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THE MAGAZINE OF ASME
No. 04
138

ROBOTS AT WORK
WHERE WILL AUTOMATION TAKE THE JOB MARKET?

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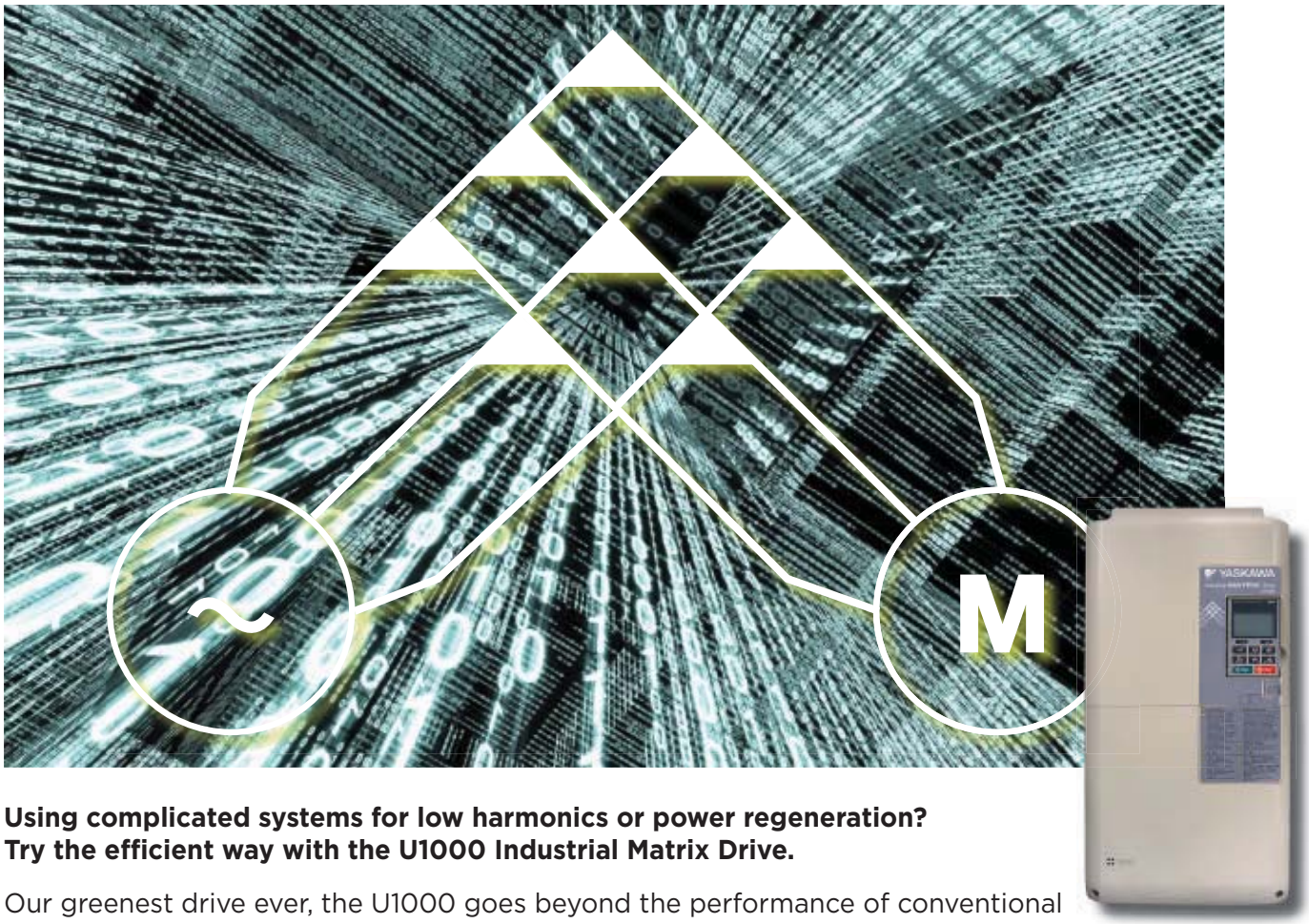

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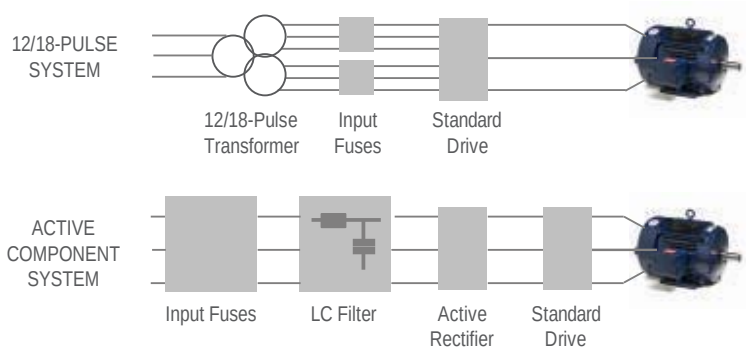

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ENGINEERING SAFETY WITH SMART HELMETS

POWERED BY AUGMENTED REALITY and a robust sensor package, a smart helmet enables engineers to overlay maps, schematics, and thermal images to see through solid objects, promising to enhance worker safety. DAQRI's smart helmet is an Industrial Internet of Things device that connects people, data, and machines by providing an immense amount of data back to the industrial Big Data servers: things like photographs, videos, thermal and environmental noise monitoring, and 3-D mapping. The device currently is in the pilot phase of product rollout with companies in the fields of oil, gas, power, construction, water, transportation, shipbuilding, and aerospace.

SHOCKING PURITY

The world doesn't need costly reverse osmosis to desalinate brackish water or remove lead before it hits the kitchen faucet. Instead, researchers at MIT have a potentially cheaper alternative, called "shock electrodialysis."

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

NEW LIFE FOR FRACTURING WELLS

Could hydraulic fracturing, the nontraditional oil and gas well drilling method, actually turn out to be greener than anyone imagined? That's one of the intriguing findings of a major new study revealing some unexpected and potentially useful underground impacts of the fracturing process.

VIDEO: BEST PRACTICES FOR METAL 3-D PRINTING

Tuan TranPham of ARCAM talks about the key growth drivers for metal 3-D printing and recommends best practices for engineers who are getting started with the technology.

NEXT MONTH ON ASME.ORG

VIDEO: GREENER CARS AND AUTOMOTIVE'S FUTURE

Prof. Hai Wang of Stanford University talks about industry innovations that are making cars lighter and more fuel efficient than ever, in a video filmed at ASME's IMECE 2015 conference.

CONSTRUCTING THE FUTURE WITH FLYING ROBOTS

A team of customized and specially programmed quadrocopters recently demonstrated cooperative construction and the benefit of flight—weaving, braiding, and tying rope to build a full-scale, load-bearing rope bridge.

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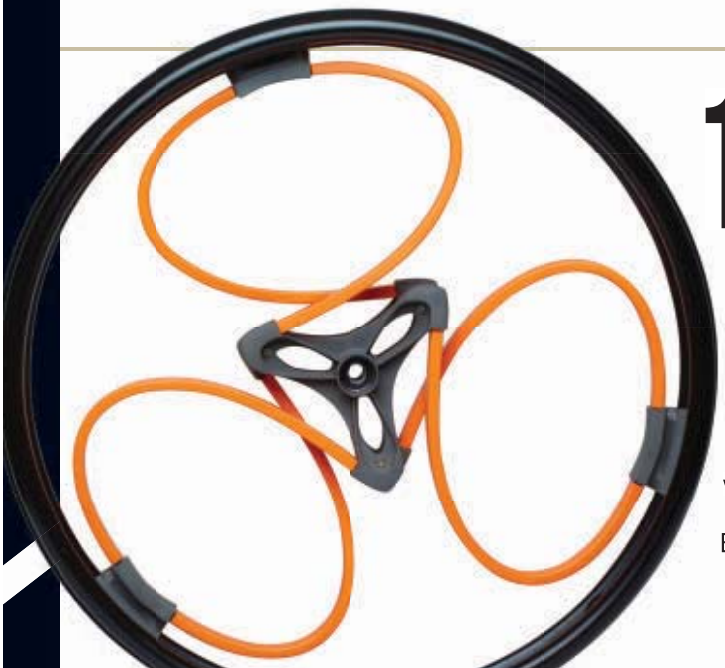

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Give me the place to stand, and I shall move the earth
—Archimedes

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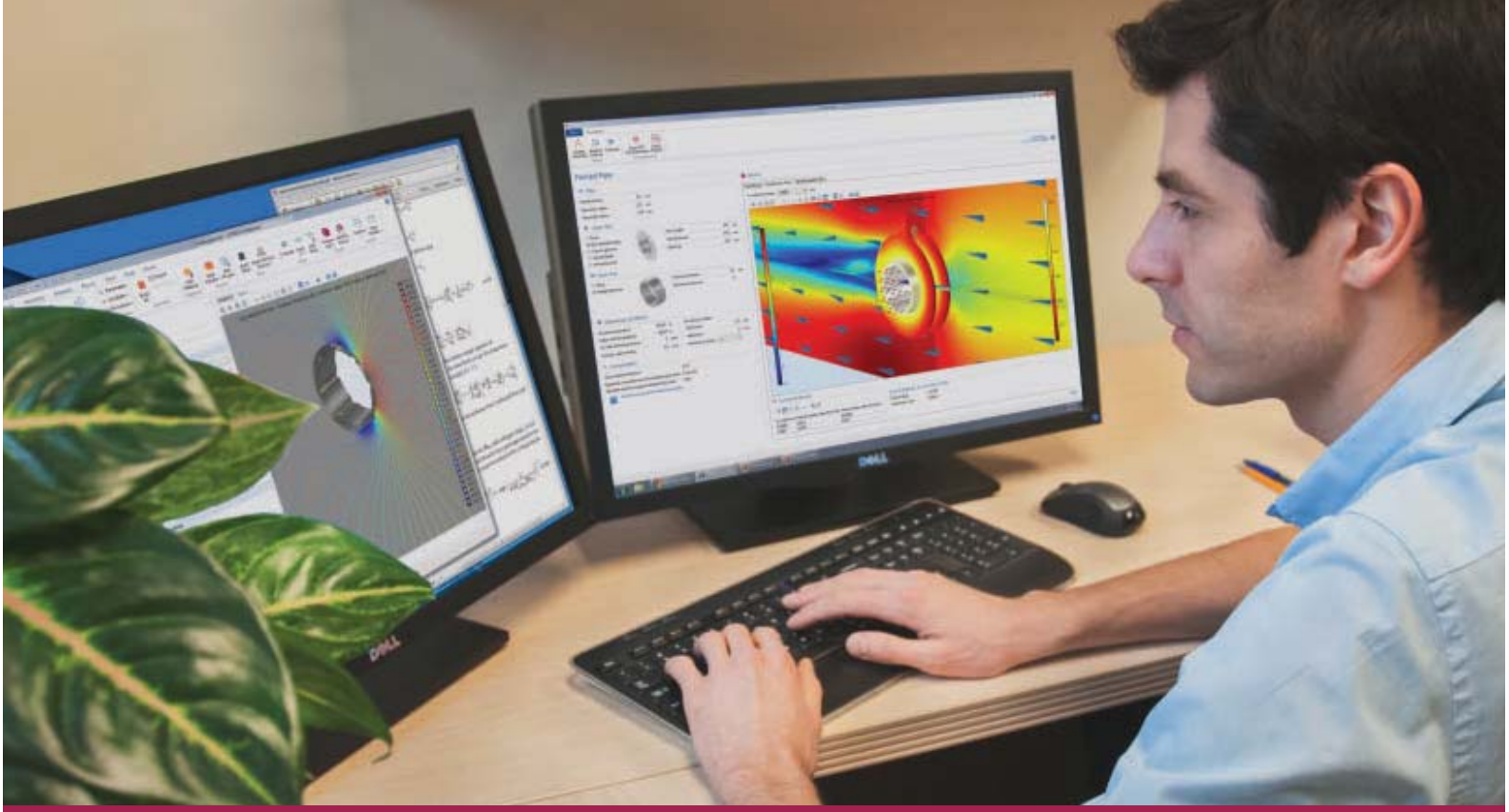

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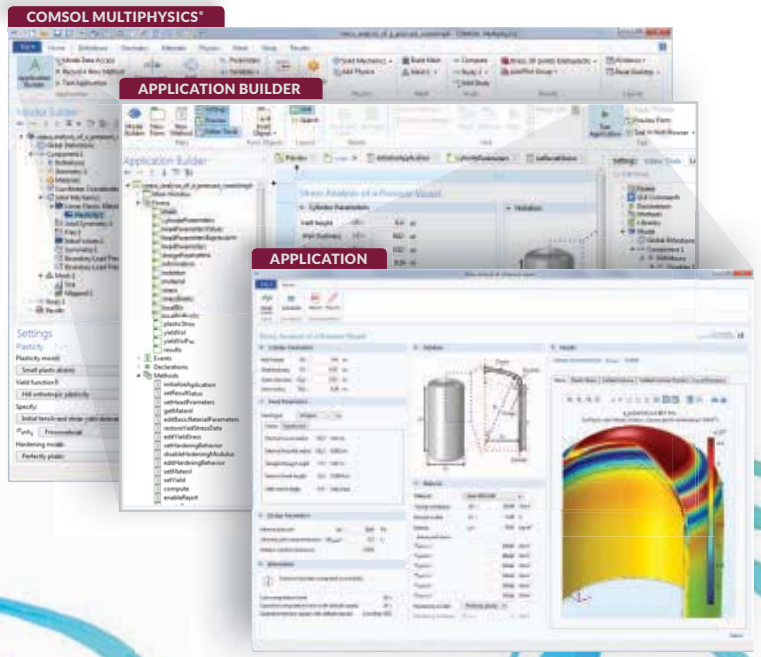

COMSOL

John G. Falcioni
Editor-in-Chief

COMING TO A GALAXY NOT FAR, FAR AWAY

Let's face it, many of us would rather have root canal surgery than shop for a new car. Navigating the art of the deal on the showroom floor leaves even the best of us (maybe not you, Mr. Trump) ready for a cup of chamomile tea, if not an adult beverage.

Dealerships understand this and are undertaking efforts to make the process seem less contrived and the customer experience more pleasant. Sales people are being trained to make more eye-to-eye contact so they seem genuine. They smile more and pat little children on the head. Unfortunately, even the most savvy car makers and their dealers still give car buyers the impression they are being taken for a ride.

Wouldn't it be a better experience to negotiate the purchase of that shiny red coupe you've always had your eye on with an automaton instead of a sales person?

Algorithms running on interconnected computers could reshape auto sales the way they have other industries. Look at where the brick-and-mortar travel agencies and video stores of yesterday are today: almost exclusively online.

In his revealing cover story this month, associate editor Alan S. Brown reminds us that automatic systems are depopulating professional offices as well as retailers. In some cases, Brown says, software has replaced loan officers, attorneys, and even writers and journalists; and engineers are relying on expert systems to evaluate designs and simulations. Even the investment community is adopting automated transactions. Robo financial advisers, which offer automated investment services and advice, often outperform human advisers who may be occasionally unscrupulous, on top of being unable to beat the market. (Nothing personal guys.)

What we're talking about here is deep learning, and networks that think like brains. These are artificial intelligence (AI) systems that go beyond following hard and fast algorithmic rules like some robot on a factory floor. IBM, for example, is advancing its Watson to diagnose diseases and to read medical images. Companies such as Google, Facebook, and Microsoft have collectively spent billions to fund the development of neural networks that can understand human speech and recognize faces in photos. In the next decade, AI could well power thousands of machines and gadgets through cloud services.

Of course, robots come in all shapes and sizes, so the time is nearing—probably before the final chapter in the seemingly endless *Star Wars* saga is ever written—when droids like C-3PO become run-of-the-mill companions in this galaxy, not in the one that is far, far away. DARPA, the Defense Advanced Research Projects Agency, is investing millions of dollars on projects to develop a kind of smart robot that is stronger and braver than C-3PO. In the DARPA Robotics Challenge, an Olympiad for robots, teams from Boston Dynamics, NASA Jet Propulsion Laboratory, and other organizations competed to develop autonomous robots with dexterity matching our own human deftness, but that can survive and work in extremely hazardous conditions, perhaps even the automobile showroom floor.

Come to think of it, maybe Damari, the sales guy I met last week at the Volvo dealer, wasn't so bad after all. **ME**

FEEDBACK

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LETTERS & COMMENTS

JANUARY 2016

Reader Lonsdale sees energy cost as a key source of competitiveness.

« One reader points to support for climate science. And in a comment, the case for prioritizing carbon emissions over smog.

SCIENCE, CULTURE, AND CLIMATE

To the Editor: You may know someone who sees climate change as a global conspiracy, manufactured to induce fear and provide an opportunity for unscrupulous profit. Those who search for something more concrete, however, soon realize that finding information isn't nearly as hard as absorbing it all.

We can Google the "climate change pie chart" and observe James Lawrence Powell's review (tinyurl.com/ktqofke) of more than 2,000 peer-reviewed scientific articles about climate change, written by more than 9,000 authors. One paper by a single author attributed the entire root cause of climate change to solar anomalies. We could cite satellite maps which show new land masses previously hidden by glaciers. Or, we could just keep it simple by observing highly scrutinized global temperature measurements to show that the Earth's temperature is rising.

Rational people will tolerate almost every form of dissent, even if it's not strongly supported. It contributes to healthy civil discourse. Allowing such dissent is what scientists may well consider to be part of the scientific method.

According to a study published by the Yale School of Forestry and Environmental Studies (tinyurl.com/os2dln2) in the journal *Climate Change*, only 12 percent of Americans understand that 90 percent or more of climate scientists concluded that human-caused climate change is happening.

The National Center for Science Education, which supports the teaching of evolution and climate science in schools, has found a strong correlation between views on climate change and political or religious affiliation (tinyurl.com/n7xjn8u).

We should acknowledge that the climate denial narrative gets some assistance from those who have invested their careers in industries which contribute to climate change. For them, the alternative concessions would be, well, inconvenient.

Mike Redler, *Bridgewater, N.J.*

COMMENT

ENGINE EMISSION REGULATIONS NEED REVISING

The recent foul play by Volkswagen and the success of the United Nations Climate agreement in Paris highlight an urgent need to consider a compromise between high engine fuel efficiency—and resulting low greenhouse gas emission—and the U.S. Environmental Protection Agency's regulation of other emissions that actually force lower efficiency.

The regulation of engine tailpipe emissions arose originally in response to poor air quality in cities and preceded any widespread acceptance that the main greenhouse gas, carbon dioxide, could become a serious concern. The subsequent progressive reduction, by the EPA, of the allowable levels of those regulated emissions has indeed succeeded in dramatically improving air quality in cities. However, many cities are so densely populated with exhaust-spewing vehicles that toxic concentration levels are often produced. To solve the emissions problem in cities requires moving quickly to electrification of urban road vehicles and, of course, to powering them electrically from renewable sources such as solar, wind, nuclear, and sustainable biofuels. But the cities are a special case.

Outside the citieson rural highways, on the ocean and in the skythe options for a sustainable solution are less obvious. Adequate batteries, for instance, are too big, too heavy, and too expensive. But, in those less crowded rural situations, natural chemical and physical processes keep the regulated emissions well below toxic concentration levels.

Carbon dioxide, however, accumulates and would do so much faster without the all-important role of plant photosynthesis. Compromise seems appropriate now so that the benefits of fuel efficiency and lower greenhouse gas emission from more efficient engines are adequately recognized. (Full disclosure: I am promoting a new engine design that targets ultra-high efficiency.)

Even in the face of any fossil fuel price disincentives, the internal combustion engine will continue to be a principal source of personal and freight mobility. But the fuel must change from fossils to a sustainable, net zero-CO_2 source.

The climate benefit accruing from

TO FIX URBAN INFRASTRUCTURE

To the Editor: Politicians don't get votes for being infrastructure proactive.

Politicians would rather see minimal dollars in an infrastructure project budget to pay for a vote-getting project. Voters never ask why infrastructure got broken.

Politicians always hope a bigger government provides the funding so they continue infrastructure budget avoidance.

John J. Schesny, *Lake Ariel, Pa.*

ENERGY FOR MANUFACTURING

To the Editor: John Falcioni's comments on the rejuvenation of U.S. manufacturing (From the Editor, January 2016) were very interesting, and good points were made.

One of the best ways to bring U.S. manufacturing back to the forefront is a reduction (and long-term stabilization) in energy prices. Fracking in the U.S.—thus increasing energy supply—has certainly helped to bring prices down recently.

Although it is not "politically correct" nowadays to cheer on fracking, cheaper U.S. energy likely will do at least as much to boost national manufacturing as all of the "government focus" and various institutes combined.

Cameron Lonsdale, *State College, Pa.*

use of sustainable fuels is leveraged by its use in engines with the highest possible fuel efficiency. Those fuel and engine research topics deserve strong government and industry support in the interest of going "green" while sustaining the mobility needs of vibrant economies.

Meanwhile it is important to review the emission regulations to ensure that they do not needlessly restrain the compromise required by this new international commitment to lowering, and even stopping, the increase of greenhouse gases.

John M. Clarke, *Woodsboro, Md.*

Editor's note: The author, a retired research engineer from Caterpillar Inc., is chief scientist at Motiv Engines, which is testing a Clarke-Brayton piston engine aimed at highest efficiency.

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.

A SMOOTHER RIDE FOR AN ACTIVE LIFE

A NEW TYPE OF IN-WHEEL SUSPENSION FOR WHEELCHAIRS EASES BUMPS IN THE ROAD

As a wheelchair user and a para-athlete, Mark Briggs expects to get everywhere an able-bodied person can go. This means the six-foot-two-inch former captain of Great Britain's full-contact sled hockey Paralympic team has high standards for his chair.

But until recently, Briggs's alternatives were limited.

A traditional chair with heavy metal-spoked wheels jolted and jostled him over every curb and every bump in the road. Flexible titanium-framed wheelchairs absorbed only some of those forces. Chairs with Spinergy wheels, which have strong but lightweight carbon-fiber spokes, provided more damping, but a day of heavy use still left Briggs achy.

