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THE MAGAZINE OF ASME

No. 04 139

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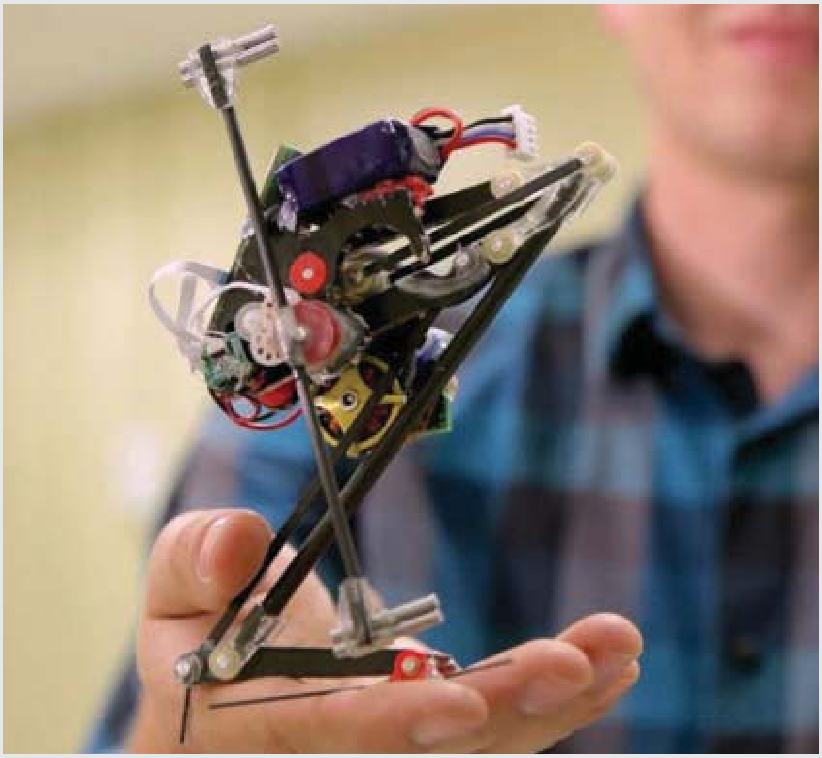


LEAPIN' ROBOTS

RESEARCHERS AT THE UNIVERSITY OF CALIFORNIA, Berkeley, have created a one-legged robot that stores extra energy in its spring as it goes into a crouch. Salto, as it's called, is a single-footed, quarter-pound automaton capable of repeated leaps that approach the heights of the galago, a nocturnal primate it is based on. The robot can bound off the ground, then bound again off a wall or tree with the dexterity of YouTube's greatest parkour stars. The speed and height of its jumps make it one of the most vertically agile robots on the planet.

A FEEL FOR FELINE INNOVATION

ALEXIS NOEL, a Georgia Tech doctoral candidate in mechanical engineering, used cat tongues as inspiration for a 3-D-printed innovation.

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

TINY 3-D PRINTED LENS TO TRANSFORM OPTICS

RESEARCHERS AT STUTTGART UNIVERSITY in Germany have used 3-D printing to fabricate a high-performance optical lens the size of a grain of salt. Future applications could include minuscule high-quality cameras printed directly on semiconductor chips for miniaturized robots and drones.

FIVE WAYS THAT CLEAN ENERGY WILL TRANSFORM DAILY LIFE

THE GROWTH AND AFFORDABILITY of solar power is expected to make dramatic changes in daily life during the next five to 10 years.

CLOSING THE GAP BETWEEN DESIGN AND ADDITIVE MANUFACTURING

JOSE CORONADO, PRODUCT MANAGER at PTC, discusses how bridging the gap between design and additive manufacturing can lead to greater adoption of advanced manufacturing across industries.

NEXT MONTH ON ASME.ORG

EMERGING TRENDS IN SMART MANUFACTURING

Enrique Herrera, market principal at OSIsoft LLC, discusses some of the best practices engineers can follow for the adoption of smart manufacturing.

BALANCING BOT LEADS THE WAY

Carnegie Mellon University researchers have improved upon their helper robot, a tall robot that balances atop a ball, by eliminating the ball's mechanical belts and drives.

TABLE OF CONTENTS

04 139

FEATURES

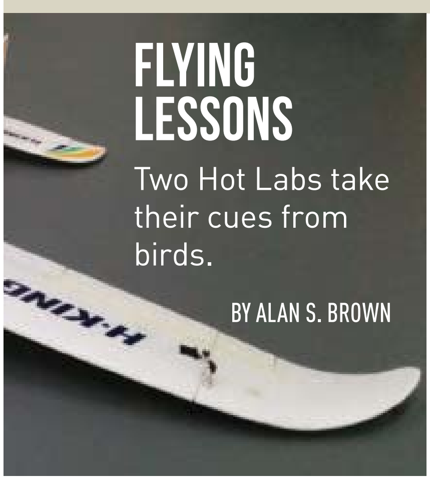
42
KINETIC SCULPTOR
Artist Arthur Ganson sees the world like an engineer.

BY JEFF O'HEIR

DEPARTMENTS

28
TAKING TASKS
Automation won't replace entire jobs, only discrete tasks.

BY JEFFREY WINTERS



FLYING LESSONS
Two Hot Labs take their cues from birds.

BY ALAN S. BROWN

CENTRIFUGE ON A STRING
A team of engineers devised effective laboratory equipment from one of the world's oldest toys.

BY JEFF O'HEIR

64

MECHANICAL ENGINEERING

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

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John G. Falcioni
Editor-in-Chief

PARTY LIKE AN ENGINEER

The dominant narrative about STEM education in the United States is that other countries do a better job than we do at teaching youngsters about science, technology, engineering, and math. My own opinion on this differs, but that's a column for another day. What's curious is that while we denigrate our K-12 STEM education, we take pride that our college and university engineering programs are highly touted and the envy of students around the world.

ASME has had a strong and clear voice in the ongoing discussion about building competence in all stages of the engineering workforce pipeline. The Society's initiatives in this area have been significant, extending from in-classroom programs meant to inspire youngsters in middle school and high school to others at the college level. ASME also works with a network of university engineering department heads and with ABET, the post-secondary engineering accreditation board, to ensure rigor in engineering curricula.

This year, ASME introduced a novel program for college students called E-Fests, short for Engineering Festivals. (See http://efests.asme.org/)

The marketing tagline for E-Fests is, "Party like an engineer." Engineers may be recognized more for how well they solve problems than for how well they party, but at E-Fests they get to do both. E-Fests bring together students from around the world to college campuses for a weekend of music, fun activities, giveaways, networking opportunities, career development, and competitions. Two programs were scheduled in March—one at the LNM Institute of Information Technology in Jaipur, India, and the other at the University of Nevada, Las Vegas. A third event will be hosted by Tennessee Tech University in Cookeville later this month.

These events are anchored around regional ASME student competitions: the Human Powered Vehicle Challenge, the Student Design Competition, the Innovative Additive Manufacturing 3D Challenge, and the Old Guard Competitions.

"E-Fests is an ambitious program built to benefit hundreds of student engineers, said ASME President Keith Roe. "We want to help motivate these young men and women. They are the future technology leaders, the ones who will drive innovation."

Support for E-Fests comes from the ASME Foundation and from industry. "We are very appreciative of the support we have received from many participating sponsors," Roe said.

"To support the development of a strong, well-trained design, engineering, and manufacturing workforce, it's important for industry to partner with academia and organizations like ASME in events like E-Fests," said John Miller, senior vice president of mainstream engineering software for Siemens PLM Software, a business unit of the Siemens Digital Factory Division. "We are very excited to be part of these events and to continue to motivate students in engineering excellence." Siemens is the platinum sponsor of the inaugural events.

The party at E-Fests is just the beginning. The real celebration happens when the students graduate and start on their career paths. Arguably, there's never been a better time to be an engineer. We're reminded of this every time we look up and notice the remarkable footprint the profession is having on the world. **ME**

FEEDBACK

How much has your college experience contributed to the success you've had as an engineer? Email me.

falcionij@asme.org

AUGUST 2016

Reader McCullough documents the regulations that govern jet engines.

« One reader questions the relationship between innovation and economic success, while another defends the Great Lakes.

NO FREE RIDE

To the Editor: In his letter in the August 2016 issue, Henry Huse claims, "Jet engines are unique among carbon-burning engines as they have no emission standards." This is absolutely false.

According to "Aviation & Emissions: A Primer," a 2005 document produced by the Federal Aviation Administration's Office of Environment and Energy, "FAA certification is required for essentially all aviation equipment and processes. For example there are more than 60 standards that apply to aircraft engine design, materials of construction, durability, instrumentation and control, and safety, among others. These are in addition to the Fuel Venting and Exhaust Emission Requirements for Turbine Engine Powered Airplanes (FAR Part 34), which guide compliance with EPA's aircraft exhaust emission standards."

There are also many other places to find information on the subject. So to answer his question—"Why is air transportation given a free ride on emission standards?"—it is not.

Shawn McCullough, *Arlington, Tex.*

INNOVATION VERSUS SUCCESS

To the Editor: The December 2016 Trending ("By the Numbers: The Competitiveness Competition" by Jeffrey Winters) discusses the Global Competitiveness Index produced by the World Economic Forum.

This index is based on 12 pillars of competitiveness. "To the extent that the measurements are meaningful," the writer concludes, "the relative rankings shed some light on the concept that the United States and other Western industrial democracies are being out-competed by developing nations, especially China. According to the World Economic Forum data, at least, China lags behind every major industrial nation, especially in measures of innovation and use of Internet technologies."

However, to understand the relative competitiveness of countries, a consideration of the innovation pillar should be accompanied by an understanding of the relative financial gains that such innovations produce.

A look at the 2016 edition of World Economic Outlook published by the International Monetary Fund reveals the 2016 figures for the current account balances of the United States and China. For the United States, the current account deficit is $469.4 billion, which is 2.5 percent of gross domestic product and just over 21 percent of exports. For China, its current account *surplus* is $270.9 billion, which is 2.4 percent of GDP and 11.4 percent of its exports.

Those results show that the countries that are best innovators are not necessarily the ones which actually obtain the most financial gains of such innovations. While the innovation pillar is a measure of technological advancement of countries, it cannot be a reliable indicator of the degree of competitiveness of an economy.

Improving the level of competitiveness of an economy cannot be accomplished only by increasing investments in innovation and without simultaneously implementing proper macroeconomic solutions and incentives.

Mehrdaad Ghorashi, P.E., *Gorham, Me.*

WATER WARNING

To the Editor: I enjoyed wetting my mental whistle, so to speak, by reading the November 2016 article on meeting future water usage requirements ("The Water Trade" by Michael E. Webber).

I would be remiss, however, if I did not add my protest to the decades old dream of diverting the great rivers of America to her deserts.

As a native of the Great Lakes region, I view any such idea with a protective attitude and immediately recall the plans our Soviet counterparts had to grow cotton from the Aral Sea.

Sam Ferber, *Ann Arbor, Mich.*

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.

MAGNETS MAKE THE MOTOR

ENGINEERS REPLACE EXPENSIVE RARE-EARTH METAL MAGNETS WITH CHEAP IRON TO CREATE A HIGH-PERFORMING EV MOTOR.

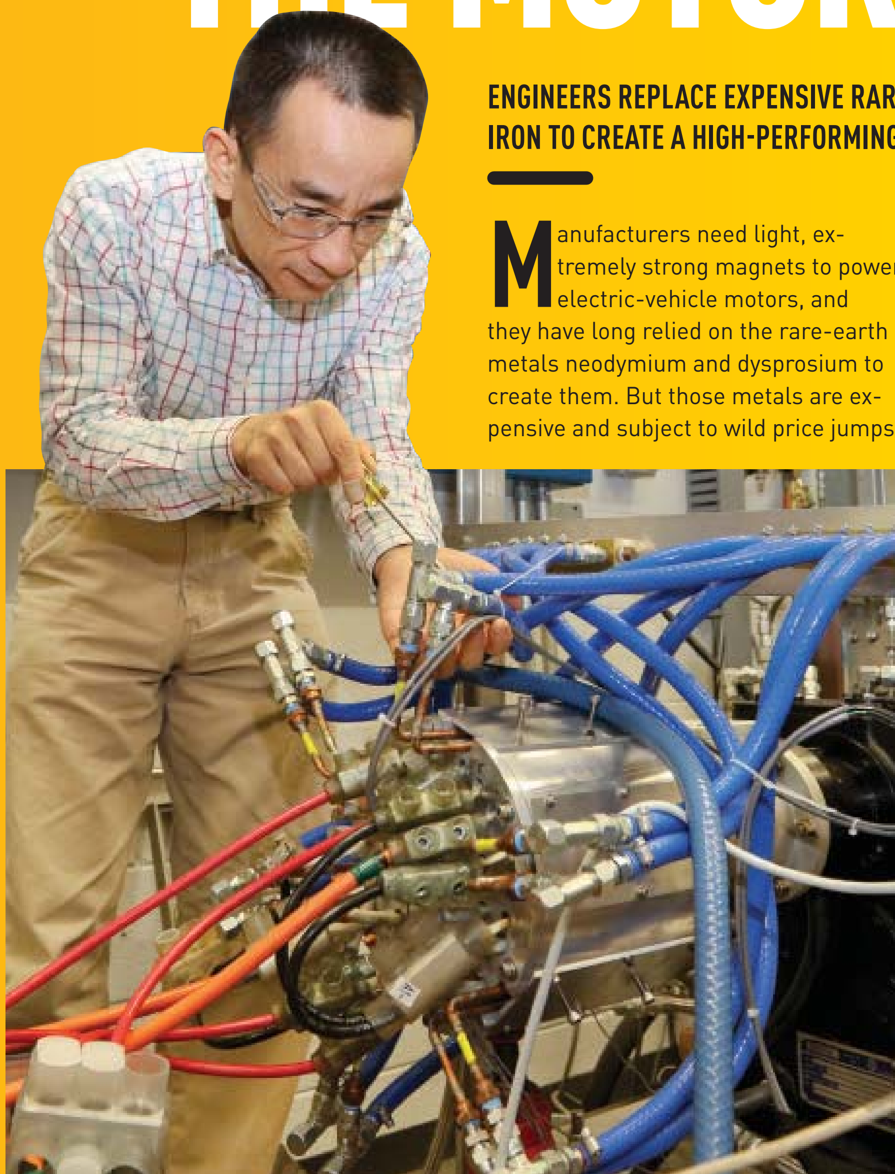
Manufacturers need light, extremely strong magnets to power electric-vehicle motors, and they have long relied on the rare-earth metals neodymium and dysprosium to create them. But those metals are expensive and subject to wild price jumps and shaky supply chains—problems that have become more acute as demand for electric cars grows.

Researchers at Oak Ridge National Laboratory say they've found a solution. They recently built a powerful EV motor that uses common ferrite magnets rather than those made from the rare-earth metals, which can cost up to 30 times more per pound.

The new motor achieves 75 percent higher power than comparably sized commercial EV motors, the researchers said, and it could be ready for mass production in a year.

"Our main target was to reach the same or higher power density, keep within the same volume, and use cheaper magnets," said Tim Burress, project leader at ORNL.

Most electric motors include two main components: the stator, which is stationary, and the rotor, which moves. Like most stators, ORNL's was made from thin, laminated sheets of steel that form a hollow cylinder. A series of copper coils line the cylinder and produce a magnetic field when charged. The rotor sits inside the cylinder, surrounded by a series of magnets and attached to an axle. The stator and rotor repel each other magnetically, causing the rotor and axle to spin.



ORNL's Lixin Tang works on an EV motor that uses magnets made from iron. It generates generates 75 percent more power than comparable motors with magnets made from rare-earth metals.
Photo: Jason Richards, courtesy of ORNL

To reduce costs, the researchers used ferrite magnets that are readily available from most suppliers. Their finished magnets cost $3 a pound, compared with $90 per pound for those made from neodymium and dysprosium.

Back in 2010, the prices of both metals skyrocketed after China, the main supplier of the metals, limited the export of rare-earth minerals. While prices have since dropped, they are still high and subject to sudden changes.

But the researchers still had a problem. Ferrite-based magnets are up to 10 times weaker than rare earth magnets. It can take up to 10 times more ferrite than neodymium to make a magnet of equal strength—and that can make a magnet so heavy it flies out of the rotor, said Jason Pries, an ORNL research associate who worked closely with Burress.

ORNL's rotor, for example, includes 16 magnets. Each of them weighs 175 grams—almost four times the weight of the neodymium-dysprosium magnets in the rotor of a 2015 Toyota Prius motor, which the researchers used for performance comparisons.

To secure the heavy magnets, the researchers machined bevels into the magnets and slipped them into *S*-shaped slots in the rotor. An epoxy prevented the magnets from bouncing around.

The team offset the extra weight of the magnets by reducing the mass of steel and copper in the rotor. The motor weighed only about one pound more than the Prius motor, a difference manufacturers can live with, Burress said.

The total cost of the magnets in the ORNL motor was $20, compared with $150 for the Prius motor.

ORNL's motor was also more powerful. It generated 103 kW (138 hp) at 9,000 rpm, compared with the Prius' 60 kW (80 hp) at the same speed. The researchers attribute the performance gains to powerful modeling, simulation and design tools, and the new class of optimized ferrite compounds.

"Optimization was the key to making this work," Pries said. **ME**

JEFF O'HEIR

These gas turbine blades, made via additive manufacturing, survived a load test that subjected them to 13,000 rpm. *Photo: Siemens.*

SIEMENS RUNS FIRST 3-D PRINTED BLADE

PRODUCTION GAS TURBINE BLADES are either cast or forged, and each method presents a trade-off. Forging produces strong blades, but the cooling channels through the blade are limited by machining technology. Casting provides more flexibility, but complex casting molds are expensive and time-consuming to make.

3-D printing, on the other hand, provides greater flexibility in cooling channel design than either forging or casting. More importantly, it slashes the lead time for design and testing, said Nigel Johnson, who heads global turbine engineering at Siemens' Power and Gas Division.

But would blades manufactured that way hold up inside a gas turbine?

Siemens researchers have completed the first-ever test run of 3-D printed blades at full load on a 13 MW SGT-400-type industrial gas turbine engine. At full power, the blades rotated at 1,600 kilometers per hour, and the centrifugal load on them reached 11 metric tons at temperatures of 1,250 °C. That's about as much as a loaded London double-decker bus.

The blades passed the test.

The blades are made from heat-resistant powdered polycrystalline nickel-based superalloys. Siemens said they feature a fully redesigned air flow that traditional casting could not duplicate.

Thanks to additive manufacturing, the team reduced the time needed to design and produce a new gas turbine blade, from two

continued on p.15 »

HYDROGEN BREAKTHROUGH BEGINS

The Swedish retailer IKEA leases liquid hydrogen-powered minivans such as this one as part of the Clean Energy Partnership Berlin.

Electric-powered cars are beginning to capture both market share and the public imagination. Much-hyped Tesla is the poster child for electric-powered cars, but Chevrolet's Volt is gaining.

Hydrogen-powered cars are lagging, but they won't go away. Backers of hydrogen think it could become dominant if the next round of research pans out.

Though it is unclear how much the new Trump administration will support hydrogen, car manufacturers and researchers are moving ahead. Hyundai, Honda, and Toyota already offer hydrogen-powered cars.

For now, industry stakeholders are concentrating on infrastructure that stores hydrogen at ultracold temperatures or at high pressure.

Today, storing the gas at ultracold tempertaures requires relatively costly equipment. Meanwhile, compressed hydrogen systems require large facilities to pressurize the gas to 700 bar (10,000 lb per sq. in.), and fuel tanks that must be "super strong" to handle the pressure, notes Peter Schubert, a professor of electrical and computer engineering at Indiana University-Purdue University Indianapolis (IUPUI). This requirement can add weight to a tank.

Schubert's start-up company, Green Fortress Engineering Inc. of Indianapolis, used a National Science Foundation grant to develop a solid-state system to deliver hydrogen at 8 bar or even less, and with higher on-board densities, thereby making storage better and more economical.

Schubert says his system has the potential to be "disruptive."

Schubert, who is also the director IUPUI's Richard G. Lugar Center for Renewable Energy, says the key lies in using cheaper and more abundant materials. Metal hydrides are the preferred material in existing low-pressure storage systems, and have been used for a long time. But they give off a lot of heat during recharge, up to 500 °C. "That makes dissipating heat more complicated," Schubert said.

continued on p.25 »

"WITH SOLAR PANELS AND WATER, YOU COULD HAVE ALL THE UTILITY NEEDS FOR A LIFETIME. AND ON A COST CURVE OF LESS THAN $8 PER KWH, IT COULD CLOBBER BATTERIES AND COMPLETELY DISRUPT ENERGY SUPPLY."

