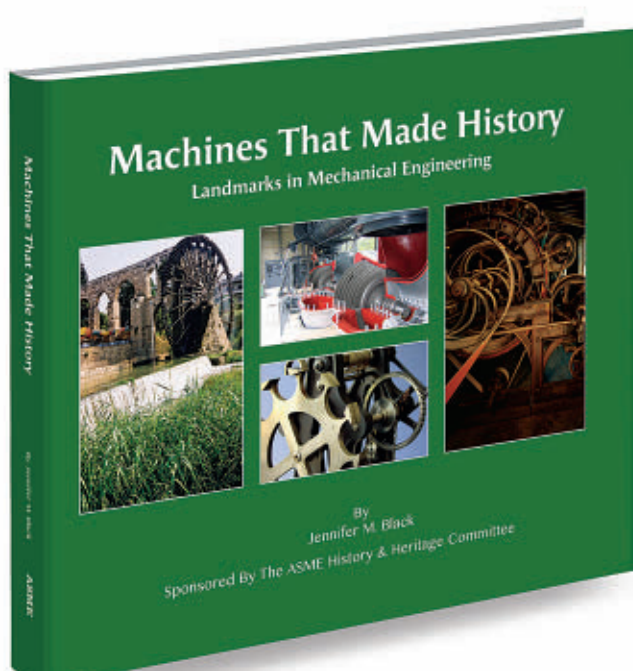
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FEATURED

MACHINES THAT MADE HISTORY: LANDMARKS IN MECHANICAL ENGINEERING

JENNIFER M. BLACK

ASME Press Books, Two Park Avenue, New York, NY 10016-5990. 2014.

This hardcover photographic book highlights 100 key landmarks in the history of mechanical engineering, devices or innovations that have shaped the world. According to the foreword: “The products of mechanical engineering sustain the very fabric of modern life. Some are obvious, like the automobile; some hide behind casings, like the disk drives of computers. Sometimes they are large and visible, like the rockets that took astronauts to the moon; sometimes they are all but invisible to the general public, like the pumps that provide water to our cities or the turbines that generate our electric power. This volume provides brief introductions to 100 key landmarks in the history of mechanical engineering, devices or innovations that have shaped the field and broadly influenced modern civilization.”

170 PAGES. \$79; ASME MEMBERS, \$59; ISBN: 978-0-7918-6030-4.



UNMANNED AIRCRAFT SYSTEMS INNOVATION AT THE NAVAL RESEARCH LABORATORY

Jay Gundlach and Richard J. Foch
American Institute of Aeronautics and Astronautics, Inc., 1801
Alexander Bell Drive, Reston, VA,
20191-4344. 2014.

Unmanned Aircraft Systems Innovation at the Naval Research Laboratory recounts the previously untold story of unmanned aircraft research and development at the Naval Research Laboratory's Vehicle Research Section. The book discusses more than 100 vehicles that have charted the course of unmanned aircraft history in the late 20th and early 21st centuries. Topics include various missions, levels of autonomy, configurations, propulsion systems, and structural materials. Written from engineering and aircraft design perspectives familiar to industry professionals, this text is nonetheless accessible to the nontechnical aviation enthusiast. It honors the accomplishments of the tireless and gifted teams who made these innovative aircraft and their technologies possible.

487 PAGES. \$69.95. ISBN: 978-1-6241-0259-2.



BIOMEDICAL ENGINEERING AND ENVIRONMENTAL ENGINEERING

Garry Lee
WIT Press, 25 Bridge Street,
Billerica, MA 01821. 2014.

Biomedical Engineering and Environmental Engineering consists of the accepted papers from the 2013 International Conference on Biomedical Engineering and Environmental Engineering held in December 2013 in Singapore. The multidisciplinary book includes contributions from academic and industrial experts from 26 different countries who work in the fields of biomedical and environmental engineering. The peer-reviewed papers in the book cover the subject areas of bioinformatics and computational biology (11 papers), biomedical engineering (19 papers), and environmental science and technology (63 papers).

