MECHANICAL
ENGINEERING

THE MAGAZINE OF ASME

No. 05 140

Technology that moves the world

Trust AND Verify

How blockchain is transforming the supply chain.

Image: Matthew Lamm, ASME.org

DRONE VERSUS SPIDER MITE

IN AN EFFORT TO HELP STRAWBERRY GROWERS COMBAT the destructive spider mite, engineers at University of California, Davis, turned to drones. They created "Bugbot,"a drone that carries a container with a paddle wheel at its center to dispense large numbers of predatory mites that in turn will kill the spider mites. The drone will eventually use machine learning to take into account variables such as wind speed, height, and the speed of the drone to determine optimum distribution parameters.

Image: Radik Shvarts, ASME.org

RODENTS HELP ROBOTICS LEAP FORWARD

A MECHANICAL ENGINEERING PROFESSOR IS studying rodents that hop, believing that their gait holds keys to creating biomimetic robots to match specific environments.

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

SAILING INTO THE STRATOSPHERE

NINETY THOUSAND FEET IS just below the threshold for suborbital travel. Ed Warnock, CEO of the Perlan Project, wants to change that using a sailplane to reach such lofty heights. But more engineering is needed for a craft with glider wings that can fly in less than three percent of normal air density and at temperatures of -70 °C.

SPEEDING UP 3-D PRINTING, BY A LOT

TO SPEED UP THE ADDITIVE MANUFACTURING process, engineers at the Lawrence Livermore Laboratory borrowed techniques from holography and turned to lasers. Their new 3-D printer sends multiple laser beams into a vat of photosensitive polymer, and the polymer hardens when lasers intersect and the light is brightest.

MAPPING THE HEART FOR FUTURE HEALTH

PHENOTYPING, A TECHNIQUE USED TO make sense of vast amounts of DNA information and classify it by type, is now making its way into healthcare research. Researchers are now using it to synthesize cardiovascular imaging information.

Image: Matthew Lamm, ASME.org

NEXT MONTH ON ASME.ORG

ADVANCES IN CLEAN ENERGY
An innovative renewable energy project in Gaildorf, Germany, combines the world's tallest wind turbines with a pumped-storage hydroelectric plant. During times of less demand, energy from the wind turbines pumps the water back to the tanks.

05

140

FEATURES

ON THE COVER

Illustrations by David Plunkert

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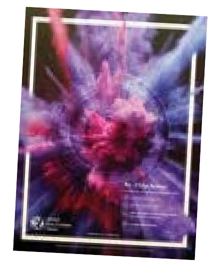

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Give me the place to stand, and I shall move the earth
—Archimedes

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John G. Falcioni
Editor-in-Chief

TOOLS OF BUSINESS TRANSFORMATION

Manufacturing has become a red-hot issue in America's boiling political climate, so much so that it often makes the discourse over global warming or off-shore drilling seem downright lukewarm by comparison. At the core of it all is which measures of the strength or weakness of manufacturing in this country should matter most.

Technology and automation are two drivers of the changes manufacturing is experiencing. Trade is another. All those factors shape the size and composition of the industrial workforce.

In reporting on these trends in this magazine, we stay away from choosing political sides. Yet, inevitably, readers from divergent perspectives often assess what they read through the lens of personal preferences. You can get a sense of what we hear by turning to the Letters to the Editor section, where our readers exchange diverse opinions and send us both brickbats and bouquets.

For the second year in a row, Senior Editor Alan Brown will likely stir some reader debate with his insightful overview article on page 36, "The State of American Manufacturing 2018." To prepare this report, Brown spent weeks scouring the data on manufacturing from leading analysts and databases. The areas he focuses on are: competitiveness, trade, automation, jobs, and the value added by manufacturing.

In the automation segment, Brown focuses on Industry 4.0. I've written about the topic in this space in its more commonly referred term, the Fourth Industrial Revolution (see my March 2016 column). Industry 4.0 refers to a suite of new technologies including smart machines, artificial intelligence, robotics, 3-D printing, material science, nanotechnology, and energy storage that are revolutionizing product development and processes.

In reporting on this new era in manufacturing, we have learned that it is as important to delve into how these technologies work as it is to understand the potential they have as tools of business transformation and economic change. Manufacturing is a political issue because it drives our economy and affects our global partners, but it derives that power from a technological foundation.

Since its founding in 1880, ASME has been internationally recognized for hosting technical conversations. It convenes dozens of conferences each year on technical topics ranging from heat transfer and tribology to nuclear power and bioengineering.

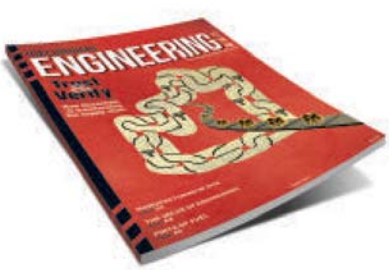
Next month, ASME is bringing together international experts to have a different conversation, the discussion of the impact that additive manufacturing is having on supply chains. The four-hour morning session on June 19, called ASME Additive Manufacturing Leadership Forum, during LiveWorx 18 in Boston (www.liveworx.com), will focus on how 3-D printing technology is transforming the business model of multinational organizations (visit additive-manufacturing.asme.org/).

The event will be moderated by the renowned additive manufacturing analyst Terry Wohlers, and is scheduled to feature executives from GE, PTC, Stratasys, UPS, Stryker, Paperless Parts, Boeing, Imperial Machine & Tool, Local Motors, and the U.S. Marine Corps. Also participating in the interactive forum will be the preeminent Penn State design and additive manufacturing professor Tim Simpson.

The ever-evolving rate of breakthrough technologies will drive changes and influence the state of American manufacturing. *Mechanical Engineering* will continue to monitor those changes. Now, we will also keep an eye on the impact of these technologies as tools of business and economic transformation, and political discourse. **ME**

FEEDBACK

What do you think is the state of American manufacturing today? Email me
falcionij@asme.org

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FEBRUARY 2018

Reader John suggests an open-access system could revitalize railroads.

« Responding to a recent article on expanding and updating rail transport, two readers offer their perspectives on improving service.

A FOOTPRINT MISSTEP?

To the Editor: I enjoyed Michael E. Webber's insightful article, "The New Age of Rail" (February 2018). After suggesting that one simple way to encourage the switch from road to rail is to put a price on carbon, he states, "Another way to increase capacity while cleaning up the transportation sector is to increase and improve the fleet of locomotives. Incentives for rail companies to buy newer, cleaner, more efficient locomotives, would simultaneously clean up and expand capacity."

Although this may ring true for railroads and other heavy industries, prematurely retiring functional equipment prior to its useful end of life may actually increase the true carbon footprint.

A huge carbon footprint was originally expended to mine, process and machine ores and produce other construction materials, as well as an additional smaller carbon footprint required to prematurely recycle the scrapped locomotive.

Also a fresh carbon footprint may be prematurely required to produce the replacement machine. Even the cost of related labor is largely spent on household energy and other products associated with their own carbon footprints.

Likely, the entire carbon footprint life cycle, including major overhauls, should be evaluated in optimizing any marginal improvements in carbon release.

For example, how much carbon was originally released to manufacture a single $1.7 million locomotive? If its useful life were to be shortened from say 25 years to 20 years, the original carbon footprint assessed per year would increase by about 20 percent.

Less efficient locomotives could be assigned to services that consume less fuel and replaced only when justified by all economic and technical concerns, including a price on carbon.

Albert R.L. Winroth, Life Member,
Saratoga Springs, N.Y.

ROAD TO RAIL

To the Editor: Absent restructuring of the railroad monopoly, the full benefits of shifting freight from long haul trucks to railroads, as laid out in the compelling article by Michael E. Webber (February 2018), will not be realized.

Rail lines are necessarily a natural monopoly, but the control of the use of the lines inhibits the kind of innovation needed to increase rail shipment. Restructuring the industry to separate ownership of the tracks (which would remain a regulated industry) from the operation of the trains on the system in order to provide open access to all transportation companies (subject to operating rules of course) would provide competitive service to all rail customers.

Such a deregulated system would benefit small shippers underserved by the rail monopoly and encourage shipping very heavy or oversized loads by rail.

As engineers, we often decide to ship by truck to avoid the uncertainty of the timing of rail shipment on our projects.

The owners of the track would be able to focus on maintaining and expanding the rail system, operators of rolling stock on modernizing equipment and operations, and service providers on customer needs.

If an electric grid, such as the Electric Reliability Council of Texas, can be restructured to offer open access, certainly a rail system can be.

Tommy John, P.E., *Bandera, Texas*

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.

FROM DESIGN REVIEW TO INSPECTIONS

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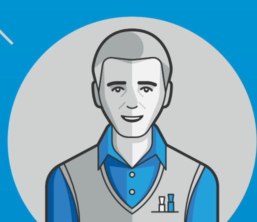

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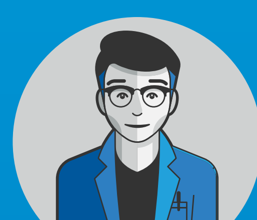

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HYDRO BIKE

In 2011, Guy Howard-Willis had the crazy idea of making a bike that could surf on water. Seven years of testing and prototyping resulted in the Hydrofoiler XE-1, which is a mix between an e-bike, surfboard, and hydrofoil.

Howard-Willis and his partner, Roland Alonzo, call their contraption a hydrofoiler bike watercraft. When standing on the ground, it resembles a stationary bike used in gyms. It's not as heavy as a water scooter, and cruises on water assisted by a pedal and a 400 W e-bike motor. A motionless hydrofoil bike can submerge a few feet without drowning so it can be restarted without a rider swimming to shore.

"When I ride the Hydrofoiler, I can draw similarities to riding my road bikes. The issue was around man's ability on water, we have so many great watercraft out there, I wanted to push the envelope on what could be done for bicycle and water enthusiasts," Howard-Willis said.

Alonzo and Howard-Willis sell the Hydrofoiler XE-1 through Waikato, New Zealand-based Manta5, and at roughly $5,500, it's not cheap.

Hydrofoils started appearing in water sports like kitesurfing and windsurfing a decade ago, and that's when Howard-Willis started investigating the idea. A keen cyclist, he conceived of Hydrofoiler XE-1 after seeing hydrofoils being used in the America's Cup yachting race. He then hooked up with Alonzo, a bike design specialist.

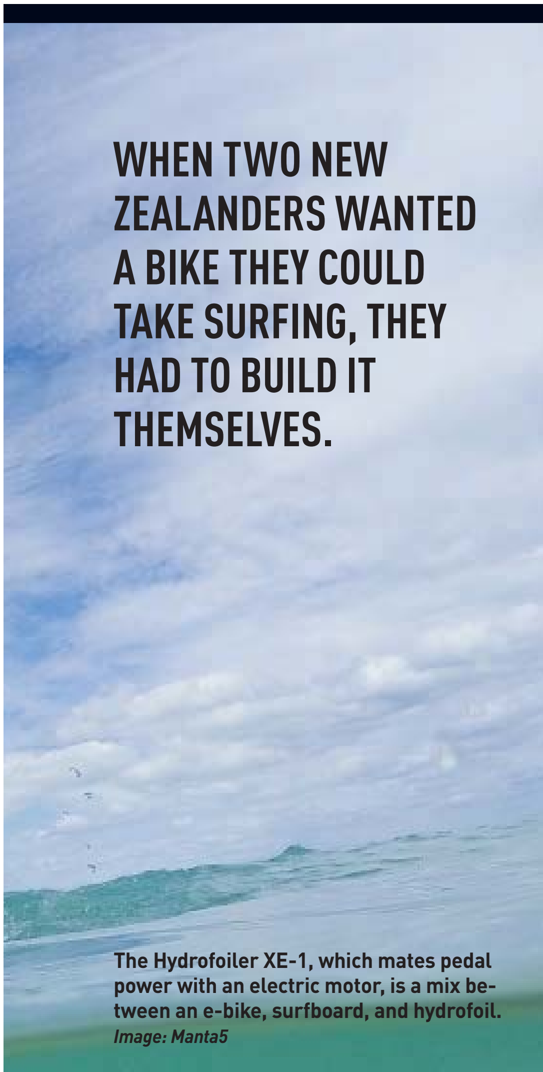
For the first two years, both hid the idea of Hydrofoiler XE-1 from their families, more to escape embarrassment if the design didn't work out. Many years were spent drafting and designing prototypes with multiple component types.

They applied "rapid validation," with new components and parts being immediately tested. They tackled hydrodynamics, aerodynamics, electrical, and mechanical challenges, and the smaller picture approach gave them design flexibility.

"We spent early mornings at local pools and lakes validating with a number of enthusiastic riders. That's a key part of our production process, we always hold our ideas lightly and we have an environment where everyone's thoughts are valued and considered," Howard-Willis said.

Critical components like the e-bike battery and motor benefitted immensely from these testing sessions. Battery life is about an hour for a 187 pound person, Manta5 estimates.

"The XE-1 is pedal assist that means you do need to pedal for this model to move forward. However, you can dial up the amount of work the motor is doing,



WHEN TWO NEW ZEALANDERS WANTED A BIKE THEY COULD TAKE SURFING, THEY HAD TO BUILD IT THEMSELVES.

The Hydrofoiler XE-1, which mates pedal power with an electric motor, is a mix between an e-bike, surfboard, and hydrofoil. *Image: Manta5*

so you might like to cruise and you would also have the motor at a high rate and be doing less pedaling," Howard-Willis said.

The engineers implemented an aerodynamic design, and worked out complexities related to hydrofoiling and propeller positioning. Work also went into developing a drivetrain mechanism that transferred power from the pedals to the propeller.

An aluminum and carbon fiber frame brought the weight down, and a nylon propeller provided thrust at the fastest speeds.

The water bike works on salt and fresh water.

"The bike is completely modular—the components that can be changed to alter power or buoyancy can be added to the XE-1 model," Howard-Willis said. **ME**

AGAM SHAH

SPREADING BACTERIA IN SPACE

Elon Musk's launch of a Tesla toward Mars was considered a stroke of public relations genius, but smart researchers pointed out the car could contaminate the planet with Earthly bacteria.

A NASA satellite may be able to shed some light on how big a danger bacterial contamination could be.

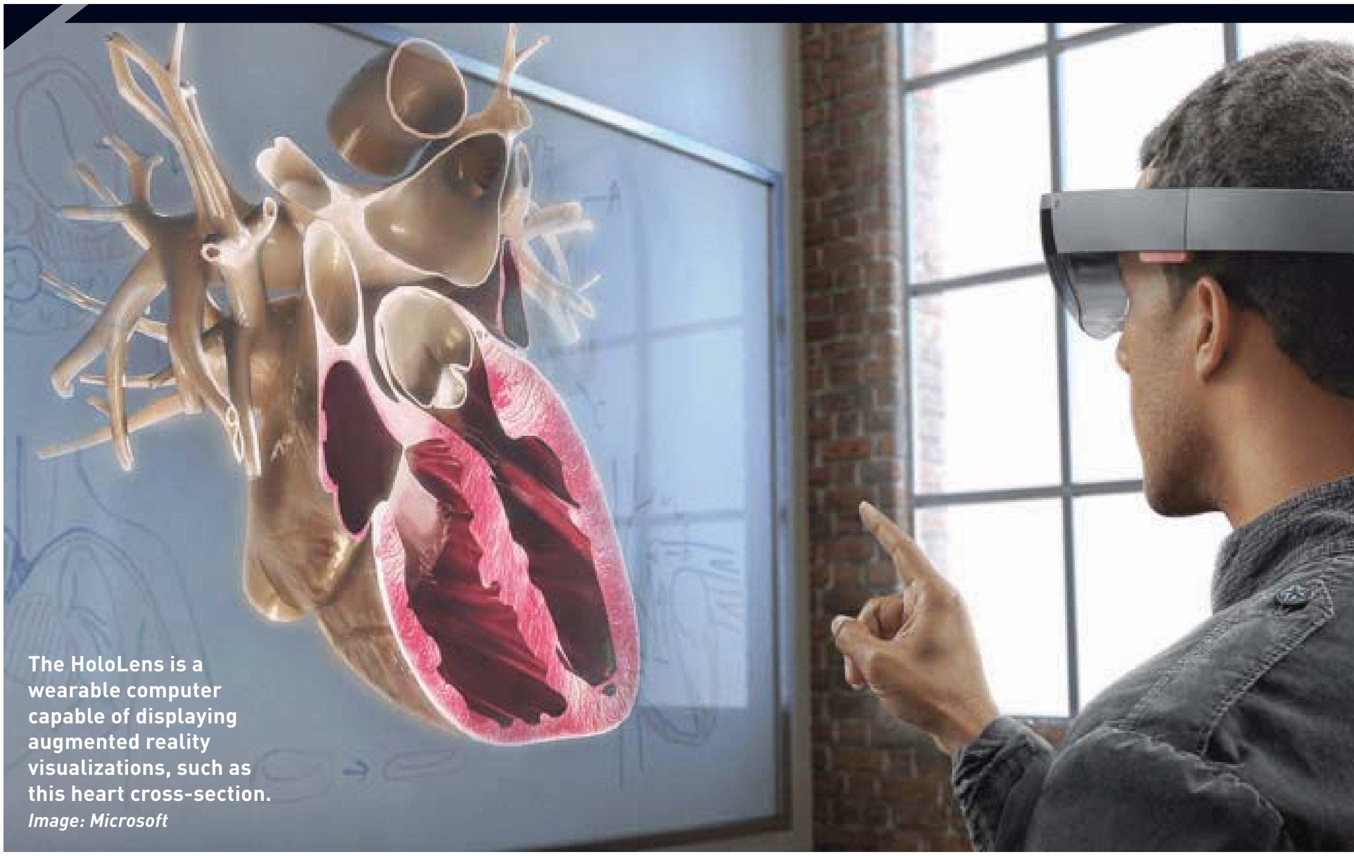
The EcAMSat nanosatellite was launched late last year to study bacterial behavior in space and how effective antibiotics are. The 23-pound satellite will run experiments that involve growing and then starving *E. coli* bacteria, applying different concentrations of antibiotic agents, and determining the lowest level of antibiotic that could deter the growth of bacteria. The study should also provide guidance on medical treatment for astronauts.

The EcAMSat is the size of a shoebox and mixes new components with legacy parts seen in older nanosatellites such as the 2006 GeneSat and PharmaSat, launched in 2009. The space agency says the redesign is a blueprint for a new generation of nanosatellites, which will feature more payload capacity, greater power, and improved instruments, avionics, and propulsion. The nanosatellite is capable of autonomous operation and can store 152 hours of data.

Like older nanosatellites, EcAMSat has solar panels and uses magnets for orientation.