PETER SCHUBERT,
INDIANA UNIVERSITY-PURDUE UNIVERSITY INDIANAPOLIS

TAKING THE GUESSWORK OUT OF COMPRESSED EARTH BLOCKS

A NEW DIGITAL TOOL PROVIDES an accurate recipe for making sustainable construction materials.

Compressed earth blocks (CEBs) are a strong and sustainable substitute for concrete blocks and can be made from soil on the building site. But soil varies from place to place, and those variations can affect the quality of CEBs. Too much clay makes blocks shrink when they dry, and too little makes blocks that crumble.

An experienced soil analyst can discover clues about the dirt with little more than water, a jar, and a knife, though discovering a soil's composition via those traditional tools is as much an art as it is a science.

But a new algorithm and simpler soil tests may soon improve the quality of CEBs by taking the guesswork out of their fabrication.

Earth blocks can perform at least as well as traditional building materials, and at a lower cost. Well-made CEBs can have a compression strength of up to 17,000 kPa (2,500 psi), while concrete blocks are usually rated at 13,100 kPa (1,900 psi). Since the raw material comes right from the ground near the construction site, there is no need to ship bricks or lumber. All they require is a block press and cement or lime to bind the soil.

CEBs also do not require firing, so they save energy. Earthen walls can regulate temperatures, dampen sound, and repel mold. If they are built well, they can resist earthquakes.

In Eastern El Salvador, families build their own homes using compressed earth blocks.

Dwell Earth, a New Hampshire-based compressed-earth construction and education venture, has collaborated with the Hunt Institute for Engineering and Humanity at Southern Methodist University in Dallas to develop on-site soil tests and software. The combination gives a custom recipe for making blocks of even quality.

"We identified great fragmentation in the knowledge of earth-block material, and we looked for a way to fill in that gap," said Adam De Jong, who heads Dwell Earth. "We developed a kit to analyze and optimize soils wherever we are."

Laboratory-based soil analysis is the most accurate method, De Jong said, but it is cumbersome and time-consuming. The traditional method is simpler. First, stir the soil into a jar of water. The sand settles first, followed by the silt, and then the clay, each in distinct layers. Measuring the width of the layers gives an indication of the ratios of each ingredient.

"We changed that test," De Jong said. "We split the three materials from the soil using three test tubes and a couple of chemicals. It's like a diluted soap. It breaks the surface tension, allows the sand, silt, and clays to break apart from one another."

The sand settles in 30 seconds, leaving the silt and clay in suspension. Those suspended solids are poured into a second tube, where they sit for 30 minutes while the silt settles to the bottom. This leaves only the clay in suspension in the water above. The clay-water mixture is then poured into a third test tube to measure it, revealing the ratio of particles in the sample.

Test-tube results in hand, the soil analyst enters the measurements into data fields of the compressed earth block analysis application.

The new technology does not herald the end of the age of the dirt-pinching connoisseur, however.

"We don't do away with the qualitative tests, but we've added a lot of quantitative analysis," De Jong said.

Once the measurements are entered, the software recommends a recipe for mixing the suitable ratio of clay, sand, and silt from the soil to make compressed earth blocks.

"The goal is to give the material the best particle distribution possible. That's the art of earth block manufacturing—a good particle distribution," De Jong said. **ME**

ROB GOODIER is editor of Engineering for Change. For more articles on development engineering, go to EngineeringForChange.org.

continued from page 11 »

AM: TURBINE BLADES

years to two months.

"With the use of 3-D printing, you can develop five or more designs, test them, and then decide which one is the best—for a much reduced price," Johnson said.

Siemens has used 3-D manufacturing for other turbine parts. It recently created a burner head for combusting mixtures of natural gas containing up to 60 percent hydrogen recycled from industrial processes. This is an order of magnitude more hydrogen than conventional turbines can handle, which is why it is often more economical to flare rather than recycle hydrogen. To mix the gases uniformly enough to burn them, Siemens used a series of framelike structures that could only be made by 3-D printing.

The company also uses 3-D printing to refurbish burner heads. The heads last about 30,000 hours. After technicians remove them, Siemens grinds off the upper 2 cm of their surface and reprints a new layer onto the part. The entire process takes only about 20 hours.

The company believes it may be able to one day create a fully digitized value chain that would enable 3-D manufacturing centers to make replacement parts for turbines and other products locally.

"The new flexibility in production allows us to more precisely tailor development to our customers' requirements and deliver individual spare parts on demand," Siemens Power and Gas CEO Willi Meixner said.

ALAN S. BROWN

This turbine blade had cooling channels built in as it was printed.

HOW TO HANDLE THE TRUTH

A reputation for honesty will precede you in your organization—and in the rest of your life.

My reputation on our campus is that I am generally outspoken. I say things that I have been told I should not say. But I am also known for being honest.

Not everyone is used to honesty, but I recommend cultivating a reputation for telling the truth. It's often the case that individuals feel implicit or explicit pressure to lie for a company. Don't do it. If nothing else, say "I can't comment on that," but don't lie.

More importantly, don't just spout off "calling it like you see it," but own up to your mistakes, errors, and omissions. This reputation will precede you in your organization and the rest of your life.

A while back, I was trying to find a way to make this point to an international student who was being put on the spot in a dispute between some other international students and their instructor. What should he say if he was interviewed by the university? My simple answer—tell the truth as he saw it—was met with something between shock and disbelief, so I told him a story about a lawyer I knew.

The lawyer once took a personal injury case to trial, and he had spoken to one of the witnesses to the accident in advance in order to find out her account. When that witness was on the stand testifying—and providing an account that bolstered my friend's case—the opposing lawyer was ready to pounce.

Had my friend told this witness what to say? he asked.

When the witness said that yes, he did, the opposing lawyer wolfishly smiled at the judge, jury, and finally my friend. My friend smiled back, which only gave the other lawyer a slight moment of pause as he moved in for the kill.

"What did he tell you to say?"

According to my friend, the jury burst out laughing when she replied. "He told me to tell the truth," the witness said, "since everyone—the judge, you, and the jury—wanted to know the truth."

The opposing lawyer was visibly deflated. At that point, my friend said, the case was over.

Colorado is an odd state, inasmuch as lawyers and juries can talk to one another after a trial. In this case, members of the jury approached my friend and demanded that he give them his business cards in case they ever needed a lawyer. Not only did my friend win the case, he cultivated some potential clients.

An ex-Navy pilot I know said he had observed this phenomenon in his time in service. One serviceman admitted to his mistake to investigators, was admonished, and was allowed to continue in the Navy. Another who committed a similar infraction stonewalled from the onset of the investigation into his case and was subsequently drummed out of the service with a dishonorable discharge.

In my own experience, when an individual comes before a disciplinary committee and is largely truthful (admittedly, some reticence is always advisable), I have seen groups of people at a loss on

OFTEN, INDIVIDUALS FEEL IMPLICIT OR EXPLICIT PRESSURE TO LIE FOR A COMPANY. DON'T DO IT.

what to do, and they tend to be as lenient as possible. If it feels as if the person is lying, however, the committee will look to apply the maximum punishment.

At any rate, the look on the face of that international student when I told him he should tell the truth as he saw it—and that I would not tell him what to say—is an indication that honesty may not be the most advisable policy everywhere.

But in the United States, at least, a reputation for honesty will precede you in your organization and in the rest of your life. People will trust you. Even untrustworthy people will trust you—or at least they know that when their word is pitted against yours, you are the one others will believe. ME

RONALD A. L. RORRER is an associate professor at the University of Colorado, Denver.

IT'S A BIRD, IT'S A PLANE ...

The Ehang 184 electric drone can run for 30 minutes between charges.

If all goes as planned, flying cars could be buzzing around Dubai's famous skyline this summer.

The city's Road and Transport Authority recently said it has tested a low-flying, one-person, self-driving drone that could be used as a taxi service as early as July.

Dubai, the most populous city in the United Arab Emirates, is working on initiatives to make a quarter of transport self-driving by 2030.

The electric Ehang 184, developed by Chinese drone manufacturer Ehang, features a touchscreen that a passenger will use to choose a destination along a preset route. A ground control center will monitor and control the vehicle.

Ehang says its full-redundancy "fail safe system" can ensure the drone immediately lands in the nearest possible area if any of its components malfunction.

The Ehang 184 can run for about 30 minutes between each two-hour recharge, and it can travel about 60 mph at altitudes up to 1,000 feet. Roughly 4 feet tall, the drone uses eight propellers, each driven by an electric motor. Two propellers are stacked on top of each other on arms that extend from the corners of the drone.

The drone is also designed to withstand extreme temperatures. That's a necessary feature for a city where the average July high temperature tops 105 °F during rush hour. **ME**

Photo: Eliza Grinnell/Harvard SEAS

Q&A DAVID MOONEY

FROM THE BEGINNING of his bioengineering career in the late 1980s, David Mooney realized that medicine had a tremendous unmet need for lab-grown tissues and organs to replace damaged or diseased human tissue. Since then, Mooney, now a professor of cell and tissue engineering at Harvard, has developed many technologies advancing both tissue engineering and medical treatments known as mechanotherapy. Mooney is on 38 U.S. patents, and in December he was named a Fellow in the National Academy of Inventors.

ME: Human skin and cartilage tissue are manufactured routinely and are approved by the FDA to treat patients. Can other human tissues be engineered at this point? If not, when will that be possible?

D.M: Many other engineered human tissues have been used in various clinical trials. The holy grail of the field is the engineering of a complete, human organ that can be transplanted and fully replace the loss of a dysfunctional organ. Recent advances in the design of new materials, new fabrication processes such as 3-D printing, stem cells, immunology, and more are moving us forward.

ME: You study mechanisms that cells use to respond to chemical and mechanical signals. How could tissue engineers use mechanical forces to create the tissues they want?

D.M: To drive tissue development, we'll likely want to expose engineered tissues in culture to specific regimens of externally imposed stress and strain. We may want to also control the mechanical loading of the tissue once it's in the body. We can control cell fate, and thus tissue formation, by appropriately designing the intrinsic mechanical properties of biomaterials used in tissue engineering.

ME: Earlier this year, your team reported that treating mice with mechanical therapy—either implanting a magnetic biocompatible gel or having the animals wear a soft-robotic pressurized cuff—helped severely injured muscles regenerate and reduced scarring. Will we see new types of medical devices that heal by applying controlled mechanical forces to human tissues?

D.M: This strategy has tremendous potential to promote regeneration and healing in human patients. We are actively exploring how to move this concept forward to human therapy with Conor Walsh's lab here at Harvard. We'll probably start with skeletal muscle regeneration. They'll probably be a soft-robotic device worn by a patient, similar to a sleeve or wrap used by athletes. These will be mechanically active, in contrast to those passive wraps, and they'll [induce] cyclic strain to promote regeneration of skeletal muscle.

ME: Do you think mechanical treatments could replace drug and or cell-based regenerative treatments for severely damaged muscles?

D.M: There's an opportunity for mechanical treatments to be used in place of drug or cell-based treatments. In other situations, it may be optimal to combine a mechanical treatment with a cell or drug therapy.

ME: Your team has found that when tumor tissue is stiffer, a chemotherapy drug is more effective. Will we see new therapies that alter tissue mechanics to enhance chemotherapy?

D.M: We may be able to alter tissue mechanics to make cancer cells more responsive to specific chemotherapy drugs. We'd do that by using a drug in concert with specific chemotherapies that alter [extracellular] matrix deposition, [tissue] remodeling, or both. Screening a patient's specific cancer cells can determine the most effective drugs for cancer cells that exist in different mechanical environments.

ME: What's the secret to creating inventions that really matter?

D.M: I don't know if there is any one secret to creating the most important inventions—sometimes the most important inventions occur due to chance. We try to focus first on the particular need, typically medical, and that often leads us to inventions that can have a direct impact. **ME**

STEPHANIE STEPHENS produces health content in Orange County, Calif.

FRESH HARVEST FROM CONTAINERIZED FARMS

No one would confuse a shipping container with a farm, but a Boston-based startup wants to merge the two.

Freight Farms has engineered a standard 40-foot-long shipping container so that it can grow as many greens and herbs in its 320 square feet as a two-acre (87,120 square foot) farm—all while using less water daily than the average American spends taking a shower.

The secret is growing the crops hydroponically, without soil, under climate-controlled conditions that optimize temperature, water flow, and lighting.

"Our trailers do not speed up the growth cycle," said Freight Farms marketing director Caroline Katsiroubas. "But they do create the perfect environment for growth, and you can control the light, nutrients, and watering to tweak the taste of your crops. Also, farmers can grow continuously all year long, no matter what it's like outside."

Yields can be substantial. According to Freight Farms, each week its farmers can harvest 500 full or 1,000 mini-heads of lettuce; more than 50 pounds of kale, Swiss chard or other hearty greens; or 35 to 45 pounds of basil, cilantro, or other herbs. It's enough produce to support at least one upscale restaurant or provide pesticide-free fresh greens to local grocers.

Freight Farms combines several technologies in its insulated continued on p.21 »

Greens growing on vertical racks inside a 40-foot container. *Photo: Alan S. Brown*

UP IN THE SKY, IT'S A TRAFFIC JAM

Urban planners tackle traffic management—for drones

Will it be UAVs versus USPS? That seemed like mere conjecture just a few years ago, but last year an Amazon Prime Air drone delivered its first parcel to a customer in Cambridge, England. Eventually, Amazon wants to use drones to deliver orders within 30 minutes, as long as customers live within 10 miles of a fulfillment center and order products that weigh less than five pounds and can fit into a drone's cargo box.

In dense cities such as Singapore, drones that deliver everything from soup to nuts—and others that inspect buildings and monitor traffic—would make for congested skies. That's why engineers at Nanyang Technological University (NTU) in Singapore are developing a system that will enable hundreds of drones to navigate safely through the city.

NTU's Air Traffic Management Research Institute (ATMRI), a collaboration between the university and the Singapore's Civil Aviation Authority, is leading this project. Its plans call for dividing airspace into a three-dimensional grid that uses technology to define drone routes the way streets and traffic lights do for cars on the ground. The grids will specify where drones can fly and where they can descend to delivery levels.

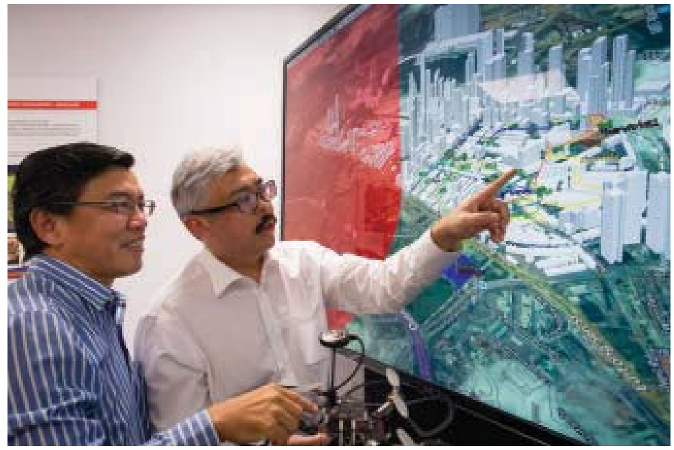
"We have already demonstrated viable technologies such as drone convoys, formation flying, and logistics, which will soon become mainstream," said ATMRI director Low Kin Huat. "This new traffic-management project will test some of the new concepts developed with the aim of achieving safe and efficient drone traffic in our urban airways."

ATMRI envisions a system of traffic-coordination centers to schedule UAV traffic flows, speeds, and distances between vehicles. The drones themselves will need to be programmed with rules of the road to ensure they move in predictable ways, and they'll need to carry sensors to warn them of potential collisions. Even then, they must follow set rules for evasive maneuvers if they are to avoid crashes without causing additional accidents.

"We will also look into proposing safety standards, for instance, on how high UAVs should fly and how far they should be flying above buildings, taking privacy concerns and laws into consideration, and we will suggest recommended actions during contingencies," said Mohamed Faisal Bin Mohamed Salleh, ATMRI's deputy director. Buildings could also act as emergency landing sites to minimize risk to pedestrians.

Geofencing—virtual fences similar to those used to keep dogs in their yards—will keep UAVs from entering restricted locations like airports and military facilities. Eventually, what humans see as open sky will be delineated into invisible zones, lanes, and layers so that unmanned couriers may not be stayed from the swift completion of their appointed rounds. ME

ALAN S. BROWN



ATPRI's Low Kin Huak and Mohamed Faisal Bin Mohamed Salleh discuss drone traffic simulation. *Photo: Nanyang Technological University*

BIG NUMBER

3.36 billion pounds

AMOUNT OF TOXIC CHEMICALS RELEASED BY U.S. INDUSTRIES IN 2015

THE U.S. ENVIRONMENTAL PROTECTION AGENCY produces an annual analysis of its Toxics Release Inventory, a database that tracks the management of chemicals by industry. In 2015, the inventory listed 27.2 billion pounds managed by 21,849 facilities, and shows that more than 87 percent of those chemicals were either treated, recycled, or burned in energy recovery plants. In fact, air emissions of these chemicals has decreased 56 percent since 2005. Of the 3.36 billion pounds that were disposed or released directly into the air, water, or soil, four industries accounted for 75 percent of the total: Metal mining, chemicals, electric utilities, and primary metals.

continued from page 19 »

AGRICULTURE: TRAILERS

trailers. An automated environmental control system uses sensors to measure and regulate temperature, humidity, and air circulation. Instead of sunlight, the crops bask under strips of low-energy LEDs that emit red and blue light, the parts of the light spectrum plants absorb for photosynthesis.

The crops are planted in vertical racks. A closed-loop hydroponic system trickles a nutrient-laden solution directly onto the roots, using only 10 to 15 gallons of water per day. An automated system manages the tanks and nutrient mixing automatically. The entire system runs on either 60 A, 120/240 V single-phase power or 120/208 three-phase power, and uses only 100 to 125 kWh daily.

Naturally, today's urban farmers can control everything from a smartphone app.

The system is streamlined to keep crops moving through the trailer. Farmers plant seeds inside small plugs of peat moss. After about a week, the seeds germinate and the farmers move them to a horizontal rack where they receive two weeks of light, water, and nutrients.

At that point, they are replanted, plugs and all, in strips that are hung vertically in the trailer. The strips rotate automatically so they receive light from the LED strips on the walls as nutrient-rich water runs down their foamed media. The plants take in what they need and the rest is recycled.

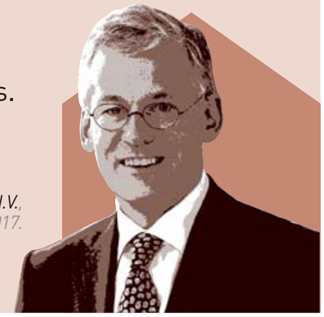
It takes about five weeks for lettuce to mature in the vertical strips. That means farmers can achieve the equivalent of 10 or more harvests per year.

The company recently introduced a scaled-down system to support individual restaurants and smaller urban farmers. It also looks like a small shipping container, but it certainly does not behave like one. **ME**

ALAN S. BROWN

"WITH 3-D PRINTING, some of the supply chain will reshore and come back to the local economies. I think we will see supply chains becoming more regional."

— *Frans van Houten, CEO and chairman of the board of Royal Philips N.V., as quoted by Reuters on January 19, 2017.*



LEARNING TO FLY FROM BIRDS

A drone practices making a perched landing.
Photo: Univ. Bristol

BIRDS ARE EVERYWHERE. That makes it easy to overlook the acrobatic grace of a sparrow's landing or the silent surveillance of an owl before it strikes at prey. Yet more and more researchers are turning to nature for inspiration about flight. This month, two labs employ sophisticated mechanical and control systems to mimic avian abilities.

When birds land, they swoop in, tilt their body back, and open their wings to bleed off speed. That maneuver brings birds to almost a full stop, enabling them to settle gracefully on a branch or the ground. This is called a perched landing.

Now, Tom Richardson, a lecturer in flight mechanics and control at the University of Bristol has built the first-ever drone that can set itself down in a similar fashion. A larger version of the drone could deliver aid in disaster areas or perhaps support military troops.

Richardson used a combination of tilt wings, machine-learning algorithms, and conventional control strategies to perch his drone.