748 PAGES. \$644. ISBN: 978-1-8456-4865-7.

SHAPIRO WINS DESIGN AWARD

Vadim Shapiro, professor of mechanical engineering and computer sciences at the University of Wisconsin-Madison, was recently named winner of the 2014 Design Automation Award. The award recognizes sustained meritorious contribution to research in design automation.

Shapiro, an ASME Fellow, has contributed a number of groundbreaking results in computer-aided engineering as it relates to geometric modeling, physical modeling and simulation, and computational design. He has developed new geometric modeling representations that overcome critical bottlenecks in CAD technology that have affected the architecture of most CAD systems in use today.

DRESSELHAUS RECEIVES MEDAL OF FREEDOM

Mildred Dresselhaus, the Massachusetts Institute of Technology professor who founded the ASME Nanotechnology Institute in 2001, was among the 19 people awarded the Presidential Medal of Freedom at a White House event in November.

The Presidential Medal of Freedom is the nation's highest civilian honor. It was established by President John F. Kennedy to celebrate individuals who have made especially meritorious contributions to the security or national interests of the United States, to world peace, or to cultural or other significant public or private endeavors.

Through her long research career Dresselhaus has investigated a number of subjects, most recently the properties of nanoscale structures such as carbon nanotubes.

According to a White House statement announcing the award, Dresselhaus is "one of the most prominent physicists, materials scientists, and electrical engineers of her generation. ... She is best known for deepening our understanding of condensed matter systems and the atomic properties of carbon, which has contributed to major advances in electronics and materials research."

Among the others honored at the November 24 event were economist **Robert Solow**, journalist **Tom Brokaw**, and singer-songwriter **Stevie Wonder**.

FELLOWSHIP OPPORTUNITIES REMAIN OPEN

ASME IS CURRENTLY accepting applications for two of its ASME Federal Government Fellowship programs: the ASME Congressional Fellowship and the ASME Foundation Swanson Fellowship on Advanced Manufacturing.

For more than 40 years, ASME has sponsored more than 100 Federal Fellows who have provided a valuable service to the nation by contributing their engineering expertise to the public policy-making process.

The 2015-2016 Congressional Fellow will spend one year in Washington working with the staff of a congressional committee, U.S. senator, or U.S. representative. Congressional Fellowships are designed to bring technical backgrounds and external perspectives to the decision-making process in Congress and provide a unique public policy learning experience to the Fellow.

Another program, the ASME Foundation Swanson Fellowship on Advanced Manufacturing, brings individuals from the private sector and government to the Advanced Manufacturing National Program Office, which is hosted at the

National Institute of Standards and Technology in Gaithersburg, Md. There the fellows work to foster advanced manufacturing initiatives as part of a nationwide manufacturing agenda.

The ASME Swanson Fellow is responsible for coordinating the National Program Office and other participating organizations, including industry, universities, and various government agencies; engaging with professionals at the intersection of advanced manufacturing and public policy to make practical contributions in federal decision-making; and promoting the understanding of federal policy and programs across stakeholder groups in advanced manufacturing.

An \$80,000 stipend will be provided for the one-year fellowships. All Fellows must be U.S. citizens and ASME members at the time of application. Applications will be accepted through Jan. 31, 2015. To apply for an ASME Congressional or AMNPO Fellowship, fill out the online application at https://fs19.formsite.com/rsvp/form13/secure_index.html and be sure to attach the requested materials.

PAPERS NOW BEING ACCEPTED FOR NEW ASME JOURNAL

The editor of a new ASME journal, the *Journal of Verification, Validation, and Uncertainty Quantification*, is currently accepting papers for the new publication. The new quarterly journal, which is expected to launch in 2016, is being developed as a vehicle for disseminating original and applied research, illustrative examples, and high-quality validation experiments and data from leaders in the field of verification, validation, and uncertainty quantification of computation models.

The new journal is intended to serve an audience of both engineers and scientists. It will feature peer-reviewed research, discipline-specific applications, and policy and regulatory perspectives, as well as sections dedicated to review articles and technical briefs reporting recent VVUQ-related advances and events.