NASA is outsourcing the interpretation of data from the nanosatellite to students at Santa Clara University. For enthusiasts who want to boast having communicated with outer space, the nanosatellite has started transmitting encoded data—unrelated to the tests—in packets smaller than Twitter posts that HAM radio operators can decode. **ME**

NASA's EcAMSat nanosatellite will check the effectiveness of antibiotics in space. *Image: EcAMSat*



The HoloLens is a wearable computer capable of displaying augmented reality visualizations, such as this heart cross-section.
Image: Microsoft

AUGMENTED REALITY GIVES SIGHT TO ENGINEERS AND DOCTORS

Surgeons, bioengineers, and medical device manufacturers have long sought ways to improve their knowledge of human anatomy, ranging from using human cadavers and animal models to wax and plastic models. The goal, of course, is designing better treatments or medical devices/implants that simplify surgical procedures and improve patient outcomes, with minimal side effects.

As virtual reality (VR) and augmented reality (AR) tools continue to advance, more bioengineers are taking a serious look at how these technologies can expand their design capabilities, especially for medical imaging and computation, simulations, and implants and devices. VR/AR also enables shared or multiuser experiences that provide an enhanced level of education and discussion, whether it is bioengineers working on a new invention or medical students studying anatomy in a classroom or laboratory.

One of the most powerful AR/VR design tools for bioengineers is Microsoft HoloLens.

This wearable holographic computer integrates 3-D medical images with the physical elements of the user's surrounding environment. The sophisticated vision processor in the HoloLens allow these images to be interactive, so they can be viewed by multiple users fitted with the same type of headsets.

Participants can walk around the holographic image (for example, a human form showing complex anatomy), looking for details which they can use to improve a surgical procedure or optimize the design of an implantable device.

The greatest benefit of HoloLens is the impressive visibility it provides to physicians and engineers. This allows them to better understand the systems they are studying, especially if they are working in torturous, tightly packed anatomy, such as the cardiovascular system or the brain.

Case Western Reserve University radiology professor Mark Griswold was immediately impressed after trying out HoloLens. Even though he had worked with datasets of brain MRIs for more than a decade, "I never fully understood their 3-D structure until I saw them in HoloLens," he said.

That, he said, is an improvement over dissecting cadavers to identify and study the body's system.

With HoloLens "you see everything truly in 3-D," he said. "You can take parts in and out. You can turn it around. You can see the blood pumping—the entire system." HoloLens will be a key piece of technology in Case Western's new health education campus when it opens in 2019, where students will study anatomy using VR.

continued on p.21 »

A BETTER PORTABLE AIR

This air-quality monitor is based on a CMOS image sensor.

Photo: University of California, Los Angeles

How much of the brown haze over a city's skyline is also in living rooms? And what, exactly, is in that haze? There may soon be an inexpensive way to find out. A new handheld air quality monitor called c-Air, in early testing now, compares favorably with much more pricey machines.

The device is based on a CMOS (complementary metal-oxide semiconductor) image sensor, the same found in some digital cameras. Aydogan Ozcan and a team at the University of California, Los Angeles, have created a monitor that collects and places samples of microscopic particles in the air directly over the sensor. No lens required. The researchers call the technology "computational lens-free microscopy."

An operator can control the device through a mobile phone application. After samples are scanned, processing takes place through analytical algorithms on a remote server. The resulting device may be more accurate and capable of sampling a much higher volume of air than commercially available air quality monitors. And it could cost one-tenth or even one-hundredth of the price.

"In our air, we're constantly breathing in molds, pollens, bacteria, and viruses. By the end of today, many of you will have inhaled more than a billion viruses," Ozcan told an audience at the Social Innovation Summit in Washington

QUALITY MONITOR

in 2016. "So, we need technologies that will, in a mobile, cost-effective platform, measure and quantify these. With the same sensitivity, precision, and accuracy you would expect from high-end institutional governmental devices."

Indoor and outdoor air pollution is linked to 6.5 million deaths each year, accounting for 11.6 percent of all deaths around the world, according to the World Health Organization. Almost 90 percent of those death occur in low- and middle-income countries.

The c-Air device counts and measures microscopic particles in air, called particulate matter, or PM. Knowing PM concentrations, and what kinds of particles are in the air, can help estimate the damage that pollution might cause. Particles that are 10 μm in size can lodge in the lungs and are a cause of cardiovascular disease, while 2.5 μm particles are thought to cause cancer.

The WHO data derived from satellites and on-the-ground air sampling installations. As Ozcan and his team explain in a research paper, air sampling stations use either beta-attenuation monitoring or a tapered element oscillating microbalance instrument. They are not very portable, weighing in at about 30 kg (66 lbs.), they cost anywhere from $50,000 to $100,000, and they require trained technicians for maintenance.

Commercially available portable air particle counters cost much less, roughly $2,000, but some can sell for up to $8,000. But they handle lower volumes of air and their accuracy may not be as high as the new c-Air device. Commercial counters can sample 3-4 liters of air per minute and their accuracy suffers when analyzing air with extremely high or extremely low concentrations of pollutants.

In contrast, c-Air screens 13 liters of air per minute and could cost as little as $50 at a high volume of manufacture, or about $200 if produced in low volumes. The device also produces images of the particles, which other portable counters are unable to do. By imaging the particles, researchers can identify their types to build a picture of what kinds of

continued on p.20 »

FROM 200 CALLS, ONE PRODUCT

How talking with technology users in the field helped us **invent a new product.**

In academia, we are comfortable writing the first paragraphs of papers that explain why we need to improve things like solar cells, engines, and membranes. Yet all too often, we fall back on generalizations that are too broad to be useful, or that miss the practical problems that beset potential users of the technology.

This is why our lab's researchers love talking with people who use the technologies we investigate. Hands-on users understand the strengths and practical limits of these technologies, and can provide feedback that efficiently drives future research goals.

Our lab discovered the importance of talking with potential users when we developed a graphene oxide filter and discovered that it was over-engineered for its intended use, water desalination. So, we wondered whether we could use it to replace thermal separations like evaporation and distillation, which consume more than 10 percent of all U.S. energy output. Yet nowhere in the academic literature could we find exactly what pain points it might solve.

Fortunately, we received a National Science Foundation I-Corps grant to leave our lab and talk with potential customers. Rather than showing us how to pitch our technology, the seven-week program taught us how to reach out to potential users, learn about their needs, and interpret their answers.

We discovered a real demand for our graphene oxide membrane and formed a company, Via Separations, to scale it up. Over the past 18 months, our team has spoken with more than 250 individuals, a number we continue to increase with a new customer discovery campaign every three to four months. Their input inevitably changes our thinking about how to apply our membranes and where to focus our development efforts.

There are tremendous opportunities for membranes with controlled electrical charges, which we can do more easily with graphene oxide than traditional polymer membranes, we found. We learned which industries are eager to adopt new technology, and which ones need to see it proven elsewhere.

The critical value of our membranes, we discovered, lies in their chemical and thermal resilience rather than our initial focus on permeability. Graphene oxide membranes are built upon a platform chemistry that is flexible, durable, and highly customizable. This makes the membranes suitable for many conditions and processes.

Our first interviews turned up a dozen different fields where Via Separations could make a difference with this material property. To develop an initial commercial product, we needed to narrow these seemingly endless opportunities. We took that step with a detailed analysis of market size, product fit, key value proposition, and customer engagement. We supplemented this data talking further with potential customers.

Given what we learned, we made our first product for the food and beverage sector. Because Via's membranes withstand higher temperatures and aggressive chemicals, plant processors can clean them faster, reducing maintenance time and boosting productivity.

We also plan to develop membranes to replace distillation, evaporation, and other energy-intensive separations. We believe physical separations could reduce the cost of some everyday products up to 75 percent. The chemical industry, however, is conservative and thinks in terms of long product cycles. By addressing food and beverage first, we can get to market faster and for less money and prove our reliability before tackling chemicals.

Our new membranes bring value to separations. By reaching out to industry, discovering the value of our research, and learning how to translate discoveries into commercial products, we have become better and more efficient researchers.

Little did we know what we were getting into when we left our lab to talk with users. ME

JEFFREY C. GROSSMAN (pictured) heads the Grossman Lab at the Materials Science and Engineering Department at the Massachusetts Institute of Technology in Cambridge. **SHREYA DAVE**, CEO, and **BRENT KELLER,** CTO, of Via Separations, Inc. also contributed to this column.

Q&A MELONEE WISE

ME: You studied mechanical engineering up to the doctorate level, but you also influenced the growth of the open-source Robot Operating System. Did you enjoy working more on the software side of robotics?

M.W: My career as a mechanical engineer has not exactly been what I expected. During my grad school I did internships with Honeywell and learned a lot about what engineers are suppose to be doing. When I came to California at Willow Garage I worked a lot on control and dynamics and ended up being a software engineer for six years. That was a step in the direction I never expected and then after a couple years I ended up doing mechanical design. I enjoyed both but sometimes I enjoy the software more because with hardware you have a definitive design cycle.

ME: From the role of senior engineer to the CEO of two companies within six years, how was the transition to the business side?

M.W: It's more when you start managing people that you become less hands on. Becoming a CEO was really about understanding how to focus your technical pursuits in a way that improves the team without getting in the team's way. I think one of the hardest transition in being an engineer to a CEO is the social transition. You are suddenly stepping out of a very technical role and you have a lot of technical people around you, who don't understand that transition, that creates some tension.

ME: Warehouse robotics is a hot space right now and there is a lot of competition in this area. Why do you think your robots will succeed?

M.W: We design both the hardware and software. The hardware is extensible, so you can put different accessories, enable integrators to work with customers. Same with our software as it enables people to deploy fast and allows automation very easily. We have invested a lot of time and energy in the usability of the product not just from a hardware but software perspective. There is a lot of pressure in the warehouse industry to move quickly and there aren't enough people to do the warehousing jobs, so it puts us in a very good position to provide automation.

ME: How do you see warehouse robots evolving? From warehouses, where do they go next?

M.W: The next biggest most possible thing is autonomous driving and it will take 10-to-20 years to really have ubiquitous adoption of it. We are starting to see testing in fair-weather cities but that's not uniform adoption. Another area where you will see more and more robots entering is eldercare. It's a very hard problem to solve and it will take people a lot of time to be successful in this space.

ME: You have been in the field of robotics for almost two decades now. Have you seen much progress being made in easing up gender disparity in the robotics world?

M.W: It's hard to look at it in the robotics world. In engineering, there has been some progress but a bigger problem for robotics is the number of students going to grad school because in robotics we need people with graduate degrees. It's really about how we inspire students early in the education cycle to think about engineering. One of the challenges we put up ourselves is that engineering is very hard and people say I can't do it without even trying it. We have to change the dialogue around mathematics to start. We must engage women throughout the entire process of STEM education. That women need extra help is not the message we should be sending. ME

CHITRA SETHI

MELONEE WISE KNOWS ROBOTS and she has been interested in them since her childhood. Wise founded Fetch Robotics in 2014 and has extensive experience in the growth of the open source Robot Operating System. She started Fetch Robotics after founding and running Unbounded Robotic, a spin-off of Willow Garage where she led a team of engineers developing next-generation robot hardware. Wise was a 2015 recipient of *Technology Review*'s TR 35 award for technology innovators under the age of 35.

continued from p.15 »

BETTER AIR QUALITY

pollutants are in the air in each area. Before c-Air, portable counters could only collect air samples to send to a laboratory for imaging.

Specialized parts, high prices, and the requirement for maintenance and laboratory support make many commercial air monitors impractical in many regions of the developing world. But c-Air seems to have solved many of those problems.

The air quality monitor is a prototype in development.

"We have made some important progress on the same c-Air technology by merging it with machine learning techniques for label-free detection of mold particles," Ozcan said. "We would like to establish c-Air technology as a robust bio-aerosol quantification platform by merging it with deep learning approaches." ME

ROB GOODIER is managing editor at Engineering for Change. For more articles on global development visit www.engineeringforchange.org.

WINDS OF CHANGE

Solar and wind energy may be poised to replace fossil fuels, but there may always be a shortfall, according to a recent study by the University of California at Irvine, the California Institute of Technology, and the Carnegie Institution for Science.

The researchers applied 36 years of U.S. weather data and compared it to U.S. electricity demand patterns. They found that potentially 80 percent of U.S. electricity demand could be met by those renewable resources.

Solar and wind energy output depends on time of the day and weather conditions.

To make up for gaps in production, a few weeks' worth of energy would need to be stored in large facilities, fed by "continental-scale transmission network facilities," which would require an infrastructure investment of hundreds of billions of dollars. By comparison, storing energy on cheap batteries is far more inefficient and could cost trillions of dollars, the researchers said.

Other energy resources like hydropower were considered for the study, but have geographical and other limitations.

Solar energy adoption is growing in the U.S., with universities like Cal Poly and companies like Apple installing solar farms to cut energy costs and reduce greenhouse gas emissions.

The research was published in the journal *Energy & Environmental Science*. ME

continued from p. 12 »

AUGMENTED REALITY GIVES SIGHT

Bioinformatics researchers at Worcester Polytechnic Institute are using HoloLens to visualize complex biological networks in 3-D. The 2-D representations of these networks, such as disease systems, are so complex and dense that "they look like a big mess," said Dmitry Korkin, associate professor of computer science at WPI and director of the university's bioinformatics and computational biology program.

Korkin is using HoloLens to develop new ways of "seeing" these complex networks.

"The topological complexity of such networks, and the abundance of the biomolecular and biomedical data, require a drastically new approach to integration and visualization of these data on the network structure," he said.

BIOINFORMATICS RESEARCHERS ARE USING HOLOLENS TO VISUALIZE COMPLEX BIOLOGICAL NETWORKS.

Stryker, a medical technology company, is using HoloLens to reconfigure operating rooms so they can better handle the needs of different types of surgeries.

Medical technology firm Scopis has created a HoloLens-based mixed-reality interface for surgeons to use during surgery.

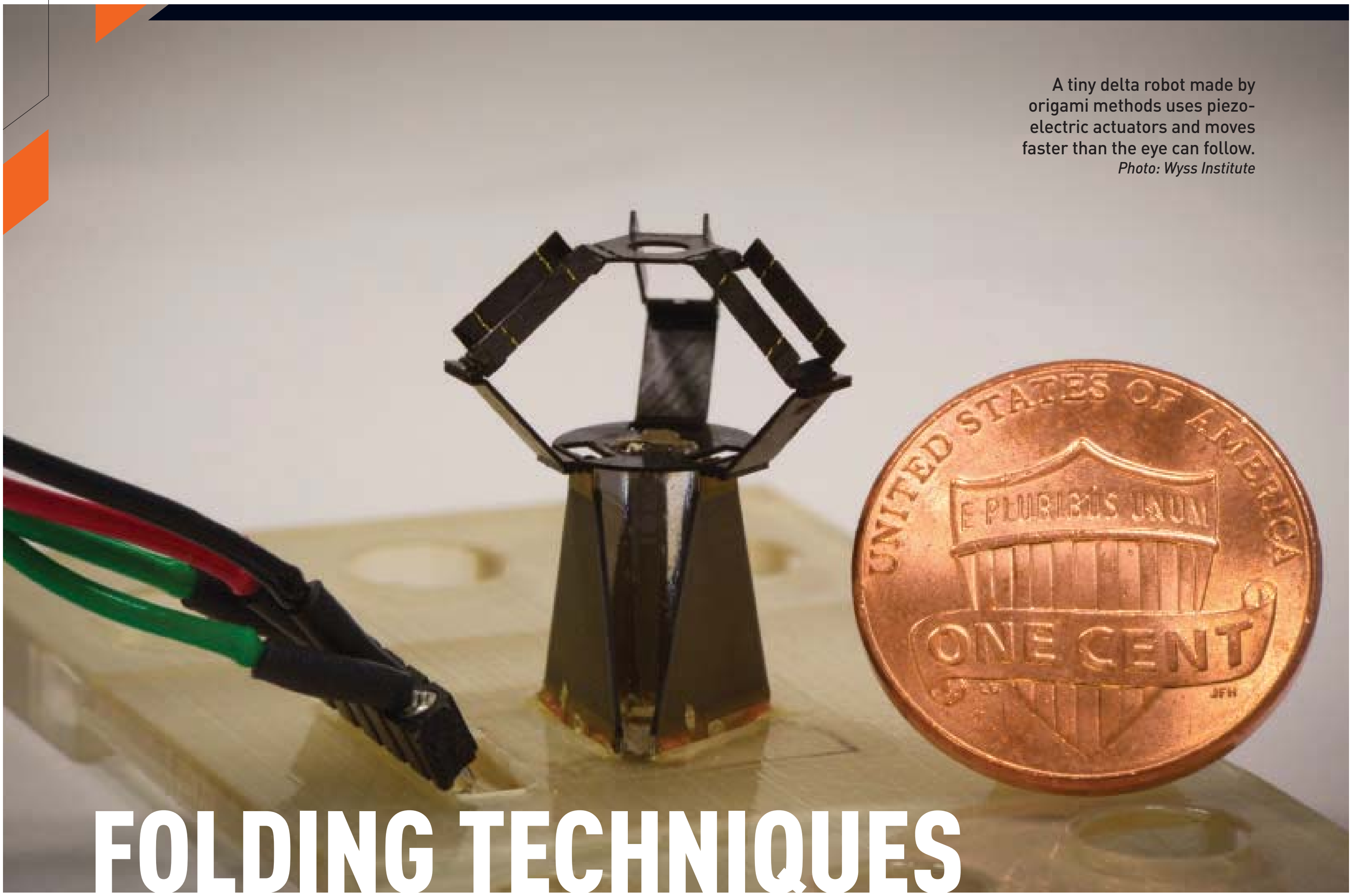
CAE, a modeling and simulation firm, has also used HoloLens to create mixed-reality ultrasound simulations to help medical staff visualize complex organs using holograms.

The University of Connecticut also uses HoloLens as the main technology to optimize gait rehabilitation of amputees and stroke patients. ME

MARK CRAWFORD is an independent writer. For more articles on bioengineering visit www.aabme.org.

"I THINK IT WILL HAPPEN FASTER than any of us understand. Real prototype vehicles are being built right now. So the technology is very doable."

Dennis Muilenburg, CEO of the Boeing Company, on the prospects of autonomous air taxis, as quoted by Bloomberg on March 1, 2018.



A tiny delta robot made by origami methods uses piezoelectric actuators and moves faster than the eye can follow.
Photo: Wyss Institute

FOLDING TECHNIQUES GET A MAKEOVER

THE JAPANESE ART OF ORIGAMI CONVERTS a flat 2-D piece of paper into a 3-D structure by using a precise set of folding techniques. The same principles are being used to deposit small and complex electronics, and actuators, or scaffolds for growing cells onto flat surfaces and then folding them into 3-D structures that act as robots or environments on which to grow synthetic livers.

INTO THE FOLD

THE LAB Microrobotics Laboratory, School of Engineering and Applied Science and Wyss Institute, Harvard University, Cambridge, Mass. Robert Wood, director. Mustafa Boyvat, postdoctoral fellow.

OBJECTIVE To apply origami to the creation of small robots.

DEVELOPMENT A millidelta robot built following origami folding principles.

Delta robots are fast and accurate, so industry often uses them to pick items off conveyor belts and pack them in cartons or trays. The reason for their high-speed precision is that they use three individually controlled arms to position—and stiffen—their end-effector.