"We wanted to achieve rapid changes in pitch to create more drag very quickly," Richardson said. "We were trying to come up with simplest way to do this, which turns out to be a wing that pivots to present more of its surface on landing."

On a conventional aircraft, this would be a recipe for disaster. But Richardson tacked an unusual course. First, he ran a series of static and dynamic tests on a swing-wing drone in a wind tunnel to see how it responded to different conditions and angles of attacks.

"We tried to generate as many configurations as possible," he said. "Then we collaborated with Anthony Waldock of BMT Defense Services, a British military contractor, to use machine learning algorithms to explore as much of the state space—including speed, angle, and position relative to final perch—to understand how the aircraft could bleed off speed and arrive at the right perching angle at zero speed."

The algorithms yielded a series of flight schedules to guide the drone's behavior during perched landings. Richardson supplemented those guidelines with a conventional controller that ran in parallel to improve the aircraft's tolerance for gusts and uncertainty.

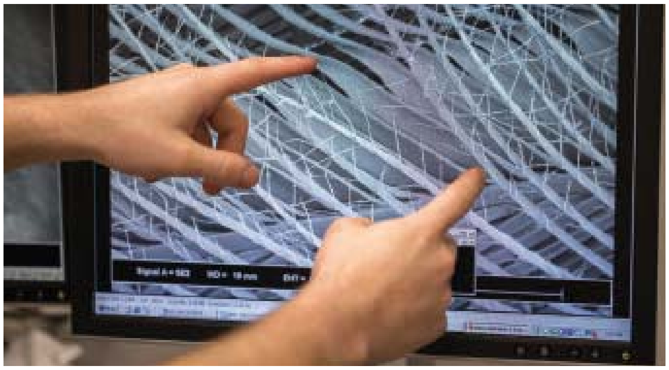
Richardson hopes to simplify the perching algorithms needed to guide the drone to calculate its path more flexibly while flying. He is also working with Shane Windsor, a Bristol biomechanical systems researcher, to develop distributed wing sensors and improve aircraft camera tracking. ME

LANDING LIKE A BIRD

THE LAB Dept. of Aerospace Engineering, University of Bristol, U.K.; Tom Richardson, senior lecturer in flight mechanics.

OBJECTIVE Deploying distributed sensors to study control strategies for conventional and autonomous aircraft.

DEVELOPMENT Developing a first-of-its-kind tilt-wing aircraft that can make perched landings like a bird.



The feathers on an owl's wing (in micrograph) have a thicket of small branches that dampen sound waves. *Photo: Lehigh Univ.*

SILENCING WINGS

THE LAB Dept. of Mechanical Engineering and Mechanics, Lehigh University, Bethlehem, Pa.; Justin W. Jaworski, assistant professor.

OBJECTIVE Understanding fluid-structure interactions, especially in nonlinear and dynamical systems.

DEVELOPMENT Designing a wind turbine blade that borrows from owl wings to reduce noise by 10 decibels.

Owls are silent predators. After studying owl wings, Lehigh University assistant professor Justin Jaworski has designed wind turbine blades that slash noise by 10 decibels (the difference between an air conditioner and a refrigerator) with no reduction in efficiency.

In graduate school at Duke University, Jaworski investigated how fluid forces caused the nonlinear elastic deformations that broke apart NASA's *Helios* solar aircraft in 2003. During post-graduate work at Oxford University, Jaworski used the same approach to explain why owls flew more silently than other birds.

It turns out that owl wings resemble forests. The feathers grow out of the surface with thin, branchlike barbs near the top. "The barbs interlock with each other to create a canopy that separates the outer flow of fast air over the surface from the slower flow of air through canopy, all within 1 mm of thickness," Jaworski explained.

This creates a shear layer. Above this layer, the rapidly flowing air would ordinarily grow exponentially more unstable and louder as it moved along the wing. At the same time, these sound waves decay exponentially as they move down through the canopy. They never even make it to the rough skin surface, where they would scatter and make noise.

Jaworski and his collaborators tried to duplicate this with a mesh suspended over a wing. The mesh, however, added drag. Through experimentation, they found they could reduce noise by 10 decibels using a series of straight grooves they call finlets. They are now working on modeling the finlets to optimize their height, width, spacing, and flare.

Finlets would be fairly simple to manufacture and easy to deploy. They could reduce noises emitted from wind farms, military drones, and perhaps aircraft as well.

Jaworski is also studying the effects of turbulence created by jets flying in close formation. Essentially, he's moving on from owls to geese. **ME**

ALAN S. BROWN

SNATCHING CARBON DIOXIDE FROM MID-AIR

CARBON DIOXIDE BUBBLES beverages, fuels greenhouse-grown plants, spews out of fire extinguishers, and even decaffeinates coffee. Typically, it's obtained as a byproduct of ammonia, hydrogen, or ethanol production, but now several companies have developed equipment that extracts it directly from the air.

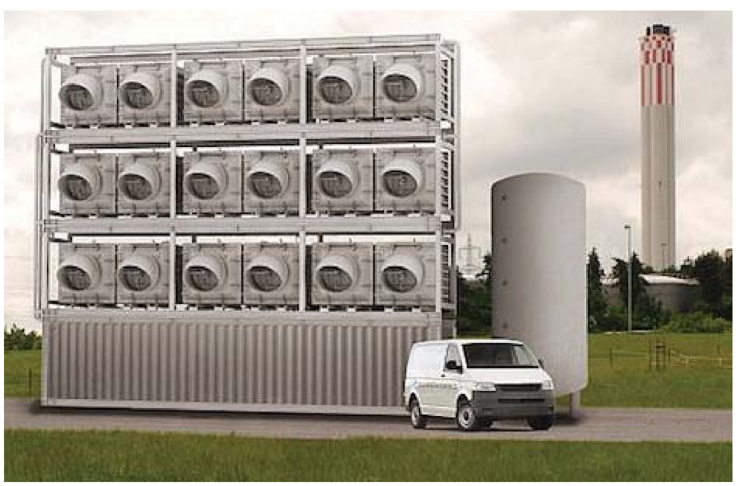
Today's commercial market uses 10-15 million metric tons of carbon dioxide. An additional 120 million tons goes for synthetic renewable fuels, said Domenique Kronenberg, COO of Climeworks, one of the companies that has developed these new CO_2-grabbing technologies, which are known as "direct air capture" of CO_2.

That might be enough to keep a few small companies afloat, and it could even be the beginning of a new industry. But it's a drop in the bucket compared to the 40 billion tons of CO_2 emitted annually.

Still, if the companies making CO_2-grabbing technology can one day achieve sufficient scale, it could contribute to offsetting global CO_2 emissions.

"The only way to prevent catastrophic climate change is to remove the CO_2 directly from the air," , said Graciela Chichilnisky, a lead author of the United Nations Intergovernmental Panel on Climate Change's Fifth Assessment report. Climeworks, a seven-year-old startup based in Zurich, Switzerland, is building the first commercial carbon-dioxide-capture plant. The plant, which is being built at the Hinzil waste incineration plant just outside Zurich, should be operational early in 2017.

To remove the CO_2, Climeworks uses a solid sorbent material, and it uses low-grade heat to release the carbon dioxide. Climeworks developed the process and the filter material in collaboration with ETH Zurich and the Swiss Federal Laboratories for Materials Science and Technology. They hope to sell their carbon-capture machines, which are modular, to other companies. These companies would then install them to obtain a free, local, and continual supply of carbon dioxide.



Six Climeworks CO_2 collectors fit in a standard 40-foot container. Each module captures 35 kg of CO_2 per hour, or 300 metric tons per year.

For the Swiss project, Climeworks' machines will capture 900 tons of CO_2 annually, and feed it to a nearby greenhouse that grows tomatoes, cucumbers and lettuce. The growers expect to see a 20 percent increase in growth, Kronenberg said. The Swiss Federal Office of Energy is paying for the project.

Ultimately, Climeworks is looking to produce synthetic low-carbon fuels from the carbon dioxide they capture.

Chichilnisky also leads a company, New York City-based Global Thermostat, that aims to combine direct-air capture of carbon dioxide with production of carbon-fiber composites. Global Thermostat has built a pilot-scale demonstration system on the campus of SRI International in Silicon Valley that consists of an air-handling chamber with an exchanger coated with a proprietary sorbent material with an affinity for CO_2. The units are designed to remove 50 percent of the CO_2 from the air passing through. Global Thermostat releases the CO_2 by heating the sorbent to 85 °C, which also regenerates the sorbent.

A Canadian company called Carbon Engineering is also using captured carbon to produce synthetic low-carbon fuels. Their technology draws streams of air and CO_2 through a high-surface-area exchanger containing corrugated plastic sheets that are coated with a liquid absorbent. They collect CO_2 in the form of a liquid carbonate solution, then release it as needed.

As direct-air-capture devices continue to become cost-effective and energy-efficient, large numbers of them could be deployed, perhaps as public-works projects to capture carbon and sequester it underground, Chichilnisky said. ME

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

continued from page 12 »

HYDROGEN: STORAGE

Schubert's system will use less expensive and more common silicon, rather than metal hydrides. "Using these less expensive materials could make solid-state hydrogen storage available to every economic market," he said.

But the long-range effects could even be greater, he says. Silicon is ubiquitous and is used in computer chips and solar panels. The fledgling hydrogen-storage technology would allow homeowners or businesses to generate their own hydrogen using rooftop solar panels to split water, then store the energy as hydrogen in silicon. In this way, a home could theoretically power itself overnight or for a number of days. "With solar panels and water, you could have all the utility needs for a lifetime," Schubert said. "And on a cost curve of less than $8 per kwh, it could clobber batteries and completely disrupt the energy supply."

That's a grand plan, but Schubert thinks its future isn't that far away if the next research steps are successful. First, researchers need to perform the first gaseous recharge of a solid-state hydrogen storage media to validate the theoretical work that led to the NSF grant. That includes working with polycrystalline silicon and metallurgical grade silicon, something Schubert's team has not yet attempted. Following that work, they will then construct a one-tenth-scale radio-controlled car fitted with a fuel cell and hydrogen storage media.

Meanwhile, other researchers are looking at hydrogen storage differently. Jose L. Mendoza-Cortes, a Florida State University professor, is designing new materials to store hydrogen more efficiently. In an article published in the *Journal of the American Chemical Society*, Mendoza-Cortes used computer simulations and mathematical equations to describe porous materials made of transition metals that allow hydrogen to bond to them.

The materials are made of abundant materials such as cobalt, iron, or nickel, which could be placed or manufactured within a fuel tank. Because the hydrogen molecules bond to the material, more hydrogen could be condensed into a tank and the tank would never really reach empty, Mendoza-Cortes, an assistant professor of chemical engineering, claimed.

Currently, cold storage of liquid hydrogen at 1 bar and 20 K, or -424 °F, enables storage at 71 g/l. High-pressure, room-temperature conditions (700 bar and 298 K, or 76.7 °F) enables storage at 37 g/l. In contrast, Mendoza-Cortes's materials promise hydrogen storage at lower pressures (less than 200 bar) and at room temperature.

"More hydrogen can be stored at lower pressure and room temperatures, making some of these materials good for practical use," Mendoza-Cortes said.

Schubert, for his part, says his real passion is space-based solar power, putting solar panels in space where they would generate electricity almost continually, beaming the power to earth. He actually thought of using silicon as a medium when writing a novel about hydrogen and the space program.

"It was a plot device," he said. "I thought—silicon—and it is porous. No one had proposed anything like that before."

Schubert was working in the private sector at the time. The theoretical work proved fruitful, and he was awarded the patents for the system, which now belong to IUPUI. If the next step is successful, he thinks a working commercial system may be five or six years away. Coupled with another plan to produce hydrogen from biomass on a local scale, he thinks hydrogen-powered cars could give electric-powered competitors a good run for their money. **ME**

JOHN KOSOWATZ, ASME.ORG

LOOKING BACK

Deregulation was forcing electric utilities to rethink their power plant operations when this article was published in 1997.

KEEPING POWER PLANTS PROFITABLE

EUGENE R. REINHART, PRESIDENT OF REINHART AND ASSOCIATES, AUSTIN, TEX.

An expert in nondestructive evaluation discussed ways to reduce power plant downtime through high-tech inspection programs.

New inspection and monitoring equipment and techniques have not always been successful. Continuous monitoring of pipe systems and hydrostatic testing of pressure vessels using acoustic emission (detection of defects by monitoring the emission of sonic energy from the area around the cracks), instead of conventional nondestructive-testing methods like ultrasonics and radiography, have been costly and generally unproductive. Acoustic emission appears to be highly dependent on its specific and often very narrow area of application, and it is difficult to qualify or quantify its results due to the extreme variability of data and the inability to correlate the data with other accepted NDE methods. There still appear to be extreme differences of opinion in the technical community regarding the value of acoustic emission. In addition, the signals produced by this technique from iron and steel components can be very weak when competing with other background noise, such as pumps, oxide cracking, or flow.

High-energy computed radiographic tomography was supposed to image flaws in high-energy piping systems in place and through insulation. Unfortunately, its performance in the laboratory could not be duplicated under field conditions, partly because of a lack of technologists' appreciation of the access and as-built conditions existing at a utility power plant.

Robotic pipe crawlers were adapted for remote inside inspection of high-energy power-plant piping from systems used to inspect petrochemical or nuclear piping. Again, the majority of attempted inspections failed. The setup time, inspection time, costs of highly trained personnel, and use charges for the system were less than competitive when compared with the conventional approach of removing insulation, cleaning the pipe, and performing NDE.

The inspection results were marginal, because usually only visual inspection could be performed, so any flaws on the outside surface or in the body of the pipe were not detected. And without cleaning, the scaled and rough surface condition of the pipe system could conceal defects. Furthermore, the inside geometry of the piping systems (such as backing bars on welds and tight bends) either did not allow the inspection crawler to negotiate passage through the piping system or precluded inspection of critical areas.

Before using these or similar approaches, the proven aspects of the technology should be carefully evaluated. Unproven technology sold as a qualified, useful product or service has been a real problem in the utility industry. ME

MAN VERSUS MACHINE

While Reinhart was writing about the limits of robotic pipe inspection, another machine was preparing to test itself against a champion of humanity. After a computer known as Deep Blue had lost a six-game match to the reigning world chess champion Garry Kasparov in 1996, four to two, a team of technologists at IBM set out to expand the machine's database and improve its ability to assess unfamiliar moves. Deep Blue, which was capable of evaluating 200 million positions per second, relied mainly on a brute-force approach to finding the optimal move. In a six-game rematch that started May 3, 1997, that relentless approach overwhelmed Kasparov, who lost game six, the match—and a claim of superiority over machines.

Kasparov contemplates a move.
Credit: Wikimedia

CHINA GROWS WIND SECTOR

COAL DOMINATES power production in China, but wind is growing fast.

In 2016, China added 19.3 GW of wind power capacity, according to the China's national energy administration. The nation ended the year with 149 GW of total installed wind power capacity.

Wind turbines in China generated 241 billion kilowatt-hours of electricity in 2016. That's 4 percent of the country's total electricity production.

Nearly 50 billion kilowatt-hours of wind power were wasted due to uneven distribution of wind resources and an imperfect grid system.

The data was reported in February by the Xinhua News Agency. ME

DIESEL TRAINS EXPOSE PASSENGERS TO EXHAUST

COMMUTING BY RAIL may be more fuel-efficient than the standard one-passenger automobile, but research from the University of Toronto suggests there is a hidden cost.

Diesel-powered commuter trains may expose their passengers to high levels of some types of black carbon and ultra-fine particles.

The results were reported in the journal *Atmospheric Environment*.

The researchers found that when locomotives pulled the train, particulate levels were between six and 16 times higher than when the engine pushed from the rear.

Exposure was highest in the coach located behind the locomotive.

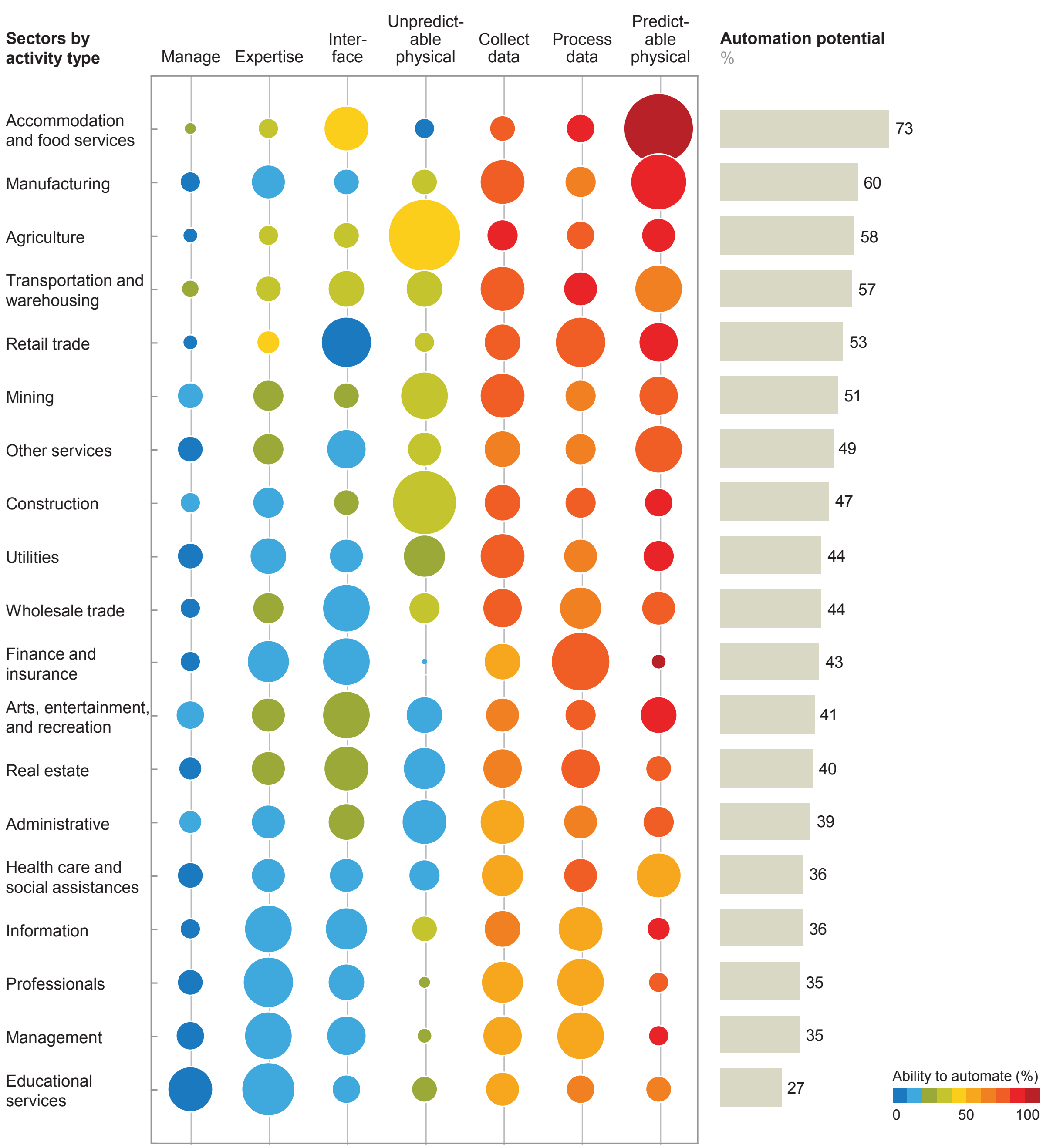
According to chemical engineering professor Greg Evans, "Imagine yourself driving down a busy highway in a convertible, and spending your entire commute sitting behind a very large diesel truck. That's comparable to the levels we see here." ME