Enter the Loopwheel.

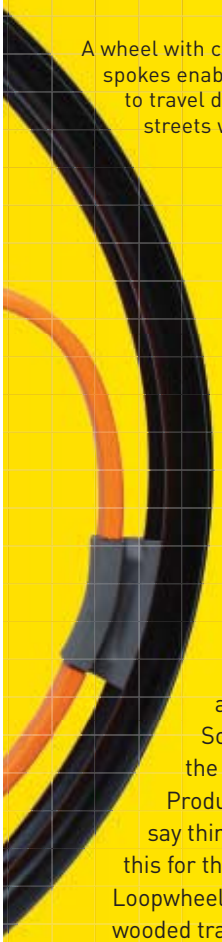
Unlike conventional fork suspensions, the Loopwheel's three loop-shaped springs absorb bumps by flexing without displacing the wheel's hub, while the three-loop design allows the hub to transfer torque to the rim.

The springs are made of the same sort of carbon fiber as archery bows—and that's no coincidence, says Sam Pearce, a mechanical engineer and industrial designer who invented the Loopwheel and sells it through his Nottingham, U.K.-based company, Jelly Products.

In 2007 Pearce hit upon the idea of designing an in-wheel suspension. He did an extensive global patent search and discovered that inventors had patented wheels with springs about 20 times over the last century, but none had succeeded. "Until recently there was no material to make springs that last," Pearce said.

Pearce lives near Nottingham, in Sherwood Forest, the real-life setting of the mythical outlaw hero Robin Hood. Archery is still popular there, and Pearce found a local bow maker named Keith Gascoigne who custom-built carbon-fiber archery bows. He worked with Gascoigne's company to develop a looped bicycle wheel.

Following a successful Kickstarter campaign to manufacture the wheel, its release in 2013 garnered favorable



A wheel with carbon-fiber loops for spokes enables wheelchair users to travel down cobblestone streets without discomfort.

coverage among cycling and technology publications and a prestigious design award. Soon, wheelchair users around the world were contacting Jelly Products, Pearce recalled. They'd say things like, "Please can you do this for the wheelchair," or, "If I had that Loopwheel on my chair I could go on wooded tracks at 11 miles per hour and it would be fantastic."

A second Kickstarter campaign last year raised $31,250 from 211 backers. This helped Jelly Products staff, which consists of Pearce, his wife and cofounder, Gemma, and an assistant, design the wheel, purchase materials and buy manufacturing equipment. They've sold 500 of the wheelchair wheels, which start at $970 a pair.

The wheelchair Loopwheels are flexible enough to dampen bumps and bounces, but stiff enough to roll easily and maneuver over obstacles.

After Briggs got a wheelchair fitted with prototype Loopwheels, he was soon taking it over grassy areas, wooded trails, curbs, and cobblestone streets in an old English village.

A year later, Briggs took his Loopwheel-equipped chair on vacation to Portugal. "I've been down cobbled hills mile upon mile and tried everything. It performed brilliantly," he said. **ME**

DAN FERBER

GETTING A GRIP ON COMETS AND ASTEROIDS

A NEW TYPE OF ROVER COULD ROAM asteroids, comets, and other small bodies that no previous robot could explore.

Rovers that have explored the moon or Mars have used wheels or tracks to grip the surface. For missions to asteroids and comets, however, the low gravity and rough terrain of such smaller bodies would make it difficult for the spacecraft to move accurately or with much stability.

To prepare for such missions, Marco Pavone, an assistant professor of aeronautics and astronautics at Stanford University, and Ben Hockman, a Stanford mechanical engineering graduate student, have designed a new type of rover: a cube-shaped vehicle with three internal flywheels, each cushioned for protection and housed in the corners of the cube. The flywheels propel the rover, which Pavone and Hockman call the Hedgehog, to hop and tumble across rough surfaces, while external spikes provide grip and stability. The rover can also spin to free itself from sandy pits and other traps.

The sealed interior of the prototype rover is roomy enough to carry miniature instruments, such as x-ray spectrometers, sensors, thermometers, microscopes, or cameras. It uses many existing technologies and off-the shelf components that have already been used for similar spacecraft.

"You want to keep things simple and limit the chance of any problems," Hockman said.

So far, the rover has performed individual hops and twists in near-weightless tests aboard an aircraft. The next step is to combine those maneuvers into sequences that allow the rover to move more reliably, accurately and free of all human control.

"This clever robot could successfully use the low gravity and rough terrain to enable an entirely new form of rover mobility," said Jason Derleth, program executive of NASA Innovative Advanced Program, which is funding Pavone's research.

The Hedgehog should be ready for its first mission in about five years, Pavone said. **ME**

An artist's rendering of the Hedgehog, a flywheel-propelled rover that can roll through low-gravity terrain, such as that of a Martian moon.
Image: Stanford University

GOT MUSHROOMS? MAKE BATTERIES

A husband-and-wife engineering team has cooked up a new recipe that uses mushrooms to replace graphite in lithium-ion batteries to power everything from cell phones to electric cars.

Cengiz Ozkan, professor of mechanical engineering and materials science and engineering at the Bourns College of Engineering of the University of California at Riverside, and Mihri Ozkan, professor of electrical and computer engineering at Riverside, and three of their current and former students, have developed a new kind of lithium-ion battery anode using portobello mushrooms. They hope this plentiful and biological ingredient can eventually replace the current industry standard of synthetic graphite, which is costly to manufacture and creates pollution during purification and preparation.

The work is especially important because of the increasing demand for lithium-ion batteries. Navigant Research predicts that the demand globally for lithium-ion batteries for vehicles will almost quadruple by 2024.

The Ozkans' respective labs have been collaborating and working on batteries and capacitors as an energy storage medium for about 10 years, testing different types of anode and cathode materials. They have noticed that while computer performance and data storage has improved with each new model year after year, battery capacity hasn't, and one of their goals is to change that.

> **"WE DON'T WANT TO USE ANY HARSH CHEMICAL OR ACID BASES, AND WE WERE LOOKING AROUND IN NATURE TO SEE WHAT WE HAVE."**
>
> **— MIHRI OZKAN**

"Over the years, we learned that porosity is quite important for the anode, especially in terms of pushing more lithium in and increasing the capacity," Mihri Ozkan said. High porosity—having many small spaces for liquid or air to pass through—creates more space for the storage and transfer of energy, which improves

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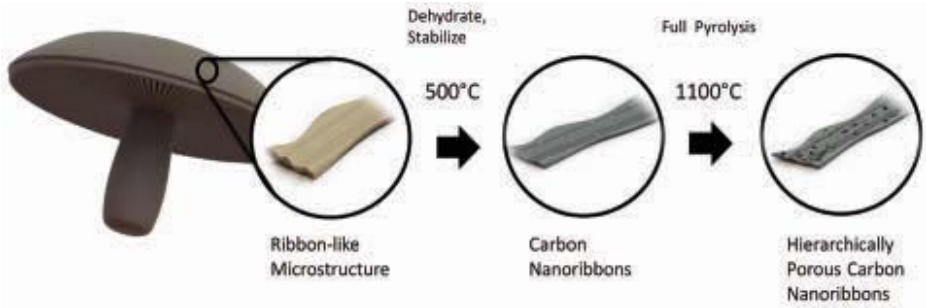


FIRST CHINESE CARGO TRAIN ARRIVES IN TEHRAN

A train carrying dozens of cargo containers arrived in Tehran in February, inaugurating what Chinese authorities call a new Silk Road. Officials in both countries hope this will open a new age in Asian transportation.

Iran's Road and Urbanism Minister, Mohsen PourAqaei, welcomed the cargo train after its arrival at Tehran's main train station.

The arrival of the train was reported by the official Chinese news agency, Xinhua.

It took about two weeks for the train to make the 10,000 km journey from Yiwu, in China's eastern Zhejiang Province, crossing Kazakhstan and Turkmenistan before entering Iran.

The opening of the cargo route to Iran was part of a larger Chinese initiative, the New Silk Road Economic Belt. This initiative seeks to link China with Europe through Central and Western Asia. A second transportation program, the 21st Century Maritime Silk Road, seeks to connect China with Southeast Asian countries, Africa, and Europe via sea routes.

In spite of the vast distances covered, the travel time for the train was more than four weeks shorter than the time to reach Iranian ports from China by cargo ship, Xinhua reported.

Xinhua also reported that PourAqaei said Iranian officials planned for a cargo train to arrive from China along this route each month. Tehran also will not be the final destination of these kinds of trains from China, the Iranian deputy minister said, adding that the goal is for the train to reach European markets. **ME**

PRINTED PROSTHESES: NOT YET READY FOR DEVELOPING COUNTRIES.

THE PRINTING PROCESS CAN TAKE DAYS, THE HANDS SUFFER PERFORMANCE ISSUES, AND TRAINED PROSTHETISTS ARE HARD TO FIND.

A Raptor Reloaded hand, produced by e-NABLE.

Three-dimensional printers are gaining popularity in low- and middle-income countries. They churn out products such as agricultural tools, automotive parts, and anatomical models for medical students. The method is great not only for lowering costs, but also for modeling a concept, adding detail, simplifying repair and maintenance, and allowing for personalization.

It has also become popular in the manufacture of prostheses, in particular prosthetic hands.

Some 2.4 million upper-limb amputees live in developing countries. Groups focused on 3-D printed prostheses—such as Nonspec, OpenBionics, and e-NABLE—often intend to provide an alternative to expensive imported devices for people in low- and middle-income countries.

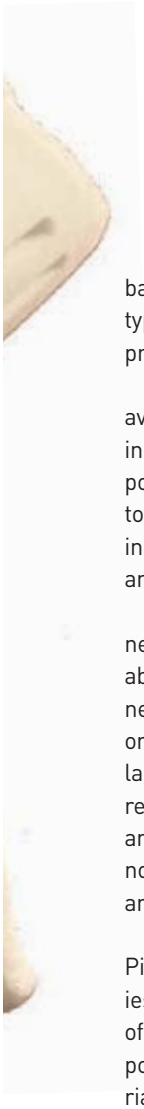
At the Humanitarian Engineering and Social Entrepreneurship (HESE) Program at Penn State University, we worked with the e-NABLE network to assess the appropriateness of these 3-D printed devices for large-scale dissemination in low- and middle-income countries. We asked, is this method of production appropriate for these assistive devices? What are the device's abilities and does it address an actual need? How would such a device reach the people who need it?

We performed extensive research in our lab and on the ground in Zambia to evaluate the viability of 3-D printed prosthetic hands and discovered the advantages and challenges to this new technology.

To determine whether 3-D printing in its current state is a viable option for prosthetic devices, HESE manufactured and tested the Raptor Reloaded, a design created by e-NABLE. The Raptor Reloaded is designed for users with wrist disarticulations—as were 10 of the 18 prosthetic hands designed for low- and middle-income countries that we discovered in our research. The CAD model for the Raptor Reloaded can be modified and scaled prior to printing.

Printing takes 32-54 hours, however, which may be an unrealistic wait time for an amputee traveling long distances to receive the prosthesis. In balancing time, cost, and customizability, we determined that a hybrid approach of 3-D printing and injection molding would be a better option to decrease manufacturing time while keeping costs low and enabling some customization.

We then followed a protocol similar to that of the Southampton Hand Assessment Procedure, a standardized test of the effectiveness of upper-limb prostheses through manipulation of objects that are common in everyday activities. The results indicated that the current design of the Raptor Reloaded has limited capabilities. For example, users were unable to pick up or maneuver small objects, such as coins and keys, though they could perform simple tasks that did not require fine manipulations of the fingers, such as picking up an empty cup or a small



ball. Designed for areas where the main source of income is typically manual labor, these limitations could reduce the appropriateness of the product.

A significant issue facing the distribution chain is the lack of availability of prosthetists and rehabilitative services. According to the World Health Organization, less than 5 percent of the population in low- and middle-income countries has access to these services. With a limited number of training facilities in Africa, a majority of countries must send their students to another country for training.

Additionally, rural workshops and hospitals serve as bottlenecks in the pathway. Even if materials and devices are available, it is still difficult to distribute the prostheses to those in need, given the length of travel often needed to visit a hospital or workshop. Access to rural amputees becomes a particular concern since successful, long-term use of a prosthesis requires maintenance and rehabilitation—at additional time and cost to the amputee. Thus, maybe we should focus should not only on providing alternative devices, but also on building an alternative system.

So, should we even work on 3-D printed devices? Absolutely! Pioneers like e-NABLE are critical for pushing the boundaries of what is possible. Although there are several limitations of current 3-D printed hands, this manufacturing process has potential. One route would be to work with a stronger material than the plastic that is used in current designs. Metal 3-D printing, although more expensive, could eventually become a viable option to strengthen the design. Moreover, a design that allows for increased and finer control over movement to allow for a broader range of capabilities would be helpful.

Also, while most of these 3-D printed prostheses are designed for wrist disarticulations, only 4 percent of the upper limb amputees in low- and middle-income countries have wrist amputations. It is likely that the number of wrist disarticulations is even lower. Furthermore, those with wrist disarticulations would be the most likely to adapt post-amputation without the need for a prosthesis.

Shifting the focus of design efforts, then, to a prosthetic leg would be more applicable, as a person is more dependent on the lower body for mobilization and the ability to work, especially in low- and middle-income countries. ME

BRIENNA PHILLIPS is a student of biomedical engineering, **SARAH RITTER** is an assistant professor of engineering design, and **KHANJAN MEHTA** is the founding director of the Humanitarian Engineering and Social Entrepreneurship Program and an assistant professor of engineering design. All are at Pennsylvania State University in State College.

THE INTERNET OF BROKEN THINGS

A network of **connected devices** can also help bring critical **life saving services** to emerging economies.

Good mornings are better when your alarm clock talks to your coffee maker," a recent ad campaign hints. Your day improves from there when your refrigerator reminds you to buy beer, your thermostat gets the house cozy before you get home, and your car guides you away from traffic jams. It's a miracle we navigated these first world problems before the advent of the Internet of Things.

IoT, a market anticipated to reach around 25 billion connected devices by 2020, doesn't have to be just about marginal quality of life improvements for suburban America. It can also help bring critical life saving services to rural Africa, Asia, and other emerging economies.

While some worry about warm coffee and cold beer, billions of people in developing countries are preoccupied with finding clean drinking water, safe sanitation, and reliable energy from sources other than firewood and kerosene.

For instance, while the proportion of people with access to sanitation has crept up slowly since 2000, access to cellular data networks has exploded. In Africa alone, the GSM Association estimates that 125 million people who lack access to safe drinking water have mobile coverage.

Adding electronic sensors, connected over the cellular networks to Internet databases available globally, can draw attention to and incentivize fixing what we might call the Internet of Broken Things.

"The IoT and connected sensors are driving improvements to human well-being in healthcare, water, agriculture, natural resource management, resiliency to climate change and energy," wrote the United Nations and CISCO Systems in a recently published report, *Harnessing the Internet of Things for Global Development*.

An energetic group of technology entrepreneurs have embraced this premise. M-Kopa in Kenya, for example, leverages IoT to replace charity donations of solar lanterns with a pay-as-you-go subscription service. In Haiti, NexLeaf Analytics has ensured that cold chain integrity is maintained and monitored for critical vaccine deliveries. Oxford University has dramatically improved water pump functionality while creating small water service providers. Nano Ganesh provides remote control of micro irrigation pumps in India. And a number of groups associated with the University of California at Berkeley use cookstove sensors and online analytics to study the behavior of households adopting—or not—improved cookstoves.

Our team at Portland State has conducted numerous public health studies since 2010 with our own IoT platform. In one recent study in Bangladesh, for instance, our instruments demonstrated more than a 50 percent exaggeration of latrine use compared to household surveys. That result may enable funders and development engineers to rethink how they implement sanitation programs.

Or in another example, in 2014 we worked on a project to install about 200 sensors in rural water pumps in Rwanda. The purpose was to identify pumps that were broken in order to dispatch repair teams. Before the sensors were installed some 44 percent of the area's pumps were broken at any given time, and it took an average of about seven months to get a pump repaired. Adding sensors reduced the repair interval to just 26 days; consequently, only 9 percent of pumps were broken at a time.

We also found that awareness of sensors makes a dramatic impact onn household use of water filters or cookstoves in rural Rwanda. On the one hand, that suggests that sensors might be a means to reinforce healthy behaviors. Yet it raises a host of issues for researchers. For instance, to accurately measure behavior, sensors may need to be hidden. And that could create privacy and ethical questions.

ADDING SENSORS TO RURAL WATER PUMPS REDUCED THE REPAIR INTERVAL FROM SEVEN MONTHS TO JUST 26 DAYS.

Such insights—and opportunities to respond and adjust to challenges in delivering poverty reduction services—are made possible thanks to the Internet of Things. FitBits for clean water filters may soon be coming to a charity near you. ME

EVAN THOMAS is an assistant professor of mechanical engineering at Portland State University, COO of DelAgua Health, and CEO of SweetSense Inc.

Q&A CHARLES ADLER

THANKS TO CHARLES ADLER, who founded Kickstarter with Perry Chen and Yancey Strickler back in 2009, the world of who makes what—and for how much—has been revolutionized. Millions of people have pledged billions of dollars to tens of thousands of projects, both big and small. Adler, who started off as a mechanical engineering student at Purdue University, left the company a few years ago; he recently started the Center for Lost Arts, a place where creative people of all types can access the tools, and the community, to put what's in their imagination into the world.

ME: What's the thread that ties the engineering student to Kickstarter and the Center for Lost Arts?
C.A: I have always been interested in the act of taking an idea and making it. Kickstarter is one form of that. A lot of the things I've done before are examples of that: my interest in the arts is an example of that, and my interest in becoming a designer is an example of that. Kickstarter was about empowering creatives. That could be an artistic expression, or a very personal expression, or it could start as a very personal expression that leads to a commercial expression. And that's something that Lost Arts is there to investigate. It's all about empowering creatives.

ME: With the Center for Lost Arts, are you coming back to the kind of hands-on experience you had as an engineering student?
C.A: I think of myself as an engineering school dropout. But whether I dropped out, got kicked out, or graduated, the door closes behind you. You don't have access to the CNC machine anymore; you don't have access to the lathe anymore. These are costly things to purchase for a poor college student coming out of school with all that debt.

ME: Did you feel pressure to come up with something that was as brilliant and influential as Kickstarter?
C.A: We'd reflected on this in the sort of heyday—that it might be the coolest thing we ever work on. And I'm cool with that. With that being a point in my life.

ME: Artists and engineers and inventors all flock to Kickstarter to get their ideas going. Were you surprised at the level of engineering that so many of the projects require?
C.A: I so badly want to reflect on the Charlie Rose interview with George Lucas. I'm still trying to digest it and understand it. He says he sees himself, very cautiously, and humbly, as an artist. He was talking about innovations. What he did with the 1977 release of *Star Wars*—he was scrappy, he didn't have a lot of money, and the technology wasn't out there. So he invented processes, he invented technology to solve a problem. A problem he was very personally confronted with. His comment was that artists do this all the time—and have forever. Architecture came out of art, as did engineering. There's a shared continuity across those things.

ME: Thanks to crowdfunding, there seems to be a new path for engineers and inventors. Are you pleased to be disruptive?
C.A: I was stupid enough to drop out of school and follow this thing and ended up in a place where you're doing an interview with me. If I'd kept at engineering I'd be miserable right now.

Now there are different options out there. If you feel like you're on to a really great idea and that idea has the potential to create a micro-economy—that's really compelling. It's not even about extracting dollars out of your idea. It's about putting your idea out there and getting credit as an individual for that idea. Because if you're at GE or Boeing—you get a salary, buddy, so there's that. They get the profit of the scale of the thing, and you're just another individual among thousands. I have nothing against any of those companies, but I think there's another option out there. And that is the domain I get really excited about.

ME: And if your daughter wants to pursue some crazy project instead of going to college, what will your response be?
C.A: Totally cool by me, it's her life. **ME**

MICHAEL ABRAMS is a writer based in New York.

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MUSHROOM BATTERIES

battery performance.

"We also said that we want to find a green solution," she said. "We don't want to use any harsh chemical or acid bases, and we were looking around in nature to see what we have. That's how we started."

She says producing one pound of graphite requires the use of up to 300 kilograms of acid and more than 2.5 pounds of water. "Imagine how much wastewater with all these contaminants you are creating and then dumping into the drain. This is clearly causing a serious problem and we wanted to find an alternative that is green and sustainable so that we can meet [growing] demand," she said.

Past research had shown mushrooms are highly porous. "If you turn a mushroom upside down you see these ribbed structures naturally that show right away

Cengiz Ozkan (left) and Mihri Ozkan developed a battery anode derived from common mushrooms.
Photo: Univ. of California at Riverside

you have different levels of porosity," Cengiz Ozkan said. "We had to experiment with different temperatures and different process conditions, and we ended up optimizing the process." The heat treatment that can range from 700 to 1,000 °C turns the nanoribbon-like structures into an interconnected porous carbon nanoribbon.

Mushrooms also have high potassium salt concentrations, which enables additional electrolyte-active material over time. "You see a gradual increase in the battery performance," Cengiz Ozkan said. "All the time your battery is becoming better and more efficient because more pores open up over time as you use the battery. This is the opposite of batteries now, which decline with use."

The Ozkans' research findings were published in a September 2015 issue of the journal *Nature Scientific Reports*. They hope to collaborate with a major car or battery manufacturer to commercialize their technology and develop the next generation of batteries.

Unlike many research projects, which can take years to be commercialized, this one may not take long with the right interest and financing, the two believe.

"We can implement this in a few months if a company wants to get going," Cengiz Ozkan said. ME

NANCY S. GIGES is an independent writer.

FLOW THROUGH THE BIG PICTURE

SOFTWARE PERFORMS THERMO-FLUID ANALYSIS FOR LARGE-SCALE SYSTEMS.