Although they are a lot simpler than jointed robot arms with multiple servos, deltas are too complex to make in small sizes. Yet Robert Wood's Microrobotics Lab has done just that. Its millidelta robot is only 1.5 cm on a side and 2.0 cm tall, and moves 15 to 20 times faster than any other delta robot ever built. Its movements look like a blur.

To build these small yet precise robots, Woods redesigned their circuitry, actuators, and joints. Most notably, he replaced mechanical motors with piezoelectric actuators, and embedded flexural joints in high-performance composites.

The researchers machined the joints and deposited the piezoelectrics and circuitry on a flat composite surface, then covered them with a second layer of composite to create a sandwich structure. They then used a technique they call "pop-up" MEMS (for microelectromechanical system) to laser-cut the sandwiches, place them in an assembly jig, and precisely bend and fold them (much like origami) to create a 3-D robot.

They believe they can combine the millideltas with systems to stabilize a surgeon's hands and perform delicate operations on the retina or organs with small blood vessels. They also think they can use millideltas to manipulate biological samples or assemble very small electrical parts.

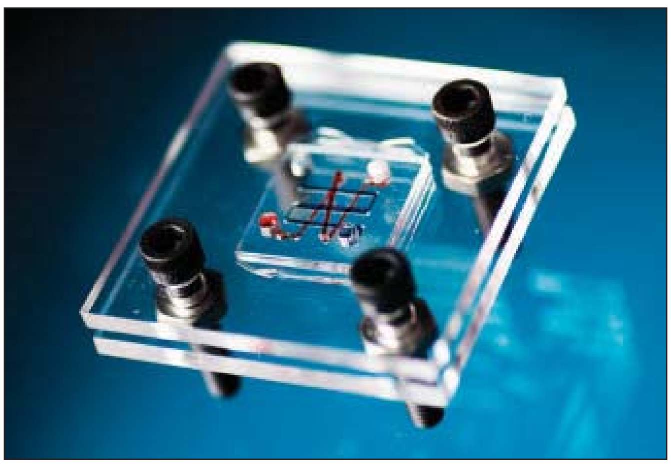
In addition to the millidelta, Woods Lab has developed origami-inspired flying bees, artificial muscles, and even a 3-D printed robot, complete with batteries.

Another concept under development by postdoc Mustafa Boyvat is a robot that changes its shape without a tethered or on-board power source. His wireless folding concept has promise in areas such as medicine, where physicians could dispatch 2-D robots to enter hard-to-reach places, then unfold them into 3-D systems to deliver mechanical forces.

Boyvat's robots are based on shape memory alloys, which change from one preset shape to another when heated. Ordinarily, this is done by passing electricity through the alloy. Boyvat induces a current by exposing the alloys to cycling magnetic fields.

"Since these SMA actuators are connected to folding parts, this produces folding," Boyvat said.

When he turns off the magnets, the alloys—and robot—return to their original shape. ME



MIMICKING THE LIVER

THE LAB Micropower and Nanoengineering Laboratory, Northeastern University, Boston. Carol Livermore, director.

OBJECTIVE To make realistic liver tissue models.

DEVELOPMENT Using origami folding to build 3-D liver tissue models from flat sheets.

A liver model created by depositing cells on a flat surface and folding to create a 3-D environment.
Credit: Adam Glanzman, Northeastern University

The interaction between drugs and the human liver is an important predictor of the drug toxicity, yet it is difficult to reproduce the structure and behavior of liver using tissue engineering methods. As a result, most pharmaceutical companies screen drugs using 2-D liver cultures, which are not every accurate.

"The liver's three-dimensionality and fine structure are absolutely critical to replicate to have cells function the right way," said Carol Livermore, associate professor of mechanical and industrial engineering at Northeastern University's Micropower and Nanoengineering Laboratory.

By folding flat sheets into 3-D constructs that mimic human liver tissue, Livermore believes she can reduce the time and expense of commercializing new pharmaceuticals.

To develop the origami techniques, Livermore is working with origami artist and physicist Robert J. Lang and three professors from Massachusetts Institute of Technology: tissue regeneration expert Sangeeta Bhatia, origami mathematician Roger Alperin, and mechanical engineer Martin Culpepper, who is building nanoscale machines.

Livermore's team is creating a set of cell-specific tissue structures and folding them together into a simplified model 3-D system that replicates key elements of liver behavior.

"You can do fine-scale features in 2-D easily," she explained. "Since you want three-dimensionality, you leverage existing technology to make a sheet that's bigger than what you need and that has a whole bunch of 2-D features. Then, when you fold it up so that the features line up properly, you have a 3-D structure that has these 2-D features."

Traditionally, if you wanted to make a 3-D device, you would have to create, align, and stack up multiple layers of flow channels. The benefit of folding is that it is faster and easier to produce a 2-D surface and then fold it into shape than to create repetitive layers, Livermore said.

Livermore and her team are now working to balance manufacturability with tissue function, and to ensure that cells wind up consistently where needed in the folded structures.

The origami approach to creating 3-D structures has far-reaching implications, Livermore said: "It is fair to say that you could potentially extend this kind of origami-based technology to make other engineered organ models and even couple organs models together to mimic more of what happens in your body." ME

ALAN S. BROWN

NASA LOOKS TO BUILD WAYSTATION

Gateway in lunar orbit will serve as a refueling point for missions to Mars and elsewhere.

Some laws are made to be broken, but the ones that govern spaceflight are ironclad. Primary among those laws is the one that dictates that the vast majority of a rocket's launch mass is made up of the fuel needed to lift not only the payload but also the remaining fuel waiting to be burned. The farther and faster you want to send something, the more fuel you'll need. For deep space missions, fuel and oxidizer can make up more than 95 percent of the launch mass.

NASA hopes to send large spacecraft to Mars, the asteroid belt, and elsewhere. In addition to new superheavy launch vehicles, the space agency is readying plans to build a habitable space station in lunar orbit that can serve as a place where vehicles can dock and refuel. Since rockets would only need to lift the spacecraft to lunar orbit, the thinking goes, they would need less propellant and oxidizer at liftoff, and less fuel at launch means bigger, more complex payloads can be lifted.

According to Ben Bussey, NASA's Chief Exploration Scientist in the Human Exploration and Operations Mission Directorate, the Lunar Orbital Platform-Gateway (previously—and more poetically—known as the Deep Space Gateway) will be built in stages. The first module, a solar electric power and propulsion element, is slated to launch in 2022. Next will come a pressurized habitation module, where astronauts will live and do science work. After the hab module, then an airlock and a logistics module will be sent up.

"The logistics module will carry materiel to fill out the hab module," Bussey said. It's envisioned that all four modules will be in place by 2024. But there could yet be more modules: "We are in discussions with international partners to see what else they might want to provide," Bussey said.

In a milestone for the project, money to build the gateway was included in the agency's 2019 budget proposal.

The gateway will serve as a staging platform for lunar surface missions, much like the Command Module of the

BIG NUMBER

43.6 percent

DANISH WIND POWER PRODUCTION IN 2017, COMPARED TO ITS OVERALL ELECTRICITY CONSUMPTION.

IT WASN'T THAT LONG AGO THAT WIND POWER was derided as an expensive toy that would never scale to useful levels. But wind turbines continue to sprout and they are contributing record amounts of power to the world's electrical grids. Denmark has a nameplate capacity of 5.3 GW of onshore and offshore wind power, and in 2017 those turbines generated about 14,700 GWh of electricity, according to Dansk Energi, a Danish power industry trade organization. By 2020, the organization expects renewable power production will equal some 80 percent of that country's electricity consumption.

Apollo program. But unlike those missions, said David Kring, a scientist at the Lunar and Planetary Institute in Houston, this new platform, landing craft, and rovers all will be reusable.

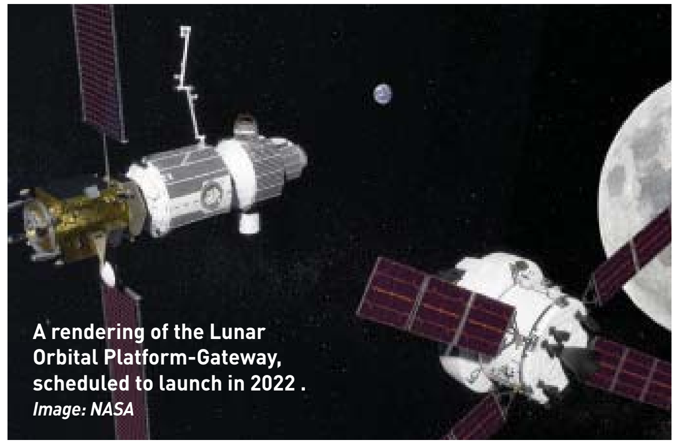
"The crew goes back to the gateway and then back to Earth, and Houston drives those rovers to the next landing sites. Then a second group of astronauts goes up," Kring said. "The landers are re-usable, so we don't have to launch a new lander every time we send a new crew up."

In addition to conducting science, it's hoped that robotic and human-led missions will find and help extract resources that could be used to produce rocket fuel.

"Right now, we have to take everything with us," Bussey said. "If we're going to explore the Solar System with people, we must make use of resources we find on the way."

A key find would be large quantities of water ice in permanently shadowed soil near the moon's poles.

"If the water is there and is extractable, then you can convert water ice into hydrogen and oxygen, which is life support consumables, but you also have rocket fuel," Bussey said. Many rockets, from the Saturn V to the Space Shuttle, burned liquid hydrogen with liquid oxygen. "So there's potential to use the Moon as a gas station."



A rendering of the Lunar Orbital Platform-Gateway, scheduled to launch in 2022 .
Image: NASA

Even before it refuels a mission to Mars or beyond, NASA's gateway could provide valuable data to help astronauts make those kinds of voyages.

"The Moon is three days away," Bussey said, "but it's still deep space. It's a hard enough proposition that we'll learn a lot by living and working there." **ME**

BRIDGET MINTZ TESTA is a technology writer based in Houston.

AIR-CUSHION VEHICLES: THEIR PROMISE

T.E. SWEENEY AND W.B. NIXON, DEPARTMENT OF AEROSPACE AND MECHANICAL SCIENCES, PRINCETON UNIVERSITY, PRINCETON, N.J.

While engineers had developed vehicles that could glide on a cushion of air, few economically viable applications had been found. Two researchers at Princeton proposed using this craft in agriculture.

It would seem that the world must have little need for the ACV [air-cushion vehicle], since it has been so slow in adopting the craft. The reason for this seems to go back to the basic criterion that the craft must outcompete its competition to be successful. It can thus be a long hard road for the tiny ACV industry to develop the craft, prove its capability in a given application, and to also develop the markets. An application not yet discussed appears to have the greatest potential of any ACV application yet considered. This is the agricultural use of the concept—the distribution of chemicals to fields prior to planting, and to spraying and/or dusting the crops as required during their growing period.

It should be mentioned that all commercial crops are in some manner treated with chemicals, whether fertilizers, fungicides, pesticides, or combinations of these materials. The crop-dusting airplane accounts for less than 10 percent of all crop spraying done in this country. The remaining 90 percent of the work is done from ground-based wheeled vehicles which seldom average more than 5 mph and, because of wheel tracks, destroy, on the average, approximately 5 percent of all crops over which they are used. Considering these disadvantages of the wheeled vehicle and the dangers and expense of the crop-dusting airplane, there appears to be a problem made to order for the ACV. However, a great deal more than just speculation is required.

A craft operating close to the ground obviously cannot be tilted very much and therefore not much in the way of a horizontal force can be generated by such an inclination of the lift vector. This is the basis for the admittedly poor maneuvering capability of the ground effect machine. However, the problem is not unsolvable. One approach is to design for a low base loading, thus permitting higher ground clearances and greater pitch and roll angles.

Another solution is to construct the lower portions of the machine to be flexible (i.e., a fabric skirt). This device permits a high degree of rotation in pitch and roll even though the ground clearance is quite low. Both of these design philosophies have application to agriculture since, on the one hand, a crop may be skimmed but essentially not contacted, while on the other hand the crop may be pushed through without damage to machine or plant because of the flexible skirt.

The initial experiment of driving the craft over full-grown alfalfa was evaluated by local farmers. This occurred in midsummer, 1964. Their comments were most encouraging and it was specifically noted that no apparent damage was done even though the plant experienced an agitated, "tumbling" motion. ME

LOOKING BACK

Engineers were seeking appropriate applications for new technologies when this article was first published in May 1968.

IT WAS EARTH ALL ALONG

When Sweeney and Nixon's article was first published in May 1968, many people could use a distraction. Assassinations of leaders such as Martin Luther King Jr. and (weeks later) Robert F. Kennedy, the demoralizing war in Vietnam, and widespread campus protests merged with the low-boiling crisis of the Cold War to create a sense of doom. However, anyone looking for a hopeful vision of the future by ducking into a movie theater would be in for a jolt. April 1968 saw the wide release of both *2001: A Space Odyssey* and *Planet of the Apes*. Both movies followed astronauts on journeys into the unknown and featured ground-breaking visual effects. As popular as both movies were at the time—and in the half century since—each portrayed an ultimately pessimistic view of human ingenuity. In our greatest tools lie the seeds of our own destruction.

Taylor and Nova, played by Charlton Heston (left) and Linda Harrison, can't escape the past in *Planet of the Apes*. *Photo: Twentieth Century Fox*

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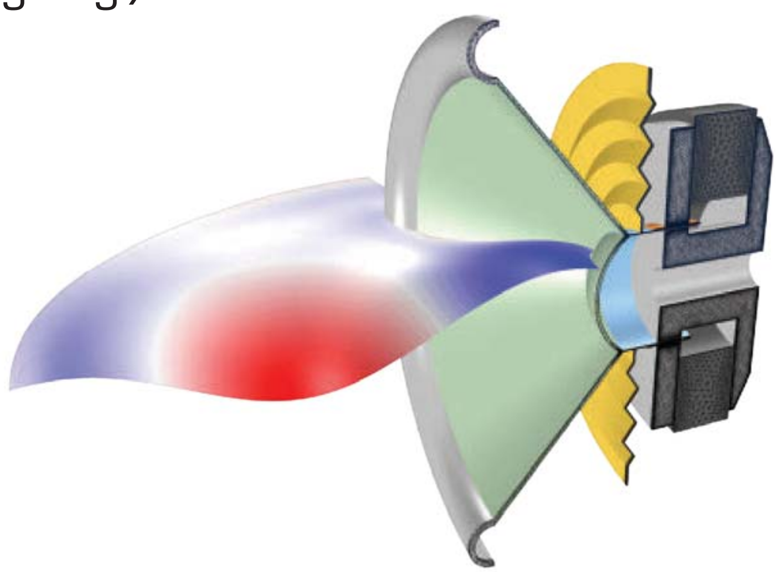
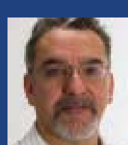


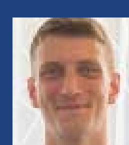
Visualization of the acoustic pressure distribution generated by a loudspeaker driver.

SPEAKERS:

RICCARDO BALISTRERI
Senior Acoustic Engineer
Klipsch Audio Technologies



MADS J. HERRING JENSEN
Technical Product Manager, Acoustics Module
COMSOL



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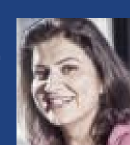
Managing Editor
Mechanical Engineering



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BY THE NUMBERS: AUTOMATION NATIONS

Around the world, robots are becoming common in factories. But no country has adopted industrial robots to the same extent as South Korea.

The South Korean automobile industry has embraced factory automation in a big way. *Image: Getty Images*

When futurists project current workforce trends into the coming decades, many see a world in which human labor has been almost entirely replaced by robots. If that is the future—and it's hard to know whether the fears of a workerless economy are just far-fetched scaremongering—then it's a future that is starting to be seen today in some corners of the world.

The International Federation of Robotics (IFR), a Frankfurt-based trade group, measures the penetration of robots into the workplace via a metric it calls robot density: how many industrial robots are operating per 10,000 human manufacturing workers. In 2016, the most recent year for which the IFR has complete data, the global robot density was 74 per 10,000 workers, or one robot for every 135 humans.

That single number fails to capture the degree of variation in automation across countries. A broad cross-section of nations, for instance, doesn't even reach half that density. Less automated economies include older industrial nations such as Poland, Estonia, and Croatia, high-tech hubs like Israel, and four-fifths of the so-called BRICS nations: Brazil, Russia, India, and South Africa. (The fifth, China, has a slightly below average robot density of 68 per 10,000 workers.)

There are 17 nations with a robot density between one and three times the global average. That batch includes the United States and Canada, Taiwan, and much of Western Europe. The U.S., for instance, has 189 industrial robots per every 10,000 manufacturing workers, or one robot per 53 workers. That degree of automation likely boosts worker productivity without replacing too many jobs.

Four nations have rushed headlong into the automated future. Japan and Germany have slightly more than 300 per 10,000 workers, and Singapore has 488.

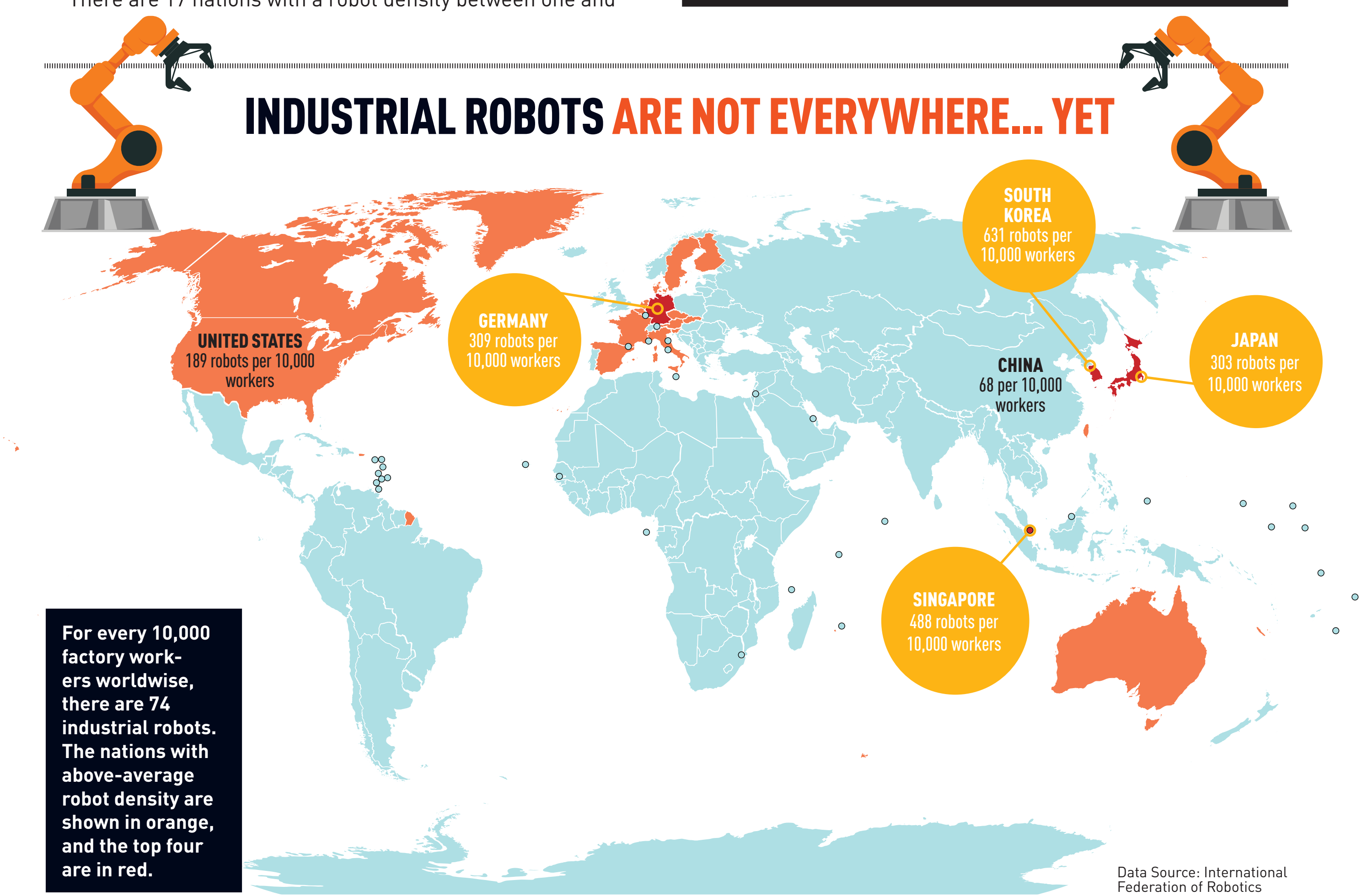
South Korea, however, stands apart: Its robot density is 631 per 10,000 workers, or one robot per 16 workers.