WIND HITS U.S. MILESTONE

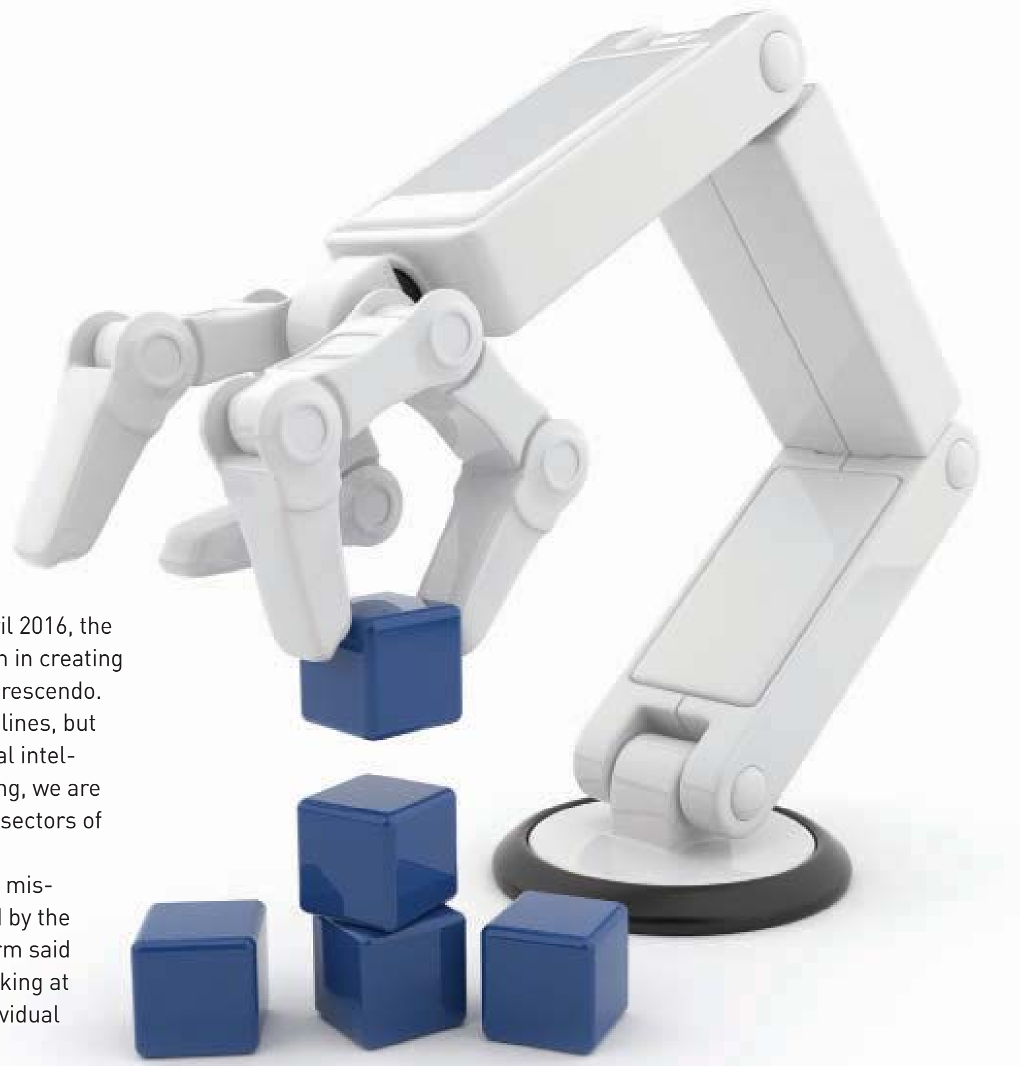
FOR A BRIEF MOMENT ON THE MORNING OF FEBRUARY 12, wind power met 52.1 percent of the load on the Southwest Power Pool, a regional transmission organization. That's a record for wind power. Wind has increased rapidly in the southwest—capacity reached 16 GW in 2016 and makes up 15 percent of the RTO's generating capacity, trailing only natural gas and coal. In 2015, wind capacity was only 12 GW. ME

BY THE NUMBERS: TAKING THE TASKS

TECHNICAL POTENTIAL FOR AUTOMATION ACROSS SECTORS



SOURCE: US Bureau of Labor Statistics; McKinsey Global Institute analysis



Robots and advanced automation don't replace jobs as much as they perform discrete tasks once done by humans.
How safe your job is depends on how much you rely on softer skills.

When we ran Alan S. Brown's article, "Robots at Work," in April 2016, the furor over the role of automation in creating industrial unemployment was reaching a crescendo. This year, global trade dominates the headlines, but that doesn't mean that advances in artificial intelligence and robotics have abated. If anything, we are closer than ever to automating away huge sectors of the world of work.

But the focus on vulnerable jobs may be misplaced, according to a recent report issued by the McKinsey Global Institute. The research firm said the best way to assess the impact is by looking at whether robots and computers can do individual activities, rather than complete jobs.

The McKinsey study, *A Future That Works: Automation, Employment, and Productivity*, looked at more than 2,000 discrete work activities that could be lumped into seven high-level categories, from operating machinery in predictable environments to softer tasks such as interfacing with stakeholders and managing and developing people. Different jobs balance those activities in different ways. Manufacturing jobs, for instance, involve a lot of repetitive tasks, while professionals do more data processing tasks and decision making. Yet almost every job involves some portion of each activity.

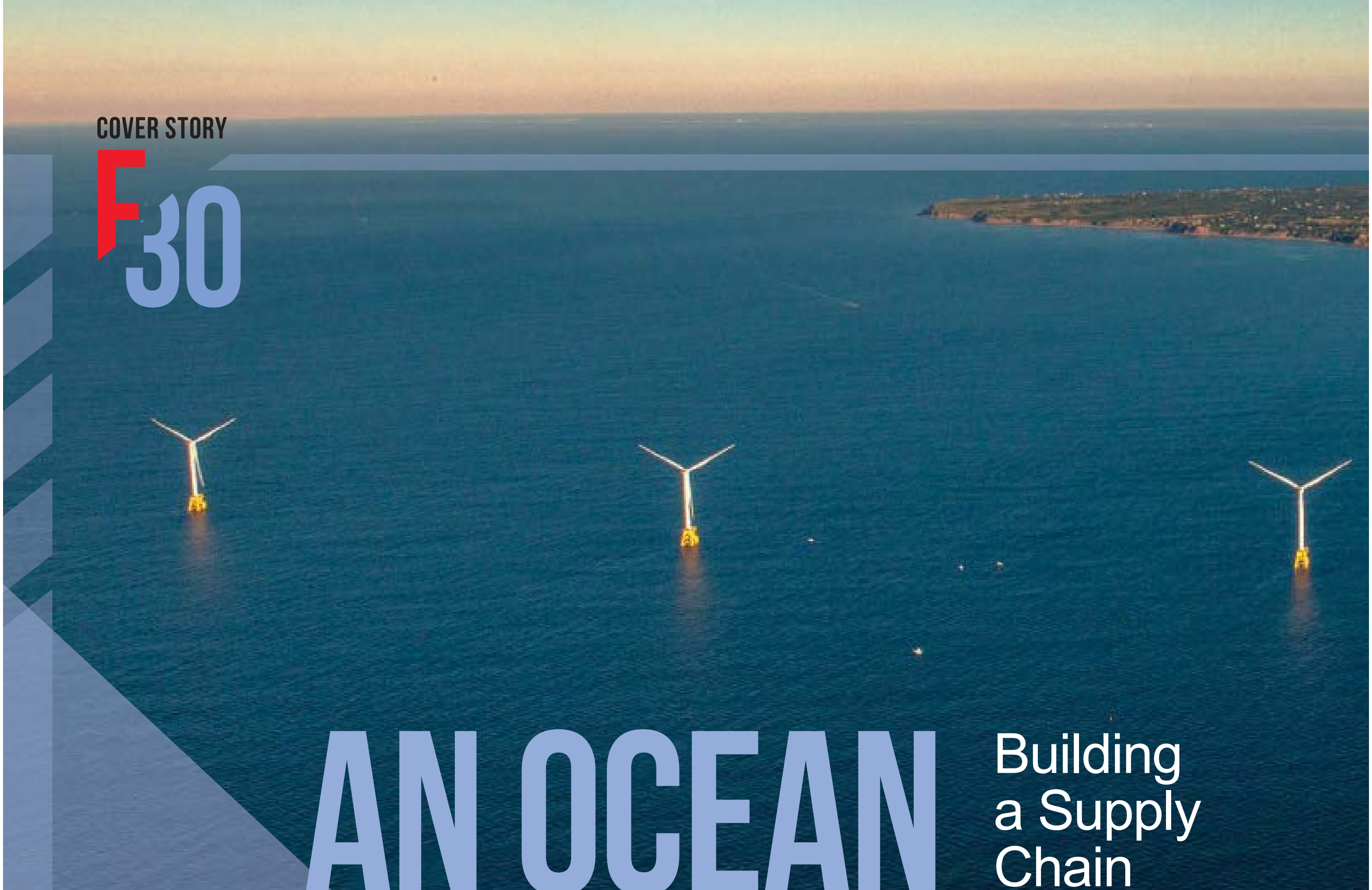
A job's potential for automation depends on the mix. At present, automation looks to be able to replicate most tasks involving collecting data, processing data, and operating machinery in predictable environments. A lot of what Americans do at work every day falls into those categories. According to the McKinsey study, about half the hours American workers spend on the job involve doing tasks in those three categories, and they earn $2.7 trillion per year in wages doing them. Workers in food services, manufacturing, and warehousing spend many hours doing those sorts of tasks, and it is little wonder that robots and artificial intelligence are replacing jobs in those sectors.

The news isn't all bad, however. The McKinsey study suggest that, rather than being a job killer, the wide deployment of automation in the coming decades will boost productivity enough for the gross domestic product in the United States (and worldwide) to grow even in the face of demographic and other economic headwinds. According to the report, "Given currently demonstrated technologies, very few occupations—less than 5 percent—are candidates for full automation today, meaning that every activity constituting these occupations is automated."

By taking away the tasks that are easy to automate, robots and artificial intelligence may enable workers to focus more on what humans are best at. Schools could prepare students for this new emphasis by focusing more on creativity, understanding human emotions, and managing and coaching others.

"As machines take on ever more of the predictable activities of the workday," the report concludes, "these skills will be at a premium. Automation could make us all more human." ME

JEFFREY WINTERS



AN OCEAN OF PROMISE

Building a Supply Chain to Fuel Offshore Wind

On a sunny day last November, Paul Rich stood in a conference room on the site of what had once been the world's largest steel plant, addressing representatives of companies that could make or break the offshore wind industry in the United States.

Rich knew that the first offshore wind turbines in U.S. history would soon begin generating electricity, feeding 30 MW of electricity to Block Island, R.I., a small community about 14 miles east of Long Island's eastern tip. After years of false starts for the U.S. offshore wind industry, getting the first wind farm built and working was a watershed moment.

But Rich was already thinking bigger—much bigger.

Rich's company, U.S. Wind, is owned by a subsidiary of the Toto Holding Group, an Italian large infrastructure construction company. It has made big strides toward building the first utility-scale wind farm in the United States. Rich's team plans to build a forest of up to 187 turbines, starting 15 miles off the coast of Ocean City, Md. The wind farm will ultimately cover 125 square miles and deliver 750 MW of electricity to the grid—enough to power 500,000 homes.

As U.S. Wind's director of project development, Rich is in charge of getting the wind farm built. But he doesn't want to stop there. He wants to build an industry.

For that, he needs a functioning supply chain. "Without local manufacturing capacity, there's no real incentive to build offshore wind," said Keegan Kruger, a global offshore wind analyst at Bloomberg New Energy Finance.

In the United States, however, a supply chain for offshore wind is nowhere to be found. Rich wants to create one.

For that reason, he had invited major offshore wind vendors, including leading

manufacturers of wind turbines and specialized underwater electrical cables, as well as shipbuilders, steel companies, and marine-services companies, to a meeting in Maryland. About 30 people made the trip to the 3,100-acre Sparrows Point site, the former home of a sprawling Bethlehem Steel plant. A company called Tradepoint Atlantic had purchased the site, renamed it after itself, and was redeveloping it into an ultramodern logistics park accessible by road, rail, and ship.

In a conference room in Tradepoint Atlantic's marketing center, Rich told the attendees that as a former steel plant, the site was perfect for manufacturing heavy offshore wind turbine parts, including 250-ton foundations and 500-ton sections of turbine tower—not just for Maryland, but for the entire East Coast. It also came equipped with a 750-foot pier with a 40-foot-draft harbor. This, he said, made it ideal for the specialized deep-draft vessels called liftboats that carry the massive nacelles, tower sections, and turbine blades out to sea.

Establishing an offshore wind supply chain would do more than launch an industry.

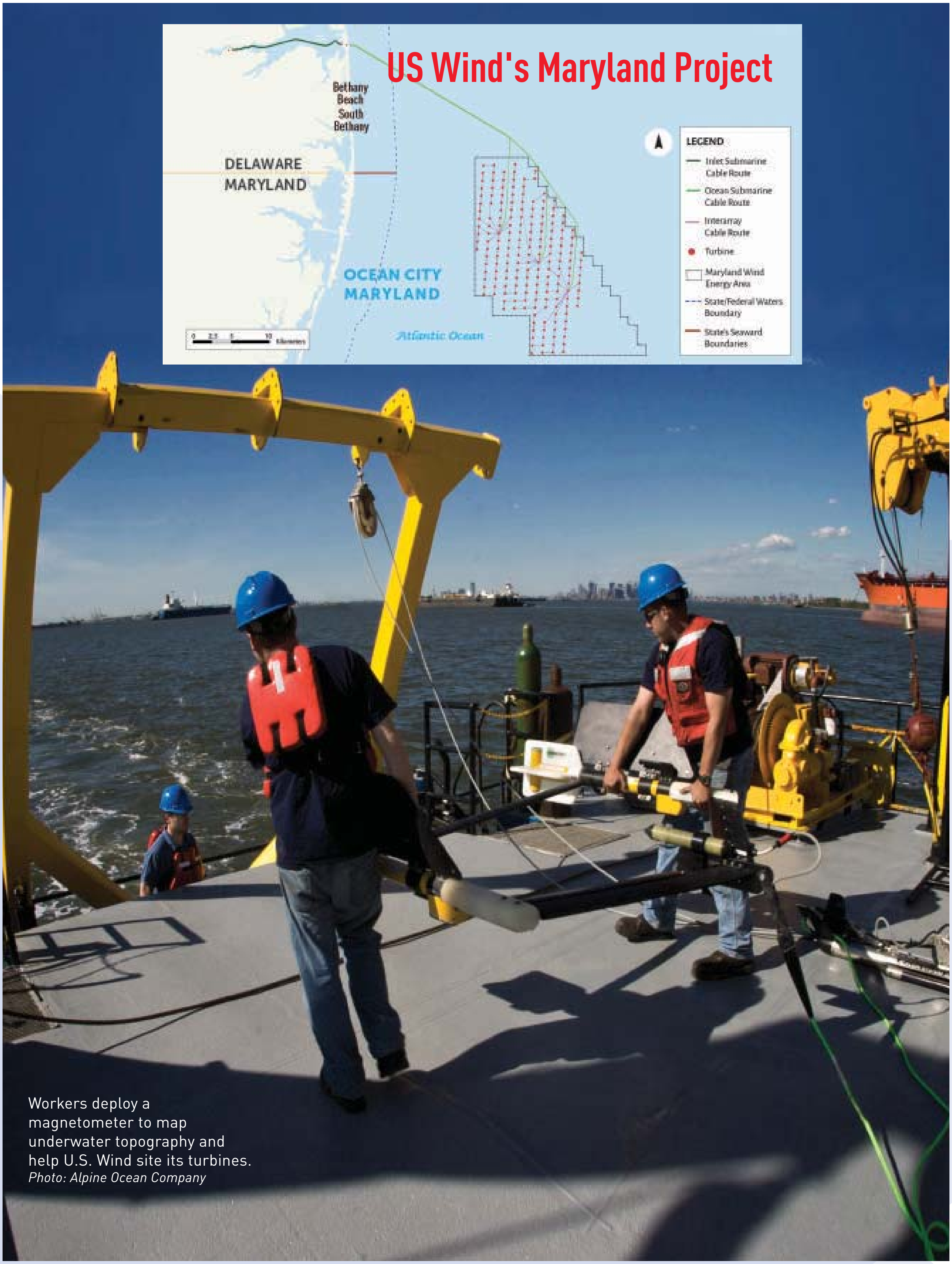
Deepwater Wind's Paul Murphy beams after leading efforts to build the Block Island Wind Farm.

It could also spur development of better ways to manufacture turbine parts, ship them to sea, assemble them, and maintain them. This could create jobs for engineers of all stripes, including civil, electrical, and mechanical engineers. "The opportunities for engineers across the board are endless," said Elizabeth Burdock, executive director of the Business Network for Offshore Wind.

Endless, that is, if the industry can get off the ground.

BLOCK ISLAND BREAKTHROUGH

Since the world's first commercial offshore wind turbines began spinning off the coast of Vindeby, Denmark, in 1991, the European offshore wind industry has evolved into a juggernaut. Today, the seas off the coast of Europe are home to 3,600 offshore wind turbines—90 percent of the world's total.



Workers deploy a magnetometer to map underwater topography and help U.S. Wind site its turbines.
Photo: Alpine Ocean Company

Those turbines have a total nameplate capacity of 12.6 GW, as much as 15 coal-fired power plants, and the Europe's offshore wind industry supports 58,000 jobs, according to data collected by the European Wind Energy Association.

What's more, the entire industry continues to grow. Last year global capital spending commitments on offshore wind reached $29.9 billion, up 40 percent from 2015, according to research by Bloomberg New Energy Finance.

The U.S. Department of Energy estimates that the United States has 404 GW of offshore wind power capacity—enough, in theory, to generate all the electricity currently consumed nationwide. But development of the first proposed major offshore wind farm, the Cape Wind project off the coast of Massachusetts, ground to a halt in 2015. Cape Wind's developers had gone big, planning a 131-turbine array across Nantucket Sound, and a coalition of wealthy local residents sued, in part to keep the wind farm from intruding on their ocean views. Ultimately, local utilities backed out of their power purchasing agreements, and financing for the project dried up.

In contrast, the Block Island wind farm's developers, Providence, R.I.-based Deepwater Wind, went small from the start. The company focused on an island community whose 1,000 residents relied on expensive electricity from diesel-based generators. Offshore wind, which produced significantly more expensive electricity than onshore wind, solar, or natural gas, was cheap by comparison.

The company spent several years navigating a maze of regulatory hurdles, gaining approvals one by one from more than 20 federal, state, and local government agencies.

Obtaining the turbine components was no easy task, either.

Offshore turbine components, including components of the five 6 MW GE Haliade turbines used at the Block Island wind farm, are manufactured in Europe to be close to the flourishing market there. This meant that Deepwater Wind had to import all of them.

For instance, the 600-ton nacelles, which sit atop 150-meter towers and contain the equipment that generates electricity, needed to be fabricated at a GE factory in France. To transport the nacelles from France to Rhode Island, Deepwater Wind hired a specially constructed vessel called a liftboat from a Norwegian firm called Fred. Olsen Windcarrier.

"Onshore, you rent a crane, drive it out to the site, and you move the turbine. Offshore, you need a liftboat."

— Paul Murphy, Deepwater Wind

Liftboats are designed to sink long legs to the sea floor, then jack the boat out of the water to create a platform stable enough for a large crane to operate.

Separately, the 27-ton turbine blades—15 in all—were manufactured in Denmark and transported by special trailer to a Spanish port for transport across the Atlantic.

ASSEMBLY REQUIRED

Assembling the turbines was also challenging, and the lack of local expertise didn't help. "Onshore, you rent a crane, drive it out to the site, and you move the turbine," Paul Murphy, Deepwater Wind's lead engineer, said. Offshore, you need a liftboat.

Since liftboats in the U.S. are primarily used to construct and maintain oil and gas platforms, they are generally based in the Gulf of Mexico rather than the East Coast. For that reason, in July 2015 Deepwater Wind called Joseph A. Orgeron, chief technology officer of a Louisiana firm called Montco that builds and operates liftboats.

The turbine towers are anchored by a four-pile jacket—a steel lattice foundation that needs to be nailed 200 feet into the sea floor with heavy steel piles. The first firm Deepwater hired struggled to do that from a floating barge, so it called Orgeron, who sent Montco's biggest liftboat, the L/B *Robert*.

The liftboat traveled two weeks from the Gulf to the work site, which was three miles off the coast of Block Island. There, it inserted the foundation's piles, affixed a giant hydraulic hammer to a deck-mounted crane, and hammered the piles into the sea floor.

A federal law called the Jones Act prohibits foreign-built or foreign-flagged vessels like the Maltese-flagged *Brave Tern* from transporting cargo between two points in the United States. To avoid violating that law, Deepwater Wind later hired two of Montco's smaller liftboats, which were U.S.-flagged, to deliver the turbine towers and blades from a dock in Providence to the work site. On one of the liftboats, Montco had to design and custom-build a box-beam cantilever and a carrier to transport the three blades, each as long as a football field, that attach to each turbine.