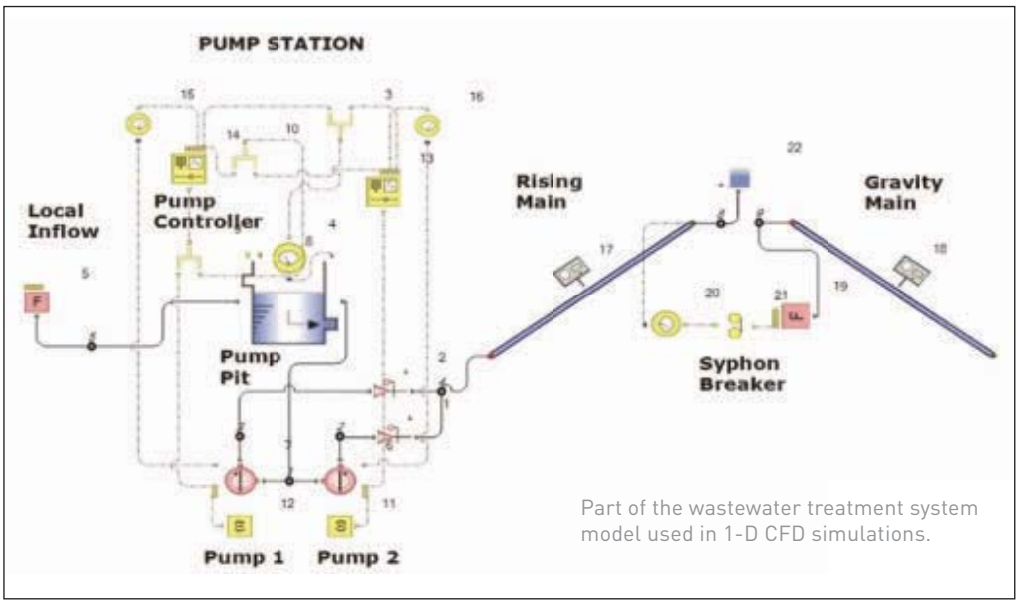
When an engineer thinks of thermal or fluid analysis, most likely 3-D computational fluid dynamics software comes to mind. It is an effective tool to examine the flow through a conduit, for example, or perhaps even a conduit-bend-conduit system.

But to analyze a more extensive network, like a series of pumps with flows through valves, fittings, and branches to delivery points several hundred kilometers downstream, the complex calculations of 3-D CFD would overwhelm available computing power because it considers the shape of all the components as well as the flow.

Water, oil, or gas distribution networks, engine lubrication circuits, fuel movement and supply on aircraft of all sizes, ballast systems on ships and submarines, and ventilation networks would benefit greatly from fluid flow simulation and analysis before actual building begins. That's why there is a simpler, one-dimension CFD alternative designed for simulation of large-scale systems. In these cases, the simulations don't need to model the intricacies of each component, instead the important consideration is the fluid flow through the system, usually in one direction.

Engineers at JS Pump and Fluid System Consultants, an Australian firm specializing in hydraulic modeling of complex fluid networks and advanced control systems for a range of industries, have more than 20 years of experience using 1-D CFD software. The company is currently working on the analysis and optimization of complex wastewater systems.

JS PUMP ENGINEERS WANTED TO TEST THAT 1-D CFD SOFTWARE, FLOWMASTER IN THIS CASE, COULD ACCURATELY PREDICT OVERFLOW EVENTS IN A COMPLEX DYNAMIC SYSTEM SUCH AS A MUNICIPAL WASTEWATER TRANSFER SYSTEM.



Part of the wastewater treatment system model used in 1-D CFD simulations.

Large wastewater systems comprise a network of pump stations connected by rising mains and gravity mains. They are designed to gather and transport domestic and industrial wastewater from the point of origin to a central wastewater treatment plant for processing.

Pump stations receive inflow from connected mains and also gather inflow from the local effluent collection system. Outflow capacity is controlled by pump performance and discharge pipe capacity. Pump station storage volume is determined by the dynamic response between inflow and outflow.

Depending on local topography and organic growth, a wastewater system may cover areas of more than 100 square kilometers. Excessive inflow during heavy rains or breakdown of essential equipment may result in overflow at a pump station and cause environmental and public health hazards.

Hydraulic modeling of complex wastewater networks is traditionally done in steady-state mode. But dynamic simulations are able to predict a time-based system response. For example, timelags resulting from filling and draining gravity mains may significantly affect the overall system capacity and require careful consideration.

JS Pump engineers wanted to test whether 1-D CFD software, Flowmaster in this case, could accurately predict overflow events in a complex dynamic system such as a municipal wastewater transfer system. They chose to conduct a hydraulic study of the wastewater transfer system for a city in Queensland, Australia. Their base case model was designed to consider the effect of weather-related surges on the system and nominal pump duty.

Actual pump duties were to be modeled in further scenarios. The pump stations are of the typical wastewater lifting type, i.e., two submersible pumps in a concrete silo of a certain volume. When overflow is detected, the pumps would be replaced with larger ones, if possible. Other alterna-

tives are to replace the pump station with a larger one or by adding a surge chamber to the existing one.

The engineers were able to analyze where the number and size of pumps was inadequate in the system and how the individual pump capacity and distribution could be changed for optimal pump starts and surge pressure. They also used the simulations to configure maximum dynamic system capacity. The simulations took them about half an hour.

The 1-D CFD software also can help engineers design and understand gas networks, for instance, by providing a solution engine that can account for ideal or real gas effects, a comprehensive fluid property database, a component library that accounts for compressibility effects when considering pressure drop, and the ability to simulate heat transfer to and from the surroundings as well as within the pipelines themselves.

One-dimensional CFD can analyze subsea networks. A transient solver takes into account the effects that submerging or burying pipes may have on temperature and fluid properties. A suite of electromechanical components provided in the software can be used to simulate hardware at different scales. A design engineer can set up and assess the response of networks to different scenarios.

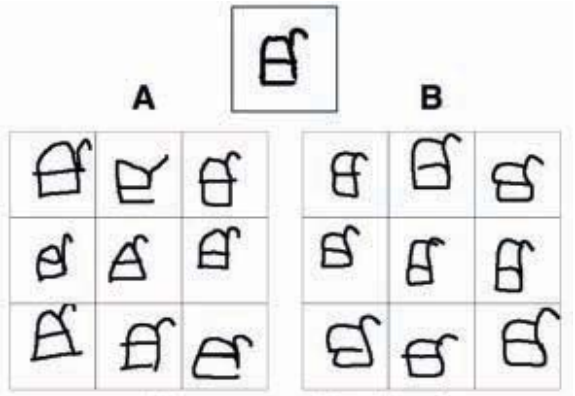
Another application for 1-D CFD is designing power-station cooling networks. The software includes a cooling-water condenser model that enables engineers to analyze in detail the effect of pressure surges on the condenser. The cooling-water condenser model also captures the geometry and elevation of the waterboxes, the positioning of the tube bundle connecting them, and the presence and nature of any gas admission or release valves. ME

DOUG KOLAK is the Flowmaster product specialist for the mechanical analysis division at Mentor Graphics.

MORE WAYS MACHINES SEE

WE WANT AUTONOMOUS VEHICLES to see the road as well as human drivers. But other applications are benefiting from advances in machine vision made by labs on two continents. One system learns to identify handwriting the same way humans do, and holds great potential for new and faster methods of "training" machines to see. The second development is a vision system that runs on a smartphone to help driverless cars navigate the road without sensors or radar.

Children pick up new concepts quickly and readily build upon what they've learned, stringing vowel sounds together to create words, and stringing words into sentences. Computers don't learn like this. They use a method called deep learning, in which their neural networks are "trained" through exposure to many—often tens of thousands, sometimes hundreds of thousands—instances of human speech, objects within images, or different types of behavior until they learn to differentiate the sounds, images, and behavior types.



Machine copies (grid B) of the character at the top look scarcely different from human drawings (grid A).
Image: Massachusetts Institute of Technology

But now researchers at the Massachusetts Institute of Technology have come up with a computer program that learns simple, visual concepts the way humans do—and as quickly. The artificial intelligence program recognizes and can recreate a handwritten character about as accurately as a human can, after seeing just one example, said Brenden Lake, a graduate student in the MIT group. And the program generalizes from what it has learned just as we do.

In fact, the "one shot" machine learning program—so named because it learns in one shot—outperformed a group of humans in identifying handwritten characters after seeing only one example, Lake said.

People use learned concepts in richer ways than conventional algorithms—to take action, imagine something new, or explain behavior, he said. The software Lake's group developed is a step towards artificial intelligence systems that would use learned concepts in similar ways.

The system uses a technique called the Bayesian program learning framework, which generates a unique program for each handwritten alphabet character. A probabilistic programming technique then matches a program to a particular character or generates a new program for an unfamiliar one, allowing the program to learn and recognize characters in after seeing them once, said Joshua Tenenbaum, the group leader.

"What we're trying to learn is not a signature of features or a pattern of features. We're trying to learn a program that generates those characters," Tenenbaum said.

Probabilistic programming allows the program to describe the causal processes inherent in the world, he added.

The program could play a key role in machine-vision systems of the future, Lake said. For example, a factory floor robot might

LEARN LIKE I DO

THE LAB: Computational Cognitive Sciences Group, Massachusetts Institute of Technology, Cambridge; Joshua Tenenbaum, group leader.

OBJECTIVE: The creation of artificial intelligence programs that can operate as human cognition does.

DEVELOPMENT: A computational model that learns visual concepts very quickly and in the same way humans learn.

learn to group similar objects together or recognize objects as the same even when viewing them from different orientations. Autonomous vehicles could "instinctively" recognize road barriers or hazards such as pedestrians and bicyclists, rather than needing to be trained to recognize all the types of barriers they might encounter.

"Bringing machine-learning algorithms closer to the capacities of human learning should lead to more powerful artificial intelligence systems as well as more powerful theoretical paradigms for understanding human cognition," Tenenbaum said. "We want to understand everyday human inductive leaps in computational terms."

The researchers' findings appeared in the Dec. 11, 2015, issue of the journal *Science*. ME

Engineers at the University of Cambridge have developed a technology that uses deep learning to give robotic sight to driverless cars. The system maps road scenes—and road barriers—onto a camera or smartphone in real time, thus performing the job of the expensive sensors used to give driverless cars their environmental awareness.

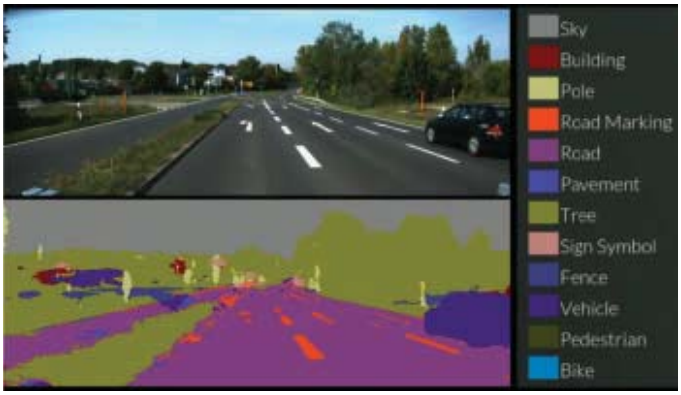
The system, SegNet, does not control the car. Instead, it enables it to "see" by identifying the road ahead of it and the scenery around it, which, of course, helps the car maneuver along the road and avoid collisions.

SegNet is an object recognition application that labels objects and maps the street scene in real time. The labels are more accurate than even the advanced radar systems on today's semi-autonomous cars, said Robert Cipolla, who led the research. SegNet views a street scene and immediately identifies its contents, placing them into 12 categories, including roads, street signs, pedestrians, buildings, and cyclists.

Rather than try to classify objects by size or shape, SegNet recognizes them by their color, intensity, texture, and spectral information, the type of data easily extracted from the pixels of digital photographs. This enables the system to identify objects, like trees or shrubs, with shapes the system has never seen before.

To train SegNet, a group of Cambridge undergraduates manually labeled every pixel within 5,000 images. The researchers then trained the system by exposing it to those images. SegNet then generated its own algorithms to identify new objects. In operation, it classifies images in a speedy 65 milliseconds.

"It's remarkably good at recognizing things in an image because it's had so much practice," said Alex Kendall, a Ph.D. student in the university's department of engineering who helped develop the technology. "However, there are a million knobs that we can turn to fine-tune the system so that it keeps getting better."



SegNet classifies objects on a digital screen by the data in their pixels, helping it identify objects it has never seen before.
Photo: University of Cambridge

FOLLOW THE ROAD

THE LAB: Machine Intelligence Laboratory, Computer Vision and Robotics Group, University of Cambridge in England; Robert Cipolla, group head.

OBJECTIVE: Exploration of machine autonomy and intelligence in uncertain and unstructured real-world environments.

DEVELOPMENT: A system that gives driverless cars sight without expensive sensors or radar.

The technology might one day replace the radar and the light and ultrasound sensors used by driverless cars currently in development. Those vehicles identify objects by relying on radar and remote-sensing technology, but they often cost more than the car itself, Kendall said.

SegNet functions in urban environments under nearly all lighting conditions, including the dark. The researchers hope to train it to recognize objects in more rural settings, under an extended range of weather conditions, and in varied climates, Kendall said.

Although the system has been successfully tested on both city roads and motorways, it's not ready for prime time, Cipolla said. But it could be used as a warning system when a collision is possible.

Beyond driverless cars, the system could be used in other applications, such as robotics, augmented reality, and surveillance or security cameras, Kendall said.

Readers can check the demo at http://bit.ly/21bLvHX. ME

JEAN THILMANY is a writer based in St. Paul, Minn.

A CLEANER GRID WITHOUT ENERGY STORAGE

A nationwide network of high-voltage dc power lines connecting U.S. regional electric grids could enable wind and solar power to slash electricity-sector carbon dioxide emissions by 80 percent by 2030.

Those connections also would eliminate the need for grid-scale energy storage, according to a modeling study published in the journal *Nature Climate Change*.

Most models of the future U.S. electrical grid have assumed that it would continue to be divided into regionalized grids. But that assumption misses wind and solar's full potential, said Alexander MacDonald, the recently retired director of the U.S. National Oceanographic and Atmospheric Administration's Earth System Research Laboratory.

That's because in an area as large the continental United States, most of the time the wind will be blowing or the sun will be shining somewhere, and excess energy from one region can make up for shortfalls in another. For example, a nationalized grid with long-distance HVDC power lines could let Nebraska wind farms or Arizona solar fields power factories and homes in Boston or New York, MacDonald said.

To find out if such a grid could help scale up renewables at a competitive cost, MacDonald, Chris Clack, who's a mathematician at the University of Colorado, Boulder, and four colleagues built a model to project out from current conditions to 2030. Called the National Electricity with Weather System, the model started with the mix of generators and power lines on the grid in 2012. It used detailed data on regional weather, electricity demand, and the cost of fuels such as coal or natural gas. It required power to be reliable, but otherwise let the various generation sources compete on an open playing field.

A nationalized grid that relied mostly on wind and solar—with natural gas as a backup—supplied reliable power at a 9 percent lower projected cost than the current mix of fossil fuels, nuclear, and hydroelectric power. In fact, it relied so much on these renewables that carbon dioxide emissions fell 80 percent below 1990 levels.

"The unique thing about the study is the 80 percent emission reductions without storage, which is amazing, and that this worked at a low cost without a change to the fossil-fuel infrastructure," said environmental engineer Mark Jacobson of Stanford University, who studies utility-scale renewable energy. ME

BODY HEAT CAN BEND MEMORY POLYMER

Shape-memory alloys such as Nitinol are found in a number of medical and industrial applications, due to their ability to flex and relax when heated or cooled.

A similar material—shape-memory polymers—has medical technologists excited about its potential use in dialysis needles, orthopedic suture anchors, and vascular stents. Up to now, however, the usefulness of the polymers has been limited by the temperature needed to activate their bending, typically 50 °C or more.

Now a team of chemical engineers has developed a new type of high-strength polymer that can change shape when triggered by simple body heat.

Mitch Anthamatten, a professor at the University of Rochester, and graduate student Yuan Meng developed their shape memory polymer to retain a temporary shape until it's triggered by a heat source with a temperature as low as 35 °C.

The team also engineered the material to store large amounts of elastic energy, which increases its ability to perform work, Anthamatten said, adding that the material can lift 1,000 times its mass.

The principle behind shape-memory polymers is relatively straightforward. When a strip of the material is stretched, twisted, or deformed, the force acting on the polymer causes the long molecular chains to crystalize and the strip becomes locked in the new shape. The only way for the polymer to return to its original shape is to add energy in the form of heat.

Anthamatten and Meng were working to control the crystallization process when they added molecular cross-links to the individual polymer strands. They found that by adjusting the number and types of cross-links, they could control the triggering temperature.

The researchers were studying the material without worrying about applications, Anthamatten said. "But I think the material may fill needs that require transition temperatures near body temperature."

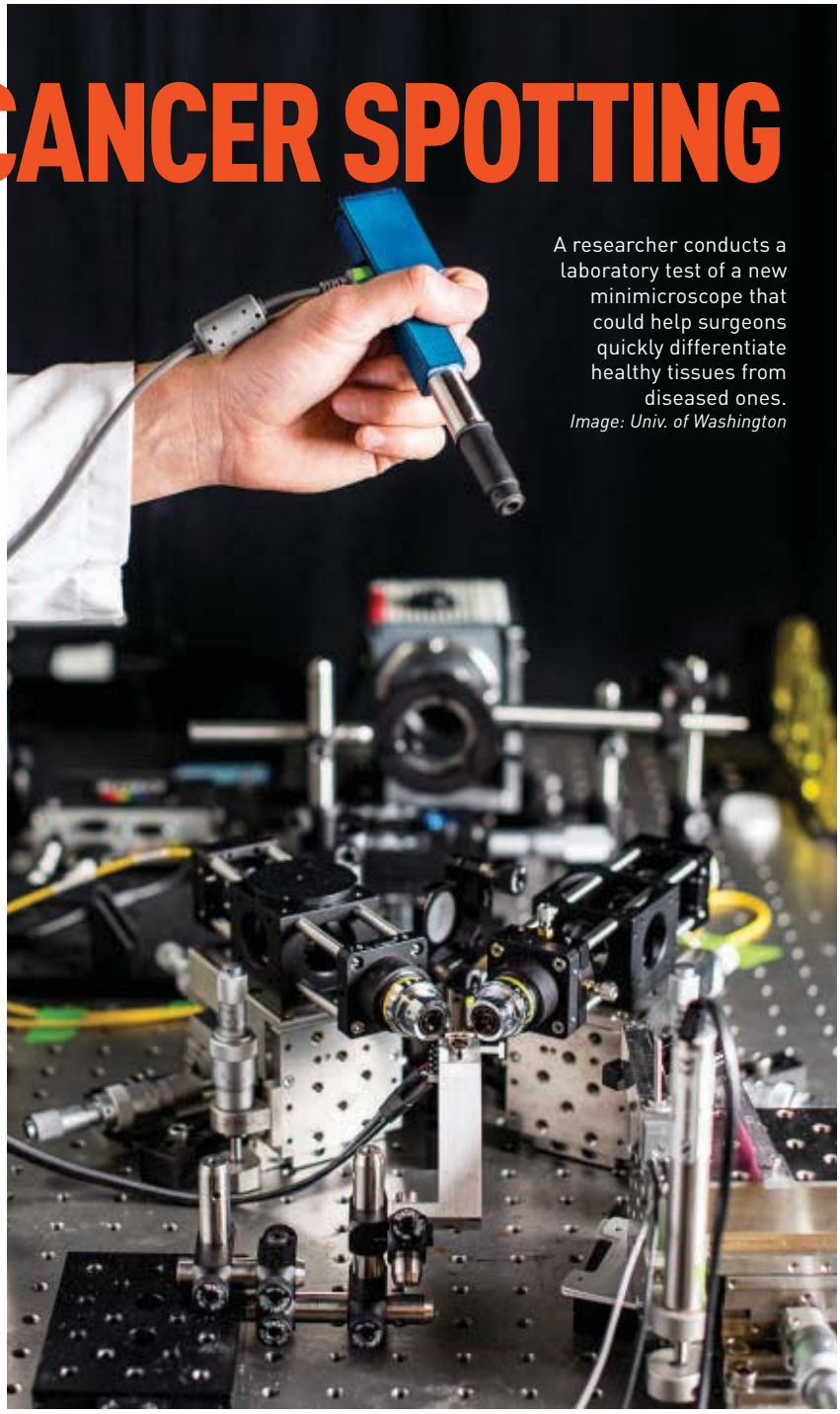
One possible use of the material is in a vascular stent that uses body heat to unfold and open a blood vessel.

The team is currently refining and improving the properties of the material, which Anthamatten expects to appear in commercial applications within a few years.

The work was published in February in the *Journal of Polymer Science Part B: Polymer Physics.* ME

REAL-TIME CANCER SPOTTING

A NEW PEN-SIZED MICROSCOPE could give surgeons, especially those removing brain tumors and oral cancers, a tool they need to peer below the surface of an opaque tissue and see in real-time at a cellular level.



A researcher conducts a laboratory test of a new minimicroscope that could help surgeons quickly differentiate healthy tissues from diseased ones. *Image: Univ. of Washington*

Jonathan Liu, an assistant professor of mechanical engineering at the University of Washington, hopes his device will eventually help surgeons and other doctors spot cancer cells and remove them without damaging the healthy tissue around them. That would solve two of the main challenges cancer surgeons face.

To remove a tumor, surgeons typically use sight, touch, and pre-operative images to determine when to stop cutting, Liu said. They can then send excised tissue samples to a pathology lab to distinguish between cancerous and healthy tissue, but that often takes days. In practice, this means that surgeons rely on their subjective clinical judgment. As a result, they sometimes miss cancerous tissue, which can lead to recurrence, or cut out too much healthy tissue, which can damage vital organs.

"There's no good, real-time method for diagnosing tissues," Liu said.

To give them one, Liu designed his microscope to overcome some of the technical problems of previous minimicroscopes, which achieved a compact size at the cost of imaging speed and quality, resolution, contrast, and field of view.

Liu's biggest engineering challenge was trying to align the tiny mirrors, lenses, and other components in such a small device. He directed micromirrors with an optical beam to scan tissue line by line. This allows the device to quickly compose an image, which reduces jitter-induced blur and could help a surgeon see clearly.