Automation in the automotive industry is driving up the Korean robot density, the IFR says. The density in South Korean car factories has doubled since 2009 to 2,145 per 10,000 workers—about one robot per five workers. And new factories for making batteries for electric vehicles are even more highly automated.

The IFR projects shipments of industrial robots to continue increasing for at least the next several years, so it is likely that factory floors everywhere will start to resemble those in South Korea today. How that plays out in terms of reduced opportunities for human workers is harder to forecast. **ME**

JEFFREY WINTERS

INDUSTRIAL ROBOTS ARE NOT EVERYWHERE... YET



For every 10,000 factory workers worldwise, there are 74 industrial robots. The nations with above-average robot density are shown in orange, and the top four are in red.

Data Source: International Federation of Robotics

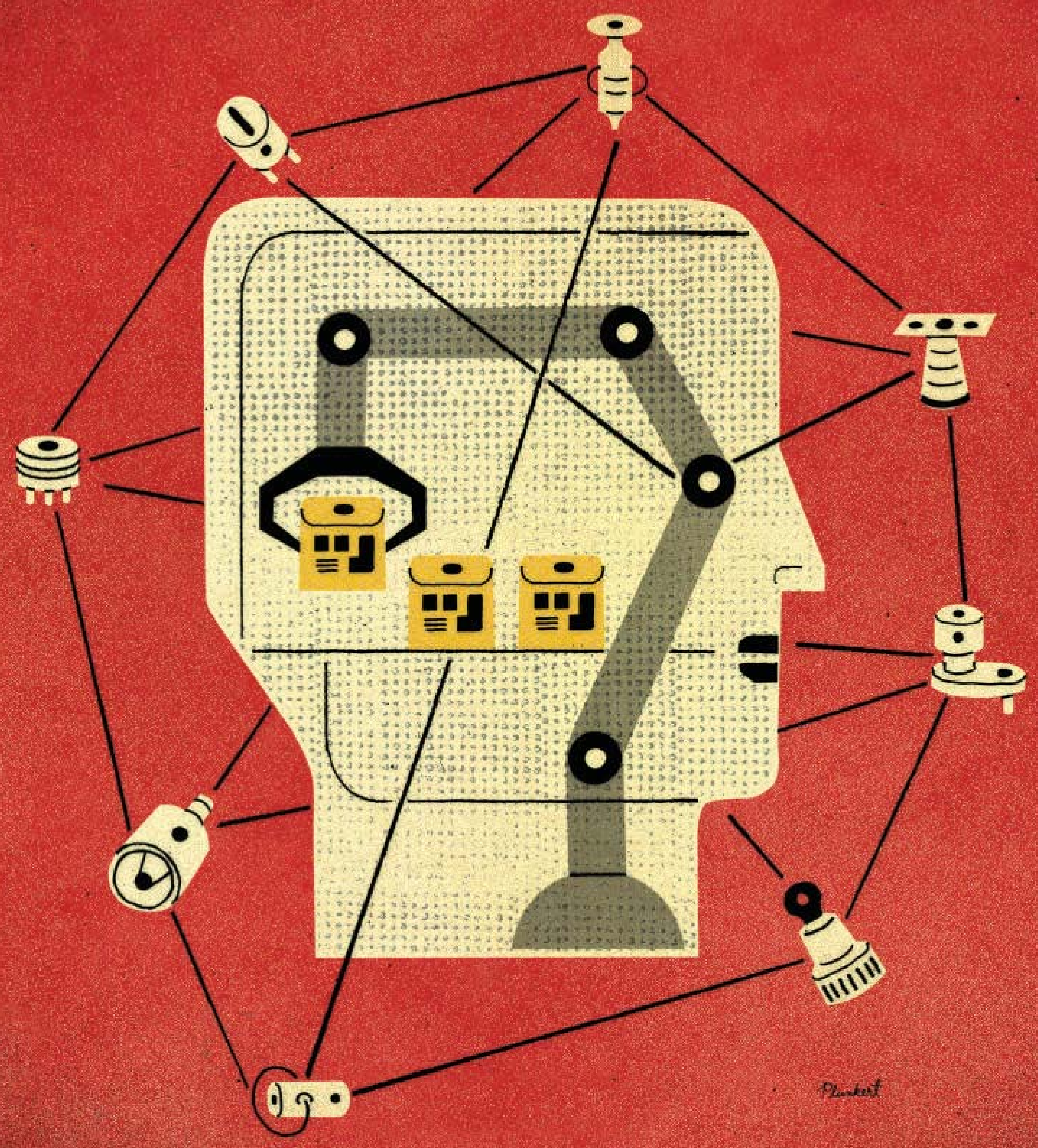


Illustration by
David Plunkert

THE Chain Gang

Manufacturing supply chains are more complicated than ever. Blockchain—the technology that enables cryptocurrencies like Bitcoin—may help unseen partners trust each other.

BY AGAM SHAH

Manufacturers can be resistant to change, but as a chief technology officer at Moog, George Small is charged with staying ahead of the technology curve. Small's latest obsession is blockchain, the underlying technology behind the cryptocurrency Bitcoin, which he believes will change the face of manufacturing.

The goal wasn't to find a new way to pay for manufactured goods, but to track them through the supply chain.

More than two years ago, Small began researching blockchain's benefits as a more effective way to digitize and decentralize manufacturing. Blockchain involves a digital ledger that is continually updated to record and track transactions, accounting and asset movement. In the context of manufacturing, blockchain can establish an organized digital thread tracking the history of a part from its digital design to production all the way to end of life. A blockchain can be shared with multiple parties that get access to the same information.

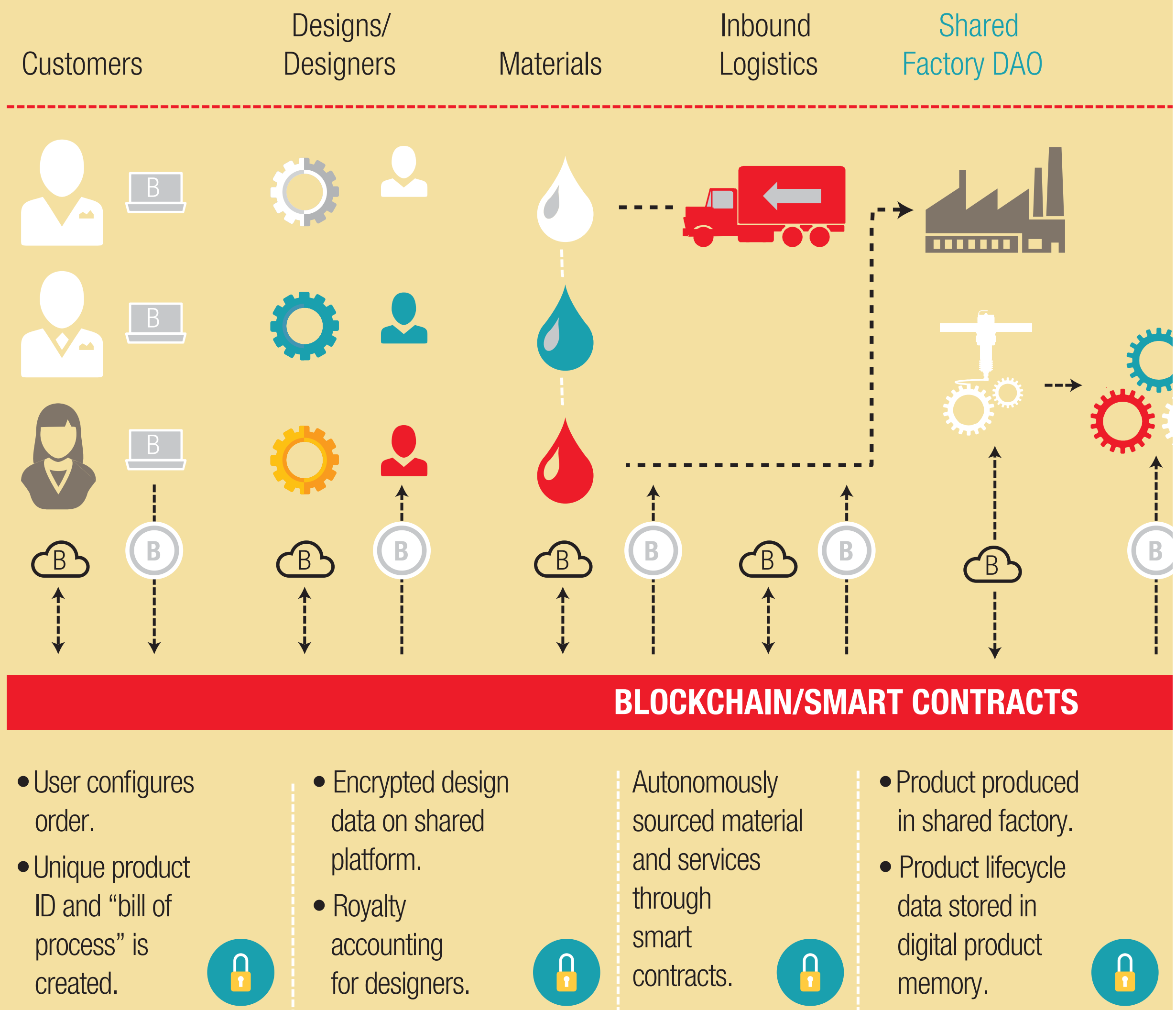
"All these paper processes that are being replaced will ultimately be digital and expand across enterprises," Small said. "You can be tracking and tracing these individual operations at the shop floor, and instead of doing it in your ERP system, it could be recorded on a ledger you share across organizations, which is hard to do right now."

With Small's help, Moog became one of the first manufacturing firms to unlock blockchain's promise. The company began a pilot project to replace insecure paper processes with an end-to-end digital paper trail to securely share digital designs with multiple manufacturers and designers. That's a critical need for Moog, which designs and manufactures parts for such highly regulated products as aircraft, satellites, and medical devices.

The company discovered that blockchain wasn't just a better record-keeping system—using blockchain added accountability and reduced production costs. Cutting middlemen helped speed orders, and as a result parts were made and shipped quickly. Data tags added to transactions ensured parts were made with specified materials and qualified machines, which reduced manufacturing errors. The deep audit trail helped better manage provenance and intellectual property.

Other manufacturers are also investigating the promise of blockchain technology to streamline their operations. They are discovering that blockchain could enable deal-making and provide a means for establishing trust between two companies on opposite sides of the globe.

THE SHARED AUTONOMOUS FACTORY MODEL



Source: innogy/Cognizant

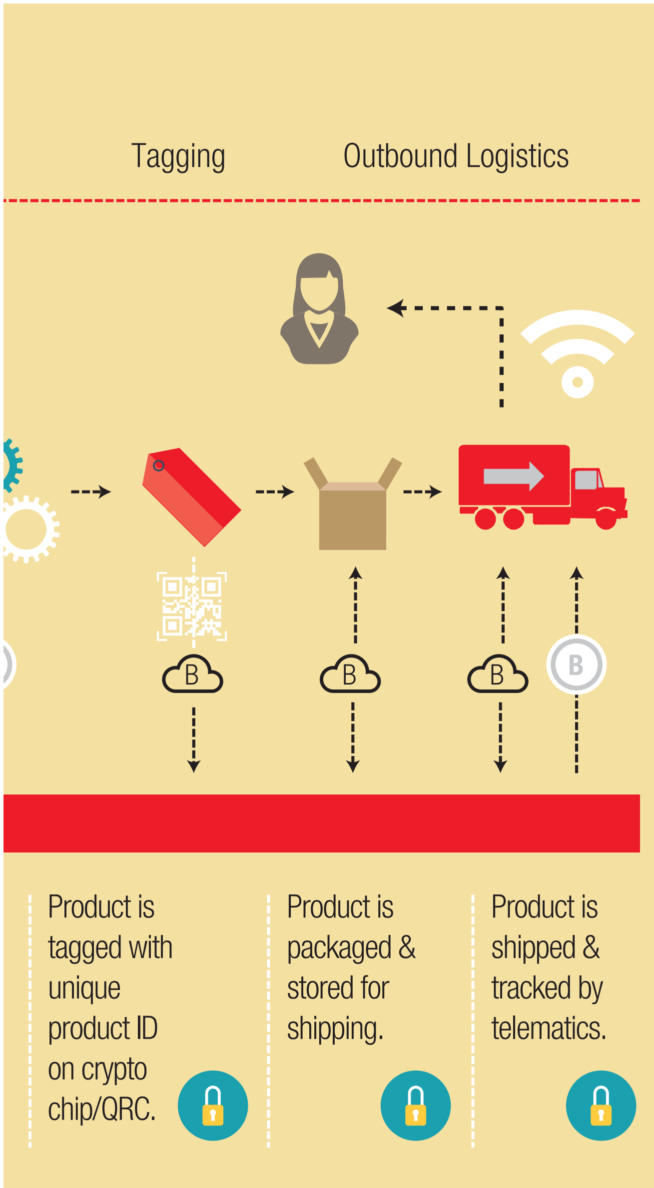
Most people associate blockchain with Bitcoin, but it is simply a file system that can operate without a centralized mechanism for establishing that the receiver can trust the authenticity of the file. Authentication is performed by a chain of computers using cryptographic and computing techniques, and only after that authentication is the transfer completed.

The documents themselves can be anything: Land titles, medical records, digital design files, or receipts. Or, many different kinds of files can be bundled together. The key is, once the data is recorded in a block, it can't be altered without the agreement of all the computers in the network. Instead, new information is tacked on to the end of chain. In this way, the entire history of the document can be traced.

For manufacturers, blockchains can contain product specifications and designs, contracts between suppliers, and the terms of payment upon receipt of the finished product.

"The blockchain technology could potentially change the way how 3-D printing or manufacturing processes are structured," said Philipp Sandner, head of the Frankfurt School Blockchain Center in Germany. It might also reduce counterfeiting and manufacturing fraud.

Research firm IDC is projecting blockchain



expenditure on manufacturing and resources in 2018 to be about $448 million, third only to financial services and distribution and services. That number will explode as more blockchain projects come out of experimental phase.

In its pilot blockchain project, Moog worked with ST Aerospace on secure 3-D printing of airline parts. ST Aerospace purchased a digital design directly from Moog, which was recorded in a ledger. Based on parameters specified in the blockchain, ST Aerospace could verify the design file as a genuine Moog part and identify the right materials and printing techniques it should use. The company could then immediately print the part on a 3-D printer in its Singapore facilities using the laser metal process. The design files pulled from Moog's database were protected by digital rights management and could not be tampered within the process of establishing a contract and delivering the file from the U.S.

The next stage demonstrated the possibility of settling the transaction via a smart contract, using a digital token in the place of hard currency. Since this was a pilot, no actual money was exchanged.

From Moog's perspective, the digitization and distribution of the manufacturing process can help the company save on transportation and warehousing costs, while getting parts to customers almost immediately.

Distributed manufacturing like this has been possible for some time thanks to the availability of additive manufacturing. But for parts used in the aerospace industry, it would not have saved much time. The Federal Aviation Administration and the European Aviation Safety Agency both require parts provenance today, which happens mostly on paper. Before a part could be printed, the paperwork would have to be put together, a process that could take days. Blockchain and additive manufacturing could synchronize those processes to meet regulatory requirements when shipping a design file for a part.

The idea that a digital file could follow a physical item around like a shadow opens up some intriguing possibilities. To test one of those possibilities, a consortium of manufacturers and information technology companies called the Genesis of Things initiated an experiment.

The experiment, run by Carsten Stöcker, CEO of Berlin-based Spherity, used a blockchain system to print 100 cufflinks using files ordered from a secure database, and delivered to specific 3-D printers in a farm in Germany that matched the parameters specified in the transaction.

Before printing the cufflinks, the geometry, material, and structure were set as custom design parameters in the form of asset metadata in the print file. These parameters—which included printers capable of making titanium products, meeting specified laser angles, and other details—were contributed by trusted parties, and the transaction was validated by multiple computing nodes in the blockchain. The parts were printed by securely linking up the individual encrypted digital files with authorized 3-D printers with right materials and printing techniques.

Each cufflink had a unique print that could not be cloned in a 2-D process, and the packaging had QR codes linked to product details such as design elements and materials used. Jointly, the goal was to minimize the risk of counterfeiting the product. The cufflink designs could be modified as the design files weren't digitally rights managed, so parameters like assets, materials and 3-D printing techniques could be added to print files.

The integrity of an execution environment was important, especially in manufacturing, where "no one trusts each other," said Stöcker. "We recorded quality assurance parameters in digital twins of the cufflinks to establish supply chain transparency that added to the provenance."

Since each cufflink printed was linked to a specific blockchain that followed it around, once that cufflink was sold, its designer could be looked up and automatically paid a royalty.

On a larger scale, blockchain provides a blueprint for manufacturing companies to establish unified exchanges with common ledgers to share designs and settle deals directly, much like how Bitcoin enables people to freely exchange currency across borders. These networks could enable deal-making on a global level, and is especially relevant for designers and manufacturers looking for a more direct way to connect to customers.

"Right now the idea is that everybody's got their own database," Small said. "Blockchain in the end is one way to have a common database that no entity owns. You can start connecting organizations in ways you could not before."