Ultimately, the *Brave Tern* and the three Montco liftboats assembled the five turbines. After four months of testing, the first commercial U.S. wind farm began spinning in mid-December 2016, generating up to 30 MW of electricity to power the homes of Block Island's 17,000 residents.

Policies can entice turbine vendors and blade manufacturers to bid on more U.S. projects.

"Now that they've got steel in the water and turbines installed and generating electricity, it changes the landscape," Orgeron said. But there's still no U.S.-based supply chain, so it's still not enough to build an industry.

MAKING MARKETS

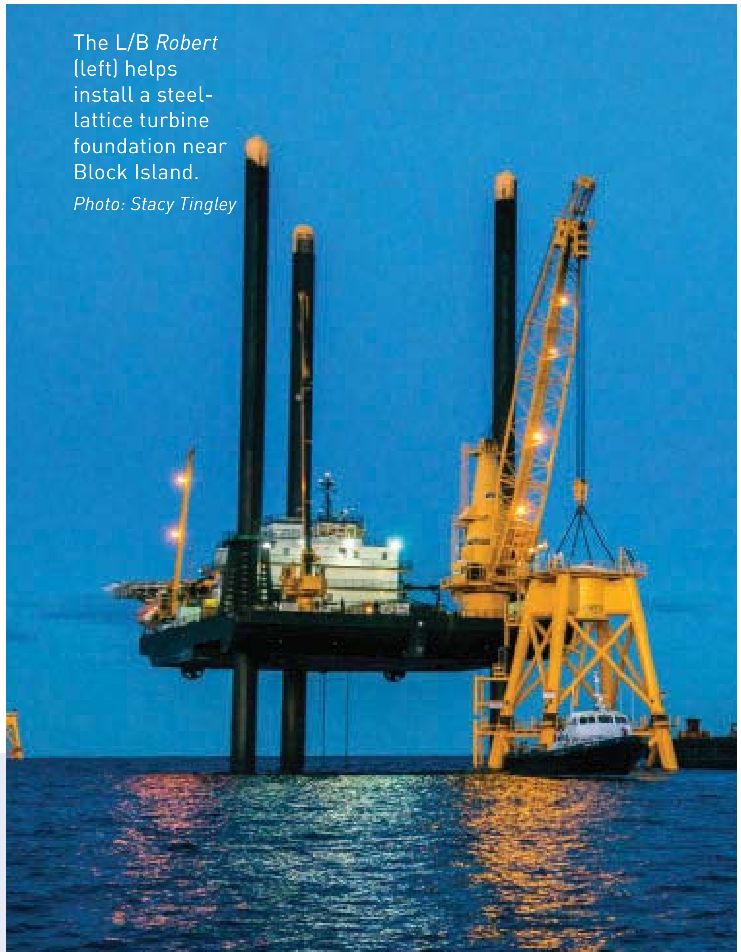
During the Obama administration, the Federal government pushed policies friendly to offshore wind, most notably by empowering the Bureau of Ocean Energy Management, a division of the U.S. Department of the Interior, to begin leasing tracts of U.S. coastal ocean to wind-farm developers. But in spite of the support, wind farms were not being built.

In 2014, Stephanie McClellan, director of the Special Initiative on Offshore Wind at the University of Delaware in Newark, launched an investigation to find out what was holding the U.S. offshore wind industry back. States, she found, were dragging their feet.

"State policymakers were saying, 'This is really expensive and we don't know what to do,'" McClellan said.

After investigating conditions in the industry in Europe and the United States, McClellan and her colleagues reported in early 2015 that states that put in place policies to reduce the cost and financial risk of building an offshore wind farm could slash project financing costs and ultimately cut the levelized cost of electricity by 50 percent.

Since the report came out, state policies have finally begun to shift. Last year Massachusetts Governor Charlie Baker, a Republican, signed legislation requiring the state's utilities to buy a total of 1.6 GW offshore wind capacity by 2027.



The L/B *Robert* (left) helps install a steel-lattice turbine foundation near Block Island.
Photo: Stacy Tingley

New York State, for its part, has committed to obtaining 2.4 GW—the output of three large coal-fired power plants—of offshore wind power capacity by 2030. In January, at the urging of Governor Andrew Cuomo, the Long Island Power Authority approved Deepwater Wind's plan to build a 90 MW wind farm 30 miles off the eastern tip of Long Island.

By guaranteeing large and sustained markets for offshore wind, policies like these can entice large turbine vendors, blade manufacturers, and other major offshore wind vendors to bid on more U.S. projects, McClellan said.

GOING LOCAL

As the offshore wind power industry grows, costs continue to fall, in part because engineers in the industry are developing better and cheaper technologies. For example, offshore turbines have been getting larger and more efficient, enabling them to produce more electricity—and revenue—per turbine, while also lowering both construction costs

and operation and maintenance costs.

Turbines that produce 5 MW of electricity were standard just five years ago. Block Island's turbines produce 6 MW, and 8 MW turbines are already being installed commercially in Europe. In December 2016, a 9 MW turbine from MHI Vestas Offshore set a world record by producing 216,000 kilowatt-hours of electricity in 24 hours—enough to meet the daily demand of 7,300 average American homes.

Offshore substations are also getting smaller and cheaper.

Substations funnel electricity from individual turbines into transmission cable connected to shore. Early offshore substations were designed like their counterparts on land, complete with diesel generators, a room for the operator, and even a helicopter landing pad. Siemens got rid of all that to create a one-story, 700-ton platform with a single, air-cooled transformer that can be mounted on the same foundation as a wind turbine. The smaller substation can cut grid-connection costs by tens of millions of dollars.

Meanwhile, experience and better logistics are making the European offshore wind supply chain more efficient. And the financing costs of wind farms, which can run in the hundreds of millions of dollars, have dropped over the last five years as project financiers "get an adequate grip on the risk associated with construction," said Bloomberg's Kruger.

Experience and better logistics are making the European offshore wind supply chain more efficient.

As costs tumble, Paul Rich and his colleagues at U.S. Wind are stepping up their effort to launch the industry in Maryland.

They're working to lure supply-chain companies to Tradepoint Atlantic so they can turn to local sources for turbine components and vessels, and ship the massive components to sea right from the site's waterfront. To manufacture wind-turbine tower sections, for example, "we can get flat steel from Pittsburgh brought in," Rich said. "We can get a manufacturer here to roll it into tubular forms, weld it, paint it, coat it, and put on all the accessories."

Ultimately, Rich said, Tradepoint Atlantic could make Baltimore a national offshore-wind center like Esbjerg, Denmark, which shipped more than 65 percent of the wind turbines manufactured in that country in 2015, thanks to its deep-water port, specialized turbine-assembly, shipping facilities, and resident offshore companies that share expertise.

"Baltimore will be a vibrant steel manufacturing and hopefully turbine manufacturing center" with government-funded R&D facilities, and it will serve the entire East Coast, Rich said.

A thriving offshore wind industry will also demand engineering expertise. Engineers will need to ensure that the installation process minimizes lift-boat time, which can cost $250,000 a day. Innovations are also needed to ensure gears fit, turbines swivel properly, turbine blades adjust to catch the wind, and more.

"I see offshore wind rapidly advancing on an industrial scale," Rich said. "Meanwhile, we're ready to put people to work right now." ME

DAN FERBER is a senior editor at *Mechanical Engineering* magazine.

Stall and surge are endemic scourges of jet engine and gas turbine operation.

By Lee S. Langston

Modern jet engines are so reliable that airline pilots can fly an entire career without experiencing an engine failure or having to shut down an engine for a minor problem. Most passengers never have to experience mechanical failure except as the reason for an otherwise unexplained grounding of a flight.

Engine failure—especially one caused by engine stall and surge—may be rare, but it is unforgettable.

Recently, I started discretely asking people in the gas turbine community about stall and surge incidents they had encountered. A retired pilot I know described to me one event, on a flight from Portland bound for Tokyo. He said that during the takeoff run, a single Herring gull was "ingested" into one of the engines. In a blink, the cowling blew right off the front of the engine and destroyed the tires of the landing gear. The takeoff was aborted.

The problem wasn't the bird itself. Jet engines are designed to withstand strikes from small birds like gulls (though the birds are not designed so resiliently). Instead, the bird disturbed the flow of air entering the engine and the compressor experienced a stall. In an instant, superheated gases from the combustion chamber that normally power

OUT through the INTAKE

One engine of this C-17A suffers a compressor surge while taxiing on an airfield.
Photo: Will Mallinson

the turbine in the rear of the engine surged forward.

Stall and surge are two words that catch a gas turbine engineer's immediate attention. Those two types of air flow disturbances in the axial compressor of a jet engine or gas turbine represent the breakdown of orderly flow through them. Modern design and fuel control systems try to keep a jet engine or an electrical power gas turbine away from operating conditions that bring about stall and surge. But they don't always succeed.

I have been thinking about stall and surge ever since the most recent International Gas Turbine Institute Scholar Lecture, when Ivor Day of the Whittle Laboratory at Cambridge University summarized the progress that has been made in understanding the phenomenon and highlighted some steps that are being taken to control it. In spite of those efforts, stall and surge present a challenge to the gas turbine research community and a worry to jet engine designers.

Under pressure

Gas turbines can produce power over many orders of magnitude, from kilowatts to hundreds of megawatts. The useful output is, however, only a fraction of the power produced by the turbine component of the machine. Some 50 to 70 percent of the turbine output

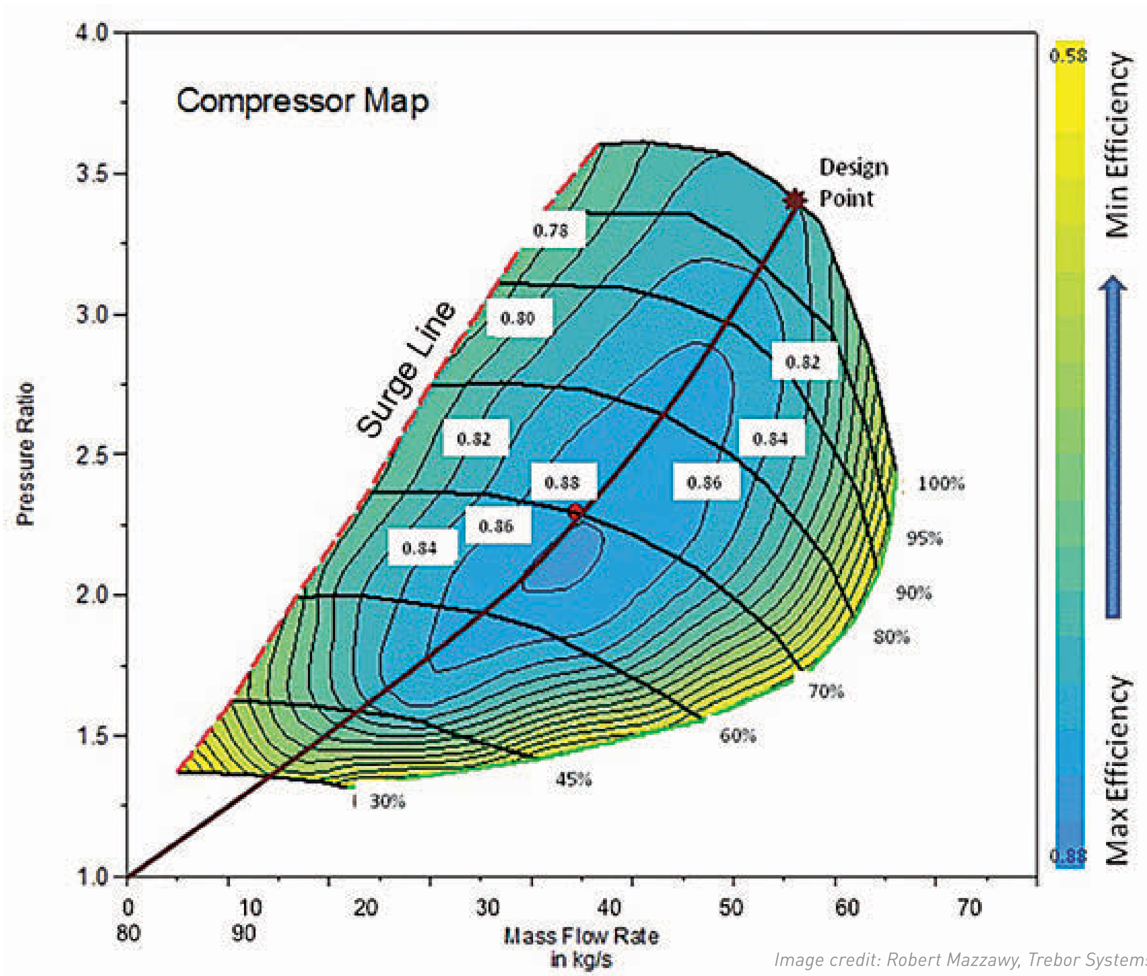


Image credit: Robert Mazzawy, Trebor Systems.

is diverted to drive the axial flow compressor upstream. Compressing a gas is not easy.

Axial compressors get their name because the path of flowing gas runs more or less in a straight line parallel to the gas turbine's axis of rotation. The compressor is assembled from stages, each comprised of a ring of moving rotor blades mounted on a rotating disc or drum and a downstream ring of case-mounted stationary stator blades simply known as stators. The rotor blades act on the gas path air flow, increasing its static pressure, total pressure, and kinetic energy. The stators remove blade-induced swirl velocity, and thus decrease the kinetic energy, while serving to increase static pressure and align airflow for blades in the next stage.

Each additional stage increases both static and total pressure of the gas path. Typically, for industrial gas turbines, each stage operates in a pressure ratio range up to about 1.4:1. Air entering a six-stage compressor with a pressure ratio of, say, 1.2:1 would see an overall compression of 1.2 raised to the power of 6, or 2.99 times the initial pressure.

The thermal efficiency of a gas turbine is directly tied to the overall pressure ratio, which creates an incentive to maximize compression. Some 70 years ago, an axial compressor with 15 stages might have an overall pressure ratio of 4:1. Today, a 231 MW GE 7F.05 gas turbine has a 14 stage compressor with an overall pressure ratio of 18.4:1 and for jet engines the ratio can be as high as 58:1. As a consequence, gas turbine efficiencies have more than doubled.

Together, the compressor blades and stators operate on the gas path flow to produce what

Over the course of the testing, **engineers will determine** for each pressure ratio the **air flow rate below** which the compressor **fails to operate properly**.

aerodynamists call an adverse pressure gradient in the flow direction—they turn low static pressure air into high-pressure air. It's analogous to pushing water up an inclined channel, with many small, rapid brush strokes. If the incline is too steep, the water runs backward, down the slope. (By contrast, the turbine operates in a decreasing, favorable static pressure field—as the expanding combustion gases act to turn those blades, their static pressure decreases.)

No matter how advanced axial compressors become, they must be carefully controlled in their operation to avoid the power-robbing effects of stall and the convulsive effects of complete flow reversal, brought about by surge.

At the boundary

What does this convulsion look like? Another correspondent described a videotape of the first few minutes of an airline flight shot through a cabin window by a passenger. First, the runway streamed by during takeoff and the jet began to climb. "Suddenly the inboard right engine gives out a boom," he wrote, "and sheets of flame start pulsating out of the engine as the countryside and fields below fall away." Alarmingly, as the video continued, the ground (and farm animals in nearby fields) started to get closer even as the nose of the plane continued to point up. Eventually, the plane recovered enough altitude, though not before the tower crew, which saw the plane dip below the tree line, alerted emergency responders of a probable crash.

To avert disaster (and near disasters like the one above) any gas turbine company that designs a new compressor will test it thoroughly, varying air flow rates and rotor speed to measure pressure ratio and efficiency, creating what they call a compressor map. Over the course of the testing, engineers will determine for each pressure ratio the air flow rate below which the compressor fails to operate properly.

In industry parlance, that's called the compressor surge line, and that line is labelled as such as it runs across the compressor map. But the actual phenomenon it measures is aerodynamic stall.

To understand why, consider the streamlines of the air flowing across the compressor blades. Going from low pressure at the blade's leading edge to a higher pressure at its trailing edge, the streamlines closely follow the blade's suction and pressure surfaces.

The flow around the blade is controlled by its boundary layer: the very thin, almost immeasurable layer of air on the blade surface, where viscous frictional effects are concentrated. Within the boundary layer, the air velocity relative to the blade decreases from that of the external streamlines, to zero at the blade surface. The concept of the boundary layer was discovered by the engineer Ludwig Prandtl in 1904, at an appropriate time to profoundly influence the design and operation of aircraft—and turbomachinery.

In aircraft, when the angle of attack exceeds a certain level, the boundary layer (which is exceedingly sensitive to an adverse pressure gradient) separates from the airfoil and the wing loses lift; the plane stalls. The same effect plagues axial compressors. Generally, what changes the angle of attack within a compressor is a reduction in air flow due to a blockage downstream in the combustor or turbine or an interference to the upstream air inlet. Roughness on the compressor blades or too large a gap between the rotating blades and the engine casing can also disrupt the boundary layer. Regardless, when the boundary layer separates from the surface such that the streamlines no longer follow along the suction side of the blade, the compressor blade is stalled.

When an airplane stalls, the aircraft loses altitude. If the pilot cannot restore lift across the wing, the plane will crash.

A stalled blade in an axial compressor loses its ability to increase a pressure gradient. What then?

With the **axial flow so disrupted**, flames from the combustor can shoot out the back of the **turbine outlet,** or even forward through the **compressor inlet.**

As Ivor Day explained in his IGTI Turbo Expo talk, a stall disturbs the compressor flow in the tangential direction, while the average axial airflow through the compressor remains steady. But a stalled compressor blade can itself create a blockage which diverts the approaching stage flow. This can trigger separation in adjacent blades opposite to the direction of rotation on the same rotor, creating something called a stall cell.

In certain circumstances, that stall cell will start to move, rotating in the opposite direction of the compressor and at half its rotational speed. Needless to say, those rotating stalls can lead to greatly shortened blade life, through increased stress and vibration.

In extreme cases, however, rotating stall can cause the compressor flow to fail altogether, disturbing the airflow in the axial direction. The airflow rate will pulse on millisecond timescales—sometimes so violently that the flow through the compressor is reversed. (This reverse flow is often accompanied by a loud bang, like a backfire.) With the axial flow so disrupted, flames from the combustor can shoot out the back of the turbine outlet, or even forward through the compressor inlet.

That degree of compressor flow failure is called a surge. It is to be avoided.

Measured in milliseconds

Another surge incident I learned about involved an airliner with an engine that had undetected erosion in the lining of its compressor casing. As the plane took off on a transcontinental flight, the engine let out a loud bang—then 57 more in the 70 seconds it took the pilot to shut down the engine. The crippled plane had to circle and dump fuel for an hour before it was able to make a single-engine landing.

How can we avert these sorts of engine failures?

Stall and surge emerge from basic physics: the behavior of the boundary layer on the compressor blades and stators. Current technology has no means to completely eliminate it.

Right now, gas turbine manufacturers resort to trial and error, plumbing the contour of the surge line of a compressor through extensive testing to determine what conditions to avoid. Engine control systems, such as the Full Authority Digital Electric Control, or FADEC, are programmed to keep the operating point of the compressor well away from the surge line. Mechanical systems within the engine, such as compressor bleeds, casing treatments, tip clearance controls, and variable pitch stators that control the direction of airflow to rotors are all used to avoid stall conditions.

Those mechanical systems work within the blink of an eye. The time needed to adjust a

A Sukhoi T-50 PAK FA suffers a compressor surge. *Credit: Wikimedia*

variable stator or a bleed is on the order of 200 milliseconds.

That is not fast enough.

Researchers have been studying stall and surge for decades, looking for ways to predict and combat the phenomena. According to Robert Mazzaway of Trebor Systems, who in 1980 was one of the first to report on the engine stress created by surges, researchers have found that subtle modal waves lead to the rotating stall that precipitates surge. Detect those waves, the thinking goes, and FADEC could act to prevent the stall. Unfortunately, a rotating stall develops over the course of just a handful of rotor revolutions—which take only 20 milliseconds for an industrial gas turbine and only 5 millisecond for a jet engine. There's not enough time, then, for the mechanical systems to counteract the rotating stall and ensuing surge.

Even so, there has been some success in using FADEC to either prevent a stall and surge or to limit the number of repetitions. In twin-spool engines, for instance, stall can be caused by a mismatch between the rotation rates of the low-spool and high-spool rotors, usually due to a disruption in the fan stream. In such cases, however, the low-spool rotor increases it rotational speed slowly enough for the FADEC to sense the mismatch in RPMs between the spools and take measures to counteract it.