The microscope also deploys a technology called dual-axis confocal microscopy that makes otherwise opaque tissue visible, enabling surgeons to see details up to one-half millimeter beneath its surface.

Liu and his colleagues described their microscope in *Biomedical Optical Express*.

Combined, the technologies produce high enough contrast and resolution to reveal subcellular details that distinguish cancer cells from healthy tissue. The device could lead to new standardized, automated diagnostic approaches, especially for skin cancers and mouth, throat and other oral cancers, the authors wrote.

Liu expects the microscope—developed with Memorial Sloan Kettering Cancer Center in New York City, Stanford University and the Barrow Neurological Institute in Phoenix—to undergo clinical feasibility studies later this year. ME

JEFF O'HEIR

PRINTING REPLACEMENT BODY PARTS

Bioengineers have long wanted a way to build a hunk of living bone, cartilage, or muscle suitable for replacing diseased or damaged tissues. But researchers have struggled to create solid tissues that are sturdy and resilient enough to function in the body, and that have a way to supply the interior cells with oxygen and nutrients and carry away cellular waste.

Now, a team led by Anthony Atala, director of the Wake Forest Institute for Regenerative Medicine in North Carolina, has developed a new 3-D bioprinting system that promises to do just that.

The method starts with an image from a computed tomography or a magnetic resonance imaging scan and translates it into a computer-assisted design file of the replacement tissue. A printer then extrudes lines of biodegradable, plastic-like material to form a scaffold that supports a matrix of nutrient-rich, water-based gel embedded with living cells. The printing process also leaves a capillary-like network of ultrafine channels to nourish the cells as they grow.

The system, which Atala calls the Integrated Tissue and Organ Printer, produced cartilage the size and shape of a baby's ear that grew under the skin of a mouse. His team also grew a jaw fragment and segments of skull bone that survived well in rats.

The researchers reported their work in *Nature Biotechnology*.

With further development, Atala's method could eventually work to construct clinical grade bone and cartilage, though it will take more research to print more complex tissues, such as liver, kidney and heart, said Aliasker Salem, a 3-D-bioprinting researcher at the University of Iowa who was familiar with Atala's paper.

"This is really quite elegant work," Salem said. ME

"**THE OIL MARKET** has witnessed over its long history, periods of instability, severe price fluctuations, and petro-economic cycles. This is one of them. Market forces, as well as the cooperation among the producing nations, always lead to the restoration of stability. This, however, takes some time."

— Saudi oil minister Ali Al Naimi, quoted by The National *(United Arab Emirates), January 17, 2016.*

STEEL'S ROLE IN NUCLEAR ENGINEERING

C.L. HUSTON JR., LUKENS STEEL CO., COATESVILLE, PA.

In an article based on an address to ASME's Nuclear Engineering Luncheon, the scion of a steel-making family reflects the enthusiasm of those engaged in establishing an industry based on a new technology.

We hear today of the rapid developments which are taking place in the adaptation of nuclear fuels to electric-power production and distribution. The Duquesne Power and Light project is under way. The Consolidated Edison Company of New York project is beyond the discussion stage. More will follow, including Commonwealth Edison's plant in Chicago. While touring England and the Continent recently, I learned that Great Britain expects to have its first full-scale atomic power plant completed by the end of 1956, and has decided to build six additional units of the same type. Another eight are considered part of the near-future program. It is no secret that the English hope to be major exporters of nuclear-power reactors for world markets. While plans in Western Europe are not yet as ambitious as in England, it stands to reason that countries such as Switzerland, Holland, and Belgium, whose industries depend so heavily upon export, will move to share in the market. ....

In spite of the hum of research and development activity for nuclear-fueled electric-power programs in the United States, the most optimistic estimates indicate that no more than 10 percent of our country's utility-power consumption will be generated from the source 10 years hence.

While we may take comfort from the probability that the industrial applications and effects of atomic energy will not upset our manufacturing processes and our markets overnight, we are negligent and shortsighted indeed if we do not bend every reasonable effort within our respective companies and industries to adapt atomic energy as fully as possible to the public welfare.

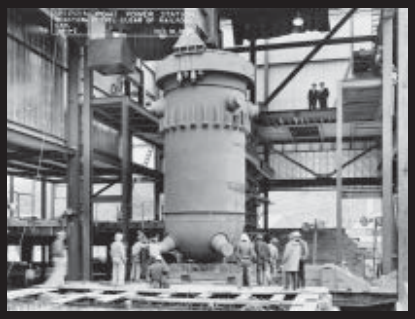
Someone has observed, "The more I know of a man, the more good I find in him." It seems to me the same may be said of nuclear power. The more we understand it, the better it will serve us. Similarly, the more we understand steel and come to know its further possibilities, the greater will be its role in nuclear engineering. **ME**

LOOKING BACK

Commercialization of nuclear-generated electric power was only months away when this article was published in April 1956.

NASCENT NUCLEAR POWER

C.L. Huston's information that the British would have a nuclear plant in operation before the end of 1956 was accurate. Calder Hall, the world's first commercial nuclear power station, connected to the grid in August and was officially opened by Queen Elizabeth II in October. The Duquesne project resulted in the first U.S. commercial nuclear power plant when the Shippingport station sent electricity to the grid in December 1957. Shippingport is an ASME Historical Mechanical Engineering Landmark.



Reactor pressure vessel during construction (1956)

BY THE NUMBERS: RENEWABLE ENERGY COMPETITIVE ON COSTS

Wind, solar, and other alternatives have always suffered from sticker shock. But according to an analysis from an investment bank, renewables now generate some of the cheapest power on the grid.

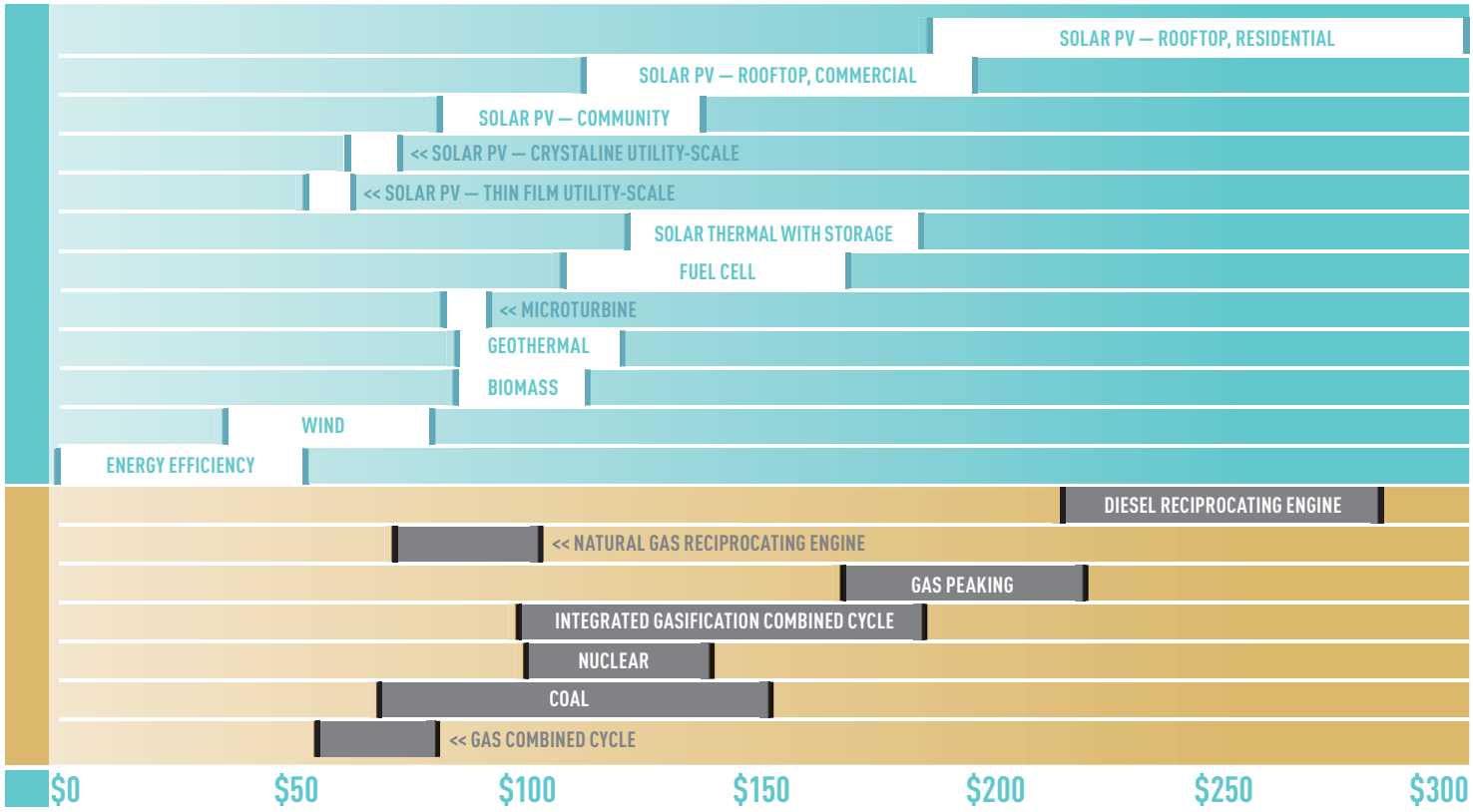
Anyone who drives is aware of the crash in oil prices over the past two years. But it isn't just the petroleum sector that is being rocked by new technology. The electric power industry is seeing some of its long-standing concepts about renewable energy sources overturned by new data on the cost of installing wind, solar, and other carbon-free power.

For instance, the New York City-based investment bank Lazard in November 2015 released an analysis of the levelized cost of energy for the U.S. power industry.

The levelized cost of energy is a measure of the total amount of money needed for building and operating a power plant over an assumed financial life and duty cycle, as a function of the amount of electricity generated. That sets a floor for the price a generating asset can charge and turn a profit.

Until recently, the source of power with the lowest levelized cost was conventional coal-fired thermal generation, especially without expensive pollution control systems. Compared to coal, cleaner sources such as solar, wind, and nuclear power were too expensive for utilities to justify to their shareholders and ratepayers.

But a combination of factors—from efficiency improvements in wind turbines and the mass production



of photovoltaic panels in China to more stringent pollution regulations for coal—has eliminated the price penalty. According to the data published by Lazard, while coal power plants have an unsubsidized levelized cost of energy ranging from $65 to $150 per MWh, the unsubsidized cost for an onshore wind farm is only $32 to $77 per MWh, and a utility-scale photovoltaic facility ranges from $50 to $70 per MWh.

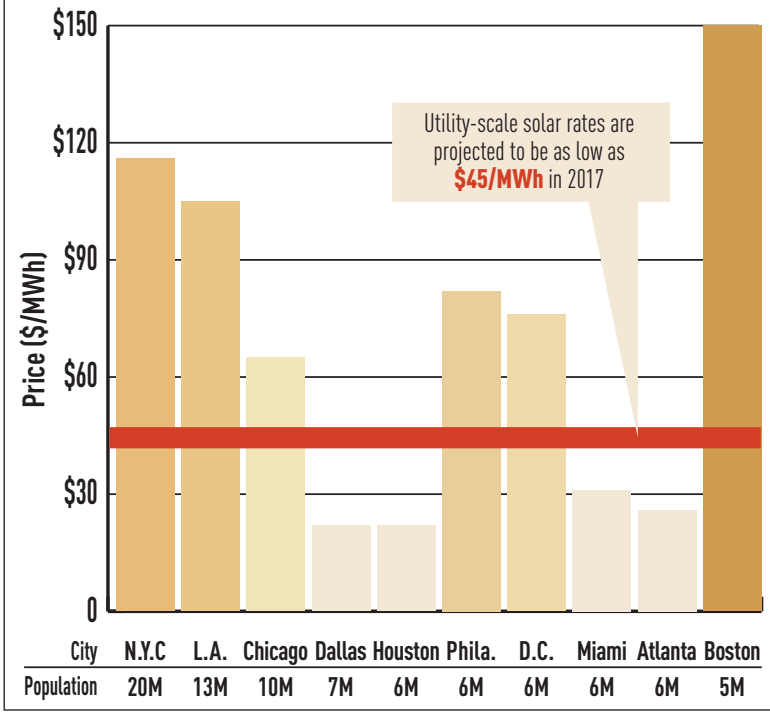
That is a drop in cost by more than half since 2010.

Indeed, the only conventional power source that is in the same range as wind and solar is a gas-powered combined-cycle turbine, which thanks to its supreme efficiency has a levelized cost of power between $52 and $78 per MWh.

Lazard found that the cost of onshore wind and utility-scale solar power is less than the wholesale rate for electricity in cities such as New York, Los Angeles, Chicago, and Washington.

While renewable energy has been pushed as a means to reduce carbon emissions and other pollution, data such as this suggests that it has become the economical choice for power, at least in the United States. And that change will likely revolutionize the U.S. electric grid going forward. ME

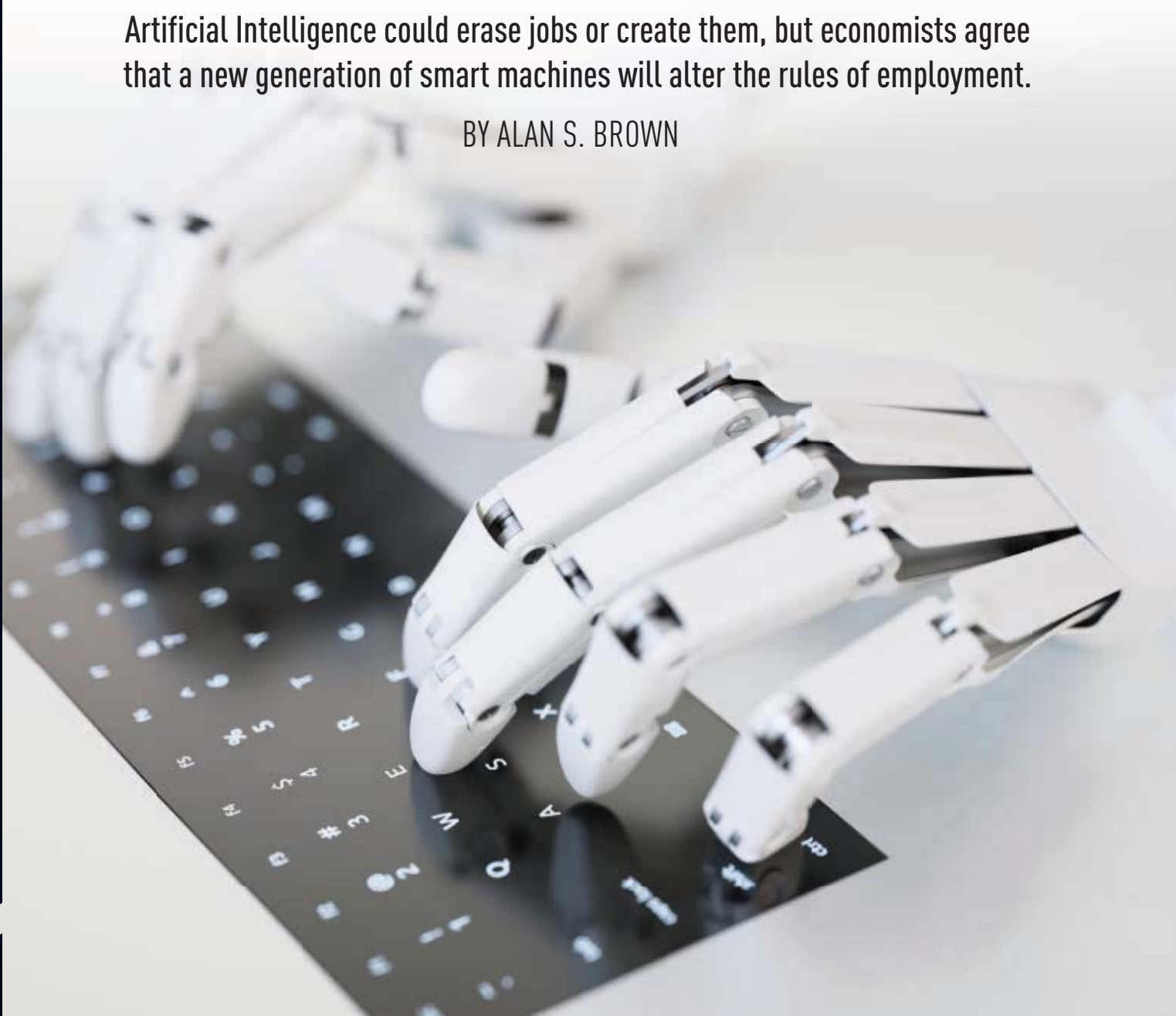
GENERATION RATES FOR THE 10 LARGEST U.S. METROPOLITAN AREAS



ROBOTS AT WORK
WHERE DO WE FIT?

Artificial Intelligence could erase jobs or create them, but economists agree that a new generation of smart machines will alter the rules of employment.

BY ALAN S. BROWN



The robots are coming for our jobs—and sooner than we think.

That's the gist of a number of recent reports by economists and technology researchers. For instance, nearly half of all U.S. jobs could be automated within a decade or two, cautions a study by an Oxford University economist and engineer. Smart machines will replace one in three jobs by 2025, warns technology research firm Gartner. Robots will perform 45 percent of all factory tasks by 2025, up from 10 percent today, blares Bank of America.

We have been down this road before, other economists fire back. Two hundred years ago, English textile workers felt so threatened by power looms that they started smashing machinery. Worries like those of the Luddites also arose when mechanization scythed through farm hands, when automation first threatened factory workers, and when PCs began to eliminate secretarial jobs. Every time, productivity grew, the economy thrived, and employment rose.

Why wouldn't that be the case today?

"What's new is that algorithms are sensing things and reacting almost as well as a human would," said W. Brian Arthur, a visiting researcher at the Intelligent Systems Lab at Palo Alto Research Center, whose theories shaped our understanding of the high-tech economy. "We're living in a world where, for the first time in human history, we can get a lot done, not just in manufacturing but in the service economy, extraordinarily cheaply and automatically."

Algorithms have already eliminated millions of jobs among factory workers, video store clerks, travel agents, bookkeepers, and secretaries. Middle-skill occupations, which require more schooling or training than high school but less than a four-year college, fell from 60 percent of all U.S. jobs in 1979 to 46 percent in 2012. Similar declines occurred in 16 European economies.

Algorithms running on interconnected computers have reshaped entire industries. Arthur points to the Blockbuster video chain: "It doesn't employ fewer people, it's gone. All the travel agents that populated Palo Alto have disappeared."

Now algorithms are invading the skilled professions. Software is replacing some loan officers, attorneys, and sports and business journalists who write news. IBM is modifying its *Jeopardy*-winning Watson technology to diagnose diseases and read medical images. And engineers increasingly rely on expert systems to assess designs and simulations.

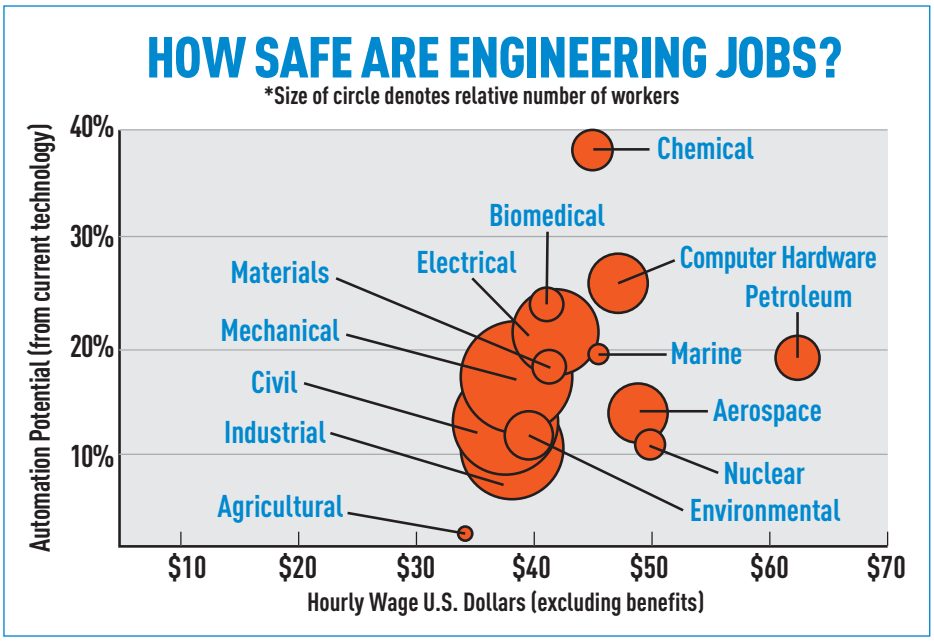
In the past, when mechanization disrupted farming, laborers took on factory jobs. When factory employment flattened, workers moved into offices. "Today," Arthur said, "we don't have a sector that is growing fast enough to mop up those people who get laid off."

THE SECOND ECONOMY

Five years ago, Arthur coined the phrase "the second economy" to describe a system in which Internet-enabled computers execute business processes once handled by people.

Twenty years ago, for example, when we wanted to travel we called travel agents, who would ask where and when we wanted to go, query some proprietary databases (or even paper catalogs), talk us through our options, and book reservations.

Today, we simply go online. This sets off a conversation among machines. Software gathers information about available flights. It charges our credit card, checks our preferences, reserves our seat, and sees if we qualify for a security clearance



or lounge access. It adds our weight and baggage to the flight manifest, and orders additional fuel for the flight.

Everything takes place within seconds, without any human intervention. Similar conversations are happening everywhere in the economy—between RFID tags and scanners at ports and warehouses, between television sets and servers that stream movies, and more.

"We're undergoing a digital revolution, a transformation of the economy comparable to the Industrial Revolution. The Internet of Things is creating masses of digital sensors, and they are going to generate masses of data," Arthur said. As new algorithms arise to make sense of the data, they will only strengthen the second economy.

This transformation is already having a profound effect on people's employment prospects. And its impact is growing because computers are getting smarter, quickly.