Other groups are looking at blockchain files as a means of enabling machine shops to bid for jobs to make precision parts for companies anywhere in the world. Jeremy Goodwin, CEO of SyncFab, a distributed manufacturing company in San Leandro, Calif., hit on the idea after seeing factories in the San Francisco Bay area struggling financially, and figured blockchain could be a better, quicker, and cheaper way to bring those factories more business.

SyncFab's procurement and manufacturing exchange enable machine shops to bid for jobs. A designer first establishes a request-for-quotation and provides the design assets, indicates the processes required, such as general dimensions, materials, volume, and turnaround time. The designer also offers incentives that could create additional income for the shops if they take on tasks such as troubleshooting or PLM documentation off the hands of designers. The entire system—bidding, tracking, asset management, and payment process—is managed via a private blockchain.

"There's a lot of older veterans, they hear blockchain, think it is Bitcoin and say 'it's a fraud,' " said Goodwin, who is also an industry partner to the U.S. Department of Energy's Clean Energy Smart Manufacturing Innovation Initiative. "What if you tell them you're going to earn a comparable income stream? It is a built-in incentive component that's powerful in addition to the technology itself."

Getting the income is not as straightforward as old-fashioned invoicing, however. Payments due as part of the "smart contracts" embedded in the blockchain agreement can be made via cryptocurrency, for instance, or a fledgling Internet-of-

GETTING PAID ON BLOCKCHAIN

Royalty accounting can be challenging for manufacturers and industrial designers, since tracking the use of products can be difficult and the billing process can drag on. Beyond tracking transactions and digital assets, many experts believe blockchain could make billing, invoicing, and receiving payments easier and more secure.

To take one example, blockchain files can track a digital asset, like a design file, through the production process to the point of being printed on a 3-D printer. At that point, the system can automatically authorize a payment to designers and other holders of the intellectual property behind the digital asset. Hoping to build the financial infrastructure needed to support those sorts of micropayments, companies such as Visa and Ripple are developing means for linking blockchain files to credit cards.

Blockchain also introduces manufacturers to potentially new sources of income by enabling them to monetize data from IoT devices, said Philipp Sandner, a professor at Frankfurt School Blockchain Center. A machine-to-machine payment protocol designed to handle micro-transactions between IoT devices is being established by the German group IOTA.

According to the manufacturing company, SyncFab, blockchain files can create incentivized contracts whereby bonus money is automatically paid out for taking on more work, and payments are automatically triggered as contract milestones are reached. Other, more far-fetched ideas for blockchain include enabling payment via the exchange of non-monetary assets, such as carbon credits or renewable energy vouchers.

For now, however, it is expected that most manufacturers will prefer cold, hard cash.

One experiment used blockchain to create a digital twin for 3-D printed objects such as these cufflinks.
Image: Carsten Stöcker

Things based machine-to-machine payment protocol. But established businesses are still subject to international financial and tax laws even if they do accept a cryptocurrency, and alternative payment methods are full replacements for hard cash.

Other projects are underway on paper or at least close to implementation. IBM, which sells blockchain software and services, is working with automakers on a project to verify timestamped IoT data to ensure the right parts are used when assembling a car. In that application, the blockchain acts as a database to track parts and plays a role in speeding up automation. The system could also help repair shops verify parts when fixing a car.

The U.S. Department of Defense has seen a growing number of counterfeit parts used in fighter jets and other equipment, and the National Institute of Standards and Technology is building a blockchain so that the DoD can pinpoint parts to the source manufacturer by tracking back over multiple levels of suppliers. Blockchain could also help the U.S. Navy do just-in-time 3-D printing of parts on ships at sea, and also establish a superior tendering process, said Sylvere Krima of the systems engineering group at NIST.

Krima was also quick to point that blockchain is not security software, nor is it bulletproof. A private blockchain could be vulnerable to hackers. NIST conducted a blockchain study that found that there's no "code of conduct" to enforce user behavior, so that malicious parties could disrupt transaction flow. But there's also a good chance that irregularities would be ferreted out in the blockchain verification and authorization process.

Another challenge to wider implementation is the energy required to mine public blockchains.

"You can implement a private blockchain where you don't need as much mining power. It's a lot less energy, you can arrange it to any existing IT infrastructure," Krima said. "That's a use benefit as you don't need huge servers or network bandwidth."

For now, blockchain is a technology that is attractive to manufacturers looking to solve a problem, not those happy with existing processes. But it's expected that as artificial intelligence and the Internet of Things grow in importance—especially with the wider availability of cheap, ubiquitous computing—blockchain applications will become relevant to even the most stodgy manufacturers.

"Blockchain is a tool that can simplify things," said Moog's Small. "As you dig more and more into it, it's a very digital intensive process and it lends itself to rethinking how the manufacturing value chain is laid out." **ME**

AGAM SHAH is associate editor at *Mechanical Engineering* magazine.

THE STATE OF AMERICAN

Don't be fooled by the rhetoric: Factory work isn't part of the past. Manufacturing is a vital part of today's economy.

BY ALAN S. BROWN

The data, as it is usually presented, is stark: 70,000 factories have closed in the United States since 2000. In that time, the country has lost one-third of its manufacturing jobs. In every year this century, more factories have closed than have opened.

Those numbers don't necessarily tell the full story. Michael Hicks, director of the Center for Business and Economic Research at Ball State University in Muncie, Ind., says the job losses are the flip side of factory efficiency. His analysis shows that production is higher than ever, and he argues that increased productivity, largely through automation, was responsible for 88 percent of all job losses.

"Had we kept 2000-levels of productivity and applied them to 2010-levels of production, we would have required 20.9 million manufacturing workers," he argued. "Instead, we employed only 12.1 million."

Indeed, U.S. manufacturing remains strong and diverse. The value added by U.S. manufacturers, $2.2 trillion in 2017, trails only China and is twice as large as third-ranked Japan. The sector, by itself, is larger than the entire economies of Brazil, Canada, Russia, or South Korea.

Even so, many experts are alarmed by the relative decline in manufacturing. They include Robert Atkinson, an economist who founded the Information Technology and Innovation Foundation (ITIF), a top think tank for science and technology policy.

Atkinson believes that predatory trade policies—government investment, subsidies, tax incentives, and protected home markets—give companies from China and other emerging economies an unfair advantage against the United States and nations with more open borders.

Atkinson claims that scholars like Hicks overstate the production of computers and electronics, which measure output by chip processing speeds rather than unit production. Subtract computers and U.S. productivity rose a dismal 0.5 percent annually between 2007 and 2016—while output in many manufacturing sectors declined.

A recent analysis by McKinsey Global Institute, *Making It in America: Revitalizing U.S. Manufacturing*, also sees cause for alarm. That report found that if you subtracted out computers, pharmaceuticals, and medical devices from U.S. manufacturing data, value-added output has changed little in 15 years.

When politicians present the dire manufacturing data, they often couple it with promises to restore the sector to its former state of prominence—and to bring back the millions of lost factory jobs. In today's interconnected economy, however, that might prove too heavy a lift for even the most dedicated leader.

DRILLING DOWN INTO MANUFACTURING

While manufacturing today accounts for only 12 percent of the U.S. economy and employs just 9 percent of American workers, the sector consistently punches above its weight in terms of impact. Manufacturing, for instance, generates 35 percent of America's productivity growth, 60 percent of its exports, 55 percent of its patents, and 70 percent of private sector R&D. It employs more than 30 percent of its engineers.

And even those numbers understate the true impact of manufacturing on the economy. The data often fails to count jobs created by manufacturers as manufacturing jobs.

For example, while many firms have outsourced their production overseas and are now considered "non-manufacturing companies," they keep their design, engineering, marketing, service, and supply chain logistics management in the U.S. At the same time, established manufacturers outsource services—everything from design and engineering to security and cafeteria services. In spite of their obvious contribution to the manufacturing sector in the U.S., government statistics do not count those types of workers as manufacturing employees.

What's more, the line between selling goods and providing services is becoming blurred. Many manufacturers have traditionally sold their products with bundled services, such as extended warranties or extended maintenance and repair coverage. Thanks to cheaper digital sensors and wireless industrial internet, they can offer more value-added services, like quality monitoring and predictive maintenance.

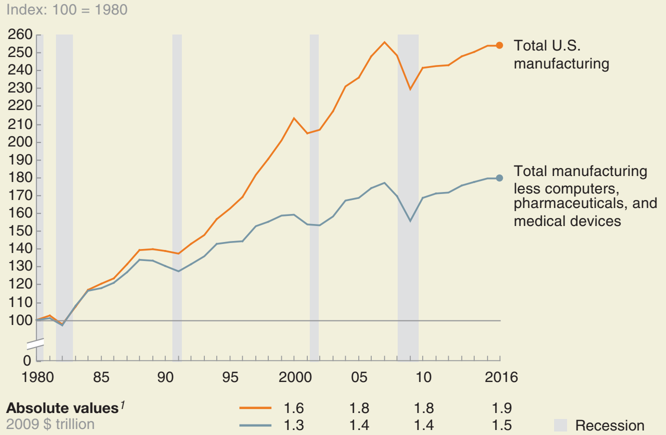
The Organization for Economic Co-operation and Development, estimated that services accounted for one-third the total value of products sold by U.S. manufacturers in 2011. Advances such as the industrial Internet of Things promise to make these service offerings even more common. Yet few of these services are captured by manufacturing statistics.

MANUFACTURING

2018

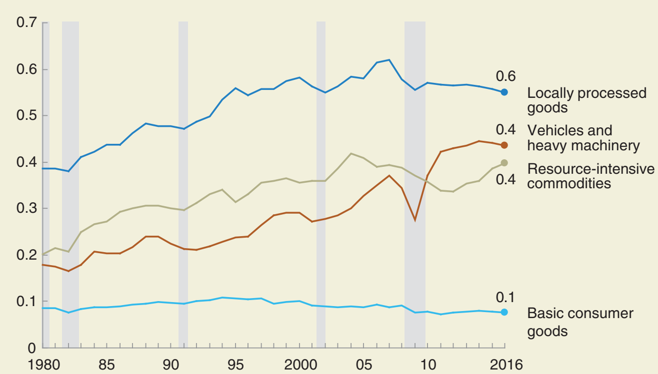
REAL VALUE ADDED IN U.S. MANUFACTURING IS NO HIGHER TODAY THAN IT WAS A DECADE AGO

The sector's real value added is sharply lower when tech products, pharmaceuticals, and medical devices are excluded
Index: 100 = 1980



SOME SEGMENTS HAVE POSTED REAL DECLINES OVER 15–20 YEARS

2009 $ trillion



1 Absolute values prior to 2000 are not displayed due to distortions in the available data.
SOURCE: BEA; Moody's; McKinsey Global Institute analysis

Chinese workers assemble electronic components at the Taiwanese technology giant Foxconn's factory in Shenzhen, China. *Photo: Getty*

COMPETITIVENESS

The plight of the American factory town is often contrasted with that of China's manufacturing hubs, where whole cities can be turned over to supplying parts for one industrial sector. How can the U.S. compete with that?

Quite well, actually.

In a January 2017 study, *Honing U.S. Manufacturing's Competitive Edge*, Harold Sirkin, a managing director at Boston Consulting Group, found U.S. and Chinese costs virtually even. According to Sirkin, wages adjusted for productivity have risen in China while remaining flat in the U.S. Meanwhile, U.S. industrial electricity and natural gas dropped sharply. Other U.S. strengths include a stable dollar, efficient logistics, ease of doing business, and markets undistorted by corruption.

McKinsey's *Making It in America* paints a similar picture. While the U.S. manufacturing has eroded in some areas, it remains a leader in innovation, application of digital technologies, and the ability to attract and retain top talent.

So if all this is true, why are factories and jobs not flowing back to the United States?

China's thriving industrial ecosystem is built to scale up consumer products for mass production. According to a 2013 MIT study, *Production in the Innovation Economy*, Western innovators frequently turn to Chinese partners to scale up prototypes, re-engineer mature products to reduce production costs, and tap local innovations in design and manufacturing.

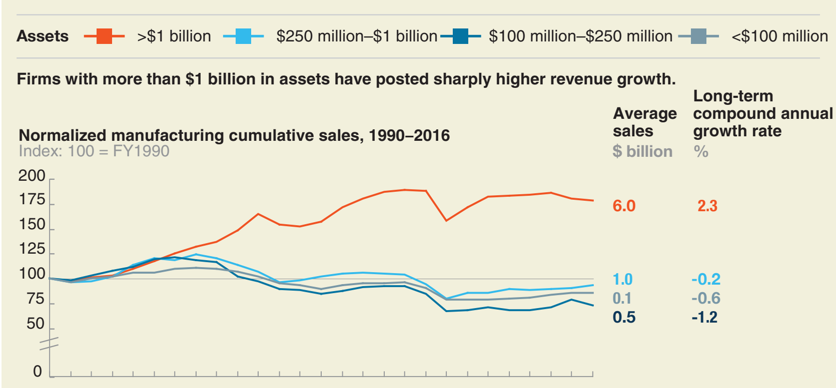
While the U.S. remains a leader in low-volume production for prototypes, its ability to scale up new products has been hollowed out since the turn of the century.

The robust industrial ecosystem found in China has been devastated by a winner-take-all mentality in the United States.

Since 1990, McKinsey said, manufacturers with more than $1 billion in assets have grown U.S. revenues by more than 2 percent annually while revenues at small and midsize firms fell. One reason they fared so well was that large firms could demand lower prices from smaller suppliers or tap global markets for cheaper alternatives. As a result, U.S. domestic content in technology-driven and basic consumer products has fallen by 13 to 15 percent since 2000, depriving smaller companies of revenue.

"Significant productivity gaps have opened up between large firms and small and midsize producers that are unable to invest in new equipment and technologies," McKinsey concluded.

LARGE MANUFACTURING FIRMS HAVE PERFORMED MUCH BETTER THAN SMALLER PLAYERS

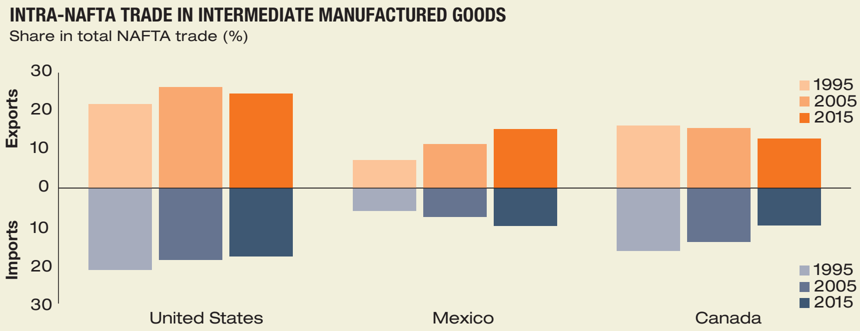


Source: McKinsey Global Institute

TRADE

The U.S. has run a trade deficit with the rest of the world since the 1990s, and that imbalance is driving policy decisions in Washington. But looking only at the bottom line can be misleading, said David Dollar, a senior fellow at the Brookings Institution. Instead, Dollar focuses on the value added at each step by each country during production.

Trade with Mexico looks different from a value-added perspective, since many of its exports contain American-made components. This reduces the real value of Mexico's whopping trade surplus with the United States, though how much is still a question. A Harvard University study found that 27 percent of the value of imports from Mexico was made up of components originally manufactured in the U.S. Another study conducted by the Organization for Economic Co-operation and Development in Paris put the number as low as 16 percent.



Source: Organisation for Economic Co-operation and Development Bilateral Trade in Goods by Industry and End-use database, International Standard Industrial Classification, Revision 4 (2016 edition).

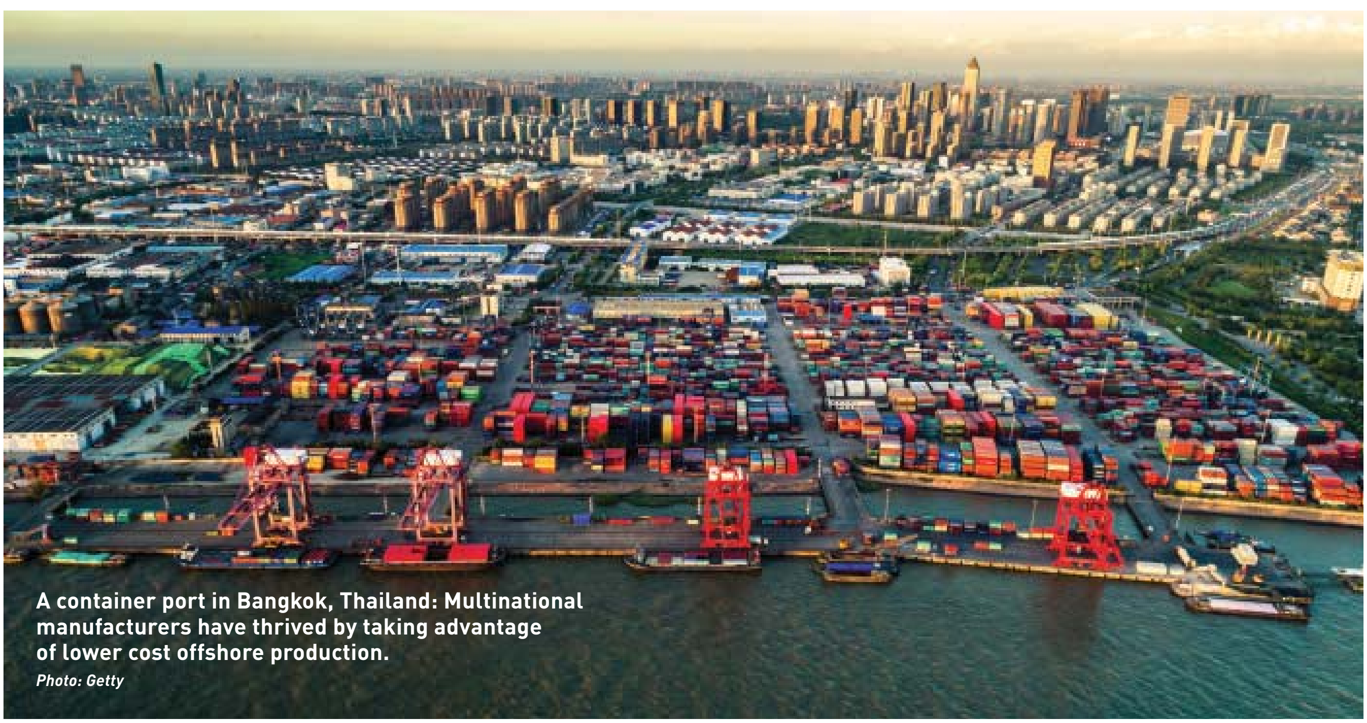
While multinational trade agreements like NAFTA make it easier for large companies to import low-cost components, U.S. firms do not always have equal access to trade partners' markets.

China has gone beyond mere protectionism, ITIF's Atkinson charges. It actively subsidizes chosen industries so they can lower prices and drive competitors out of business.

Atkinson points to solar panels as an example. China acquired technology through commercial espionage, he charged, and once Chinese companies could produce at scale the government blocked imports and subsidized local manufacturers. Those firms were able to drive down prices and undercut unsubsidized U.S. producers and drive them out of business. Chinese firms then bought the bankrupted U.S. firms for their technology.