FADEC can also step in during flights in heavy rain or hailstorms. In those conditions, extra fuel is needed to process and evaporate the water being swallowed by the engine. The electronic control system can sense the mismatch between the power setting and the fuel flow and take action to prevent possible engine instability.

Fortunately for me, my interest in stall and surge is one of curiosity, spurred by Ivor Day's comprehensive IGTI lecture. For others, however, it is a vivid experience that still raises the hairs on the back of their neck.

"It felt just like we had hit a telephone pole with the right wing," one acquaintance told me about a surge event on a flight he was on. "It was short and abrupt, but scary as hell." **ME**

LEE S. LANGSTON is professor emeritus of mechanical engineering at the University of Connecticut in Storrs and a frequent contributor to *Mechanical Engineering* magazine.

TO LEARN MORE

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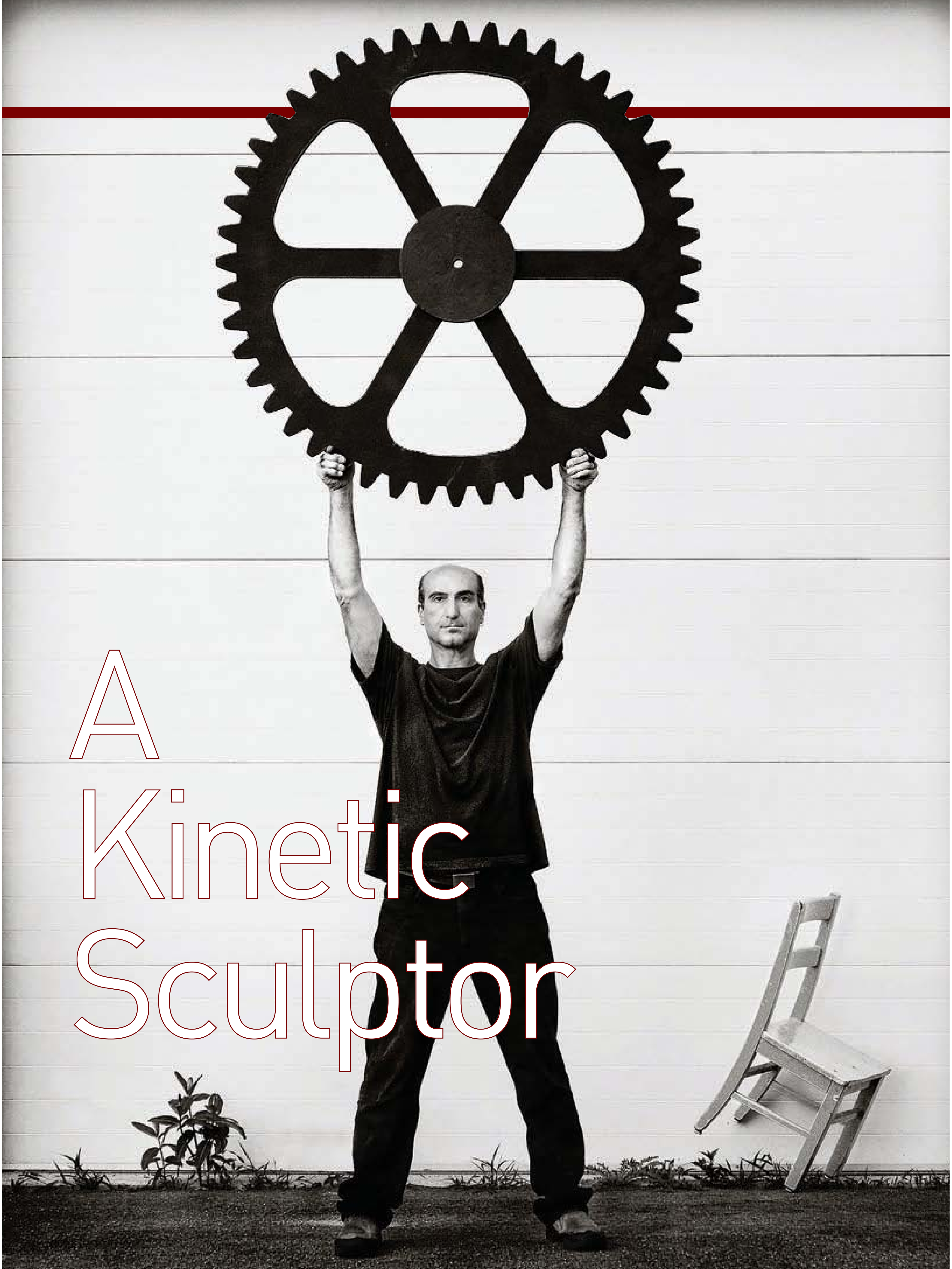


A Kinetic Sculptor

The fundamentals of mechanical engineering inform every piece of Arthur Ganson's moving sculptures.

By Jeff O'Heir

Photos By Chehalis Hegner

Just like their maker, the mechanically complex and quirky works of Arthur Ganson are filled with contradictions.

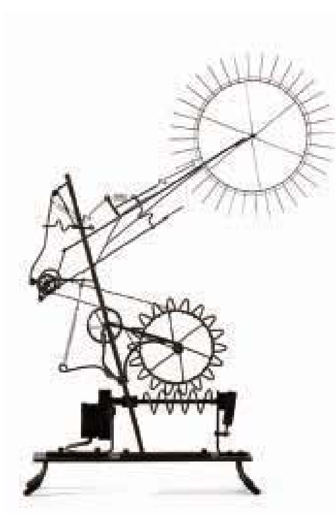
Take, for example, one of his most popular pieces, "Machine with Wishbone." Ganson secured the legs of a turkey wishbone with a wire harness and connected it to a set of spindly flywheels riding on a simple chassis. The flywheels spin, the harness pulls, and the wishbone takes one lumbering step after another.

Perhaps the frail wishbone is engaged in the Sisyphean task of perpetually dragging around intrusive technology. Maybe the benevolent machine is helping the wishbone complete its lonely journey. In Ganson's world, there's no one right answer.

The way he builds his kinetic sculptures makes it easy to interpret them in any of these ways, and that speaks to the contradictions in the man himself.

Ganson, who is as much an engineer as he is an artist, works with unpolished steel, found objects, homemade gears, and roughly soldered wires. Yet he assembles them with such care that their movements create an elegant and mesmerizing beauty. His machines may reflect strong and dark emotions, but they share a sense of humor that draws smiles, if not outright laughter.

"There's something very clear in every machine, and there's also something that's also very open-ended," Ganson said. "The clarity allows people to grasp and hold onto something, while the ambiguity allows them to create their own story and their own meaning."



Portrait of J.H.

Whatever theory lies behind the work, people like what they see. Audiences, such as the one at a TED Talk Ganson gave a few years back, often cheer and clap when they see videos of his sculptures. Twenty-one of his pieces have been featured by the MIT Museum since it opened in 1995, and the museum's 140,000 yearly visitors consistently rank it as their favorite exhibit.

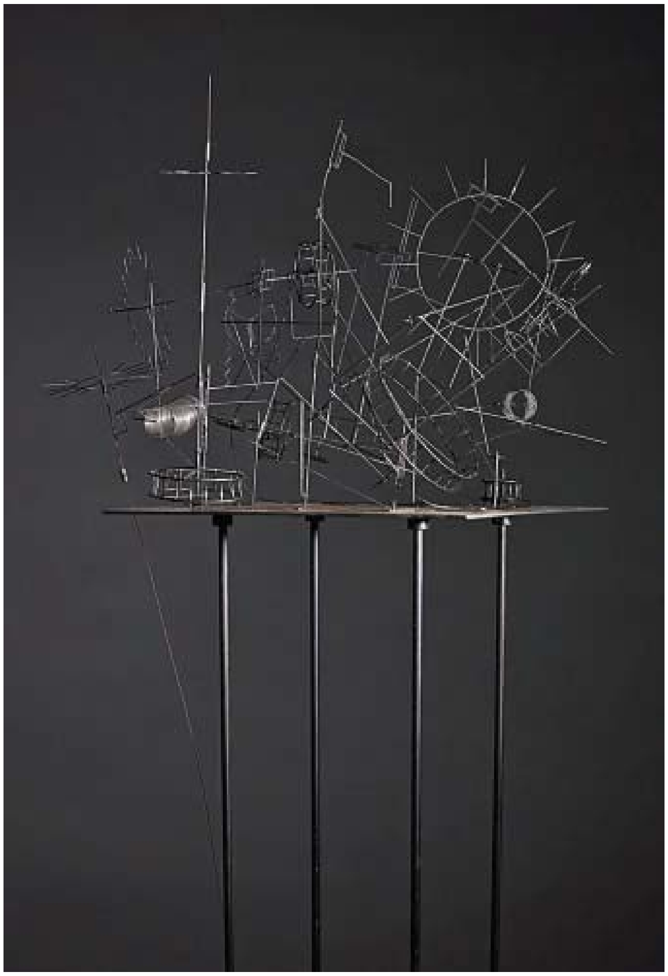
"We don't like having to close that exhibit," museum director John Durant said after reopening "Gestural Engineering: The Sculpture of Arthur Ganson" after months of renovations. "We have too many disappointed visitors."

Despite nearly 40 years of creating popular sculpture, Ganson is still considered an outsider as an artist.

His permanent installations tick, whiz and hum at the National Inventors Hall of Fame in Ohio and at the Smithsonian Institution's Lemelson Center for the Study of Invention and Innovation. His work has been featured at numerous museums and galleries around the world, and he has even appeared in "Muffy's Art Attack," an episode of the children's cartoon *Arthur*.

Still, Ganson's work has never been considered part of the mainstream or championed by the day's tastemakers.

"He doesn't follow what those in the art world follow," said Jeff Lieberman, a fellow kinetic sculptor who helps run Ganson's F.A.T. (Friday After Thanksgiving) Chain Reaction, a yearly event that brings aspiring engineers of all ages onto the MIT campus to create a massive Rube Goldberg device. "He doesn't seem to care about any trends. He's off doing his own thing and not subject to the same types of rules. He's an outsider artist."



Fragile Machine

While most engineers spend their careers hiding the pieces that make their machines move, Ganson reveals his.

But if art's mainstream doesn't seem to know what to make of him, Ganson knows who and what he is. Like Henry Ford, Cyrus McCormick, and Eli Whitney, he is a self-taught mechanical engineer.

"All the concerns and thoughts I have are a subset of the world of mechanical engineering," Ganson said. "Any mechanical engineer looking at the sculpture will find an echo or mirror of the engineering process."

The main appeal of Ganson's work lies within yet another contradiction. While most engineers spend their careers hiding the pieces that make their machines move, Ganson reveals his. The clever combination of spinning wheels, creeping chains, and revolving cranks and cams unveils the mystery of the machine.

"Arthur hides nothing," said MIT's Durant. "He's interested in exposing as much of the work as possible so that you get the intricacies of mechanical engineering. That intrigues people."

In "Corey's Yellow Chair," for example, a tiny chair hovers above a black board, surrounded by a star-shaped chain. At each of the star's six points, a set of gears drives a metal arm and rod attached to a precut section of the chair. As the chain advances, the arms rotate and send sections of the chair flying to the edge of the board. There, they spin slowly, then rapidly fall back into place.

It's like watching an explosion moving both forward and in reverse. Ganson says it's an attempt to capture the essence of vision.

In another work, "Machine with Oil," a wire arm slowly swings into a small trough filled with oil. When the chain-driven gear raises the arm to the top of its cycle, the trough empties its load, bathing the machine's parts in a rich, thick coating of 70-weight motor oil. As Ganson wrote in a short vignette about the work, "For a machine, could there be anything more satisfying?"

Whatever humor or meaning Ganson's sculptures impart, movement is their most important element.

"It is one of the things that initially draws people into my work," he said. "It's based on the long association we have with machines in our lives. My sculptures are machines, but they have a function that's not perceived as utilitarian. There's a humor that's inherent in a machine when it's not functioning in a utilitarian way."

In fact, his sense of humor is what led to the walking wishbone. Ganson came up with the idea during a Thanksgiving dinner, while playing with his food. He could make the turkey wishbone waddle like a cowboy, and wondered how he could make it move on its own.

Communicating through Movement

Ganson himself is as contradictory as his work and career. He's tall and bald. When he lets his mustache grow in, he looks a bit intimidating. His hands are big and his nails usually dirty. But he uses his long fingers to patiently bend wires into gears or delicately craft small pieces of metal into sculptures that typically stand less than two-feet tall.

You could picture him working on a construction site with a dog-eared book by Camus stuffed in his back pocket. Or sitting quietly behind a table making a watch. Or playing with a Thanksgiving

"There's a humor that's inherent in a machine when it's not functioning in a utilitarian way."

Machine with Wishbone

wishbone.

When asked about his work, he launches into comprehensive, multifaceted answers. It's clear he likes to talk. But that wasn't always the case.

While growing up in Bloomfield, Conn., he was a painfully shy child who was afraid to talk to other people. He found it much easier and comforting to express himself by drawing pictures and creating simple sculptures from wood, cardboard, and other available materials.

On aptitude tests, Ganson proved a slow reader, but he was quick to figure out the spatial relationships of objects. What he couldn't do with his voice, he did with his hands. "Making things for people and creating with my hands in the safety and solitude of my basement was the safest way to communicate," he said.

During elementary school, Ganson developed his interest in movement. He found new ways to express himself by making a flipbook movie of a speeding car, or an ice sled made from shortened skis propelled by a gas-powered model-

Machine with Roller Chain

airplane engine.

In high school, he became intrigued by more than physical movement. He fell in love with the logic and orderly flow of computer programing. "It's kind of amazing that I didn't get into computer programming," he said. "But there was something missing in it, which was the human contact."

Instead, he took premedical courses and studied art at the University of New Hampshire, with the intention of becoming a surgeon. "I loved working with my hands in very critical situations," Ganson said. Yet he hated the amount of rote memorization that was required for a career in medicine.

As a result, he focused solely on art: "I had found something that allowed all of these different parts of me to come together. A lot of this was accidental. I was just following my intuition."

An assignment for a 3-D design course drew him to mechanical sculptures. For one project, he soldered together wires to make a small car that could be powered by houseflies. For another, he drew up a mock experiment where he glued the end of a pin to a fly and attached it to the blade of a pinwheel. His plan was to heat it to various temperatures to see how temperature affected their flight speed.

"That would never work," he said of the concept. But each project drove him to explore new mechanical possibilities. He soon learned that with the right combination of design, materials and execution, he could create functional mechanical sculptures that represented specific ideas.

A revelation came when one of his art teachers introduced him to the work of Swiss artist and kinetic sculptor Jean Tinguely, whose use of exposed gears and movement immediately influenced Ganson's style, medium, and materials.

"You could do anything with wire," Ganson said. "That opened a part of my brain that loved to solve problems in three dimensions."

The Art of Engineering

If Ganson speaks like an engineer, that's because he is one, despite his lack of a formal engineering education. He spent as an artist-in-residence in MIT's mechanical engineering department. "With every piece I make, I'm in school," he said.

To construct each sculpture and engineer its movement, he relies on the fundamentals of mechanical engineering and physics the same way that a painter uses color theory as a guide for creating a visual effect. The art, for Ganson, is inseparable from the engineering.

"I basically do what mechanical engineers do, but I do it for a different outcome," he said. "In my work, every decision is based on a physical, utilitarian, and emotional aspect: How does it work; how does it feel? I'm always thinking of both."

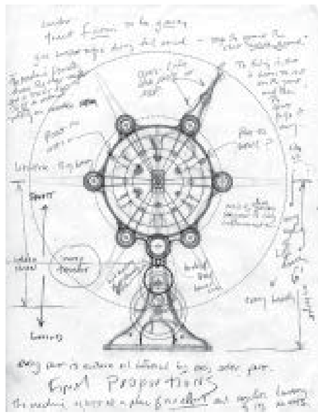
Ganson said this while talking on speaker phone in the kitchen on a sprawling farm north of Chicago, where he moved recently after living for many years in the Boston area. His wife, the photographer Chehalis Hegner, sat within earshot.

"Arthur wouldn't say this," she chimed in, "but I can't tell you how many times engineers from MIT and kids in grade school have said they want to be engineers because Arthur's work inspired them. They say, 'You showed me that engineering can be creative and inspiring.'"

Lieberman, the kinetic sculptor, was one of those students. Lieberman, who was also the former host of the Discovery Channel's *Time Warp*, first saw Ganson's work while visiting the MIT Museum during a campus tour. "I was blown away because it was the first time I saw someone combining engineering and art," he said.

After he was accepted to the school, he would frequently visit the museum to sketch the sculptures, reverse engineering them to better understand how they worked. He applied those lessons while earning MIT degrees in mechanical engineering, physics, math, and media arts and science.

Ganson's work also influenced Lieberman beyond the classroom. "The thing I missed most in my education, which is the most fun thing about learning, is being able to figure out, 'How would I do this,'" Lieberman said. "When I see his work, my brain asks, 'How does he make a wishbone look like it's walking.' It's about the search for how you make something do what you want."



"Machines are an embodiment of my joy and my love for engineering."

Moving Toward the Future

For Ganson, that search continues. He has been exploring new avenues of creativity since moving to the farm. Some of those projects are certain to add new sets of contradictions to his legacy. He spent most of the winter, for example, renovating a few old barns into studios where he'll build larger pieces to flesh out his portfolio of small, intimate work.

He is also planning to mass-produce sculptures of his more popular work to sell online, starting with Cory's Yellow Chair. To produce them, he'll have to develop a more standardized form of manufacturing that will undoubtedly smooth out some of rough, handcrafted features that make his work so approachable.

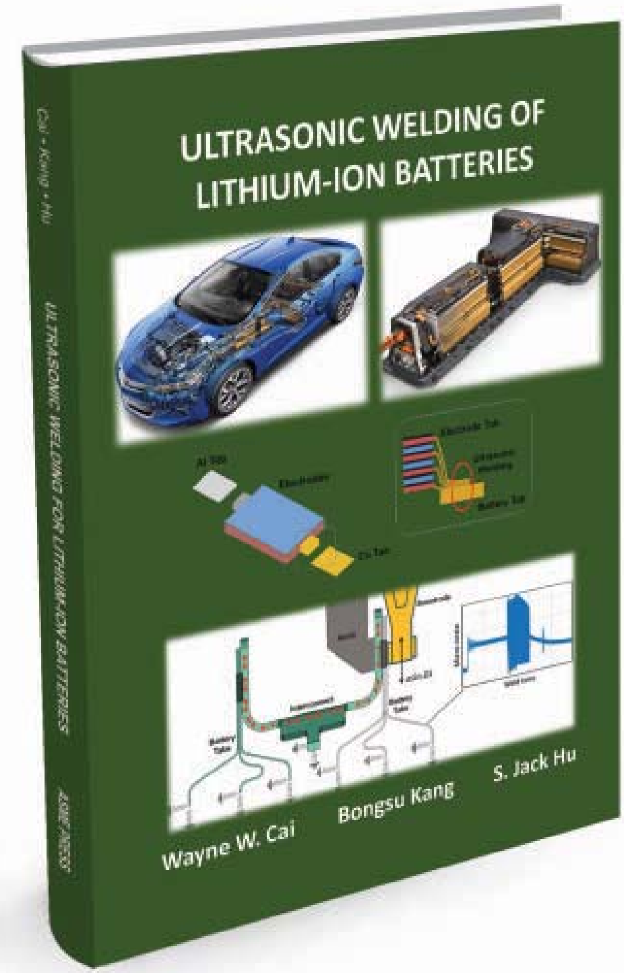
He's also looking forward to getting a 3-D printer. "I can't wait," he said. "But there's another part of me that just wants to bend wire."

With that in mind, Ganson is delighted to report that the farm is inundated with insects. The creatures will give him a chance to revisit his early attempts to harness a bug's energy to drive tiny machines.

"Machines are an embodiment of my joy and my love for engineering," he said. "Maybe that's the most important thing."

And it's also the thing that ties together all of his contradictions. **ME**

JEFF O'HEIR is a New York-based freelance technology writer.



FEATURED

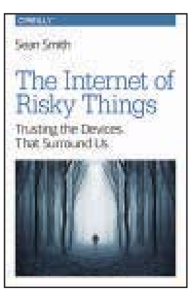
ULTRASONIC WELDING OF LITHIUM-ION BATTERIES

WAYNE W. CAI, BONGSU KANG, AND S. JACK HU

ASME Press Books, Two Park Avenue, New York, NY 10016-5990. 2017.