Only a few years ago, for example, voice recognition worked in highly structured dialogues, where it expected certain types of responses. Today, Apple's Siri and its competitors provide (mostly) relevant answers to unstructured questions. Some apps even translate languages on the fly.

Autonomous cars show just how fast AI can evolve. In a 2004 DARPA challenge, the best car chugged only seven miles down a straight road. Three years later, six autonomous vehicles completed a 60-mile circuit through an abandoned military base among moving cars, pedestrians, and street signs.

Their performance was not as good as a human. This led Silicon Valley entrepreneur Martin Ford to predict that AI was not likely to replace human truck drivers anytime soon.

One year later in 2010, Google announced that its fleet of autonomous cars had logged 100,000 incident-free miles. Today, nearly every large auto company has an autonomous car program. This past May, Nevada granted the first commercial license ever to an autonomous truck.

Ford, meanwhile, appears to have reconsidered the speed of change. He named his most recent book, *Rise of the Robots: Technology and the Threat of a Jobless Future*.

GETTING SMARTER FASTER

According to Gill Pratt, who spearheaded DARPA's robot challenge and now heads Toyota's $1 billion robotics program, two emerging technologies will help robots learn even faster.

The first is cloud robotics. In the past, memory and processor speed limited robots' ability to learn. Today, robots can upload what they learn into the cloud. Once there, other robots could access instructions for everything from cooking chicken cordon bleu to performing surgery. What

one robot knows, every robot can know.

The second is deep learning, an advanced type of machine learning that allows robots to learn things that humans understand tacitly. Robots, for example, have trouble telling tables from chairs. Both may have the same number of legs, similar surface areas, and stand tall or short. Yet humans usually know where to sit and where to place their drinks.

Deep learning tries to overcome this problem with algorithms that sort through vast amounts of data and come to their own conclusions.

Google, for example, used deep learning software to scour YouTube cat videos and come to its own conclusions about what defined a cat. It used this algorithm to identify cats twice as well as any other image recognition software. It took Google only 16,000 computers and 10 million videos to learn to do this.

Compared with even the youngest children, who know a cat when they see one, such results may seem pathetic. Yet Google learned enough from its experiment to improve its search engine, slash translation errors, and provide more relevant newsfeeds. Recently, a Google deep learning program, AlphaGo, soundly defeated the reigning European champion of the game Go, a feat that most AI specialists expected to take another decade.

Pratt imagines a world where robots and distributed sensors would send data to the cloud. Deep-learning AI would then analyze the data and use it to make robots and other types of AI software smarter. In this way the combination of cloud robotics and deep learning could yield rapid advances in machine intelligence, and displace many workers in a very short time.

This may already be happening. In 2011, Erik Brynjolfsson and Andrew McAfee of MIT's Sloan School of Management warned in their book *Racing against the Machine* about technology's potential for disruption.

> "The Industrial Revolution replaced people and animal power with machines. Now we are developing a neural system to go with it."
>
> *— W. Brian Arthur, Palo Alto Research Center*

Building on Arthur's research, they noted that between 1947 and 2000, automation increased productivity, employment, and wages. Since 2000, however, U.S. productivity continued rising, but new job creation slowed and median income actually declined. They see smart machines at work.

"It's not so much a matter of jobs in general as specific types of skills being substituted for by new technologies. People with those skills see falling demand for their labor, so they will have lower incomes and less work unless they develop new skills," McAfee said.

Typically, the easiest tasks to automate are routine and repetitive, such as classifying information, routing files, or operating a metal press.

On the other hand, jobs for restaurant workers, janitors, and home health aides are growing. They require few skills, which keeps wages low, but they involve multiple tasks and human interaction that are difficult to automate.

The true winners in the new economy have specialized skills and often use computers to amplify their knowledge and capabilities. They are the ones, for example, who create software to book the lowest fares or prepare taxes. Their companies may make billions of dollars, but their websites and software put hundreds of thousands of people doing routine jobs out of work.

"Two hundred years ago the Industrial Revolution replaced people and animal power with machines," Arthur said. "Now we are developing a neural system to go with it. It is a huge and unstoppable transformation."

FASTEST GROWING/SHRINKING OCCUPATIONS (UK)

OCCUPATIONS	EMPLOYMENT IN 1992	EMPLOYMENT IN 2014	% CHANGE 1992-2014
TOTAL EMPLOYMENT	**24,746,881**	**30,537,415**	**23%**
Nursing auxilliaries and assistants	29,743	300,201	909%
Teaching and educational support assistants	72,320	491,669	580%
Management consultants and business analysts	40,458	188,081	365%
Information technology managers and above	110,946	327,272	195%
Welfare, housing, youth, and community workers	82,921	234,462	183%
Care workers and home carers	296,029	792,003	168%
Actors, dancers, entertainment presenters, producers, and directors	47,764	122,229	156%
Financial managers and directors	88,877	205,857	132%
Footwear and leather working trades	40,715	7,528	-82%
Weavers and knitters	24,009	4,961	-79%
Metal making and treating process operatives	39,950	12,098	-70%
Typists and related keyboard occupations	123,048	52,580	-57%
Company secretaries	90,476	43,181	-52%
Energy plant operatives	19,823	9,652	-51%
Farm workers	135,817	68,164	-50%
Metal macining setters and setter-operators	89,713	49,861	-44%

THE TECHNOLOGY JOB MACHINE

Others are more optimistic. They believe that technology will spur employment, just as it always has.

In 2015, three economists from international management consultant Deloitte defended that view in a paper, "Jobs and People: The Great Job-Creating Machine," which was short-listed for the Society of Business Economists' top honor, the Rybczynski Prize. Machines "seem no closer to eliminating the need for human labor than at any time in the last 150 years," the authors wrote.

"The problem is that, while it is easy to point to jobs lost due to technology, it is not as easy to identify jobs created by technology," Alex Cole, one of the authors, said.

Cole and his fellow researchers found those jobs by analyzing labor data going back to 1871. Some of their findings were not surprising. Machines replaced muscle on farms and in factories, while employment grew among people who create, implement, and maintain technology.

Employment also rose for those with specialized knowledge. For example, Britain's 1871 census recorded only 28,000 nurses. They held low-skilled positions closer to domestic service than medicine. With better training, the value of nurses increased and their numbers swelled to 300,000 in 2014.

Demand also surged for service and caring jobs like hairdressers and bar staff. Cole attributes this to technology.

Why? The ability of technology to raise productivity slashed the cost of many necessities, Cole said. In 1950, for example, food made up 35 percent of what the average Briton spent on essential goods and services. By 2014, food's share had fallen to 11 percent. Meanwhile, the real cost of U.K. cars fell by half over the past 25 years, while the U.S. cost of televisions plummeted 98 percent since 1950.

Technology-driven price decreases give consumers more money to spend. Over the past 20 years, they increasingly spent it on health (think nurses), education (more teachers and teacher's aides), and services that were once considered a luxury, Cole said. In 1871, for example, there was only one hairdresser per 1,800 people; today there are more than six. Because Britons can afford to go out more frequently, the number of bar staff has quadrupled since 1951. Other researchers have reached similar conclusions.

Nevertheless, these studies can be misleading:

If smart machines are truly game changers, then past trends and historical data say little about the future. For that reason, leading MIT labor economist David Autor looks instead at the inherent limitations of smart machines in an aptly named 2015 paper, "Why Are There Still So Many Jobs?"

For example, why do robots install car windshields in factories, but humans repair them when they break, Autor asks. The answer is that robots require controlled environments, while humans, who are more flexible, can cope with unstructured tasks. That same adaptability is essential for medical technicians, plumbers, electricians, and many other middle-skill jobs.

Autor is also underwhelmed by machine learning, finding it cumbersome and often riddled with surprising errors. Humans leave computers scratching their digital heads when it comes to identifying cats or not sitting on tables. Even IBM's Watson, which trounced the world's best *Jeopardy* player, got one question spectacularly wrong, he noted. Asked which U.S. city named two airports for a military hero and a battle, it named a city in Canada—Toronto. No one wants a self-driving car to make a similar mistake.

JOBS ON THE REBOUND?

Although they disagree about the long-term impacts, nearly all experts agree that smart machines are creating a very different job market.

Autor and like-minded optimists expect pressures on middle skill jobs to eventually reverse because these jobs combine not only knowledge, but also adaptability, problem solving, common sense, and the ability to communicate with other people.

"Many of the tasks currently bundled into these jobs cannot readily be unbundled—with machines performing the middle-skill tasks and workers performing only a low-skill residual—without a substantial drop in quality," Autor has written.

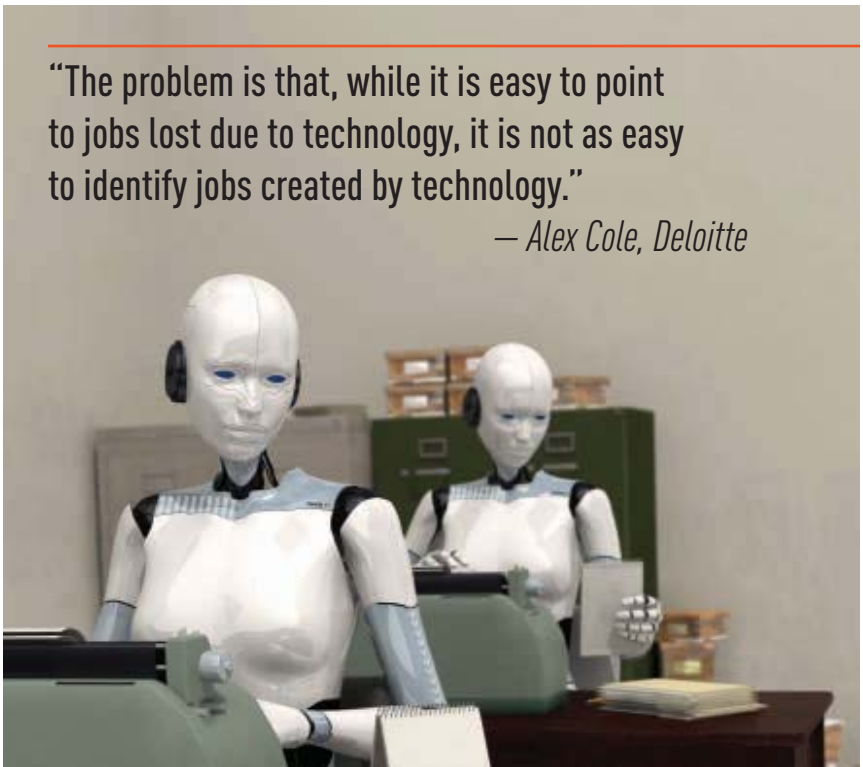
Businesses are already pairing human flexibility with mechanical precision. In 2012, for example, Amazon bought warehouse robot developer Kiva Systems. Kiva's robots work alongside people, bringing shelves of parts to workers. The robots even use laser pointers to show workers which parts to pick, but only humans are flexible enough to rapidly manipulate and wrap parts for shipment

Arthur is not as sanguine. The growth of the second economy is great for people plugged into the system or working with robots. Meanwhile, those without the right skills are finding it harder to secure good, full-time jobs.

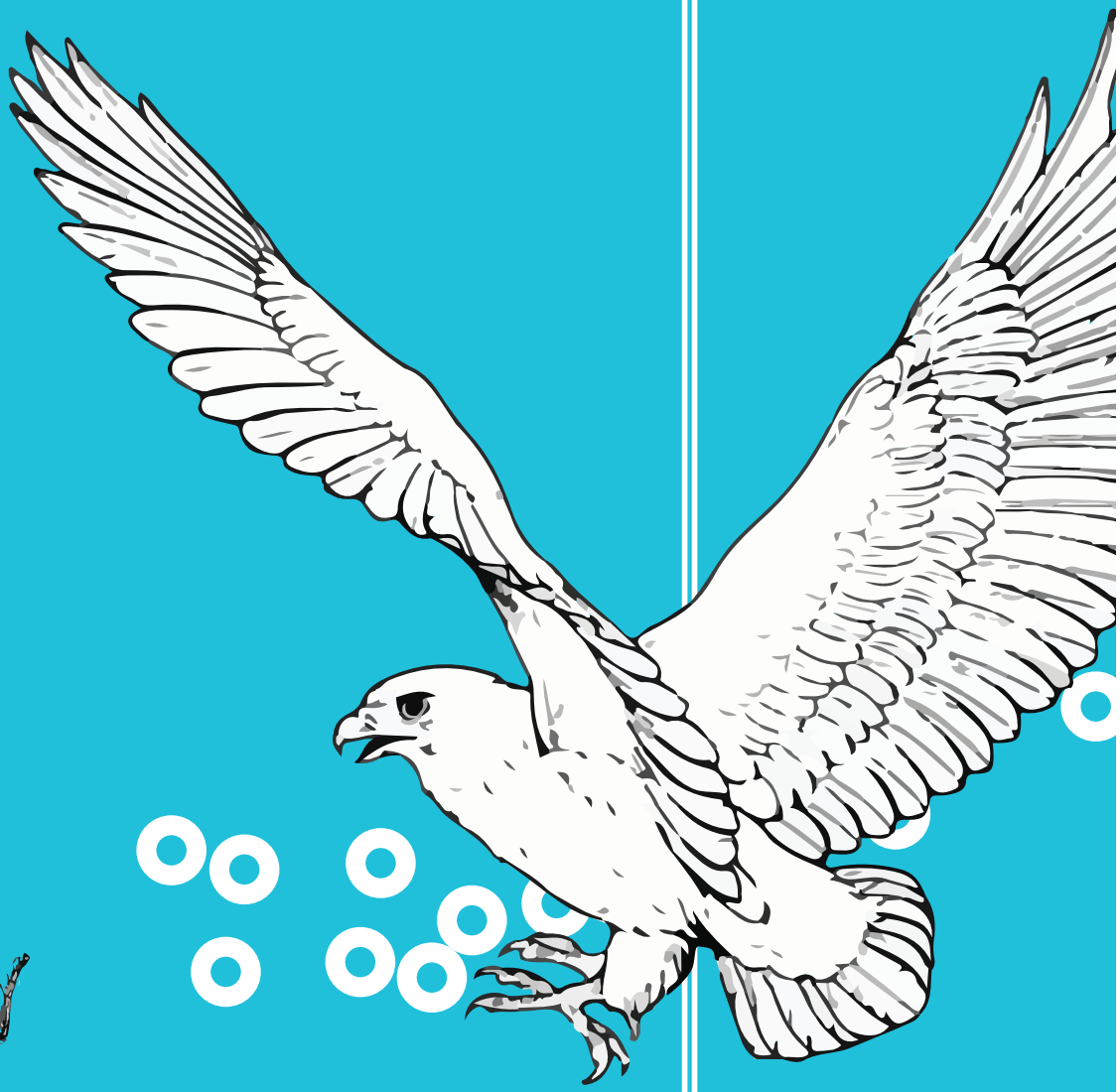
"It's not just that we've lost jobs, but that the middle class has steadily lost hope that life would become better. In America, it was always taken for granted that the next generation would do better. Many people cannot take that for granted anymore," Arthur said.

"It's going to be a large social problem over the next 20 or 30 years," Arthur said. "We'll solve it, because as human beings we always solve our problems with new institutions and new types of arrangements. But until that day, it is not going to be easy." **ME**

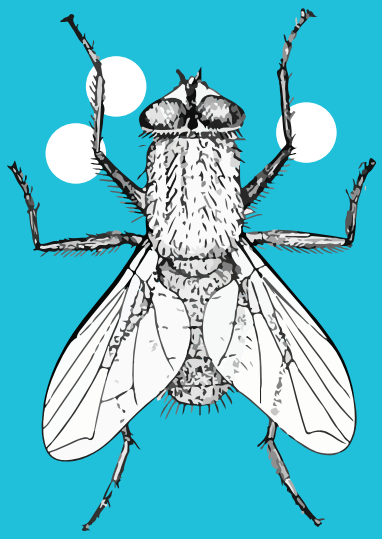
ALAN S. BROWN is associate editor at *Mechanical Engineering* magazine.



ACCELERATED EVOLUTION



ON A CONTINUUM
Houseflies, falcons, and jetliners are all subject to the same evolutionary rules involving moving a weight through the air.



In the development of aircraft, humans advanced their ability to fly and to understand animal fliers.

By Adrian Bejan

Sadi Carnot the French engineer did not build engines. He built something much more lasting: a theory that became thermodynamics. He studied the engines coming from Britain and invading the Continent, and questioned why they were becoming more efficient. Is there a ceiling to engine efficiency?

Carnot's answer is now history. The most efficient is, at best, imaginable in designs where all kinds of "friction" are avoided by making changes, purposeful choices.

The example of Sadi Carnot is a lesson worth teaching to the new generations: take the bird's-eye view. This need is acute today, because we tend to get lost in the deluge of data and information—mountains of empiricism calling for a theoretical framework.

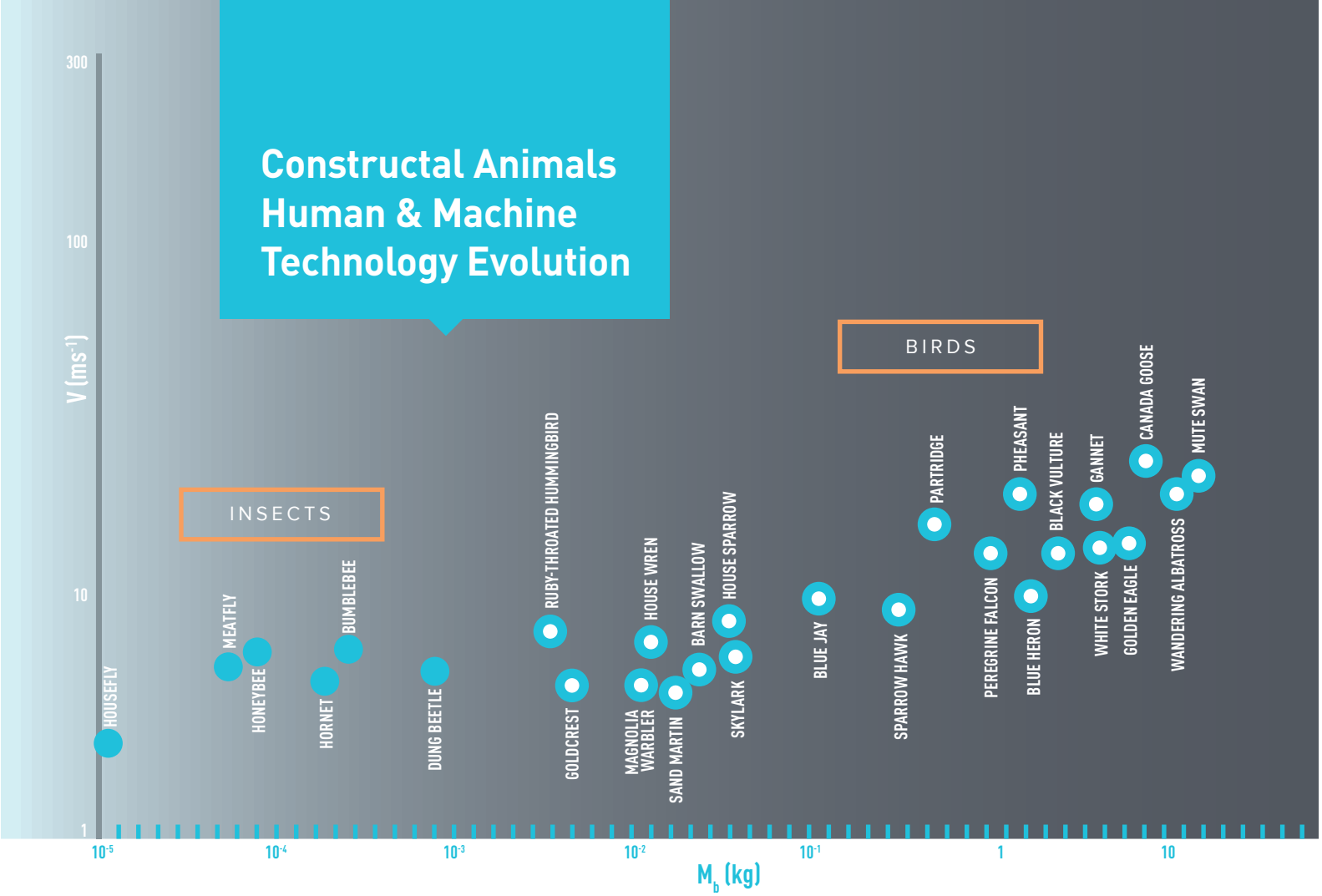
The recorded evolution of flying machines calls for the bird's-eye view and its theoretical, predictive principle. Along with my colleagues Sylvie Lorente and Jordan Charles, I took this step in an extensive study published in the *Journal of Applied Physics*. In this essay we introduce readers to the predictions explained in detail in our study: the broad lines of the evolution of the airplanes and the law of physics, the Constructal Law, which governs evolution everywhere, animate, inanimate, and man-made.

To predict evolution is an important step. The prevailing view in science is that one cannot witness biological evolution because it occurs on a time scale immensely greater than our lifetime. I argue, though, that we can witness evolution in our lifetime.

Humanity is the species that created the engineered world. The modern human is not only the result of slow biological adaptation, but also of human technology.

We can watch the evolution of the flying "human-and-machine species": people encapsulated in and empowered by airplanes, and sweeping the globe. Through application of their knowledge and technological ability, human beings have evolved the ability to fly and continue to enhance that power.

We can document this evolution, and we can also predict it based on physics.



HUMANS AND MACHINES

Look around: the things we see and touch are changing. Some change from day to day; others from year to year, and many from decade to decade. Then there are broad-based changes that can take centuries or millennia to develop.

Airplanes, too, are evolving to carry more and more people all over the globe.

The advancement of airplanes is toward ever-greater efficiency. Each successful new model was presumably more economical than its predecessors of the same size, because otherwise it would not have been economical to adopt it. One of the important trends is that, although new models come in all sizes, the big airplanes of one decade are joined by even bigger models in the next decade.

We can consider the steady advance of aircraft as an example of the natural phenomenon of evolution. Evolution as physics, not as metaphor. Evolution means flow organization (or flow design) that changes over time. Evolution happens everywhere you look, in biological and nonbiological systems. This is why evolution is a phenomenon of physics, of all nature.