As a result, China raised its share of global solar panel market from 5 percent to a whopping 70 percent today. Atkinson warns that China plans to use the same playbook to dominate advanced industries ranging from robotics and medical devices to aviation and autonomous vehicles.

Yet Atkinson prefers a strategic approach to China rather than tariffs. Tariffs work well in commodities like steel, he said. But in fast-moving technologies like solar panels, they are often "a day late and a dollar short."



A container port in Bangkok, Thailand: Multinational manufacturers have thrived by taking advantage of lower cost offshore production.

Photo: Getty

Economists and consultants nearly unanimous in their belief that technology—and specifically Industry 4.0—could change manufacturing's playing field.

Industry 4.0 is a rapidly evolving concept that brings together digital brains and manufacturing muscle. It includes everything from Internet of Things, cloud analytics, and artificial intelligence to robots, additive manufacturing, and digital simulation tools. By building a digital thread that ties manufacturing to upstream design and downstream logistics, use, and maintenance, companies hope to improve products, reduce costs, and offer entirely new services.

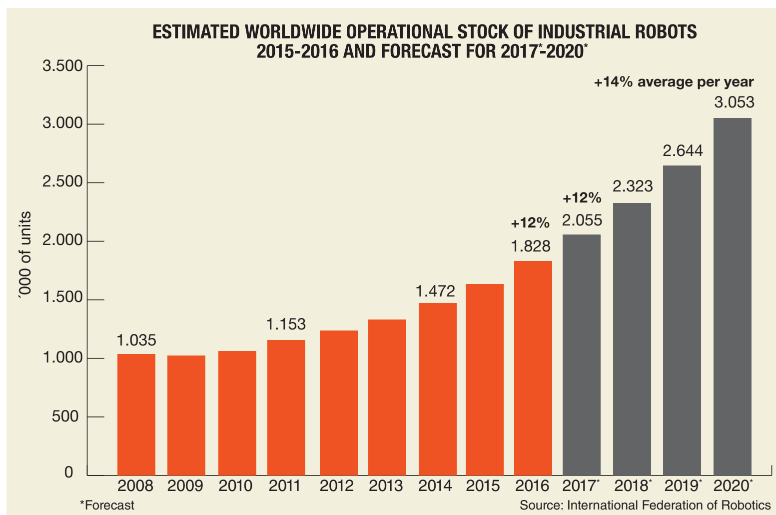
The emphasis on services is not surprising. Services account for as much as 55 percent of total sales in some industries. Rolls-Royce, for example, "leases" its turbines to airlines and analyzes data from embedded sensors to schedule preventive maintenance and minimize downtime. Swedish bearing maker SKF not only provides predictive maintenance for rotating parts, but now lets customers diagnose problems with an app. SKF uses the information from the app to improve designs, develop solutions, and offer new services.

Embedded intelligence could bring manufacturers closer to their customers, making it more difficult for other nations to compete on price alone.

It sounds great, but Industry 4.0 is not an off-the-shelf technology. Major software companies are still gearing up to deliver on its promise, while large corporations are struggling to weld what are now discrete digital technologies into something resembling a coherent system.

Yet smaller firms will not be priced out of the market forever. Digital technology has a way of raising value while forcing down prices. Consider, for example, the evolution of computers. Once, giant mainframe computers cost millions of dollars and required climate controlled rooms. Today, we carry the same computing power in our smartphones.

The same thing is happening to robots, which were once expensive, difficult to program, and too dangerous to work around. Newer robots are smarter, cheaper, safer, and more flexible. Industry 4.0 is using the same recipe—better software running on cheap, mass-produced chips and off-the-shelf hardware—to push down the cost of plug-and-play IoT sensors, on-demand cloud analytics, and additive metal manufacturing.




A new generation of robots, called cobots, are designed to boost productivity by working with people.
Photo: Think Robotics

Manufacturing jobs require advanced degrees or skills. Even on the factory floor, workers increasingly need computer and analytical skills to manage highly instrumented machinery.

JOBS

The manufacturing workforce pipeline used to run directly from high school graduation ceremonies to the factory floor. That connection has been severed, probably for good. Ball State's Hicks analyzed job data since 2000 and found that manufacturing jobs held by non-college graduates declined nearly 45 percent.

Over the same period, however, manufacturing jobs held by college graduates rose almost 17 percent.

"That means in net, all the new jobs and almost all the replacement jobs in manufacturing are going to college graduates," Hicks said. "That trend also accelerated during the Great Recession."

Boston Consulting Group's Sirkin analyzed manufacturing jobs by dividing them into skilled workers—college-educated professionals and such trades as machinists and welders—and low skill labor. Between 2003 and 2014, Sirkin found the number of skilled employees rose modestly while unskilled laborers fell by near 3 million workers, or 20 percent.

Over the next decade, Sirkin predicts U.S. manufacturers will hire 280,000 IT specialists, 150,000 R&D professionals, 90,000 robotics coordinators, 70,000 logistics specialists—but only 30,000 production workers.

Even on the shop floor, the nature of the work will require employees with higher skill levels. Instead of tending one machine and monitoring its output, Sirkin explained, future machine operators will need to know how to work with computers to monitor several machines at a time and use automated tools to diagnose and resolve quality issues.

This calls for critical-thinking, problem-solving, time-management, and decision-making skills that were rarely required by line workers in the past. Creating programs to teach those skills will be critical to U.S. competitiveness in the future.

For low-skill workers, the prospects are not great.

As McKinsey points out, real wages for production workers have risen by only 0.1 percent annually, and have declined in some distressed industries. While manufacturing still has good jobs, some positions barely pay subsistence wages. One-half of manufacturing's 1.2 million temporary workers and one-third of all production workers, rely on food stamps or other federal assistance programs to make ends meet. Even if high school graduates do land manufacturing jobs, those jobs are increasingly less likely to lead to middle-class lifestyles. **ME**

ALAN S. BROWN is a senior editor at *Mechanical Engineering* magazine.

Engineering is the great liberator. Until the advent of the Industrial Revolution, agriculture and industry were powered by animal and human muscle, generally under various degrees of coercion. Engineers can point to steam power as their contribution toward the end of slave labor.

The power of engineering is that it provides the foundation for further advancements. We enable access to natural resources, the access increases the potential for human freedom and creativity, and that freedom allows for the creation of new engineering advances.

I believe that most people not only do not know what engineering is, but also have no idea of its value. To me, it is simple: *Without engineering, civilization does not exist.*

But it isn't enough to just make a statement. One has to make the case. And so, as an avowed advocate for the central role of engineering in society, I want to lay out my argument here, building from some simple observations.

WITHOUT ENGINEERING, Civilization do

Pont du Gard, near Nîmes, France, has stood for almost 2,000 years as a symbol of engineering genius.
Photo: Getty

es not exist

By Adrian Bejan

First, nothing moves unless it is driven. That driving impetus can come from natural forces such as gravity or from food for animals and humans or from fuel for machines. Once a natural system begins to move, it continually evolves its configuration toward flowing more and more easily. A stream cuts its way through impeding rocks and, just as naturally, changes occur in organisms to make them more ergonomically efficient.

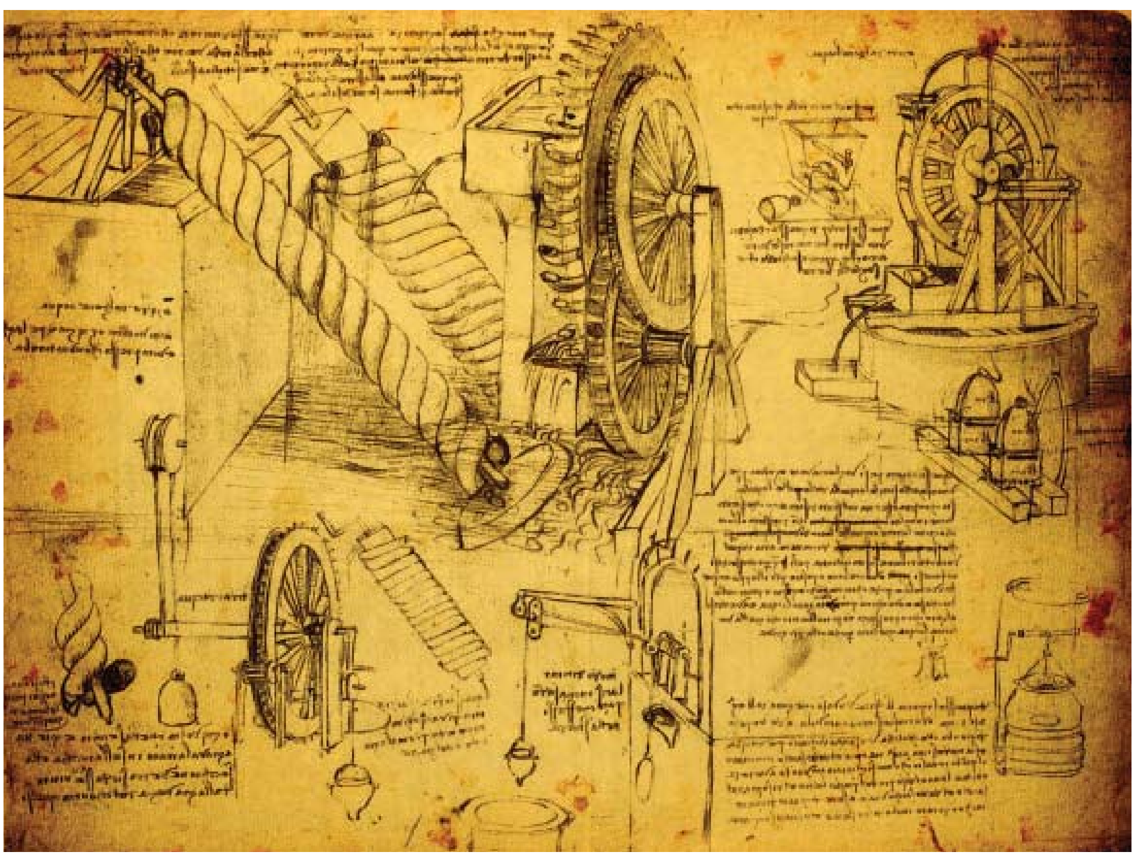
As systems evolve to become more efficient, they also become more complex and more hierarchical in how they flow and move. It turns out that joining and moving together requires less power than moving individually. This principle underlies any number of phenomena. It explains why river systems evolve into embroideries of small tributaries flowing into a major river and why flocks of birds and schools of fish move as one. The bigger stream, animal, and vehicle is a more efficient mover than the smaller, though also more complex, with hierarchy in its architecture.

What's true of flocks and schools—that it is easier to move across the Earth as a member of a group than to move alone—is also true of people. A peloton moves more quickly than an individual cyclist. When exiting a crowded stadium or theater, it is much easier to step into the space vacated by the person in front of you than to elbow your way alone through a milling crowd. Conga lines through the impenetrable jungle are prefigurations of social organization.

As I explored in my recent book, *The Physics of Life*, the same physics is also behind the larger human social organization. The life movement of a population, what we commonly refer to as the economy, will become bigger and more complex and hierarchical over time. For instance, the amount of fuel consumed by a population is directly proportional to its gross domestic product, a measure of the wealth that population generates each year.

Physics and economics are two sides of the same coin. The same hierarchical flow architecture accounts for both. The hierarchy—many small tributaries flowing together with a few big rivers—exists because that's how the whole live system evolves to thrive.

People have intuitively structured societies to make best use of this "social physics." Over time,



Leonardo Da Vinci sketched several water-lifting ideas on this folio from the 500-year-old Codex Atlanticus.
Photo: Getty

The first dedicated engineering university, École Polytechnique (today in Palaiseau, France) is still supervised by the French ministry of defense.
Photo: Getty

we have found that a society moves more, produces more, and lasts longer when it is endowed with freedom, hierarchy, and allowed to flow, as it were, in a free-questioning and self-correcting way. When human activity is projected on a global map, we can see the physical flow that carries all the human material and concerns, and this flow follows the same laws as rivers and the branching architecture of blood vessels. Activity from the far reaches flows together, running to large streams and then to the central pools of human creativity and productivity.

While it is true that good ideas can come from anywhere, creativity—the creation of new and innovative designs—does not occur uniformly across the earth. It concentrates hierarchically on the globe, as does movement and wealth and people who are free to question.

THE SCIENCE OF USEFUL THINGS

I have stated that engineering is a science of what is useful to human life and social organization. Engineering is the body of science that sustains the muscular activity that propels the world today.

The first branch of engineering that was widely recognized was what is now called civil engineering (the constructing of city living), even though most of that science was invented in antiquity and the middle ages for military purposes: the mechanics of roads, bridges, and ramparts, in addition to catapults, weapons, and military campaigns. The first engineering education was primarily military education, and we are reminded today by the École Polytechnique in Paris, founded in 1794 as the first engineering university in the world.

Other kinds of engineering emerged as natural add-ons, because of dramatic changes in the technology and availability of power. Mechanical engineering, for instance, was the new science of "machines," driven by heating from burning fuels or the captured motion of water or wind. In addition to being used directly, mechanical power could also be converted into electrical power so that it could be tapped by users far from the source, and those myriad uses necessitated the development of electrical engineering.

Chemical and petroleum engineering became distinct disciplines at the turn of the 20th century, as the demand for explosives and new fuels in large quantities became dominant. Aeronautical engineering gained attention during the First World War, again because of the military importance of human flight. Nuclear engineering also was born out of military need, during World War II and the decades after.

Today, biomedical engineering is all the rage in university education and modern hospitals, primarily because wealth and many new technologies have made it easier to improve the human body by design. Still, biomedical engineering is as old as civil engineering and traces its roots to military applications: Shields, helmets, bandages, and prostheses.

This B-24 Liberator is one of more than 19,000 built during the Second World War. Engineering marvels such as the Liberator helped rescue Europe from the grip of fascism.
Photo: Mike Haggerty, Commemorative Air Force

Engineering has always been a liberating force. Advances in engineering knowhow have made humanity freer, wealthier, and longer living. Thanks to engineering, the human species has expanded to every continent and can support more than 7 billion people.

Without fruits of engineering—without power derived from engines and chemicals produced in factories—we would perish. We are so dependent on power, devices, and products that we have become a "human + machine" species. Our machines, which are the products of engineering science, are organs. They are part of us.

The liberating effect that the organs of machine power have on humans is similar to the effect that the organ for vision (the eye) had on the spreading of animals. The emergence of vision 541 million years ago, during what paleontologists call the Cambrian period, enabled animals to explore their surroundings (for food, mate, and shelter) far more deeply, and with much greater safety, than what was possible with touch. The vision revolution touched off a rapid increase in animal life and new animal species that paleontologists call the Cambrian explosion.

The evolutionary change in movement on earth occurred in the constructal-law direction, from the biosphere without vision to the biosphere with vision. Every animal and "human + machine" specimen lives longer, travels farther, and arrives faster with a better organ for vision. This evolutionary direction is why the newer movers such as birds have better eyes than the more ancient fish, and why predators in all media have better vision (along with greater speed) than their prey.

In a way, the Cambrian explosion triggered by vision continues today in the evolution of technologies for warfare, transportation, and surveillance. Vision, or the advance knowledge that vision makes possible, is the ability to see ahead in space and in time. Imagine what ancient and medieval defenses would have been without fires lit on earth mounds to announce the approaching barbarians. Today, our most advanced weapons systems would be useless without specialized systems for fixing their position and that of the adversary; for instance, submarines would be disabled without periscopes and sonar. Likewise, all aviation requires radar and GPS, and vision platforms placed in Earth's orbit warn us to take shelter from impending storms.

Thanks to engineering, humans have gained the kind of sensory abilities over the course of one century that have taken millions of years in animal evolution. These new abilities enable us to answer the urge, explained by constructal law, to move more easily and farther into the world.

THE GREAT LIBERATOR

The fruits of engineering empower us in many ways, not just through enhanced vision. These engineered contrivances are diverse—coming in many sizes and configurations, being as ancient as rope or as new as self-driving vehicles—and at first sight appear complicated, disorganized. That is not the case. Contrivances (literally, all artifacts, from μηχανή or *mēchanē* in Greek) come from a continuous phenomenon of evolution of the "human + machine" species, toward more power and more movement, which means life.

Access to more power—that is, the ability to move across space, in opposition to the forces that oppose motion—due to the application of engines touched off an explosion in new contrivances, similar to the explosion of new animal senses and body plans seen in the Cambrian strata of the fossil record. New classes of contrivances became possible—so many, so efficient and useful, and so diverse, that we take their mother (the engine) for granted.

Most of the people who have access to electric power today have no idea how it got there except as the output of the electrical outlet. It is only when access to the fruits of engineering is severed, due to earthquakes and hurricanes or accidents and acts of despotism, that most people become aware of the monumental role that engineering plays in our lives today.

We engineers can point with pride at who we are and at the work we do. We are developing new contrivances and improving old ones, all with the goal of making each of us a more powerful and longer living member of the "human + machine" species. This is no exaggeration. The old man in 2018 who is aided by hip implants, hearing aids, and trifocal glasses is more capable than the young man of 1518, whose body was ground down by physical labor and who struggled against disease.

Think of such comparisons, and recognize your own great fortune. You carry with you both the contrivances derived from centuries of work and the knowledge that came to you from the science of useful things: Engineering. They came to you not because you are deserving, but simply because you were lucky to be born in the advanced society that was built by others, humble and modest, and hungry, too. **ME**

ADRIAN BEJAN is the J. A. Jones Distinguished Professor of Engineering at Duke University in Durham, N.C. Bejan has been awarded the 2017 ASME Ralph Coats Roe Medal and the 2018 Benjamin Franklin Medal in Mechanical Engineering.

Acknowledgement: This essay is a tribute to the Roe family and the ASME for establishing the Ralph Coates Roe Medal "for a better public understanding and appreciation of the engineer's worth to advanced society."

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2. Adrian Bejan & J. Peder Zane, *Design in Nature: How the Constructal Law Governs Evolution in Biology, Physics, Technology, and Social Organization* (New York: Doubleday, 2012).
3. Adrian Bejan, "Without engineering, civilization doesn't exist," Speech on the acceptance of the 2017 ASME Ralph Coats Roe Medal, https://www.youtube.com/watch?v=A3no1zjWlSo&t=58s.

Today, biomedical engineers are working to improve and extend lives. They are part of an engineering tradition that extends for millennia.
Photo: University of Arizona, Aliza S. Ramdass

SKETCHING TOOL FOR ANDROID

AUTODESK, SAN RAFAEL, CALIF.

SKETCH BETTER WITH AUTODESK'S SKETCHBOOK 4.0 for Android devices, which is now on parity with its iOS edition. The software has a new drawing engine with a 100 megapixel canvas, unlimited layer support, and the ability to undo and redo sketches. It also has a better user interface tailored to Android mobile device users, with the removal of excessive menus and new drag and drop features, and more shortcuts to open features. The software has more than 60 new brushes that can be customized. There are also better precision features, with draw art and ellipses to certain specifications. There are more color options, and also an improved time-lapse screen recording feature that shows how art turned out over a period of time.