Lithium-ion battery production has increased rapidly in the past decades as the technology's advantages of high voltage and high energy density make it particularly attractive for electric vehicles. Cost remains a challenge, however, which is why manufacturing processes such as ultrasonic metal welding are getting critical attention. In ultrasonic metal welding, high-power ultrasonic vibration is used to produce relative tangential motion and then frictional heat to create bonds between two or more metal sheets. It is now being used for joining lithium-ion battery cells, modules, and packs. The book focuses mainly on two-layer and multi-layer aluminum (with and without anodizing) and copper (with and without nickel coating) welding configurations, but it may also be of use in developing more effective solid-state joining processes such as cladding, impact welding, and ultrasonic consolidations for additive manufacturing.

264 PAGES. $124; ASME MEMBERS, $99. ISBN: 978-0-7918-6125-7



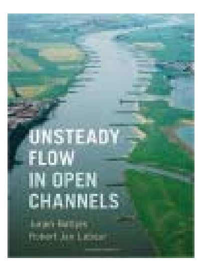
THE INTERNET OF RISKY THINGS

Sean Smith

O'Reilly Media, 1005 Gravenstein Highway North, Sebastopol, CA 95472. 2017.

Don't say we weren't warned: The Internet of Things has been ballyhooed even before it has had a chance to become much of a thing itself. But as Dartmouth professor Sean Smith wrote in *The Internet of Risky Things*, in a few years 25 billion devices will be networked together and monitoring not just cyberspaces, but the real-world aspects of human life. Unfortunately, Smith contends, for a system so vast and vital, little thought has been put into making the Internet of Things secure. "The way we build and deploy devices today won't work at the scale of the envisioned IoT and will backfire," Smith wrote, "and will backfire like so many hidden chemical dumps."

240 PAGES. $29.99. ISBN: 978-1-4919-6362-3



UNSTEADY FLOW IN OPEN CHANNELS

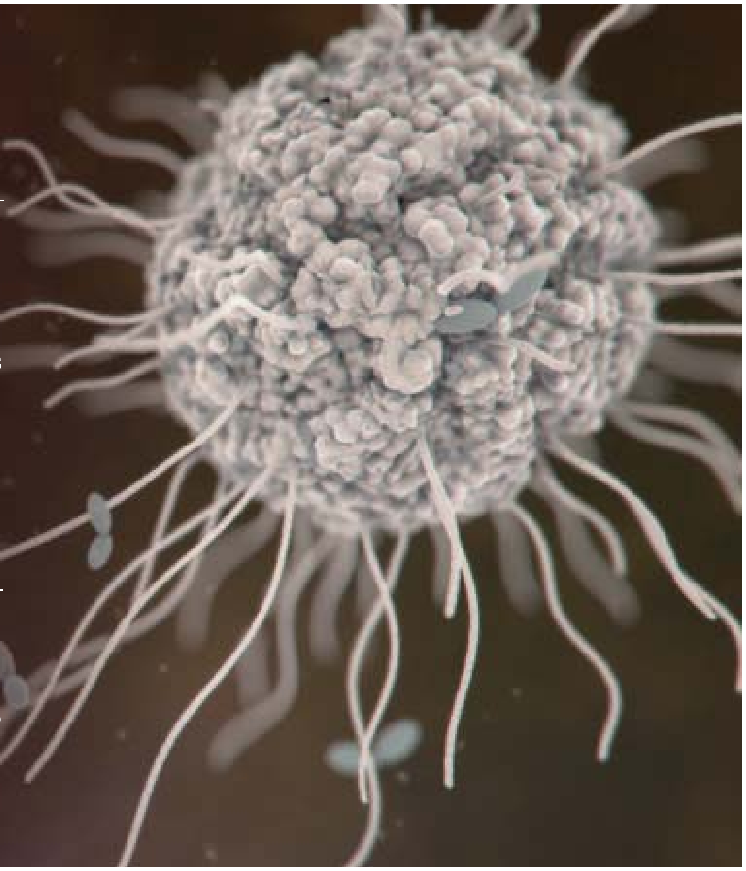
Jurjen A. Battjes and Robert Jan Labeur

Cambridge University Press, 1 Liberty Plaza, 20th Floor, New York, NY 10006. 2017.

Steady flows are easier to model, but natural and manmade canals must handle everything from trickles to surges. Battjes and Labeur work to develop a mathematical model for those unsteady flows and long waves, and they propose a theoretical framework for the different types of shallow flow, providing a coherent approach to interpret the behavior of such flows. The authors intend for the book to be used by professionals at hydraulic engineering works in tidal areas, estuaries, rivers, and canals, and by students who are learning how to work on those systems. The book includes practical examples and is supplemented by online problem sets and computer codes.

304 PAGES. $79.99. ISBN: 978-1-1071-5029-4

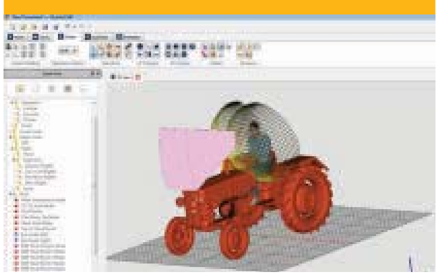
RENDERING



THINKBOX, WINNIPEG, MAN.

Intended to be a go-to tool for meshing particles and fluid simulations, Frost MX 2.0 nearly doubles the performance of previous releases, integrates more deeply with Chaos Group's V-Ray, and introduces new workflow improvements for greater ease of use. The application's integration with V-Ray v3.1 and higher enables customizable particle scattering for distributing and rendering millions of mesh instances in a custom geometry meshing mode. Frost MX 2.0 continues to support all custom geometry features in V-Ray Instancing mode, including particle channel propagation, material and shape ID controls, animation timing offsets, and motion blur from particle velocity. The new region of interest option enables users either to define a custom bounding box region that can be applied to viewport meshing for faster previews while adjusting settings of complex particle data sets or removing unwanted areas in render-time meshing.

HUMAN FACTORS



NEXGEN, MONTREAL

HumanCAD 4 is the latest version of NexGen's digital human modeling platform. HumanCAD creates digital humans in a three-dimensional environment on which a variety of ergonomic and human-factors analysis can be performed in order to aid users with the design of products and workplaces by determining what humans of different sizes can see, reach, or lift. New features in v4.0 include improved skinning algorithms, the ability to attach objects together, and a new editor that allows the ability to save and reuse custom ranges of motion databases. There is also a new animation capability which enables the creation of movements for mannequins and objects by selecting posture, position, and orientation for each key frame as well as collision detection and attached objects support.

BENCHMARKING

SPECGPC, GAINSVILLE, VA.

The SPEC Graphics Performance Characterization Group, known as SPECgpc, has released an updated version of its benchmarking application. SPECviewperf 12.1 benchmark features a new Autodesk 3ds Max viewset, Microsoft Windows 10 support, and GUI and reporting improvements. SPECviewperf software measures the 3-D graphics performance of systems running under the OpenGL and Direct X application programming interfaces. The benchmark's workloads, called viewsets, represent graphics content and behavior extracted from professional applications, without the need to install the applications themselves. The new 3ds Max viewset measures DirectX performance for a variety of scenarios using the application's most popular rendering modes. The SPECviewperf 12.1 benchmark runs under the 64-bit versions of Microsoft Windows 7 and Windows 10. Results from v12.1 remain comparable to those from v12.0.1 and v12.0.2.

MACHINE ANALYTICS

AUTHENTISE, MOUNTAIN VIEW, CALIF.

3Diax Machine Analytics is the first off-the-shelf component of 3Diax platform, the modular process automation platform for additive manufacturing. 3Diax Machine Analytics enables companies to monitor the status of all their additive manufacturing devices simultaneously, regardless of manufacturer. The application is designed to coexist with corporate IT systems and displays key statistics such as machine utilization and material usage on a dashboard. Users can identify available devices no matter where they are based or reduce material waste by detecting inefficient printers or forgotten half-used material caches.

PIPE ANALYSIS

INTERGRAPH PROCESS, POWER, & MARINE, HUNTSVILLE, ALA.

Intergraph Process, Power, & Marine has released CAESAR II 2017, an application that evaluates the

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structural responses and stresses of piping systems to international codes and standards. The 2017 version adds features such as the ability to evaluate creep conditions for all piping codes using EN-13480 guidelines, and a new dialog to specify custom nozzle stiffnesses from the piping input. The version also features several interface and usability improvements, including model symbols to show displacements, rotations, forces, and moments, and improved display of node numbers and axial stops in piping models. In addition to including updates published by major international standards organizations, the application provides an option to either let the software determine the restrained or unrestrained state of the pipe elements automatically, or the ability to specify the state themselves.

CAD

KUBOTEK, MARLBOROUGH, MASS.

Driven in part by new technology upgrades, the release of KeyCreator 2016 version 14.0 offers powerful updates to the application's efficient design-to-manufacture ability. The application's CAD data reuse is enhanced in the release with new design data import options and updated file reading capabilities. Two new functions can retrieve data from an Excel file, and those functions can be used everywhere the calculator is used. Also, the new version includes an Edit Hyperlink option, which opens an edit dialog listing all hyperlinks found in the file. That function allows users to select an item from the list to allow editing hyperlinks, change a link, and change link type.

DYNAMIC MODELING

HONEYWELL PROCESS SOLUTIONS, PHOENIX, ARIZ.

Honeywell Process Solutions has launched UniSim Design Suite Release 450, which enables engineers in the oil and gas, refining, petrochemical, chemical, and power industries to create a number of steady-state and dynamic models for plant and control design and optimization, hazard and operability and safety system studies, and asset management. Release 450 features enhancements to the UniSim Blowdown option, which allows for the sizing and rating of blowdown networks and the selection of appropriate construction materials, in compliance with the API 521 industry standards. In addition, the UniSim Flare product, used for the sizing and rating of new or existing flare systems from relief device to the flare tip, has been re-platformed and enhanced for better performance, data visualization and reporting, and scenario automation.

MULTIPHYSICS SIMULATION

ANSYS, PITTSBURGH

ANSYS 17.2 offers enhanced multiphysics coupling, new workflows for antenna design, and automated temperature characteristics for electric machines. To support design work of Internet of Things-enabled devices, a new streamlined interface between ANSYS HFSS and ANSYS HFSS SBR+ (formerly Savant) enables antenna designs created in HFSS to easily be imported to the HFSS SBR+ advanced shooting and bouncing-ray solver to validate the design and placement of the antenna. The new releases includes a new SCADE Test environment capability to automate the testing of embedded displays and to provide enhanced support of hardware-in-the-loop testing with National Instruments Veristand and AUTOSAR system design import capabilities. Improved links to IBM DOORS and Dassault Systèmes Reqtify requirements management tools enable ANSYS SCADE solutions to be easily incorporated into existing workflows.

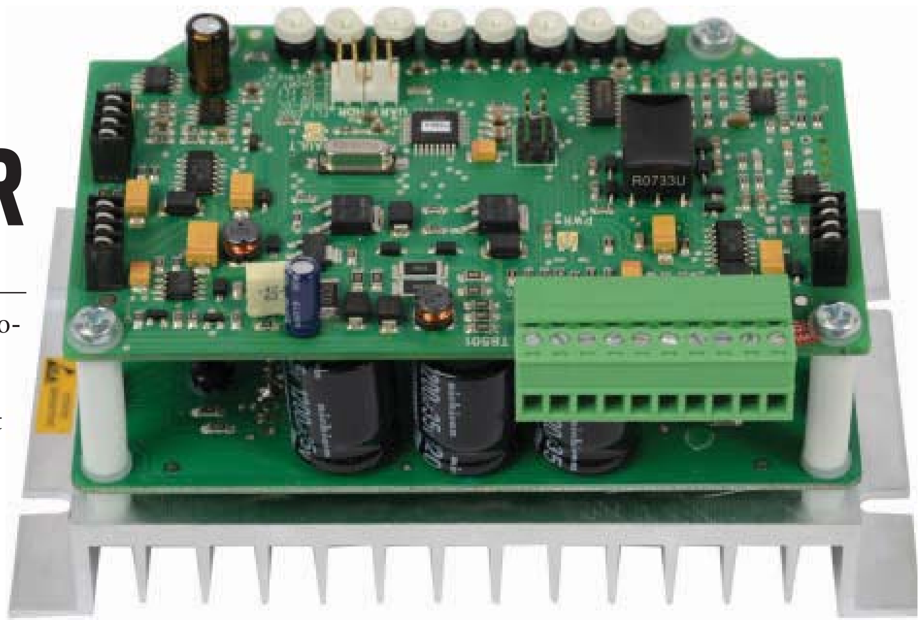
MACHINE AUTOMATION

SIEMENS INDUSTRY, ATLANTA

The Converting Toolbox is a set of standardized automation tools for the integration of various machine components that previously had to be performed individually. The goal is to simplify web processing applications and offer greater flexibility for machine designers and builders of paper, film, foil, and other converting machinery. The Converting Toolbox is intended to enable machine builders to reduce the time required for engineering, programming, commissioning, and documentation. The company suggests paring the Converting Toolbox with SiMotion, the Siemens motion control system, because applications can then be operated directly on an intelligent drive without need of an additional PLC.

MOTOR CONTROLLER

AMERICAN CONTROL ELECTRONICS, SOUTH BELOIT, ILL.



AMERICAN CONTROL ELECTRONICS HAS introduced its DCR Series, a low-voltage 4-quadrant drive that provides control of permanent magnet dc motors. The DCR Series can maintain variable speed control while batteries discharge, delivering an increased run time for battery-powered devices. The device can operate over a wide range of power, from as little as 0.01 hp up to 7.5 hp, and can handle input dc voltages from 12 to 48 V. The microprocessor-based design offers flexibility for customized OEM solutions with multiple input-output configurations, wired and wireless control capabilities, and packaging options. The company says the DCR series can also control portable or remote products that utilize solar power.

ELECTRIC LINEAR MODULE

SCHUNK, MORRISVILLE, N.C.

The Schunk ELP can be adjusted in two simple steps. The electric linear module features end positions that can be mechanically adjusted with a screw, and its speed of extension and retraction is adjusted using rotary switches on the side of the unit. Speed can be automatically adjusted, depending on extension weight, and because the drive automatically regulates the brake process, there is no need for shock absorber adjustments. The control and power electronics for the ELP are directly integrated into the module, and can be accessed via a fieldbus distributor or through digital signals..

LIDAR

FARO, LAKE MARY, FLA.

The FARO VectorRI is intended to deliver a continuous stream of high-resolution surface data via accurate lidar HSI technology. The system uses advanced galvo-mirror beam steering as opposed to the conventional gimbal arrangement found in many other systems. The advanced steering system provides high speed scanning. The FARO VectorRI also features a proprietary large-volume, high-definition 3-D imaging and recognition functionality to enable it to detect features within the scan, improving the ability to measure and inspect corners, fasteners, tooling balls, and hole centers as well as fitting 3-D shapes over very large areas. The scanning is capable of composing an image of 400 million pixels, providing high-resolution zoom capabilities on critical features.

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INFRARED CAMERA

INFRATEC GMBH.,
DRESDEN, GERMANY

The VarioCAM HD head series of thermal imaging cameras are based on the latest generation of uncooled microbolometer FPA detectors. The thermal radiation of the measurement object strikes a rotating germanium disk and is deflected through a tumbling motion of the disk according to a precise pattern. The detector array produces 1,024 by 768 infrared pixels to provide 16-bit thermographic images. In combination with a thermal resolution of up to 20 mK, the thermal imaging cameras are suitable for sophisticated fixed-mount stationary measurement and test tasks from production, quality assurance, process optimization, research and development, and aerial imaging.

FORK SENSOR

AUTOMATIONDIRECT, CUMMING, GA.

The PS series fork sensors are offered in visible red light and laser models. Available in PNP and NPN styles and designed for easy installation, the one-piece metal construction provides constant alignment. The high-resolution PS-series fork sensors feature glass optics, selectable light on/dark on operation, adjustable sensitivity potentiometers, high switching frequencies, and are fitted with M8 connectors with 360° viewable LED indicators. The visible red light fork sensors have a sensing range from 5 mm to 220 mm, depending on model. The laser fork sensors feature a Class 1 laser to detect small objects and have a sensing range of 30 mm to 120 mm, depending on model. All PS-series fork sensors are IP67-rated, have cULus approval and are CE, RoHs, and REACH compliant.

ETHERNET SWITCH

BELDEN, ST. LOUIS

The Octopus 8TX-EEC is an 8-port, unmanaged Ethernet switch now offered by Hirschmann, a brand of Belden. The company says that engineers, system integrators, and machine builders running smaller industrial networks may look to the Octopus 8TX-EEC to provide a simple-to-install and space-saving solution for specific application needs. With an IP67/65 rating, this compact switch can be mounted in many locations without the need for protective cabinets. The switch is also deigned to withstand harsh conditions, including dirt, dust, vibrations, and water, as well as extreme temperatures. With a ruggedized metal housing, the 8TX-EEC is intended for transportation, general manufacturing, machine building, and automotive applications.

POWER SYSTEM

MARTIN ENGINEERING, NEPONSET, ILL.

The Martin Roll Gen system is a self-contained mini power station designed to enable operators to run electrical monitoring systems and safety mechanisms. Roll Gen uses the kinetic energy from a moving conveyor belt to generate power and can be retrofitted on existing idler support structures. Operators do not need to maintain a special stock of conveyor rollers, since the generator can be employed on virtually any steel roller. On conveyors that already employ Martin's Trac-Mount Idlers outside of a loading zone, installation is as easy as removing the wing slide on one end and replacing it with the Roll Generator slide. The slide-in/slide-out roller frames enable maintenance without the need to raise the belt or remove adjacent idlers.

LOAD CELL

METTLER TOLEDO, GREIFENSEE, SWITZERLAND

The company says its new compact, single-point SLP85xD load cell can be built into large networks, which makes it suitable for applications where multiple bottles, cans or drums are weighed within a fraction of a second simultaneously and in parallel. The load cell can be used either to control the entire filling process with its digital outputs or as a sensor only to provide fast weight results to the control system. The load cell's sensors can capture 1,200 weight values per second, and connectivity via EtherNet/IP, PROFINET IO RT, or PROFIBUS DP is incorporated. SLP85xD load cells are hermetically sealed (IP69K), meaning they can be cleaned with high-pressure water jets. This fulfills Clean-In-Place requirements and reduces downtime for the cleaning process.

MOTION CONTROLLER

SEM USA, MARLBOROUGH, CONN.

The Lexium Motion Module, an ultra-compact programmable motion controller, is now offered in a CANopen version to support the CiA DS301: CANopen Application Layer/Communication Profile and DSP402: Device Profile for Drives/Motion Control standards. The Lexium Motion Module may be suitable for CANopen motion systems with tight space constraints, since the module's form factor is 2.7 by 1.4 by 0.16 in. (68 x 35 x 4 mm). A selection of motors are available, with rotary stepper motors in NEMA sizes 8 (20 mm), 11 (28 mm), 14 (36 mm), and 17 (42 mm) offered as standard options. Custom motor sizes and styles are also available, as are modules with alternate power levels and communication platforms.

PLUMBING KIT

EXAIR, CINCINNATI

New stainless steel plumbing kits simplify the installation of the Stainless Steel Super Air Knife by including all of the proper fittings and tubes for hooking up to a compressed air supply. The kits also eliminate poor performance attributed to undersized fittings and compressed air supply lines. Upon request, the plumbing kits can also be fully assembled and installed on a Super Air Knife at the factory. The kits include cut-to-length type 316 stainless steel pipe and fittings and are available in lengths ranging from 24 in. (610 mm) to 108 in. (2,743 mm).

FLOW CONTROLLER

ALICAT SCIENTIFIC, TUCSON, ARIZ.

The MCRH mass flow controller can accommodate flow rates of up to 5,000 slpm, without compromising speed or precision of gas control. The controller manages industrial processes with more chaotic upstream fluctuations, such as control of industrial combustion gases, or mass flow into food and packaging processes. The instrument's Gas Select firmware includes a library of up to 130 preloaded gases, user selectable in the field. The MCRH can be programmed with the instrument's push button menus and onboard display, or via remote connection. Digital communications options include RS-232 or RS-485 serial, Modbus, or PROFIBUS, as well as analog 0-5 Vdc, 1-5 Vdc, and 0-10 Vdc, or 4-20 mA.