In biology, evolution is a descriptive narrative built on imagination, because the time scale of animal evolution is immense relative to the time available to us for observations. One cannot witness animal evolution, and this places the biology argument for evolution at a disadvantage. It would be useful to have access to the evolution of one species in real time.

The history of the airplane satisfies precisely this need. The species to watch is us. New airplane models do not happen by themselves. They are extensions, enclosures of the humans who come together to move on the globe more easily.

The species to watch is the human-and-machine species.

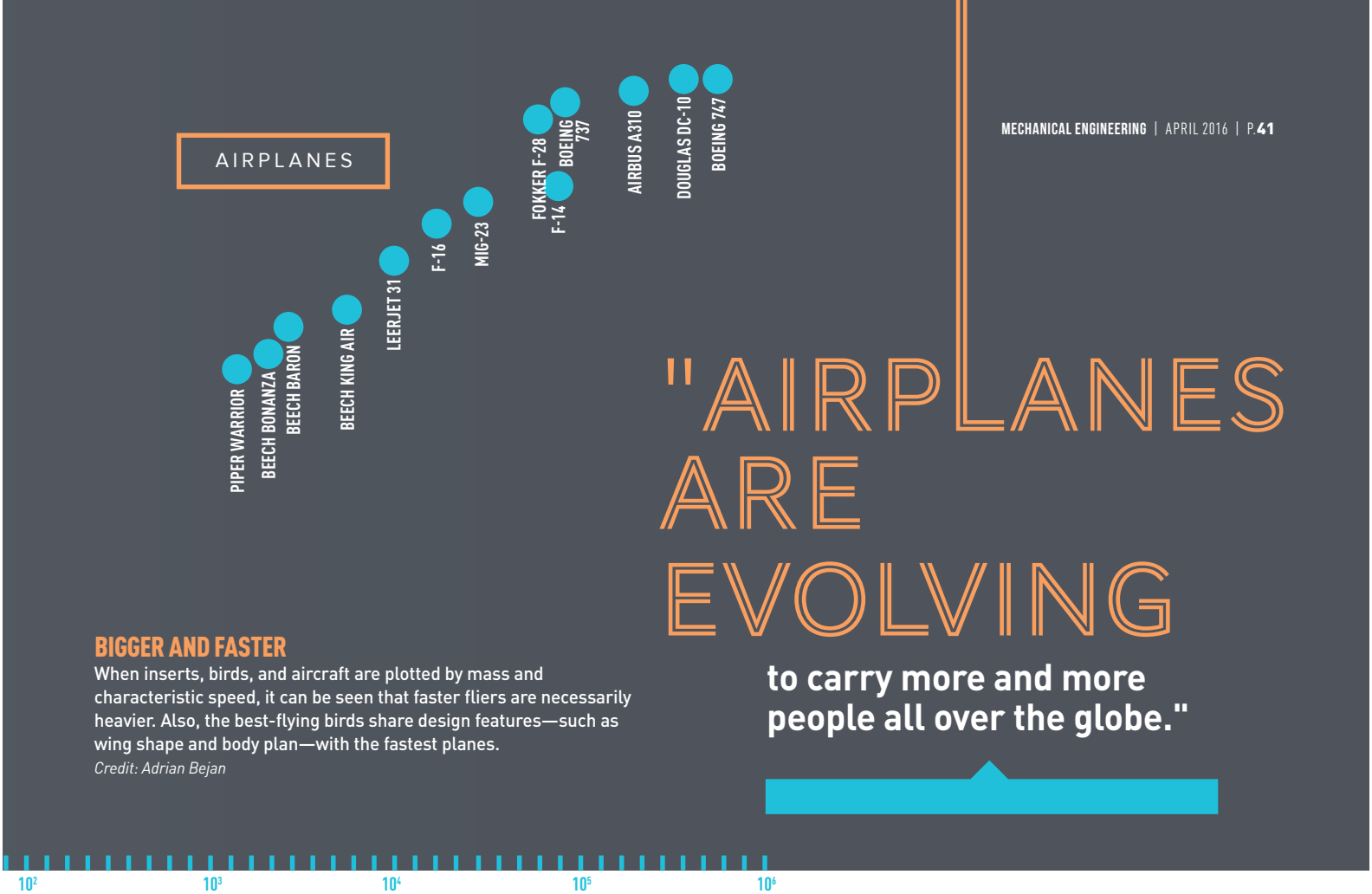
The human species is not defined only by its advanced biology—bipedal walking and nimble opposable thumbs—but also by the technology that is the fruit of human knowledge, which means action with purpose.

The word "machine" in the human-and-machine species requires some explaining. It is not about automobiles, power plants, refrigerators, and manufacturing. "Machine" in this instance is used in accord with its oldest meaning, which is "contrivance" (*mihaní* in old Greek), a sophisticated tool that allows for more effective use of human effort.

Every artifact that we attach to ourselves is a contrivance: the shirt, the harvested food, and the power drawn from an animal or an electrical outlet. Over the centuries new contrivances have made us much more powerful, bigger, and longer lived.

Every model of aircraft is a new human-and-machine design for moving our bodies, groups, and belongings over the entire globe. This design is changing, and what evolves with it is the movement of humans. This spreading flow gets better, faster, more efficient, and farther reaching.

This is just like the evolution of animal fliers. The bigger fly faster. The slow evolution of animal fliers has brought numerous forms of animal movement to converge on



BIGGER AND FASTER
When inserts, birds, and aircraft are plotted by mass and characteristic speed, it can be seen that faster fliers are necessarily heavier. Also, the best-flying birds share design features—such as wing shape and body plan—with the fastest planes.
Credit: Adrian Bejan

"AIRPLANES ARE EVOLVING to carry more and more people all over the globe."

the same design features as the evolution of human fliers.

(In this evolution "movie" there are images that deviate from the plot, some faster and others slower, from the hawk and the chicken, to the Concorde. The physics law of evolution is not about outliers. It is about the holistic view, which is the evolving organization, the morphing flow architecture. The fact that the theoretical thread is hairy in some spots is nature. Evolution is a movie in two colors: predictable organization hand-in-glove with random details.)

Equally important is the observation that over time the cloud of flying designs has been expanding. In the beginning were the insects; later came the birds, and even later, the airplanes.

The animal mass that sweeps the globe today is a weave of a few large species and many small. The new are the few and large. The old are the many and small. The new do not displace the old. The new add themselves to the old.

The airplane models evolved in the same way. In the beginning was the Douglas DC-3 and many smaller airplanes; then the DC-3 was joined by the DC-8 and the Boeing B737; next the B747 joined the smaller and older models still in use. In this evolutionary direction, the size record is broken every time. This trend unites human fliers with animal fliers.

ORGANIC SCALE

Think of a vehicle that consumes fuel and moves on the world map, and ask how large one of the organs of this vehicle should be—the engine, for example, or a duct that carries fluid, or the heat exchanger surface of the environmental control system. Because the size of the organ is finite, the vehicle is penalized (in fuel terms) by the component in two ways.

First, the organ is alive with currents that flow by overcoming resistances of many kinds. In thermodynamics, this universal phenomenon is called irreversibility, or destruction of useful energy (exergy), or entropy generation. This fuel penalty is smaller when the organ is larger, because larger means wider ducts and larger heat-transfer surfaces. In this sense, larger seems better.

Second, the vehicle must burn fuel and destroy more exergy in order to transport the larger organ. The fuel penalty for carrying the organ is proportional to the weight of the organ. This second penalty suggests that smaller is better, and it comes in conflict with the first penalty.

From this conflict emerges the discovery that the organ should have a certain, finite size, not too large, not too small, but just right for that particular vehicle.

The organ size recommended by this trade-off is such that larger organs, from engines to fuel loads, belong on proportionally large vehicles, and small organs belong on small vehicles.

During the evolution of airplanes, proportionalities have emerged among the mass of the heat engine (M_e), the mass of the whole aircraft (M), and the fuel load (M_f). The engine data are correlated in a statistically meaningful way as $M_e = 0.13\ M^{0.83}$, where both M and M_e are expressed in tons.

The sizes of engines and airplanes increased by factors of order 20 from 1950 to 2014.

Larger vehicles also travel farther, just like the bigger animals and rivers. The range L is predicted to vary in proportion with M^{α}, where the value of the α exponent is smaller than 1. This is confirmed by the L vs. M data for airplane evolution, which are correlated as $L = 324\ M^{0.64}$, with L in kilometers and M in tons.

Commercial air travel is becoming more efficient. The trend of fuel spent per seat is visibly downward. The unit cost expressed as liters of fuel spent per seat for 100 kilometers flown has decreased by one order of magnitude during the past half century. On average, every year there has been a 1.2 percent decrease in fuel burn per seat.

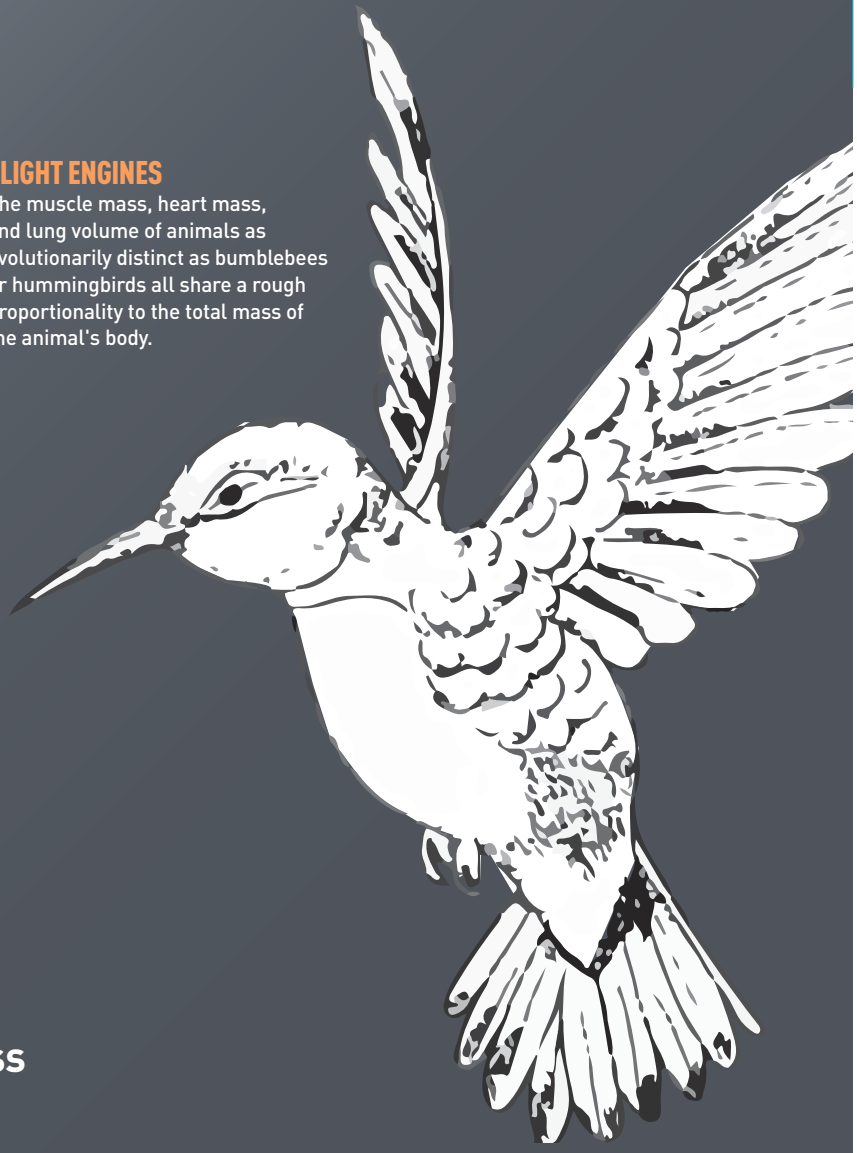
In sum, aircraft technology evolution is about the evolving design of the human movement on the Earth's surface: people, goods, materials, and everything else. As the whole vehicle or animal evolves toward becoming better at moving mass on the landscape, the organs remain imperfect, because each represents a compromise. The whole vehicle or animal is a construct of organs that are "imperfect" only when examined in isolation. The vehicle design evolves over time and becomes a better construct for moving the vehicle mass on the world map.

LIKE THE ANIMALS

Everything that we can say about vehicles applies to animals. The organs that constitute the motor system of the animal (muscles, heart, lung) are the counterparts of the engine of the vehicle.

In biology, it is well known that muscle mass, heart mass, and lung volume are empirically proportional to the animal's body mass. The animal organ scaling is the same as the engine mass versus vehicle mass.

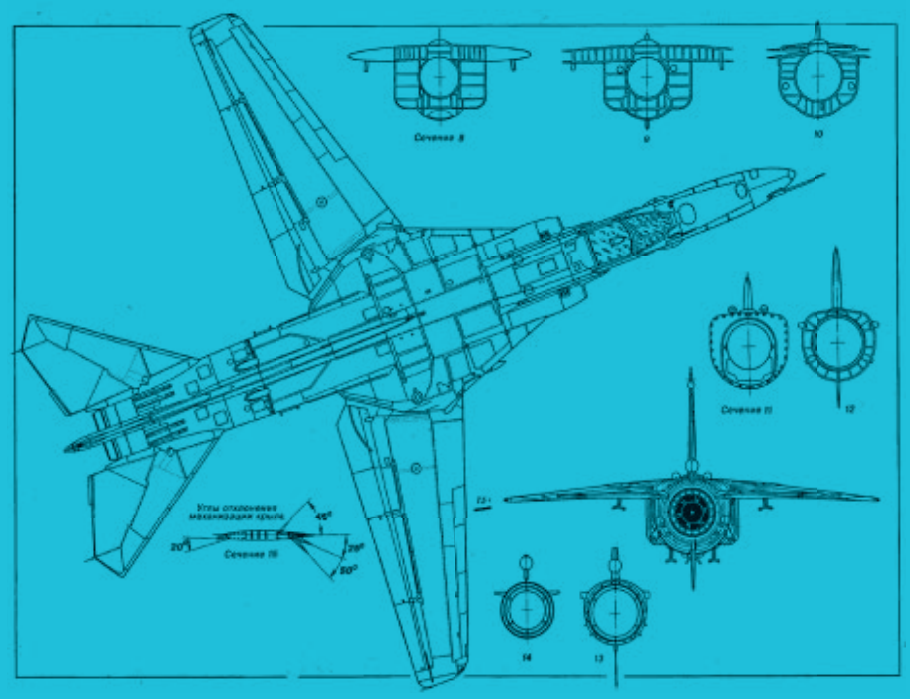
Small or large, airplanes do not look



FLIGHT ENGINES
The muscle mass, heart mass, and lung volume of animals as evolutionarily distinct as bumblebees or hummingbirds all share a rough proportionality to the total mass of the animal's body.

"ANIMAL ORGAN SCALING

is the same as the engine mass versus the vehicle mass."



FLIGHT PLAN
The design of the MiG 23 (above) is consistent with the predictions of Constructal Law. For instance, the fuselage and wings are geometrically similar.

TO READ MORE

A. Bejan, J. D. Charles, and S. Lorente, **"The evolution of airplanes,"** *Journal of Applied Physics*, 116 (2014) 044901.

A. Bejan, **The Physics of Life: The Evolution of Everything**, New York: St. Martin's Press, 2016,

like animals. They do not flap wings or spread tails. They have engines that provide steady power for cruising speed and constant altitude.

Yet, airplanes exhibit features (body-size rules) that unite them with birds and other animals. Their engines scale with their body sizes and with their fuel loads. The larger airplanes are more efficient vehicles of mass, and travel farther, just like the larger animals.

Small or large, airplanes are evolving such that they look the same. The airplane body has two main parts, a fuselage that carries passengers and freight, and wings that lift the fuselage. Every shape (aspect ratio) of this structure is predictable from the same law of physics (the Constructal Law) that predicted the evolutionary trends.

The primary objective of commercial airplanes is to carry as many people as possible to a specified distance while using as little fuel as possible. The fuel consumed is proportional to the work delivered by the engine over the distance, and the work is equal to the total force overcome by the airplane times the distance traveled. In sum, to reduce the fuel requirement of an airplane of specified size is to reduce the total force subject to two constraints: the total mass (fuselage and wings) is fixed, and the wings must be strong to support the weight of the whole.

The key prediction is that the wingspan should be proportional to the fuselage length. In addition, the fuselage cross section must be rounded, and the fuselage and the wing must have slender profiles that are geometrically similar.

Everywhere you look, the fuselage length is one order of magnitude (that is, roughly ten times) greater than its diameter. The swept length of the wing is roughly ten times its thickness. Seen from the side, these many shapes are one shape, which is reminiscent of everything else that has evolved to penetrate its medium: bird or fish.

EVOLUTION AS PHYSICS

Technology evolution is about us, about the evolutionary design of all the flows and movements that facilitate human flow, which means life on the Earth's surface (people, goods, and so on). The evolution of airplanes illustrates this convincingly.

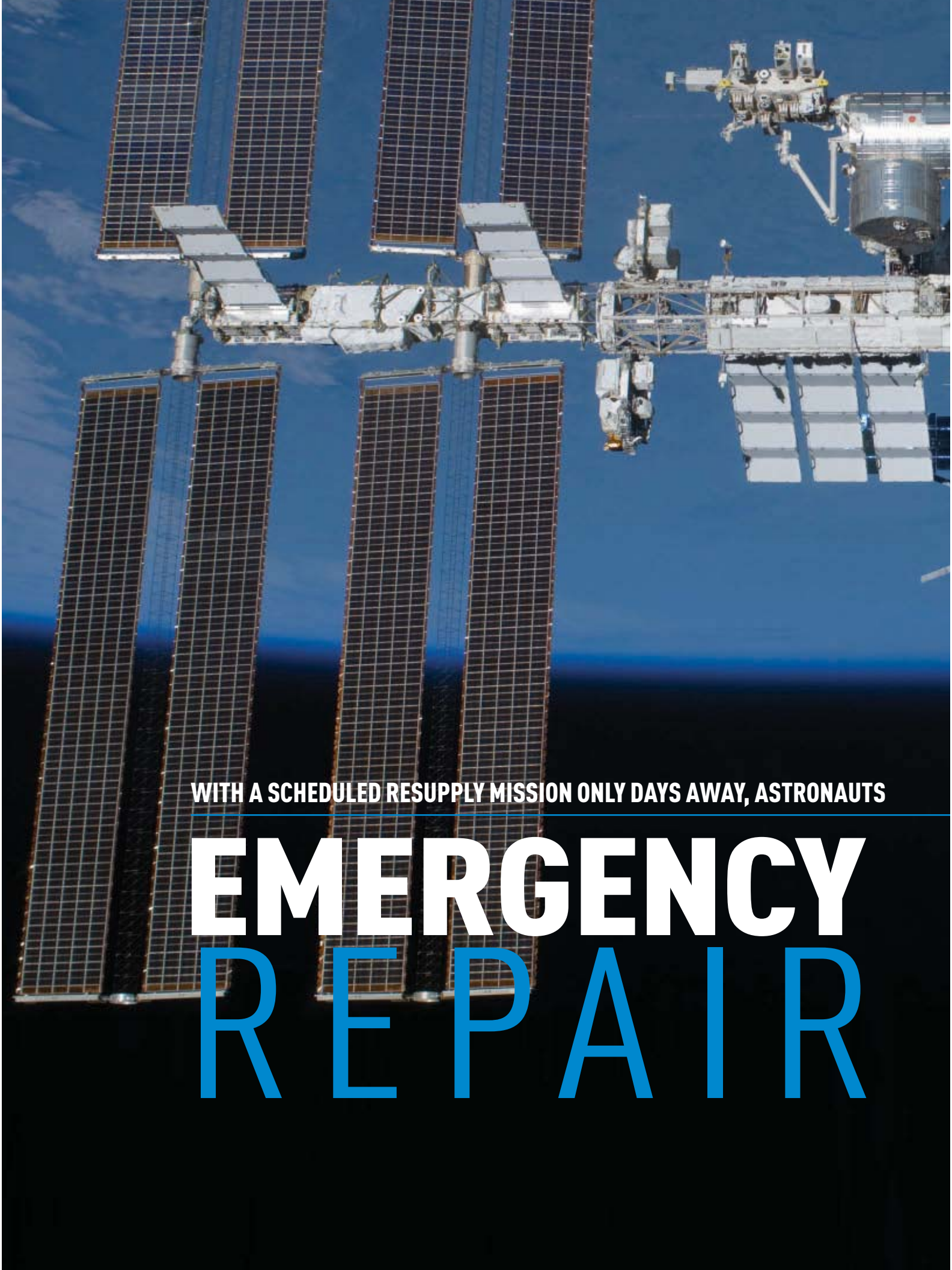
What works is kept. Flow architectures that offer greater access persist, and are joined by even better ones. Together, the vascular tapestry of old and new carries the human flow easier and farther than the old alone. Air mass transport with new and old airplane models mixes the global sphere more effectively than in the absence of new models.

Flow architectures are evolving right now, throughout nature and in our technologies. The legacy of all flow systems (animate and inanimate) is this: they have moved weight horizontally and improved the efficiency of that movement because of design evolution.

The view that emerges is that the evolution phenomenon is broader than biological evolution. The evolution of technology, river basins, and animal design is one phenomenon, and it belongs in physics. ME

Acknowledgement: This research is supported by the National Science Foundation.

ADRIAN BEJAN is the J. A. Jones Distinguished Professor of Mechanical Engineering at Duke University in Durham, N.C.