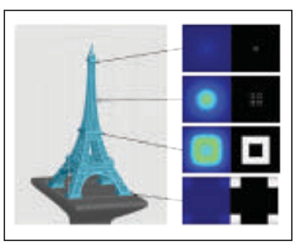
3-D PRINTING SOFTWARE

CARBON, REDWOOD CITY, CALIF.

Carbon's new 3-D printing software provides better design tools so the company's printers can take advantage of a wide range of materials for additive manufacturing. The software adds more design tools and features, and reduces the number of errors in 3-D printing with more accurate simulation and cloud-based analysis. The cloud-based computational tool, called finite element analysis (FEA), can analyze where parts may need more support, thus allowing objects to be accurately printed in the first attempt. Also new is "fence" support so edges print accurately while minimizing material usage. Other features include the ability to figure out 3-D printing with the effective mix of fluids and materials; algorithms to create better structures; and the ability to create multiple printer profiles. The software also reduces the load on computers by offloading the FEA function to the cloud.

GRAPHICS TOOL FOR AUTOMATION

QA GRAPHICS, ANKENY, IOWA



QA Graphics—which creates custom graphics for building automation—is also now using the Metasys User Interface from Johnson Controls for services it provides to customers. The new design capabilities provided by QA Graphics includes the implementation of "spaces" that can be broken down from an entire site down to a room hierarchy; mapping of equipment to a space in a room; and further software integration services. The new features are important as the building industry continues to grow around advanced modeling and graphics tools. The Metasys UI is in addition to other custom graphics tools used by QA Graphics for their customers.

IOT PLATFORM FOR VERTICALS

AVNET, PHOENIX, ARIZ.

Avnet's IoTConnect cloud-based software platform uses Microsoft's Azure cloud service for distribution and analysis of data across cloud and on-premise systems. Users can deploy homegrown apps and solutions, and Avnet is collaborating with 14 suppliers to provide custom IoT cloud services for various verticals. The product offerings include Smart Factory, Smart Asset Monitoring, Smart Connected Worker, Smart Building, Smart Healthcare, Smart Retail, Smart Office, Smart Fleet Management and Smart Warehouse, which can be deployed out of the box. Users get real-time access to data via the cloud, and can make business decisions based on the information.

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.

In This Issue

Global Gas Turbine News

Volume 58, No. 2 • May 2018

ASME INTERNATIONAL GAS TURBINE INSTITUTE

It's Turbo Time!

ASME Turbo Expo 2018 | June 11 - 15

Norway Exhibition and Convention Centre, Lillestrøm, Norway

Now in its 63rd year, ASME Turbo Expo is recognized as the must-attend event for turbomachinery professionals. Whether you are a student, professor, engineer, or other industry professional - there is something for you!

Networking Events

Female registrants are invited to join their colleagues for a networking event that will feature motivating talks by GE and Pratt & Whitney representatives. Attendees will have the opportunity to network with women in the industry and learn about the career paths of some successful women in the industry.

If you are a student or early-career engineer, network with your peers at the mixer on Wednesday night.

Join your colleagues for complimentary light refreshments during the welcome reception. The casual atmosphere of these events is ideal to catch up with friends and meet the thinkers from around the world who are shaping the future of turbomachinery and the power industry.

The Advance Program is online, which allows you to look over the technical sessions and decide, now, which sessions you would like to attend. See if there is anything new that sparks your interest—perhaps a new technology that could be of great significance in the future. For a small additional registration fee, consider attending one of the six Pre-Conference Workshops.

Plan now to join 3,000 turbine colleagues from around the world at ASME Turbo Expo, ASME's premier turbine technical conference and exposition!

Turbo Expo 2018 | June 11 - 15

Norway Exhibition and Convention Centre, Lillestrøm, Norway. For more information, visit https://www.asme.org/events/turbo-expo

Tuesday Plenary

Impact of Additive Manufacturing on Future Gas Turbine Engines and Parts

Wednesday Plenary

Big Data in MRO

Featuring

- Michael Winter, *Pratt & Whitney, Senior Fellow Advanced Technology*
- Neil A Mantle, *Rolls-Royce, Head of Additive Layer Manufacturing*
- Masahito Kataoka, *Mitsubishi-Hitachi Power Systems, General Manager Large Frame Gas Turbine Engineering*
- Markus Seibold, *Siemens Power & Gas, Head of Additive Manufacturing*
- Bernhard Krüger-*Sprengel, Lufthansa Technik, Senior Vice President Engine Services*

Keynote Panel MRO in the Light of Digitalization

Mr. Paul Stein is currently Research & Technology Director at Rolls-Royce. He joined the company in 2010 as Chief Scientific Officer. Previously he was Director General, Science and Technology at the UK Ministry of Defence, responsible for national investment in defence science and technology. Prior to that role, Paul was Managing Director of Roke Manor Research, at that time owned by Siemens and was a member of the Siemens UK executive management board, leading on technology and contributing to business strategy.

Dr. Zuo Zhi Zhao is currently Chief Technology Officer in the Power & Gas division at Siemens. He joined the company in 2009 at its Chinese hub in Shanghai as Program Manager of Gas Turbine Technology Development and held the positions of Engineering Manager of Gas Turbine Shanghai Engineering Hub, General Manager of Gas Turbine Business Operation and General Manager of Gas Turbine Business Unit. Previously he was a Project Leader on aircraft engine research and development at GE Global Research in Niskayuna, NY, USA.

As the Turbine Turns...

#34 May 2018

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

New Bird Ingestion Tests?

For those of us who attended last year's ASME TURBO EXPO '17 in Charlotte, North Carolina, there was an opportunity to visit a unique museum jet airliner display. The largely intact wreck of the Airbus A320 that landed safely in the Hudson River is on display at Charlotte's Carolinas Aviation Museum, complete with its two bird-ingested disabled jet engines.

As you may recall, this was an airline bird strike incident that has come to be called "Miracle on the Hudson". On January 15, 2009, US Airways flight 1549, this Airbus 320 with 150 passengers was taking off from La Guardia Airport bound for Charlotte. About 3 minutes from takeoff and at about 2800 feet altitude, it struck a flock of Canada geese just northeast of the George Washington Bridge. Each CFM56 engine ingested at least two geese (weighing about 8 pounds each), one of which was ingested into each engine core. This caused mechanical damage, which prevented both engines from maintaining thrust for sustained flight. The crew then successfully ditched the aircraft in the Hudson River with no loss of life.

Dual bird ingestion engine incidents in twin engine jets are proving not to be a rare occurrence. Three other such incidents occurred in 2009 (a Boeing 737 destroyed at Rome's Ciampino Airport, an A320 on takeoff at Bourgas, Bulgaria, and a Boeing 737 in Ireland).

Aviation regulators are now proposing new bird ingestion tests for aircraft engine certification to address these growing flight safety issues. I'll give a short review of all of this in what follows.

Bird Ingestion Engine Damage

As Boeing points out [1], bird strikes occur at various aircraft locations (see Fig. 1) but usually inflict most damage to the engines. Airplane damage and effect on flight from bird strikes are closely correlated to kinetic energy, derived from the mass (determined by the bird species) and the velocity of collision squared. (A 20% increase in speed raises the kinetic energy by 44%.)

Just how many engine bird strikes occur for civil aviation? Dolbeer, et al [2] report on statistics for the U.S. (which includes U.S. registered aircraft in foreign countries) for the recent quarter century, 1990-2015. During these 25 years, 17,494 jet engines were struck in 16,694 bird strike events. Out of these, 4516 engines were damaged in 4370 bird strike events (4227 events with one engine damaged, 141 with two engines damaged (such as the Hudson landing event), 1 with three engines damaged, and 1 with four engines damaged).

These U.S. statistics indeed show that bird ingestion in commercial jet engines is significant and even more so, when combined with records from the rest of the flight world.

Current statistics show that incidents of commercial aircraft jet engine bird ingestion are increasing, and are considered to be a continuing challenge over the next decade. Factors that contribute to this avian threat are increasing populations of large birds and increased air traffic by quieter, turbofan powered aircraft [2]. These and other factors have been discussed in two past issues of this column [3] [4].

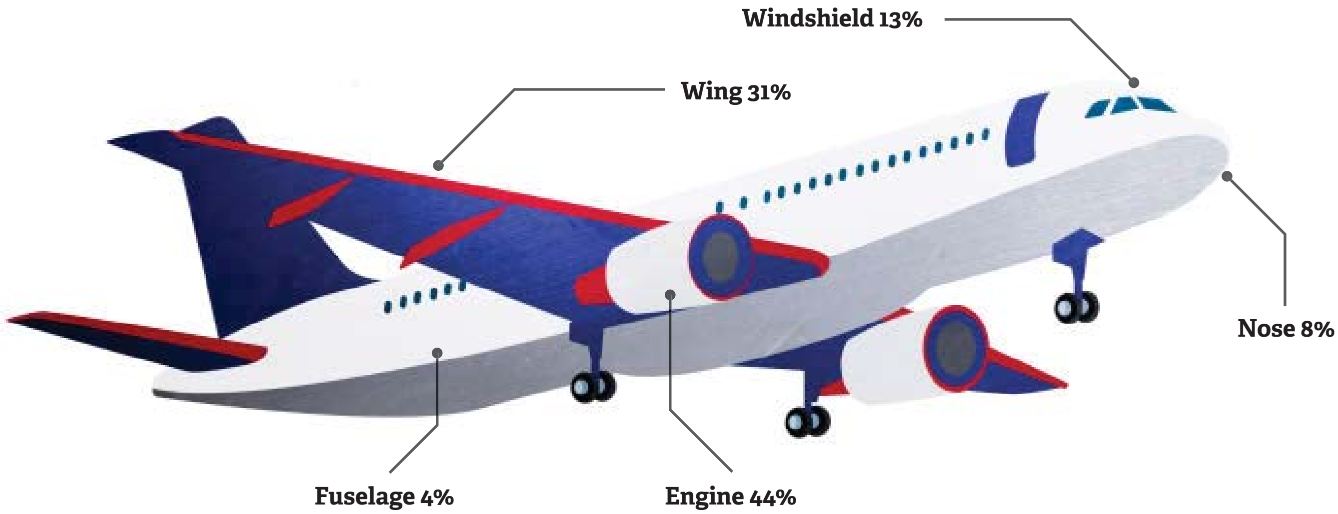


Figure 1: Locations Of Bird Strike Aircraft Damage [1]

Bird Strike Certification Testing

All commercial jet engines must comply with bird ingestion regulations established by regulatory authorities such as the U.S. Federal Aviation Administration (FAA) and the European Aviation Safety Agency (EASA). These regulations involve certification testing of commercial jet engines for bird ingestion, calling for demonstrations of an engine's ability to ingest birds in small, medium and large categories at takeoff power and still maintain a specified level of performance. I refer the reader to a concise and a fascinating GGTN article by Robert Mazzawy [5] on details of current bird strike certification testing by OEMs.

Recently, EASA, working with other authorities, is proposing additional OEM bird ingestion testing requirements for an engine operating under climb conditions, following the ingestion of a medium sized bird into the engine core. The test engine must continue to operate with a fan speed representative of climb conditions, and then approach conditions for a safe landing. (If the test engine includes features that prevent bird material from entering the core, the engine should continue to operate at approach conditions, after ingestion.)

It seems that the major findings in the EASA led proposal, is that current tests don't result in enough bird mass reaching the engine core where it can lead to significant power loss. They want OEMs to increase the threat mass (bird size and/or number) and to adjust the engine RPM and bird velocity to increase the chance for a bird to get through fan blades and reach the core (as happened with the Hudson landing incident). They also are placing priority on doing run-on tests of the engine after the strike to validate its ability to safely land. Fan blade design has advanced to where blade failure is not the issue (although proving this is still part of the certification testing) so any new testing is focused on the core intrusion by the bird(s) along with run-on requirements.

A Few Comments

As I commented in an earlier column [4], approaches to solve birdstrike issues by the civil aviation community are rather fragmented. Engine companies are repeatedly called upon to make their engines strong enough to endure bird ingestion, rather than regulations being enacted to prevent the bird strikes themselves.

As Capt. Paul Eschenfelder, a retired Delta airlines pilot has told me, the proposed regulations discussed above are a big and best change, in that they require an engine robust enough to last until a successful turn back can be made. But what is really needed is a new systems approach to adequately mitigate the risks of aircraft and bird occupying the same air space at the same time.

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How Graduate School Prepared Me For A Career In Industry

Kenneth Clark, Senior Engineer, Pratt & Whitney

Gas turbines have fascinated me since I first started working on them my senior year of college. They are complex, powerful machines, with endless exciting technical challenges to work on—they are a mechanical engineer's dream, or nightmare depending on how you look at it. About a year ago I fulfilled a long-term goal of mine, to complete my doctoral program and begin a career as an engineer at a gas turbine company. In this article I will discuss how my graduate education has helped me begin my career at Pratt & Whitney, and I will share advice I have for those who will soon graduate or for those who have recently graduated and started a career in industry.

During the last year of my undergraduate degree at Brigham Young University, I got involved in gas turbine research. I worked as a research assistant performing computational fluid dynamics (CFD) simulations to study compressor aerodynamics. I enjoyed the research, and stayed at Brigham Young to pursue a M.S. degree, learning many important skills while there, including how to dig deep into a research question, how to accurately perform numerical simulations, and how to process large data sets. My gas turbine experience, however, was narrowly focused as I only did numerical work. To prepare myself better for a career I needed to expand the breadth of my gas turbine knowledge.

After my M.S. I chose to pursue a Ph.D. at Penn State University, as there was a great opportunity to develop a new turbine research facility and perform experimental research. While at Penn State I helped develop the Steady Thermal Aero Research Turbine (START) Lab in close partnership with government and industry sponsors, including the U.S. Department of Energy – National Energy Technology Lab and Pratt & Whitney. I learned a lot about facility design, instrumentation, test planning, data collection, data analysis, turbine hardware, cooling flows, and heat transfer. Doing experimental work helped me gain a breadth of understanding that I lacked, which helped immensely when I interviewed for industry jobs. I also learned important soft skills in graduate school, including teamwork, time management, technical communication, and being able to accept and learn from criticism.

"Doing experimental work helped me gain a breadth of understanding that I lacked, which helped immensely when I interviewed for industry jobs."

Through Penn State's close partnership with Pratt & Whitney I was fortunate to meet and associate with many professional engineers while at graduate school. Networking with engineers while still in graduate school also helped me when I interviewed for jobs. After graduation I began working as an engineer for Pratt & Whitney in the aerodynamics group. In my first year of employment I have worked on a wide variety of projects ranging from commercial to military programs, from preliminary to detailed designs, and from single airfoil to full engine tests. The transition from graduate school to industry has been surprisingly natural. Being a graduate student in the START Lab truly prepared me for the rigors of an industry job. Just as in graduate school, there are a host of complex technical problems to solve as we push the envelope to more efficient and more powerful engines. It is the opportunity to work on these exciting technical problems that motivates me.

My Ph.D. work was in the area of turbine heat transfer. I now work in compressor aerodynamics. Although my current job has little in common with my Ph.D. work, the skills I learned in graduate school are what have really helped me at Pratt & Whitney. Those skills include learning how to dissect and analyze complex problems, always examining the fundamental physics, and thinking critically about both models and data. I have enjoyed applying the same research skills that I learned in graduate school to the many technical challenges of operational gas turbines. Realize that in industry you will have the opportunity to apply your research skills to design and research problems to create exciting new products. Your research skills will help you excel in a career in industry.

"Your research skills will help you excel in a career in industry."

Although there are similarities between graduate school and industry, there are differences that should be highlighted. For example, even though Penn State had a close partnership with Pratt & Whitney, there was always an insulative layer between the START graduate students and the product. We didn't always know all the details about why we were testing specific hardware. Now that I am working at Pratt & Whitney, I see how my work directly impacts current and future products. Working in industry close to the products has been especially rewarding.

Graduate students receive substantial mentoring from their advisors, research associates, and fellow students. The soft skills you learned in graduate school of teamwork and collaboration will be stretched even further in industry as you join a much larger team of engineers. It was eye opening to me to see how much engineers in industry must rely on each other in such a highly collaborative environment. It is important to complete your work assignments, as others are relying on you. You are not on your own though, as you will be able to seek mentorship from many experts in your company. That said, be mindful of others' time, as everybody is extremely busy balancing their own workload. Be patient as you go through the learning process; someday you will be the expert and young engineers will come to you for help.

Finding your first job after graduate school is stressful no matter if you want to work in industry, academia, or government. With so many commercial and military engines currently on order and many future applications yet to be designed and tested, there will always be lots of engineering work at gas turbine companies. Remember that you are at the beginning of a long career. You will hold many different positions, and there will be many opportunities to work on a variety of projects. Try to apply the same skills you learned in graduate school to learn as much as you can on each project, and you will find success and satisfaction in your work.

Awards Information

ASME IGTI Student Scholarship Program

Student application deadline is June 15, 2018 for the 2018-2019 School Year. Scholarship winners will be notified by the end of October 2018. Scholarships will be dispersed in November.

Application is available at: https://community.asme.org/international_gas_turbine_institute_igti/w/wiki/4029.honors-and-awards.aspx.

The ASME R. Tom Sawyer Award

The R. Tom Sawyer Award is bestowed on an individual who has made important contributions to advance the purpose of the Gas Turbine Industry and to the International Gas Turbine Institute over a substantial period of time. The contribution may be in any area of institute activity but must be marked by sustained forthright efforts. The award was established in 1972 to honor R. Tom Sawyer who, for over four decades, toiled zealously to advance gas turbine technology in all of its aspects and includes a US $1000 honorarium and a plaque presented during ASME Turbo Expo.

The nomination must be complete and accompanied by three to five Letters of Recommendation from individuals who are well acquainted with the nominees' qualifications. Candidate nominations remain in effect for three years and are automatically carried over. The completed reference form from a minimum of 3 people will need to be sent in with the nomination package. It is up to the "Nominator" to submit all required information.

Your nomination package should be received at the ASME Office no later than August 15, 2018 to be considered. igtiawards@asme.org

Congratulations to the 2017 ASME R. Tom Sawyer Award winner Dr. Alan H. Epstein, Vice President Technology and Environment, Pratt & Whitney

The ASME IGTI Aircraft Engine Technology Award

The Aircraft Engine Award recognizes sustained personal creative contributions to aircraft gas turbine engine technology.

The Aircraft Engine Technology Award will include an optional opportunity to deliver a lecture or present an invited technical paper on the work for which the award is being bestowed, at ASME Turbo Expo. The recipient of the award will very desirably, but not necessarily, be a member of The American Society of Mechanical Engineers. The award will be made to a single individual.

Nominating and supporting letters for the Aircraft Engine Technology Award should be sent by October 15, 2018 to: igtiawards@asme.org

Congratulations to the 2017 Aircraft Engine Technology Award winner Professor Michael G. Dunn, Director of the OSU Gas Turbine Laboratory- Department of Mechanical Engineering at The Ohio State University.