VISCOMETER

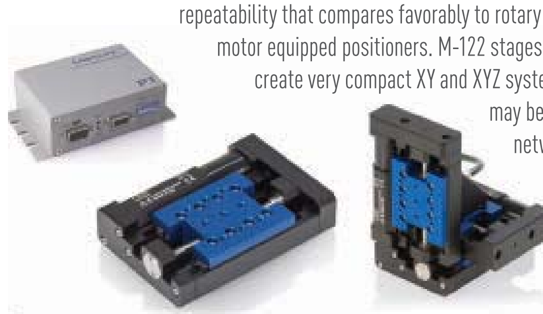
PAUL N. GARDNER, POMPANO BEACH, FLA.

The new Visco portable viscometer can run on battery power to enable testing in remote locations. The instrument is small enough to be carried in one hand and can be placed directly on the beaker, making it possible for quick and simple measurements to be taken. The device needs only a 15 ml sample to make an accurate measurement, the company says, and the full digital display allows for readings to be read quickly. The simple construction and one-button operation is designed to enable non-technical workers to assemble and operate the unit.

MOTORIZED POSITIONING STAGE

PI (PHYSIK INSTRUMENTE), AUBURN, MASS.

The M-122 is a low-profile motorized positioning stage with a footprint of 60 by 86 mm and a travel range of 25 mm. The compact closed-loop positioning stage can handle payloads to 11 lbs. with velocity to 20 mm/sec. The optical linear encoder provides 100 nm resolution and according to the company, it provides linearity and repeatability that compares favorably to rotary encoder or stepper motor equipped positioners. M-122 stages can be combined to create very compact XY and XYZ systems. M-122 stages may be combined with the networkable C-863 Mercury servo motor controller, also offered by PI.



COMPRESSOR

GARDNER DENVER TRANSPORT, MILWAUKEE, WIS.

The new Hydrovane T02 is a rotary vane compressor module developed to provide maximum space savings and weight reduction in addition to producing low noise. The product features direct drive by means of a 400 V ac IEC E-motor in a speed range of 800 to 3,000 rpm and can produce an air volume flow of 6.7 l/min. at the maximum pressure rating of 13 bar. Power consumption ranges from 1.1. to 4.0 kW. The compressor is intended to serve as part of an auxiliary unit for local transport and commercial vehicles, such as supplying compressed air for door openers on passenger buses.

ROTARY ENCODER

LEINE AND LINDE, SCHAUMBURG, ILL.

Leine and Linde's RXI and RXA 500 series are incremental and absolute encoders that are now offered in stainless steel versions for motion control applications in severe environments or where regular wash-down is necessary. Two types of steel are available, 304/A2 or 316/A4, which are both austenitic and can be used in a variety of corrosive applications. Absolute versions of the 500 series are available with up to 14-bit single-turn outputs, with parallel TTL, HTL, SSI, and CANopen interfaces. Incremental versions are available with up to 10,000 PPR resolution and are capable of operating at temperatures up to 100 °C. The new encoders feature a stainless steel enclosure, flange, and shaft.

POWER SUPPLY

POWERBOX, GNESTA, SWEDEN

Powerbox has introduced four new power supplies—OBM33, OBM35, OBP37, and OBP38—designed to power Industry 4.0 applications. As part of the Powerbox Industrial Line, the four series include more than 28 models delivering a single output voltage of 12 V, 15 V, 18 V, 24 V, 30 V, 36 V and 48 V within a power range of 80 W to 400 W. The OBM33, OBM35, OBP37, and OBP38 utilize an LLC half-bridge topology, complemented by synchronous rectification and low standby power consumption. Those technologies contribute to characteristics such as efficiencies as high as 93 percent, high energy density, and high peak output current. The technology also enables low power consumption at no load, below 0.5 W and below 1 W when using the power-failure detection signal.

EAR PLUGS

FLARE AUDIO LTD., LANCING, U.K.

Instead of using foam or other soft material to absorb incoming sound, Isolate ear protectors reflect sound away from the ears and therefore achieve much greater attenuation. The company says its new design is particularly suited for blocking bass frequency sound, such as that coming from industrial and agricultural machinery. The Isolate ear protectors are made from solid metal, either standard aluminum or titanium, and are reusable. Replaceable foam tips ensure a comfortable and secure positioning of the protectors in the ear canal.

RESOURCEFILE

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

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

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

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

TRAINING & DEVELOPMENT: For a listing and description of ASME Training & Development educational opportunities, visit the ASME Education website at http://www.asme.org/kb/courses/asme-training-development.

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

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

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

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

MAYRA SANTIAGO, Secretary A
ASME Standards & Certification
Two Park Ave., M/S 6-2A
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ASME maintains approximately 500 codes and standards. A general categorization of the subject matter addressed by ASME codes and standards is as follows:

Authorized Inspections
Automotive
Bioprocessing Equipment
Boilers
Certification & Accreditation
Chains
Controls for Boilers
Conveyors
Cranes & Hoists
Cutting, Hand, & Machine Tools
Dimensions
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Gauges/Gaging
Geometric Dimensioning & Tolerancing (GD&T)
High-Pressure Vessels Systems
Keys and Keyseats
Limits & Fits
Materials
Measurement of Fluid Flow in Closed Conduits
Metal Products Sizes
Metric System
Metrology & Calibration of Instruments
Nondestructive Evaluation/ Examination
Nuclear
Performance Test Codes
Personnel Certification
Piping & Pipelines
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Surface Quality
Turbines
Valves, Fittings, Flanges, Gaskets
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Water Efficiency for Plants
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The ASME Standards & Certification section is published as submitted to Mechanical Engineering magazine by ASME's Standards & Certification Department.

NEXT MONTH IN MECHANICAL ENGINEERING

★ ★ ★ ★ THE STATE OF ★ ★ ★ ★ AMERICAN MANUFACTURING 2017

Manufacturing was at the very center of the 2016 U.S. elections, yet its breadth and depth is far more complex than the way politicians and media usually portray it.

In this snapshot of U.S. manufacturing, we look at such key issues as jobs, foreign trade, innovation, automation, and productivity.

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The department is dedicated to innovative interdisciplinary research and teaching in both aerospace and mechanical engineering. The department's research specialties include active flow control, aerospace guidance navigation and control, astrodynamics, biomechanics, computational and experimental fluid and solid mechanics, mechatronics, multibody dynamics, nanotechnology and renewable energy.

Research at the University of Arizona is strongly multidisciplinary and the department works extensively with, among others, the UA Department of Planetary Sciences, Arizona Health Sciences Center, BIO5 Institute for Collaborative Bioresearch, College of Optical Sciences and the Program in Applied Mathematics, all of which enjoy international recognition as centers for world-class academic programs and research.

The University of Arizona is located in Tucson, which has a vibrant, multicultural community – in 2016 UNESCO named it a World City of Gastronomy – and is home to a thriving industrial sector that includes Raytheon, Rincon Research, Paragon Space Development and Vector Space Systems.

POSITIONS OPEN

ENVIRONMENTAL ENGINEERING SYSTEMS COMPANY (HILLSBOROUGH, NJ) SEEKS MANAGER OF TECHNOLOGIES to ensure company products meet technical requirements & specifications, evaluate and implement new thermal process and pollution control technologies. Systemize & document the existing technologies for marketing purposes. Oversee the proposal & design stages of various projects, coordinate and supervise company engineering team and maintain ISO standards and meeting code requirements. **MAIL RESUME TO:** Hankin Environmental Systems, Inc., 1 Harvard Way, Ste. 6, Hillsborough, NJ 08844

Massachusetts Institute of Technology (MIT) Integrated Design and Management Academic Director and Senior Lecturer

Integrated Design and Management (IDM) develops visionary leaders focused on the human centered design process and the integration of engineering, management, and design. IDM is jointly offered by the MIT School of Engineering (SoE) and the MIT Sloan School of Management. As a new and growing program, IDM is developing new positions.

The Academic Director/Senior Lecturer is the primary contact to both teach and lead the integrated core. S/he will also be responsible for helping guide the multidisciplianry and experienced student cohort through their program to meet the academic rigor of MIT and chart a course that meets their academic and professional goals. This position would be part of the Integrated Design and Management (IDM) leadership and teaching team.

Required Qualifications:

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- Teaching experience at a university level
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Apply:

For more information, and to apply please visit the MIT website (referencing job #14467) at: http://careers.mit.edu/

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Texas A&M Ocean Engineering Three Open Rank Positions: Ocean/Off-Shore Structures (Galveston) Coastal/Subsea Systems (College Station) Any ocean engineering specialization (College Station)

The Department of Ocean Engineering at Texas A&M University invites applications for three tenure-track or tenured faculty positions at the assistant, associate, or full professor level. (i) Galveston Campus: candidates must have expertise in some area of structural engineering. Expertise in ocean/offshore structures is desirable. (ii) College Station Campus: candidates are sought in the general area of subsea/coastal systems engineering. (iii) College Station Campus: candidates in any specialization of ocean engineering. Successful applicants will be required to teach; advise and mentor undergraduate and graduate students; develop an independent, externally funded research program in their area of expertise; participate in all aspects of the department's activities; and serve the profession. Strong written and verbal communication skills are required. Applicants should consult the department's website to review departmental academic and research programs (https://engineering.tamu.edu/ocean).

Applicants must have an earned doctorate in ocean engineering, civil-structural engineering, naval architecture, marine engineering, mechanical engineering, aerospace engineering or a closely related discipline. Applicants should submit a cover letter, curriculum vitae, teaching statement, research statement, and a list of four references (including postal addresses, phone numbers and email addresses). Candidates should apply for a specific position at www.tamengineeringjobs.com. Full consideration will be given to applications received by April 30, 2017. Applications received after that date may be considered until positions are filled. The appointment will begin fall 2017 or later.

The members of Texas A&M Engineering are all Equal Opportunity/Affirmative Action/Veterans/Disability employers committed to diversity. It is the policy of these members to recruit, hire, train and promote without regard to race, color, sex, religion, national origin, age, disability, genetic information, veteran status, sexual orientation or gender identity.

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COMSOL, Inc.	5, 57	comsol.com/products comsol.com/showcase/mechanical	
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RECRUITMENT

MARSHALL SCHOLARSHIP FOR CAVUTO

MATTHEW CAVUTO, an ASME student member at the Massachusetts Institute of Technology in Cambridge, was recently selected as one of the winners of the 2017 Marshall Scholarship competition.

The Marshall Scholarship program, which is sponsored by the British government, provides an opportunity for up to 40 American students to pursue two years of graduate study in any field at a university in the United Kingdom. The winners are selected based on academic merit, leadership potential, and ambassadorial potential.

Cavuto, from Skillman, N.J., is majoring in mechanical engineering with a concentration in biomechanics and biomedical devices.

As a Marshall Scholar, Cavuto will take part in advanced prosthetic and assistive technology research during his two years studying at Imperial College London and Cambridge University. During his first year, Cavuto will pursue a master's degree in biomedical engineering and will work on an initiative to enable amputees to experience sensory feeling through their prostheses. In his second year, he will pursue a Master of Philosophy degree in engineering while designing assistive technologies and exoskeletons.

Cavuto hopes to earn a Ph.D. in biomechatronics and, ultimately, design the world's first successful robotic exoskeleton. **ME**

V&V SYMPOSIUM SET FOR LAS VEGAS

The ASME Verification and Validation Symposium, now in its sixth year, provides engineers, computational scientists, software developers, analysts, and other stakeholders who use computational modeling and simulation with a venue for showcasing and exchanging ideas, methods, and solutions in verification, validation, and uncertainty quantification.

This year's symposium, which will address the theme "Connecting the Computational Modeling and Simulation Community," will take place from May 3 to 5 at the Westin Las Vegas Hotel.

Attendees of this year's symposium will have the opportunity to meet and interact with V&V specialists from a number of leading international organizations, including Los Alamos National Laboratory, Ansys, Westinghouse Electric Co., Dassault Systems, Bechtel National Inc., Sandia National Laboratories, Southwest Research Institute, the U.S. Air Force Research Laboratory, the Federal Aviation Administration, Kinectrics Inc., the Medical Device Innovation Consortium, and Vextec Corp., as well as a number of universities.

A pair of two-day ASME Training and Development seminars will be offered concurrently prior to the start of the V&V Symposium. The seminars begin on May 1.

"Probabilistic and Uncertainty Quantification Methods for Model Verification and Validation" will be led by David Riha and Ben Thacker of Southwest Research Institute.

The second seminar, "Verification and Validation on Scientific Computing," will be presented by Chris Roy of Virginia Tech and engineering consultant William Oberkampf.

In addition, six ASME standards development committees will hold meetings at the symposium to discuss V&V practices for solid mechanics, fluid dynamics, nuclear power, medical devices, advanced manufacturing, and energy systems.

For more information on the ASME Verification and Validation Symposium, or to register, visit go.asme.org/vandv.

For information on sponsorship opportunities for individuals or companies at the conference, contact James Pero, advertising and sponsorship sales representative, at peroj@asme.org. **ME**

BARTLES TO HEAD ROBOTICS INNOVATION HUB

Dean Bartles, a technology development consultant at ASME who is helping the Society develop an organizational strategy focused on robotics and manufacturing, has been named to lead the Advanced Robotics Manufacturing Innovation Hub within the U.S. Department of Defense.

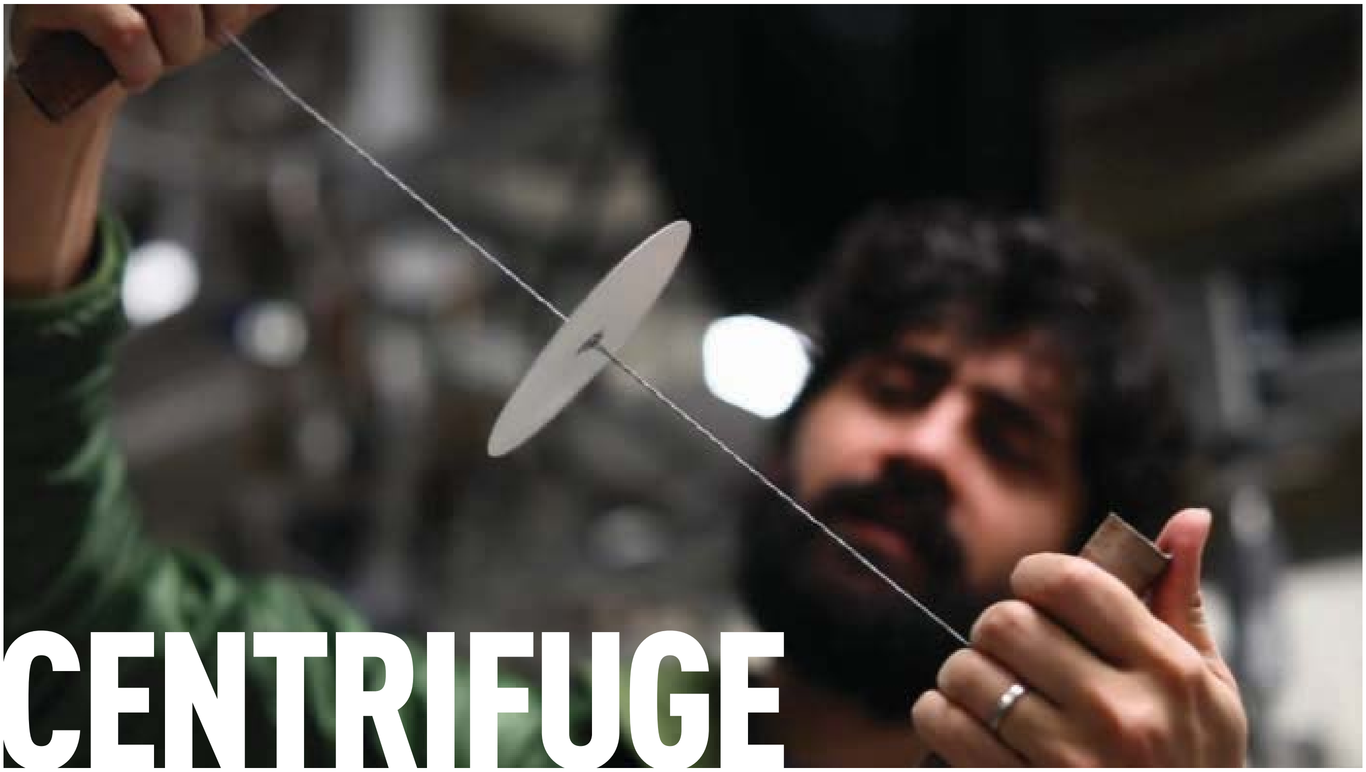
In his role in the new center, Bartles will work with public and private partners to advance the practical application of robotics and automation in a wide range of manufacturing sectors with a focus on job creation.

The Advanced Robotics Manufacturing Innovation Hub is a collaboration involving 123 companies, 40 academic institutions, and 64 government and nonprofit agencies in 31 states.

ASME has selected robotics as one of five technologies to guide future programs within the organization and grow new markets.

Bartles is the former chief manufacturing officer of UI LABS in Chicago, and the founding executive director of the Digital Manufacturing and Design Innovation Institute. Prior to joining DMDII, Bartles held several positions at General Dynamics and its predecessor companies, most recently serving as vice president and general manager of a key strategic business unit within the Ordnance and Tactical Systems division.

Bartles, an ASME Fellow and member of the ASME Industry Advisory Board, was also the recipient of the M. Eugene Merchant Manufacturing Medal of ASME/SME in 2014. **ME**



CENTRIFUGE ON A STRING

Manu Prakash works the paperfuge, a device based on a whirligig toy that can serve as an alternative to electric-powered centrifuges in remote locations.

Tests for malaria, HIV, and tuberculosis require centrifuges to separate parts of the blood sample. But in remote locations that lack electricity, such essential laboratory equipment is worthless.

Manu Prakash, a professor of bioengineering at Stanford University, and his team of engineers found a way to overcome that problem by copying one of the oldest toys in the world, the whirligig. Also known as a button spinner or buzzer, the whirligig is nothing more than a looped string passed through two holes punched out of the center of a disc. Pulling the string with two hands causes the disc to spin.

Prakash, a 2016 MacArthur Fellow, focuses on so-called frugal science using low-cost materials, and often turns to toys for inspiration. "Toys are like little magic tricks that spark your imagination," he said. "They do something you didn't think could happen."

He came across the centrifuge problem while in the field in Uganda, where he saw one centrifuge put to use as a doorstop. Back at the lab, Prakash posed a simple question to his research group: What's the optimal way to turn linear human power to rotational power? The team considered and rejected yo-yos, salad spinners, and egg beaters, before hitting upon whirligigs, something everyone in the group had played with and understood.

The device is simple, but optimizing it for the lab was challenging. At first, the team explored the whirligig's mechanical principles, something Prakash said had never been done. Then they built, iterated, and optimized their device, called a paperfuge because the spinning part is made from simple paper disks that hold small capillary tubes containing the blood sample.

The disk can also be 3-D printed or designed for larger biological samples and other types of molecular separation.

Early iterations of the paperfuge—loaded with two capillaries and spun by both a male and a female for 1.5 minutes—yielded the same hematocrit results as a CritSpin electric centrifuge. The paperfuge cost 20 cents and hit 20,000 rpm, compared with the $700 CritSpin's max of 16,000 rpm.

The engineers experimented with disk radius and string thickness and length, and eventually hit 125,000 rpm. Prakash believes it's the fastest rotational speed achieved by a human-powered device and is waiting for the Guinness World Records to confirm.

Meanwhile, the team planned to travel to Madagascar last month for a second round of field testing and will continue to iterate until the paperfuge is ready for mainstream use.

"If you don't just put constraints on performance, but also on cost and other parameters, it forces you to think of what the solution actually is," he said. "And sometimes that solution is right under our noses." ME

JEFF O'HEIR

ASME E-Fests™

For more information on our global E-Fest events, visit efests.asme.org

= E-Fests

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March 3-5, 2017
LNM Institute of Information Technology
Jaipur, India

E-Fest West
March 17-19, 2017
University of Nevada
Las Vegas, Nevada

E-Fest East
April 21-23, 2017
Tennessee Tech University
Cookeville, Tennessee

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What's part of the E-Fest Program?

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- Career briefs + mentoring
- Career development events – Professional skill development and leadership training with a practical twist
- Roundtables + networking – Students team up on fast-paced brainstorming, engineering mini-challenges, hackathons, networking events, etc.

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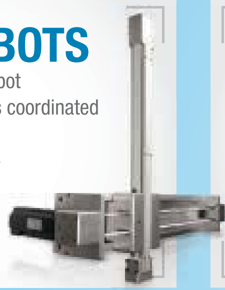

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