WITH A SCHEDULED RESUPPLY MISSION ONLY DAYS AWAY, ASTRONAUTS

EMERGENCY REPAIR

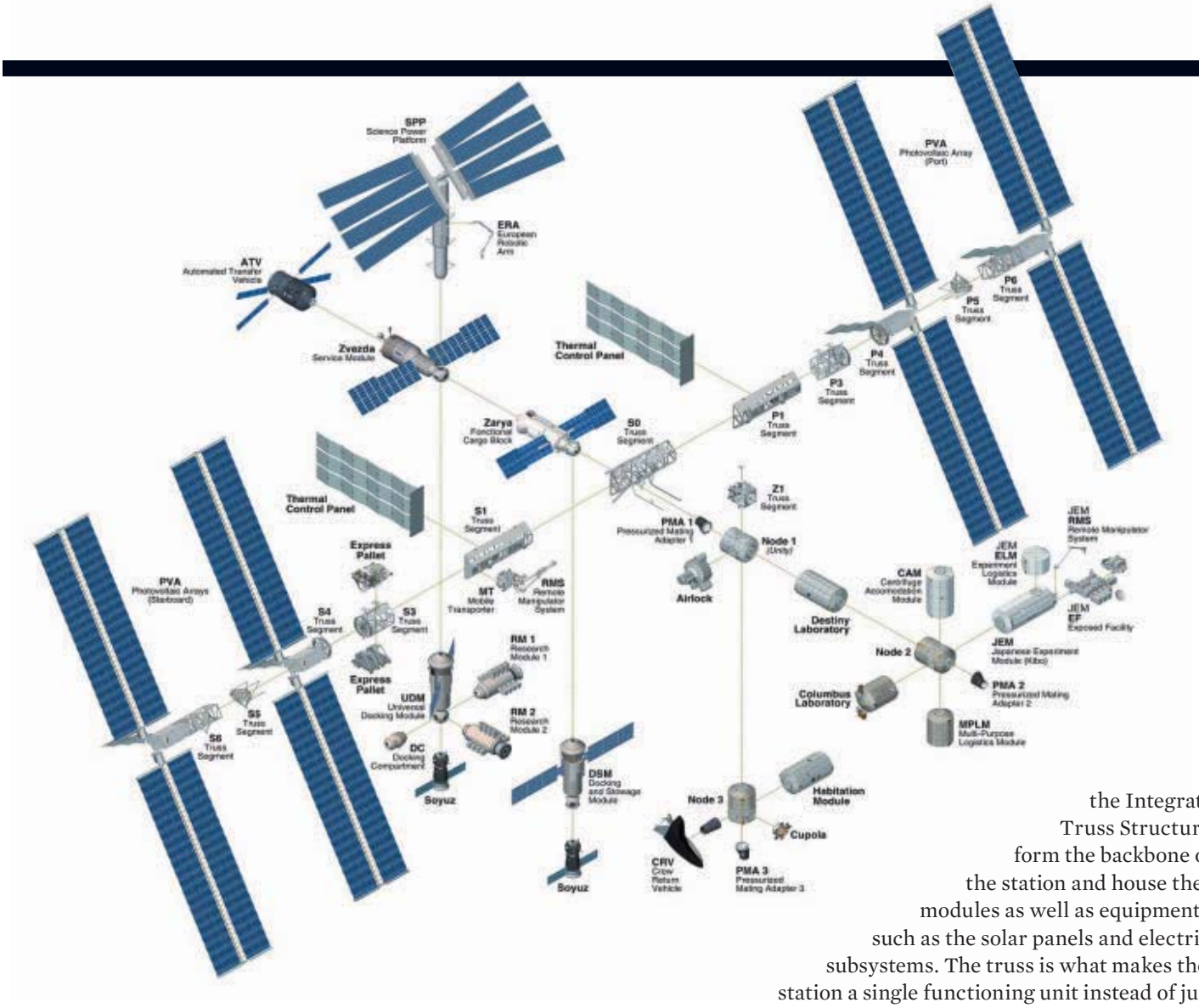
HAD TO CONDUCT AN IMPROMPTU SPACEWALK.

BY BRIDGET MINTZ TESTA

NASA doesn't do drama.

That statement may come as a surprise to anyone who has been to the movies in the past couple years. In *The Martian*, released last October, a team of NASA scientists and astronauts improvise to bring a stranded spacefarer home. The 2013 movie *Gravity* told the story of a pair of NASA astronauts who escaped the in-orbit destruction of a space shuttle and struggled to make their way to another vehicle.

NASA may love the publicity movies like those bring, but the actual flesh-and-blood space agency hates the sort of improvisation they depict. Extravehicular activities—spacewalks—are planned months, even years in advance. The astronauts who are scheduled to perform them spend hour upon hour practicing them in the controlled environment of the Johnson Space Center in Houston. Every action is as tightly choreographed as



a Soviet May Day parade.

So when astronauts Scott Kelly and Tim Kopra opened the airlock of the International Space Station on December 21, it may have looked like an ordinary day in orbit, but it was really a step into somewhat uncharted territory. But they had no choice. Without the emergency repair that Kelly and Kopra were to perform, there was a possibility that the station could tear itself apart.

The International Space Station is comprised of modules, some of which are pressurized and can be inhabited by the crew without space suits. Most of those pressurized modules are strung together along one axis; the ISS's architects call that the forward-aft or *x* axis. (In spite of the terminology, the forward-most Node 2 or Harmony module does not always lead the station in orbit.)

Extending through the port-starboard or *y* axis is the other major structural component, an unpressurized truss that stretches more than 350 feet. Made of a lightweight aluminum alloy, the dozen pieces of the Integrated Truss Structure form the backbone of the station and house the modules as well as equipment such as the solar panels and electrical subsystems. The truss is what makes the station a single functioning unit instead of just a number of separate modules, nodes, orbital replaceable units, and other elements spinning about in the same orbit.

Running along the length of the truss is a set of rails, and on those rails runs the Mobile Transporter. The MT is a trolley that carries the Space Station Remote Manipulator System, which is the large robotic limb known as the Canadarm2, and its smaller two-armed cousin, the Special Purpose Dexterous Manipulator, or Dextre, which is designed for finer motions. The MT carries both robots and any cargo they are holding to one of the eight designated work sites built into the truss. The MT-Canadarm2-Dextre system weighs about 11,000 pounds.

"We rely on the Mobile Transporter to position Canadarm2 and Dextre at outboard worksites on the extreme edges of the ISS that would not otherwise be reachable," said Laura Lucier, a NASA robotics flight controller. "We use them as a platform for extravehicular activities (spacewalks), to capture re-supply ships, such as the Cygnus, Falcon, and Japanese HII transfer vehicle, and dock them to the ISS, to install science experiments, to take visual surveys of and

"WE TRIED TO MOVE THE MT FOR 10 OR 11 HOURS UNTIL WE FELT WE HAD EXHAUSTED ALL OPTIONS." —LAURA LUCIER, NASA ROBOTICS FLIGHT CONTROLLER

repair and replace items on the ISS. We position the robots on the MT and drive them up and down the truss members or 'rails' of the station to reach equipment on the extreme ends of the station."

Each rail that the MT runs along has a different shape and function. The rails are offset along the zenith-nadir axis of the space station, perpendicular to both forward-aft and port-starboard. The "top" rail has a simple, flat flange that the MT's drive wheels roll over. The drive wheels are held against the rail by other wheels that reach around to the other side of the flange. Only one drive wheel is engaged at a time.

The "bottom" rail has a more convoluted shape. The MT has two wheels at each bottom corner to constrain it in the nadir-zenith axis and three others at each corner that hold its place in the forward-aft axis. The only directions left for the MT to move are port and starboard.

When the MT is latched down at one of its worksites, the drive wheels are disengaged from the rail; at each nadir MT corner, four strong latches are clamped hard to the station truss. The truss is also beefed up at those sites, so as to resist the forces and torques applied as the robotic arms pull and twist various payloads. Those locations also provide the only spots on the truss to park the MT to ride out changes in attitude or altitude, when a crew vehicle or resupply vessel docks, or when the station needs to jet out of the way of a piece of space debris—and space debris is an ever-present possibility.

"When we are at a worksite and clamped down," said Laura Merritt, NASA's Deputy Systems Manager for ISS Structures and Mechanisms, "we understand the load path very well. The MT has a set of structural load limits. The forces in the $+x$ and $-x$ directions are in the hundreds of pounds, and moments of inertia are in the low thousands of inch-pounds. The force paths are pretty linear.

"When we're not at a worksite," Merritt continued, "there are several degrees of freedom. Depending on the direction of the load and how high the peak load is, you can get high loads in several different directions. You go from linear to non-linear analysis of the load paths. The forces when the MT is not latched down are 3,800 pounds in each direction and the moments range from 108,000 inch-pounds to 146,000 inch-pounds. That could do some damage. The concern is that this can create little cracks in the truss beam. Then it becomes a long-term loading issue and reduces the lifetime of the beam."

The problem as the spacewalk started on December 21 was that the MT wasn't at a worksite. It was sitting on ordinary truss, and it was stuck. It was just four inches from a worksite, but it might as well have been miles. With the Canadarm2 and Dextre attached, all of those very large moments could have been in play if the station had to jet out of the way of debris—or undergo the docking of another spacecraft.

And a Russian Progress resupply vehicle had already launched and was due to dock in just two days.

Mission Control first discovered the problem with the Mobile Transporter on December 17. "We were trying to translate the MT to get to a worksite to do some tasks," Lucier said. "But we couldn't translate." The MT has drive motors to move it along the truss. "Those motors were turning, but we weren't moving—the electric switches that show us movement weren't switching. So first, we tried the motors again. We tried separate drivewheels—lowered the first and raised the second.

"We didn't give up easily in Mission Control," Lucier said. "We tried all sorts of things. We tried to move the MT for 10 or 11 hours until we felt we had exhausted all options.

"We had also been doing camera surveys, which is how we discovered that the Crew and Equipment

Translation Aid cart brake was on."

Two CETA carts are coupled to the MT, one on each side. They also attach to the truss and move along it whenever the MT moves. Crewmembers can detach them from the MT and use them to manually move along the truss without the MT during extravehicular activities. The crew also uses them to perform various EVA tasks when the MT and the other two robots aren't needed.

In this case, the camera survey showed that a hand brake on the starboard-side CETA cart had been engaged, thus preventing the MT from moving. There was no way to disengage the hand brake remotely.

Having the scheduled Progress re-supply vehicle come up and loiter around the station a while before it could dock was a possibility, but one NASA was not keen on. Loitering takes fuel, and that fuel was intended to support the ISS. NASA engineers also engaged in a parallel effort to see if the Progress resupply vehicle could dock with the MT where it was, or if the Canadarm2 could "walk off" the MT and then pick up the Dextre arms to get them off the MT.

THE ANALYSIS WASN'T FAVORABLE, SO NASA WENT INTO HYPERDRIVE.

"We were looking for ways to lessen the mass of the system by getting the robots off of the MT," Lucier said. Less mass on the MT would mean less potential for it to apply destructive force in the event the ISS suffered an unexpected jolt during docking.

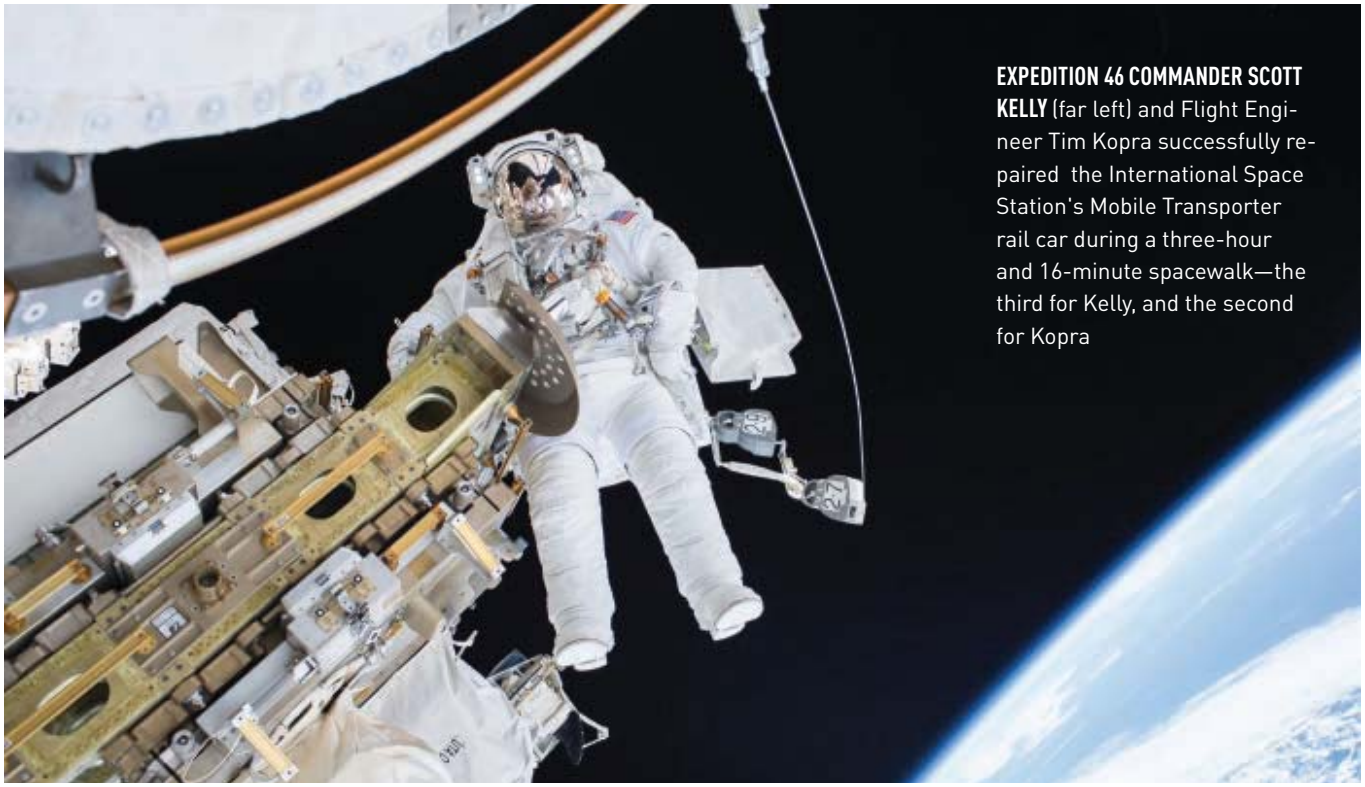
"Ongoing analysis was being run to determine if ISS would be in an OK position to dock," said Alex Kanelakos, the lead Spacewalk Officer in Mission Control. "If the analysis was very favorable, we could delay the EVA task until the scheduled EVA this January."

But the analysis wasn't favorable, so NASA went into hyperdrive.

Usually EVAs are planned months or even years in advance. Not this one. Late Thursday night, December 17, "the team kicked off their efforts to make an EVA feasible for the following Monday," Kanelakos said.

"We basically had 72 hours to check out our spacesuits and hardware, perform fit-checks, configure all the tools, write the procedures, train the crew on the procedures, and execute an EVA," he said. "EVA does perform planned spacewalks in which we know well in advance that we are going to perform certain tasks. We can train the crew and optimize the procedures so that when we go out EVA, we are extremely efficient with the crew time. We risk crew life every time we send an astronaut out EVA. In this instance, we did not have the benefit of being able to create these efficiencies."

To do the EVA on such short notice, "the EVA tasks were chosen to minimize tool and airlock configura-



EXPEDITION 46 COMMANDER SCOTT KELLY (far left) and Flight Engineer Tim Kopra successfully repaired the International Space Station's Mobile Transporter rail car during a three-hour and 16-minute spacewalk—the third for Kelly, and the second for Kopra

Photos: NASA

tion, minimize required crew study time, minimize ISS reconfiguration, and have acceptable break-out points during any phase," Kanelakos said.

The ground team also performed a scuba dive so they could tell the astronauts what the best body orientation was to provide the approximately 20 pounds of force needed to release the CETA cart brake. Though the brake was set by hand, it had to be released with a pedal. And when the brake was released, there would be a mechanical reaction force—a pushback—to prepare for as well. To help address these issues, a CETA cart down on Earth was also used to make videos for the astronauts and explain to management the goals of the EVA.

The goal was for the emergency repair to be as routine as possible.

By the time astronauts Scott Kelly and Tim Kopra pressed the pedal to release the brake, NASA's prep work had drained most of the drama out of the emergency. The astronauts handled the minor pushback force with no trouble. And to make the best use of EVA time, after they took care of the MT problem, Kelly and Kopra did some other tasks as well, including opening some doors so the Canadarm could perform future replacement activities, routing several cables in preparation for the International Docking Adapter and the Russian Multipurpose Laboratory Module, and retrieving some hardware needed for another EVA to be done later in 2016.

The Progress vehicle docked as scheduled with no problems, meaning it didn't burn fuel the station needed for re-boosts, attitude adjustments, and other orbital maneuvers.

The smoothness of the EVA is a testimony to NASA's ability to handle emergencies—and make no mistake, this was one—with a calmness the agency strives to project. Unless you knew what it meant to plan an EVA in two days, you'd have never known anything out of the ordinary was going on.

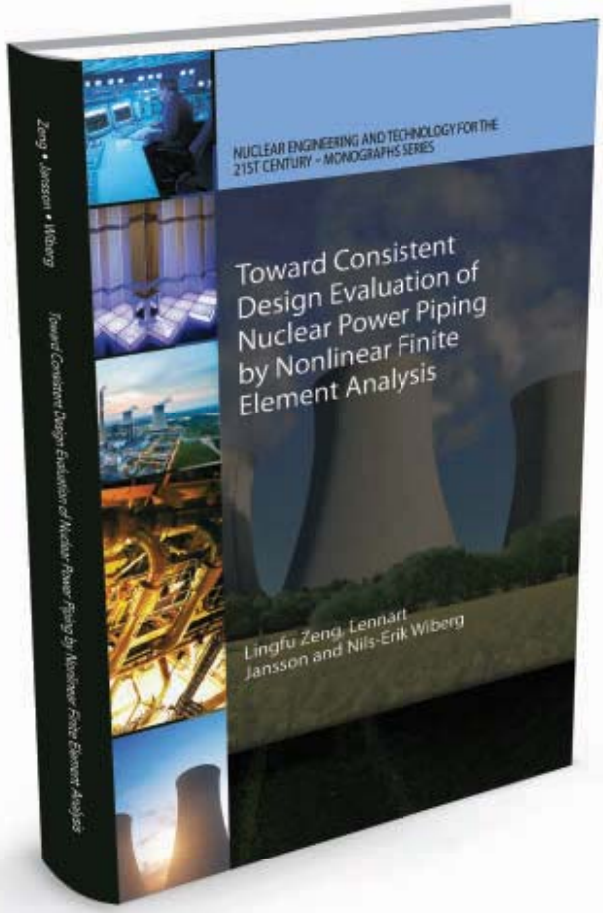
It was fitting that Kelly was one of the astronauts who fixed the brake problem. On an EVA a month earlier, Kelly had tied down the brake handles to fix them in position and make sure they would stay clear of any MT worksites and stay disengaged. In tying down the brake handles, Kelly inadvertently engaged the one on the starboard side. Thus, it was appropriate that he also released it.

Will NASA change anything as a result of this emergency?

"The major lesson learned from the EVA is that a thorough worksite inspection checklist will be made to ensure crew do not leave ISS in a poor configuration after an EVA," Kanelakos said.

Averting crisis through the use of an inspection checklist—that is so NASA.

BRIDGET MINTZ TESTA is a writer based in Houston.



FEATURED

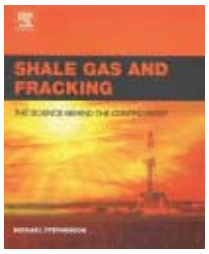
TOWARD CONSISTENT DESIGN EVALUATION OF NUCLEAR POWER PIPING BY NONLINEAR FINITE ELEMENT ANALYSIS

BY LINGFU ZENG, LENNART JANSSON, AND NILS-ERIK WIBERG

ASME Press, Two Park Avenue, New York, NY 10016-5990. 2015.

The nuclear power industry in the United States increased capacity through power uprating and life extension. This has raised questions with regard to piping, including whether a conducted finite element analysis is sufficiently good and whether relevant code requirements are reasonably met. This monograph, part of the series *Nuclear Engineering and Technology For The 21st Century*, addresses issues for achieving a consistent Design-By-Analysis in accordance with the ASME Boiler & Pressure Vessel Code, including nonlinear alternative rules, fatigue, thermal ratcheting, dynamic loads, and strain-based criteria. The authors focus on commercial software and current practices for power uprate and life extension of aging nuclear power facilities.

80 PAGES. $99; ASME MEMBERS, $79. ISBN-13: 978-0-7918-6104-2.

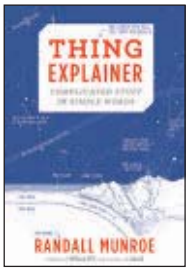


SHALE GAS AND FRACKING: THE SCIENCE BEHIND THE CONTROVERSY

Michael Stephenson
Elsevier, 225 Wyman Street, Waltham, MA 02144. 2015.

Stephenson is an expert on shale gas resource assessment as well as the environmental impacts of producing that gas through use of horizontal drilling and hydraulic fracturing—what is colloquially known as fracking. That makes Stephenson an ideal guide for touring the controversies that have surrounded this technology, from contamination of the groundwater and the stimulation of earthquakes to pollution and noise from the drilling platform on the surface. He tackles each one with a review of the physical principles involved, followed by a recounting of peer-reviewed case studies that have examined the topic and a judgement of the general risks involved. The book is written in an accessible and engaging style and includes many illustrations and charts.

170 PAGES. $100. ISBN: 978-0-12-801606-0.



THING EXPLAINER

Randall Munroe
Houghton Mifflin Harcourt, 215 Park Avenue South, New York, NY 10003. 2015.

Keep explanations as simple as possible without being too simple. That's great advice for technology writing and the great challenge set before Munroe, the artist behind the cult web comic strip, *XKCD*. In *Thing Explainer*, Munroe combines hand-drawn technical illustrations of various technologies and scientific phenomena—smart phones, the periodic table of elements, the Saturn V rocket—with captions and descriptions limited to the thousand most common words in the English language. It's a bit of a stunt (nuclear power plants, for instance, are called "heavy metal power buildings") but one that gets at the heart of what we really know about things when we strip away the jargon. In the end, Munroe's explanations err on the side of too simple, but they are delightful nonetheless.