The *Journal of Verification, Validation, and Uncertainty Quantification* will be a major focus of the upcoming ASME Verification and Validation Symposium, which will take place from May 11-15 in Las Vegas, Nevada.

The meeting, which will focus entirely on the emerging field of verification, validation, and uncertainty quantification of computer simulations, will provide prospective authors with an opportunity to meet the journal's editor, Ashley F. Emery, and to submit papers to the journal.

The journal will publish papers covering a variety of specialties from every engineering discipline. Among the fields of focus are atmospheric and earth science; defense applications; fluid and thermal mechanics; high-energy density physics; materials science; medical device design and analysis; nuclear power system design and analysis; solid mechanics; space science and astrophysics; and structural dynamics.

Papers can also be submitted through ASME.org. To learn more about the new journal or to submit a paper, visit <http://journaltool.asme.org> and select "Verification, Validation, and Uncertainty Quantification." For more information, contact the editor by e-mail at emery@uw.edu.

FULL METAL PIXELS

An artistic data visualization employs suspended balls set in motion.



Photos: Hypersonic

A SCULPTURE RECENTLY INSTALLED IN CAMBRIDGE, MASS., IS IN SOME WAYS VERY SIMPLE: 804 METAL BALLS suspended from wire ropes. But the installation isn't static. The strings are mounted a motorized mechanism that puts the balls in motion in a wave-like formation. The pixelated wave reaches a crest and then breaks, and the balls hover in a cloudlike mess.

From many perspectives in the room, it's pure chaos.

The sculpture, "Breaking Wave," is being used to describe the work of Biogen Idec, a Cambridge biotechnology company. The company, which specializes in medicines for people with neurodegenerative diseases, hematologic conditions, and autoimmune disorders, commissioned an artistic collaboration between the design firm Hypersonic and technological sculptors Plebian Design to capture the essence of how to make a scientific breakthrough.

The collaboration was brokered by David Small, creative director of the New York-based design firm Small Design, tasked with designing the lobby "experience" in the company's headquarters.

Peter Washabaugh, founder of Hypersonic, said, "I had discussions with Biogen Idec and other biotech firms about how the science of what they do happens, and what their exploration process is." He found out that it involved testing parts of drugs on different protein sequences and genetic markers in an attempt to find a combination that would get the effect the researchers were looking for.

"The folks at Biogen are looking at these vast amounts of data," Washabaugh said, "and they have to find the right point of view to create

what they want."

According to Jeff Lieberman, founder of Plebian Designs, the sculpture has an entirely analog control system. One motor is tasked with driving over 800 other moving parts. His team did a large amount of software programming up front to allow them to design a system that was completely hard coded: it cannot do anything except what the individual sees. As Lieberman put it, "It is largely like some of the analog computers that were made in the 19th century."

In this case, the software gave them the sizes of the 804 pulleys; the larger the pulley, the higher it lifts the ball. The software then takes the images that they want to appear from two different perspective points, and with a "Monte Carlo method" (a broad class of computational algorithms that rely on repeated random sampling to obtain numerical result) finds suitable locations for balls that will create both images simultaneously.

Lieberman says that the primary goal of "Breaking Wave" was not to impress anyone, but rather to "give people a moment of beauty and awe, and to have them stop thinking so much about their day and get lost in pure sensation." **ME**



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Heat Transfer in Solid and Fluids