The ASME IGTI Industrial Gas Turbine Technology Award

The Industrial Gas Turbine Award recognizes sustained personal creative scientific or technological contributions unique to electric power or mechanical drive industrial gas turbine technology.

The Industrial Gas Turbine Technology Award will include an optional opportunity to deliver a lecture or present an invited technical paper on the work for which the award is being bestowed, at ASME Turbo Expo. The recipient of the award will very desirably, but not necessarily, be a member of The American Society of Mechanical Engineers. The award will be made to a single individual.

Nominating and supporting letters for the Industrial Gas Turbine Technology Award should be sent by October 15, 2018 to: igtiawards@asme.org

Congratulations to the 2017 Industrial Gas Turbine Technology Award winner Dr. Eisaku Ito, senior general manager in marketing and innovation at the headquarters of MHI.

ASME IGTI Dilip R. Ballal Early Career Award

Early Career Awards are intended to honor individuals who have outstanding accomplishments during the beginning of their careers. Historically, there has been no such award to recognize early career engineers working in the area of turbomachinery.

An early career award is intended for those starting a professional career, which is typically after a relevant terminal degree: BS, MS, or PhD. A criterion of seven-years-from-degree will be used to define the nominee's eligibility. The nominee must receive the award prior to the completion of the seventh year beyond the terminal degree.

Nomination packets are due to ASME on or before August 1, 2018. Send complete nomination to: igtiawards@asme.org.

Congratulations to the 2017 Dilip R. Ballal Early Career Award winner Dr. Subith Vasu, assistant professor at the Center for Advanced Turbomachinery and Energy Research (CATER), Mechanical and Aerospace Engineering at the University of Central Florida.

SELF CALIBRATING TEMPERATURE SENSOR

ENDRESS+HAUSER, REINACH, SWITZERLAND

Endress+Hauser's iTHERM TrustSens hygienic RTD is a self-calibrating temperature sensor designed to meet the conformance of regulatory requirements. TrustSens reduces the need for manual calibration, and is designed for hygienic and aseptic processes. Calibration cycles for standard temperature sensors are typically done every six to twelve months, which leaves risk for undetected drift in the sensor between cycles, and affect product quality issues. With TrustSens, the temperature sensor is calibrated after every SIP (sterilize in place) cycle, and eliminates the risk of a bad batch of products and undetected calibration drift. The calibration procedure can store up to 350 calibrations. Readings can be submitted to various regulatory agencies for verification of compliance issues.

LANGUAGE PROGRAM CONTROLLER

SIEMENS, MUNICH

Siemens' CPU 1518 ODK advanced controller and Simatic ODK 1500S engineering package streamline the configuration and functionality of high-level language programs, including C/CC++. High-level language programs are generated in an Open Development Kit and are integrated into the Step 7 program of the controller. Existing codes, such as algorithms written in C/C++ and complex Simulink models, are automatically generated in the controller as well. The engineering package includes the Eclipse open program development environment designed for real-time applications, including control functions and complex mathematical algorithms. Ready-made function libraries are also available for numerous applications, including wind power generation.

AR SMART GLASSES

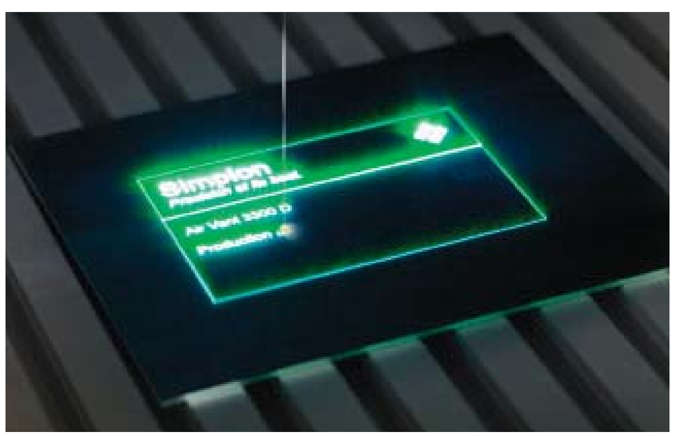
VUZIX, ROCHESTER, N.Y.

The mixed reaction to Google Glass hasn't stopped other companies from developing smart glasses, and the features are getting better. The Vuzix Blade is an augmented reality headset in the form of smart glasses, where virtual images can be overlaid on the real-world scenery. The Blade also works to present smartphone information on the lens. It can be used by field technicians to augment repairs of equipment, or in the medical field to get access to patient information or images. Vuzix Blade is Amazon's Alexa-enabled, meaning you can speak out commands to the glasses. The AR headset runs on Android. Additionally, it has a 8-megapixel camera, a DLP display, a rechargeable battery and Wi-Fi and Bluetooth wireless support. It works with collaboration apps provided by Vuzix in its app store.

LASER MARKING

TROTEC, PLYMOUTH, MICH.

The MOPA fiber laser source, used with the company's SpeedMarker galvo laser marking systems for metals and plastics, allows the user to select pulse durations (between 4 and 200 ns), which provides a wider range of laser parameters, more options for creating high-contrast, homogeneous markings, and the ability to mark colors on some metals. It can be adjusted to mark certain plastics, especially dark-colored ones, with shorter pulses that produce clearer, lighter markings with higher contrast and less burning and foaming. It has the ability to mark (natural anodized) aluminum in black, and a faster, corrosion-free annealing marking. With pulse durations between 4 and 200 ns, its wide spectrum of possibilities for marking on metals includes producing different annealing colors on steel.



MASS FLOW CONTROLLERS

ALICAT, TUSCON, ARIZ.

Alicat Scientific's MCE mass flow controllers have been integrated into MDC Vacuum Products' XpressStick MFC gas stick. With precision control of gas flows of up to 20 SLPM and onboard display, Alicat's MCE provides gas programming functionality to the gas connection module, which links pressurized gas inputs to vacuum chambers. The all-in-one design of the XpressStick MFC gas stick eliminates complex hardware specification in processes that include a combination of specialty gases, pressure, precise regulation, and vacuum. Its easy programming and precise gas control system allows users to go from bottle to process in one simple step. Designed to meet ultra-high purity process requirements, the XpressStick is also offered in a stainless steel model for corrosive environments.

LINKING DEVICE

HMS INDUSTRIAL NETWORKS, HALMSTAD, SWEDEN

The EtherNet/IP to PROFIBUS DP linking device connects devices on PROFIBUS to a Rockwell ControlLogix or CompactLogix PLC, making it possible to include any automation device with PROFIBUS DP communication into an EtherNet/IP-based network architecture. It can be mounted close to the devices and connected by a single Ethernet cable, and it supports ODVA's Device Level Ring (DLR) for ring topology. Users access their PROFIBUS DP network and device configuration through their existing Studio 5000 software. All configuration is made inside Studio 5000, where there is support to process variable data tags, as well as manual and automatic generation of named and structured Studio 5000 controller tags without any required user logic. It supports up to 7,000 bytes of IO data, 3,500 in each direction.

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.

LASER SCANNING

HEXAGON, NORTH KINGSTOWN, R.I.

Hexagon Manufacturing Intelligence's RS4 laser scanner for the portable ROMER Absolute Arm with Integrated Scanner (SI) series offers new optics and electronics, delivering a major performance leap with a scan rate nearly 60 percent faster than the previous model. The fully integrated scanner is optimized for measuring objects with challenging surfaces such as carbon fiber or machined steel. It delivers exact measurements that are fully verifiable and traceable. The ROMER Absolute Arm SI with the RS4 scanner works for point-cloud inspection, product benchmarking, reverse engineering, rapid prototyping, virtual assembly, and CNC milling. The solution provides tactile and noncontact dimensional measurements for applications in aerospace, automotive, power generation, medical, heavy equipment, defense, consumer products, and more.

LINEAR ACTUATORS

SCHNEIDER ELECTRIC MOTION, MARLBOROUGH, CONN.

Lexium MDrive (LMD) linear actuators aim to deliver clean, quiet linear motion to a wide range of applications from medical to packaging. These compact motion products combine robust motor, electronics, and linear mechanicals. The actuators integrate NEMA size 17 and 23 1.8° 2-phase stepper motors with an external threaded lead screw. This screw is integral to the motor's rotor, rotating to move a nut attached to a load axially along the threaded shaft. A wide range of lead screw options are offered as standard, with custom solutions also available. Integrated LMD linear products may include fully programmable motion controllers, encoders, and closed-loop performance. Available communication protocols include EtherNet/IP, Profinet, ModbusTCP, CANopen, and serial RS-422/485.

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Attendees of the Knight Foundry redesignation event tour the facility after the ceremony.
Photo: Wilfred Haywood, ASME

KNIGHT FOUNDRY REDESIGNATED AS AN ASME LANDMARK

The Knight Foundry in Sutter Creek, Calif., one of the few water-powered foundries in the United States, was recently redesignated as an ASME Historic Mechanical Engineering Landmark. The cast iron foundry and machine shop, which had been closed for 20 years prior to its reopening last year, was recognized for its significance—particularly to the Northern California mining industry—at a ceremony held March 10 at the facility.

Approximately 85 people attended the ceremony, including members of the ASME Sacramento-Sierra Nevada Section and members of the Native Sons of the Golden West, a service organization that also supported the event. ASME History & Heritage Committee member Lee Langston spoke at the event, which also included remarks from Jeff Muss, program chair for the Sacramento-Sierra Nevada Section.

Established in 1873 as Campbell, Hall and Co., the Knight Foundry was used to cast metal parts for the tools and machinery that were necessary to sustain Northern California's booming gold and copper mining industry in the late 1800s.

After years of work developing improvements to the wooden water wheel technology that powered foundries of the era, Samuel Knight, a partner in Campbell, Hall and Co. who later bought out the foundry's other partners, eventually created the patented cast iron, high-speed Knight Water Wheel, a breakthrough innovation that was a dominant force in the mining machinery industry prior to the introduction of the Pelton Water Wheel in the mid-1880s. Knight also developed a water motor—a small water wheel enclosed in a cast iron housing that could be attached to a high-pressure water source.

The Knight Foundry, which continued producing mining equipment as well as machinery for the lumber industry and machine parts for pump and agricultural equipment manufacturers for most of the 20th century, was originally designated as an ASME's 182nd Historic Mechanical Engineering Landmark in 1995. The facility was shuttered shortly thereafter, and it fell into disrepair in the ensuing years. Efforts to restore the foundry began in 2015, however, when members of the Sutter Creek City Council negotiated with the foundry's owners to have the site donated to the city. The council members, who went on to form the Knight Foundry Alliance, then spearheaded initiatives to clean up the site and raise funds to reopen the facility to the public. ME

FIRST AABME CONNECT EVENT TO ADDRESS MODELING AND SIMULATION

The Alliance of Advanced Biomedical Engineering (AABME), an initiative that ASME launched last year to provide resources for engineers, scientists, and physicians within the biomedical engineering community, will introduce a new event this spring. On May 14, the Alliance will present the first event in its new series, AABME CONNECT: Where Biomedicine and Engineering Come Together, which is intended to provide a forum for senior leaders from the biomedical engineering community to discuss recent developments in the field and encourage innovation and growth for the community at large.

Each AABME CONNECT event is expected to focus on a different topic, showcasing innovative work from a variety of biomedical engineering areas. The inaugural forum, which will address the theme "Modeling and Simulation: Transforming the Future of Healthcare," will spotlight modeling and simulation throughout the healthcare industry, featuring examples and best practices. The workshop will be held on May 14 at the Hyatt Regency in Minneapolis in conjunction with the ASME Verification and Validation Symposium, which will take place from May 16-18 at the same venue.

In addition to providing opportunities for networking and discussion, the event will include a number of informative sessions. Scheduled speakers include Scott Taylor from Stryker Corp., Markus Reiterer from Medtronic, Mark Horner of ANSYS, Payman Afshari from Depuy-Synthes Spine, Kalyan Pasupathy of the Mayo Clinic, Joshua Kaizer of the U.S. Nuclear Regulatory Commission, Leonardo Angelone of the Food and Drug Administration, and David Moorcroft of the Federal Aviation Administration.

Representatives from a number of organizations that share a commitment to biomedical innovation for the benefit of human health will take part in AABME CONNECT (www.aabmeconnect.asme.org) this month. **ME**

ASME JOINS THE ADVANCED REGENERATIVE MANUFACTURING INSTITUTE

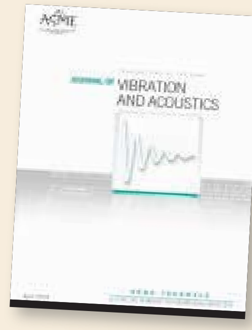
ASME recently joined the Advanced Regenerative Manufacturing Institute (ARMI), a coalition of more than 100 organizations seeking to further the field of tissue engineering and regenerative medicine to deliver therapies to patients in need.

The partnership unites ASME with a consortium of organizations from industry, government, academia, and the non-profit sector working to develop next-generation manufacturing processes and technologies for cells, tissues, and organs. ARMI, which is based in Manchester, N.H., will receive nearly $300 million in public-private investment from these groups to develop scalable manufacturing processes for engineered tissues and organs.

Already a player in biomedical engineering, ASME in 2017 launched the Alliance for Advanced Biomedical Engineering, which provides technical articles, reports, and other resources on topics ranging from cell therapy and thermal medicine to medical devices and 3-D printing.

ARMI's efforts are supported by 47 industrial partners, 26 academic and academically affiliated partners, and 14 government and nonprofit partners. **ME**

ASME SPECIAL JOURNAL ISSUE TO FOCUS ON BIO-INSPIRED SYSTEMS



The ASME *Journal of Vibration and Acoustics* is currently accepting manuscripts for a special issue on bio-inspired systems, which is expected to be published in April 2019.

The deadline to submit a paper for the special issue is June 1, 2018.

Many scientific breakthroughs in areas such as sensors and actuators and materials and structures have drawn their inspiration from systems found in nature. The special issue of the *Journal of Vibration and Acoustics* will feature original research and high-quality review articles on bio-inspired systems, including experimental, computational, or multi-disciplinary research, with a particular concentration on vibrations, dynamics, acoustics, and sensing/actuation.

Topics to be covered in the special issue will include modeling of dynamical and acoustical structures in biological systems; bio-inspired acoustic and vibrational sensors and actuators; bio-inspired materials and structures for vibration control and isolation; vibration and acoustics-based energy harvesting inspired by biological materials and structures; and bio-inspired robotics.

Papers submitted by June 1 will be reviewed in time for inclusion in the special issue. Papers received after the deadline may still be considered for the special issue, time and space permitting.

Papers that are not ready in time to be included in the special issue may be considered for a regular issue of the journal.

Miao Yu of the University of Maryland in College Park is the special issue editor for "Bio-inspired Systems."

The guest editors for the special issue are Sarah Bergbreiter of the University of Maryland, Xinyan Deng of Purdue University in West Lafayette, Ind., and Haijun Liu of Temple University in Philadelphia. **ME**

A researcher testing beer in the lab.
Image: University of Bristol

PINTS OF FUEL

Butanol derived from beer could be better fuel than ethanol.

After hours, researchers have a reputation for knocking back a few beers. Research chemists in England recently brought some of the pub back to the lab, converting beer into fuel that could be used in existing automobiles.

The goal behind the experiment was to create a sustainable fuel that is better than ethanol, which is mixed with standard gasoline and used in vehicles today.

The alternative was butanol, which has fuel properties such as energy density and octane rating that are closer to standard gasoline when compared to ethanol.

But in the experiment, the creation of butanol still required ethanol, which is found in beer. "What we call 'alcohol' in an alcoholic drink is always ethanol," namely the chemical formula C_2H_5OH, said Duncan Wass, professor of chemistry at the University of Bristol in England.

The ethanol in alcoholic drinks comes from the fermentation of either sugar-containing crops like grapes, or starch-containing crops like corn. The starch has to be converted into sugars, a process the brewers call malting.

The researchers used a catalyst—a chemical compound that can speed up chemical reactions without undergoing any permanent change themselves—based on metal ruthenium to convert ethanol to butanol.

The demonstration was a fun way of showing the possibilities of creating butanol-based fuel. Besides beer, anything with ethanol could be a source. "You wouldn't really use beer, unless there was a surplus or something," Wass said.

The ethanol-to-butanol process, when implemented, will look much like a traditional petrochemical process, and the catalyst will be central piece of technology. The process will be scalable and also easy to implement at an industrial level.

"Fuel ethanol is already made on scale, and an industrial fuel ethanol fermentation broth is chemically the same as beer, so it's an excellent model," Wass said.

A good beer with high alcohol content would make for great fuel, so "lite" beers don't make the cut. "The only thing that matters is the ethanol content, so a strong beer would be easier to convert than a weak beer," Wass said.

Other types of alcohol such as wine and gin were also tested, according to a paper published by the researchers.

The butanol-based fuel wasn't tested in a car so the researchers couldn't provide metrics on its efficiency. But the obvious opportunity lies as a replacement to ethanol, which is widely available. In 2016, the U.S. market consumed 143.4 billion gallons of finished motor gasoline, with another 14.4 billion gallons of ethanol mixed in, according to the U.S. Energy Information Administration.

The Bristol effort is one of many looking at biofuels for vehicles and airplanes, and follows a fast growing public-private initiative to reduce carbon emissions. ME

AGAM SHAH

REGISTER FOR ASME Additive Manufacturing Programs at LiveWorx 2018

Use code ASME18 to receive your ASME discount!
liveworx.com

The rapid adoption of additive manufacturing—especially metal AM—has the potential to disrupt every business, customizing commodity products to improve margins to rethinking spare parts and supply chain operations.

ASME will tackle these issues in an executive forum of industry leaders and a series of design workshops at LiveWorx 2018, a gathering of more than 7,000 engineers, designers, and executives in Boston this June.

Additive Manufacturing Leadership Forum / Tuesday, June 19 – $295

This half-day forum will show industry executives how a broad range of manufacturers and service providers are beginning to use AM to optimize factory workflows, revitalize commodity products, compete with established industries, and supply just-in-time spare parts—and that's just for starters. Speakers include industry leaders such as Terry Wohlers, the world's top AM analyst; Alan Amling of supply chain giant UPS; Jay Rodgers of AM vehicle producer Local Motors; and speakers from Boeing, Stryker, Imperial, Paperless, and more.

Design for Additive Manufacturing Workshops / Wednesday, June 20 – $300

These 3-hour workshops show engineers what's different about designing for metal AM—and how to take advantage of best practice design techniques, technology developments, and time-saving strategies. They will also explore leading edge designs, and show how AM can help address the toughest design and manufacturing challenges.

ASME Additive Manufacturing Leadership Forum and/or Design for Additive Manufacturing Workshop registration includes a complimentary LiveWorx Explorer Pass (a $695 value). Registrants for ASME programs also qualify for discounted tickets to the LiveWorx All Access Pass—which includes access to all technical sessions, including the **ASME Additive Manufacturing Technical Sessions.**

Questions? Contact AMForum@asme.org.

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