64 PAGES. $24.95. ISBN-13: 978-0-5446-6825-6.

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PERMANENT GRIPPER

SCHUNK, MORRISVILLE, N.C.

Schunk's PGN-plus permanent gripper's multi-tooth guidance features grease pockets to ensure continuous and even distribution of lubricant. That helps to increase the gripper's lifespan and makes it practically maintenance free. The gripper's oval piston drive ensures high forces in confined spaces. The PGN-plus family is typically used in applications with high temperatures, contaminants, and aggressive media, as well as in clean rooms and explosive environments.

WATER LEVEL GAUGE

BLUE RIBBON, GRAND ISLAND, N.Y.

Blue Ribbon recently introduced Model BR1102/BR1103 series of submersible level transmitters designed to deliver up to ±0.2 percent FSO accuracy and reliable level measurements up to 700 ft. or 213.4 m. The series is optimized for submersible level measurements within irrigation systems, water and wastewater treatment, groundwater monitoring, wet wells, points, rivers, and tank applications. Standard models feature stainless steel housings for extended service in corrosive environments. Additional options include titanium housings, sludge screens, and lightning and surge protection.

LEVEL WINDING DRIVE

AMACOIL, ASTON, PA.

On a standard rolling ring level winding drive, the spacing between the rows is set using the pitch control lever on the unit. A new option, now offered by Amacoil on Uhing rolling ring level winding drives, enables users to spool cable and other material with a specified pitch. The option is engaged by inserting a set screw into one or both ends of the drive housing – no complex electronics or programming is needed, nor are adjustments to motor speed. The option is intended to provide machine designers with an effective, low-cost solution for spooling applications that require special spacing of rows on the take-up reel.

NETWORKING MODULES

DIAMOND SYSTEMS, MOUNTAIN VIEW, CALIF.

The new Janus-MM-LP family of CANbus 2.0 I/O modules features independent isolation for each port and data rates up to 1 Mbps. The rugged I/O modules offer two or four CAN ports and are available in the compact PC/104 and PC/104-Plus form factors. The Janus-MM-LP-XT family has two or four opto-isolated CAN 2.0B ports and 16 digital I/O lines. Models are available with PC/104-Plus (PCI + ISA) and PC/104 (ISA only) bus configurations. Each port also has its own combination isolator and transceiver chip. The module provides 16 programmable digital I/O lines organized as two 8-bit ports.

RATCHETING WRENCHES

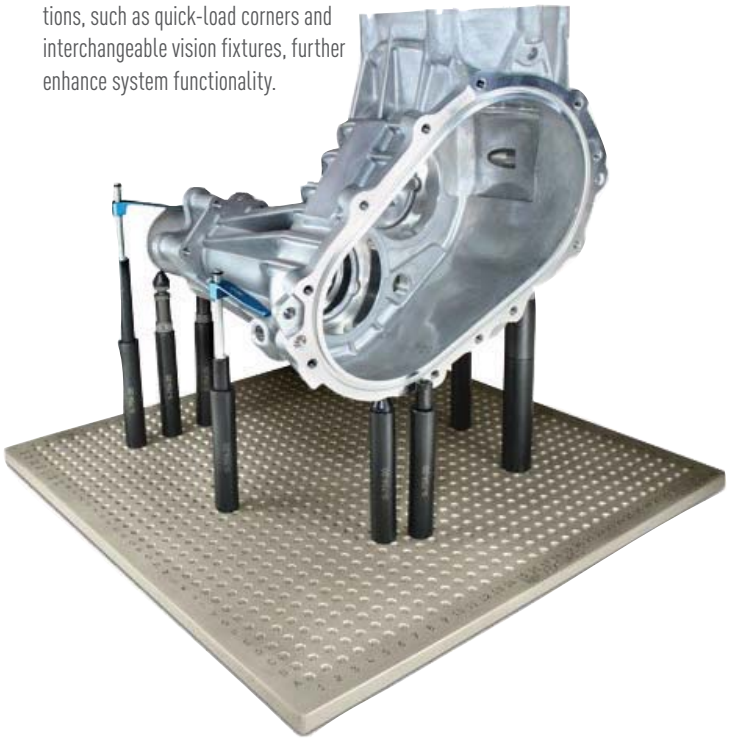
AUTOMATIONDIRECT, CUMMING, GA.

The new Wera Joker series of combination ratcheting wrenches features a fine-tooth ratchet on the box end and a 12-point open end with a six-point stop plate for easier turning of hexagonal bolts. The 80-tooth ratchet mechanism is designed for working in confined spaces. Combination ratcheting wrenches in standard inch (SAE) sizes start at $17 and range from 5/16 to ¾ inches. Metric sizes, starting at $18, range from 8 mm to 19 mm. Four-, eight- (SAE), and 11-piece (metric) sets start at $93.

METROLOGY FIXTURES

RENISHAW, HOFFMAN ESTATES, ILL.

Renishaw's new line of modular metrology fixtures—for use on CMMs, equator gaging systems, and multi-sensor inspection systems—provides a flexible solution for efficient, precise part holding. The fixturing plates have a hard-anodized coating to resist wear and scratching. Steel components are black oxide coated for improved durability. Magnetic standoffs are made with alnico magnets for temperature stability and wear resistance. New features for vision and multi-sensor machine applications, such as quick-load corners and interchangeable vision fixtures, further enhance system functionality.



COMPACT ROTARY ENCODERS

PEPPERL+FUCHS, TWINSBURG, OHIO.

Built for mobile equipment, steel production, wind turbines, and other applications, Pepperl+Fuchs' CVM42H CANopen Multi-Turn Absolute Encoders are designed to withstand shocks, vibrations, high bearing loads, dirt, and temperature fluctuations. The compact rotary encoders feature a stainless steel housing, flange, and shaft. Available with an IP66, IP68, or IP69K environmental rating, the encoders offer axial and radial shaft load capacity to 270 N. They're vibration resistant to 30 g, shock resistant to 300 g, and rated for use in operating temperatures from -40 °C (-40 °F) to 85 °C (185 °F).

POWER SUPPLY

IDEC, SUNNYVALE, CALIF.

The new PS5R-V line of DIN-rail power supplies comes in 10 W, 15 W, 60 W, and 120 W versions. All versions feature compact form factors; IDEC reduced the form factors by up to 25 percent from previous generations. The company also improved operating temperature ranges, now up to -25 to 75 °C, and claims to have increased operating efficiencies by up to 16 percent. The power suppliers can be used in control panels without the need for air conditioning or other cooling devices. Approved for installation in Class 1 Division 2 environments in standard control cabinets, the PS5R-V line is suitable for hazardous location applications, such as oil and gas processing facilities.

MICROPOROUS INSULATION

MORGAN ADVANCED MATERIALS, WINDSOR, ENGLAND.

WDS UltraShell microporous insulation enables the construction of smaller, lighter, and more cost-effective double wall pipe-in-pipe solutions in energy applications that demand hot piping, such as power plants, refineries, and renewable energy facilities. The insulation, custom engineered to each application, is designed to keep the temperature of the product in the piping constant and to minimize the pipe's diameter and thickness. Made from fumed silica and other inorganic silicates, the WDS Ultra's core material minimizes radiation, is not flammable, and meets the requirements of ASTM E84 with Smoke/Flame Spread rating 0/0 (U.S.) and DIN ISO 4102 for fire protection class A1 (EU).

HIGH-PRESSURE CONNECTOR

AMETEK, BERWYN, PA.

Ametek Subsea Interconnect's Elite Series Wet-Mate three-channel connector is designed to communicate electrical signals from downhole pressure and temperature sensors in extreme subsea oil and gas application environments. Measuring 15.8 mm in diameter and tested to 1,034 bar and temperatures up to 150 °C, the connector features concentric contacts that are individually sealed within a pressure-balanced, oil-filled plug and receptacle connector housing. The design protects plug and socket contacts from the seawater environment and ensures reliability along with repeated subsea mating capabilities.

SLIM SAFETY RELAY

OMRON AUTOMATION AND SAFETY, HOFFMAN ESTATES, ILL.

The G9SE safety relay unit features a slim profile (17.5 mm or 22.5 mm), screw-less push-in terminal, and diagnostic LEDs that are designed to reduce the cost of installation and troubleshooting time for machine builders. The G9SE can be used in a wide range of safety input devices, such as emergency stop switches, door switches, and light curtains.

PRESSURE DENSITY CUP

GARDCO, POMPANO BEACH, FLA.

Density or specific gravity is affected by entrapped air bubbles in the liquid being tested. Gardco's new VF2095 pressure density cup takes a fixed volume (100 ml) of a sample and compresses it so that errors caused by entrapped air or gas are eliminated. The sample's true density can then be calculated by weighing the pressurized sample. Gardco designed the cup for minimizing the effect of entrapped air bubbles, repeatable testing, and easy cleaning.

SUBMISSIONS

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

ANGLE ENCODERS

HEIDENHAIN, SHAMBURG, ILL.

Heidenhain's RCN series of angle encoders features a fault exclusion for loosening of the mechanical connection. This is a prerequisite for encoders meeting the functional safety standards required for machines shipped to Europe. When the RCN encoders are used within proper speed parameters, temperatures, and angular accelerations—and with the addition of a catch ring or spring pins, depending on the coupling method—they achieve a positive mechanical connection that helps eliminate the possibility of the encoder loosening and producing false data.

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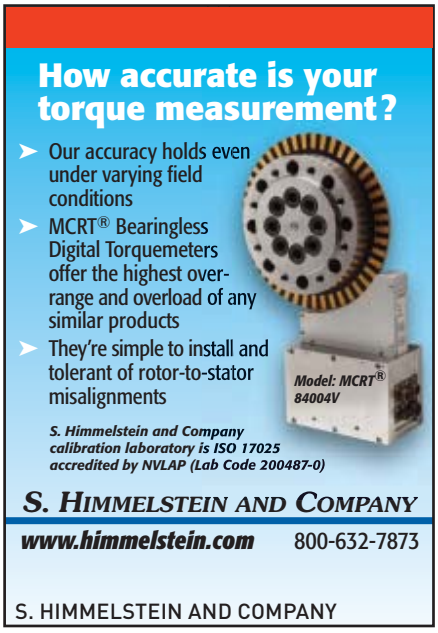

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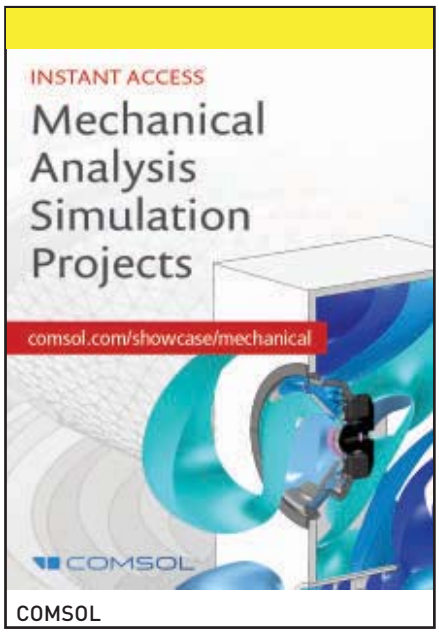

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RECRUITMENT

WEBINAR ON CONGRESSIONAL FELLOWSHIPS NOW AVAILABLE

An ASME Government Relations webinar highlighting the perspectives of former ASME Congressional Fellows is now available for viewing.

The webinar, "ASME Federal Government Fellowships: Technology Intersecting Policy and Politics," is archived at https://engage.vevent.com/rt/asme~asme_congressional_fellowships.

Kalan Guiley, chair of the ASME Committee on Government Relations, hosted the webinar and provided general information about the Fellowship program and current opportunities. Guiley has been a member of the ASME Committee on Government Relations since 2007, and has served as VP/Chair since 2013. He works for The Boeing Company as the Manager of Continued Airworthiness for Twin-Aisle Airplanes.

The first presenter was **Briana Tomboulian**, ASME's 2015 Congressional Engineering Fellow. Tomboulian served in the office of Sen. Edward Markey, where she worked on energy, environment, and manufacturing issues.

Tomboulian came to ASME's Fellowship program from a NASA Space Technology Research Fellowship program, where she spent time at NASA's Marshall Space Flight Center and Glenn Research Center developing critical components for deep-space power systems

Stephen Lehrman followed Tomboulian. He served as ASME's 2006 Congressional Engineering Fellow for Sen. Mark Pryor. After his fellowship ended in 2006, Mr. Lehrman accepted a position as legislative assistant for Sen. Pryor and was ultimately promoted to senior legislative assistant for the economy, tax, budget, banking, housing, small business, energy, environment, and science and technology policy issues.

Before working on Capitol Hill, Lehrman founded an intellectual property consulting and marketing firm, LabraTek Consulting, and worked for RTI International, Fuentek LLC, Corporate Consulting and Development Company, and Stone & Webster Engineering. Lehrman is currently working as an independent contractor for the National Nanotechnology Coordination Office. ME

Rep. Tim Ryan of Ohio explains the importance of Congress's role in enabling economic competitiveness during an ASME-sponsored briefing in February.

ASME SPONSORS ADVANCED MANUFACTURING BRIEFING

Representatives from academia, industry, and government attended "Advanced Manufacturing: Gaining the Advantage in a Fiercely Competitive Global Economy," an ASME-sponsored congressional briefing convened in conjunction with the House Manufacturing Caucus.

ASME Industry Advisory Board member **Thomas Gardner** of Jacobs Mission Solutions began the event with his introduction of Rep. **Tim Ryan** of Ohio, co-chair of the caucus. Congressman Ryan spoke to the important role advanced manufacturing plays in strengthening the U.S. economy.

Michael F. Molnar, director of the Advanced Manufacturing National Program Office at the U.S. Department of Commerce's National Institute of Standards and Technology, then gave an overview of NIST's National Network for Manufacturing Innovation.

Next, **Mark Johnson**, director of the Advanced Manufacturing Office in the Office of Energy Efficiency and Renewable Energy at the U.S. Department of Energy, spoke about EERE's mission to develop and implement technologies for energy efficiency in manufacturing. Johnson emphasized the importance of ensuring energy technologies translate from scientific discovery to competitive domestic manufacturing and jobs.

Adele Ratcliff, director of Manufacturing Technology in the Office of the Deputy Assistant Secretary of Defense for Manufacturing and Industrial Base Policy at the U.S. Department of Defense, then provided insight into the established DOD-led NNMIs and touched on two future institutes that DOD would be pursuing this year. The goal is to have a total of 15 institutes before the end of 2016.

Finally, **Pramod P. Khargonekar**, assistant director of engineering for the National Science Foundation, presented a talk about the NSF's commitment to a public-private collaboration on advance manufacturing.

In addition to ASME, the briefing was co-sponsored by the Minerals, Metals & Materials Society, the North American Manufacturing Research Institution of SME, the National Center for Manufacturing Sciences, and other societies and universities. More than 140 people attended the event.

For a more information, please visit the ASME Public Policy Education Center at: http://ppec.asme.org/latest-news/asme-sponsored-a-congressional-briefing-on-advanced-manufacturing/. ME

CELLI RECEIVES SILICON VALLEY HONOR

The Silicon Valley Engineering Council honored **John Celli**, the president of Space Systems Loral (SSL), in Palo Alto, Calif., and a member of the ASME Industry Advisory Board, at an event in February. Celli was inducted into the Silicon Valley Engineering Hall of Fame during the council's 2016 Silicon Valley Engineers Week banquet.

Prior to becoming president of SSL, which designs and builds satellites and spacecraft systems for commercial and government use, Celli served in a number of leadership positions at the company, including chief operating officer, executive vice president, and senior vice president of engineering, manufacturing, and test operations. During his 35 years at SSL, he has led the company through numerous advances, including the development of the first high-capacity satellites for broadband service and the first 20-kW satellites that facilitated early high-definition television distribution.

In addition, Celli has advocated for the training and mentoring of students and championed STEM education initiatives, including the Change the Equation STEM literacy organization.

"An engineering background is essential to designing systems that get launched into space 22,300 miles above the earth," said Celli, a native of Italy who received his master's degree in mechanical engineering from the University of Rome. "I hope my induction into the Hall of Fame reminds young people that mechanical engineering is a great foundation for a broad range of career paths."

SVEC is a non-profit educational organization that serves as an alliance for Silicon Valley engineering leaders to support technical societies, outreach programs, and public awareness of the impact of engineering and science

Through its Engineering Hall of Fame program, SVEC recognizes engineers for their outstanding professional achievements in engineering and technology, and for their important contributions to the community. ME

MCCLUNG WINS FATIGUE AWARD

ASME member **R. Craig McClung**, program director at Southwest Research Institute in San Antonio, has received the Coffin-Manson Fatigue Achievement Award from the ASTM Committee E08 on Fatigue and Fracture. McClung's career has focused on research and program management in fatigue and fracture, including both detailed scientific studies of basic phenomena and the development of robust engineering models and software for structural life prediction. He has been a member of the Southwest Research Institute staff since 1988, and has held a variety of positions including senior research engineer and section manager. He assumed his current position in 2006.

An ASTM member since 1990, McClung serves as a member-at-large on the E08 executive subcommittee. He is an ASTM Fellow, having received the Award of Merit, ASTM's highest honor for individual contributions to standards activities, in 2011. McClung earned a master's degree in theoretical and applied mechanics and a Ph.D. in mechanical engineering from the University of Illinois at Urbana-Champaign. He also holds a master's degree in religion from Harding Graduate School of Religion. He has been a member of ASME since 1989.

WIGHT TOP ENGINEER IN VERMONT

ASME Life Member **Gregory D. Wight** has been named Vermont's 2016 Engineer of the Year by the Vermont Society of Professional Engineers. Wight, who has served as both associate dean and director of the David Crawford School of Engineering at Norwich University in Northfield, Vt., is an expert in the field of air quality engineering. He currently holds the Charles A. Dana Professorship of Engineering, the highest honor available to Norwich University faculty.

In addition to being a life member of ASME, he is a member of the Vermont Society of Engineers, Tau Beta Pi, and the American Society for Engineering Education. He has also been actively involved with programs including MathCounts, FIRST Lego League, and Engineers without Borders.

Wight served in the armed services as an Engineering Air Force Officer in the United States Air Force Contract Management Division at the General Electric Aircraft Engines facility in Evendale, Ohio. He then joined the Connecticut Department of Environmental Protection, where he served as principal air quality engineer, supervising the development of air pollutant emission inventory, air quality modelling, and strategies designed to achieve the National Ambient Air Quality Standards. He has been at Norwich University since 1978. ME

A SOFTER SOCKET

STUDENTS USE A RE-MOLDABLE PLASTIC TO MAKE PROSTHETIC LIMBS EASIER ON AMPUTEES.

Jessica Menold, with a cast for a prosthetic leg.
Max Petrosky, Daily Collegian

You never know where you'll find inspiration. A team of graduate students trying to build a cheaper, more efficient prosthetic socket for amputees in developing countries found it in an ordinary mouth guard.

"During one of our brainstorming sessions, someone said they saw an athlete with a mouth guard and thought it would be a great material to use," said Jessica Menold, a doctoral student at Pennsylvania State University in State College and a member of the team. "From there, we came up with the idea to use some type of re-moldable thermoplastic."

The five-member team, which included students from Rensselaer Polytechnic Institute in New York and Hasso-Plattner Institute in Potsdam, Germany, recently won the EXIST Business Start-Up Grant from the German Federal Ministry for Economic Affairs and Energy. The team has received €130,000 in EXIST funding to refine the socket and bring it to market.

Sockets, Menold explained, are the most expensive and carefully crafted part of a prosthesis. To optimize comfort and function, a prosthetist has to customize each socket to accommodate different load patterns on the residual limb. The process can take up to a month and requires several office visits by amputees. That isn't always possible in the developing world—amputees there often have to travel several hours to reach a prosthetist, so return visits can be a burden.

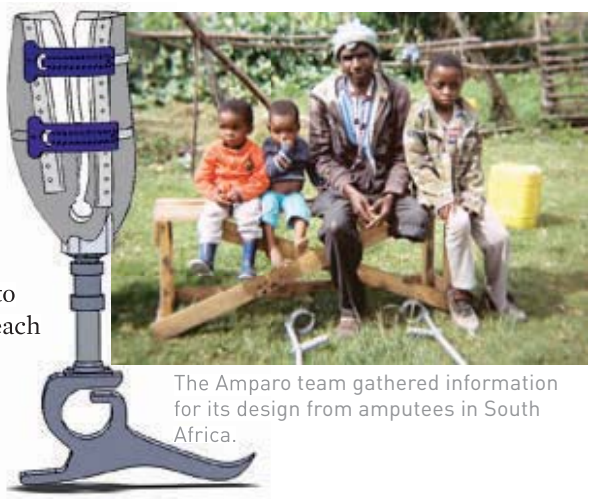
Today's sockets also create another problem the team knew it had to solve. Typically made from a stiff, carbon-fiber material, the sockets can't adjust to the size of the limb when it swells and contracts, sometimes up to 20 percent, when temperatures fluctuate. That flaw makes a socket extremely uncomfortable or unwearable in tropical regions.

"The traditional socket is not well-suited for this market," Menold said. "We wanted to focus on making the process cheaper, faster, and more efficient, while maintaining a high level of quality. We took a typical engineering approach: How can you standardize the process?"

Enter the mouth guard. The concept inspired the team to use a similar type of thermoplastic. The material is easy to melt, mold, cut, and recycle. It's also readily available and inexpensive. Menold estimates the use of thermoplastics will reduce the entire process–fitting, customizing, and building to about a day. The students are now experimenting with a combination of materials to create a socket that's stiff enough to secure a standard base plate and support the pylon that attaches to it.

The student team founded a company, Amparo, to develop the technology. The company plans to launch the first human trial of the socket in about 18 months. Amparo will probably be divided into a for-profit that sells the sockets, as well as kits that nurses in villages can be trained to use, and a not-for-profit that will focus on training and mobile clinics, Menold said.

"Our goal is to launch a company that cares as much about people as profit," she said. "We start with the user and constantly come back to them. We hope the amputees feel that somebody cares enough to help them return to an active life." ME



The Amparo team gathered information for its design from amputees in South Africa.

JEFF O'HEIR

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