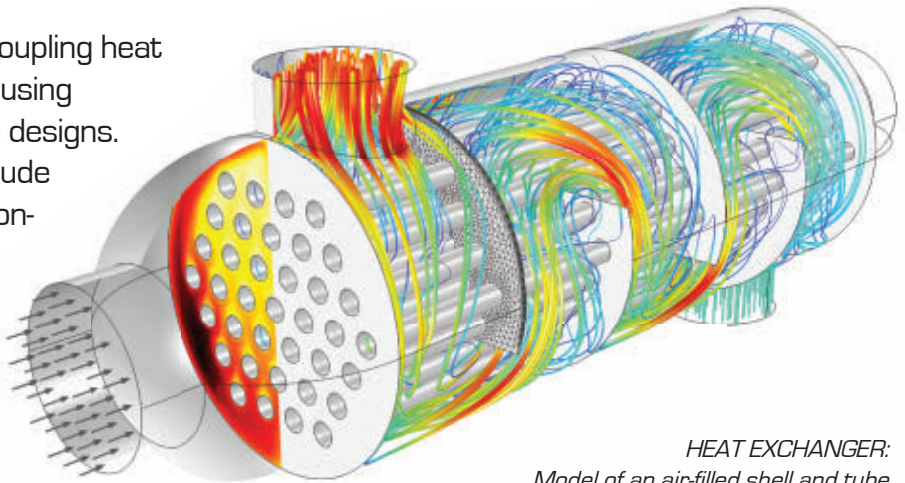
January 15, 2015 2:00 p.m. EST 11 a.m. PST

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In this webinar, we will explore coupling heat transfer with other physics and using simulation to verify and optimize designs. We will show examples that include structural thermal expansion; convection, radiation, and conduction; and chemical, acoustic, and electromagnetic heating.

Jon Ebert, Director of SC Solutions, will discuss his use of COMSOL Multiphysics for a range of heat transfer applications. Dr. Ebert will demonstrate modeling techniques and show how to use simulation results for temperature control with real-time feedback.

The webinar will include a Q&A session.



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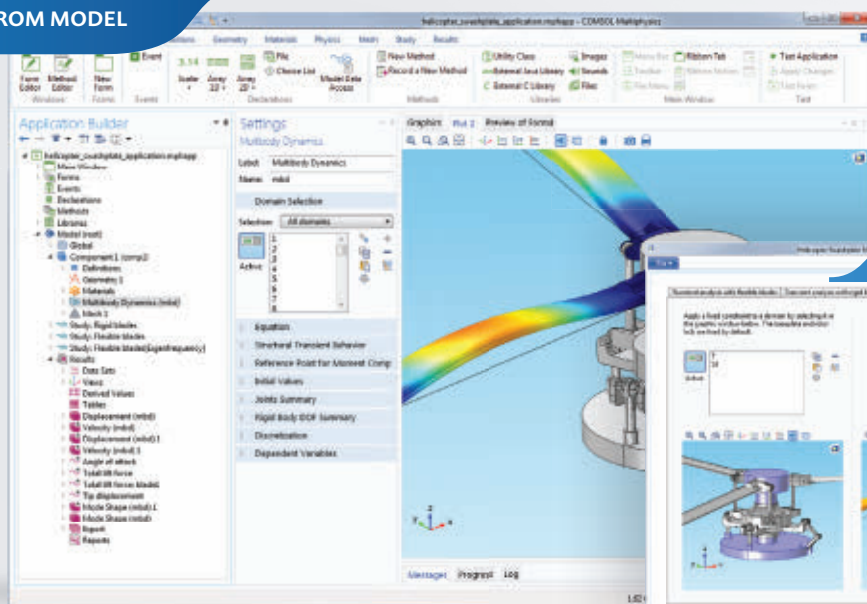
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Fatigue Module
Multibody Dynamics Module
Acoustics Module

FLUID

CFD Module
Mixer Module
Microfluidics Module
Subsurface Flow Module
Pipe Flow Module
Molecular Flow Module

CHEMICAL

Chemical Reaction Engineering Module
Batteries & Fuel Cells Module
Electrodeposition Module
Corrosion Module
Electrochemistry Module

MULTIPURPOSE

Optimization Module
Material Library
Particle Tracing Module

INTERFACING

LiveLink™ for MATLAB®
LiveLink™ for Excel®
CAD Import Module
Design Module
ECAD Import Module
LiveLink™ for SOLIDWORKS®
LiveLink™ for Inventor®
LiveLink™ for AutoCAD®
LiveLink™ for Revit®
LiveLink™ for PTC® Creo® Parametric™
LiveLink™ for PTC® Pro/ENGINEER®
LiveLink™ for Solid Edge®
File Import for CATIA® V5

