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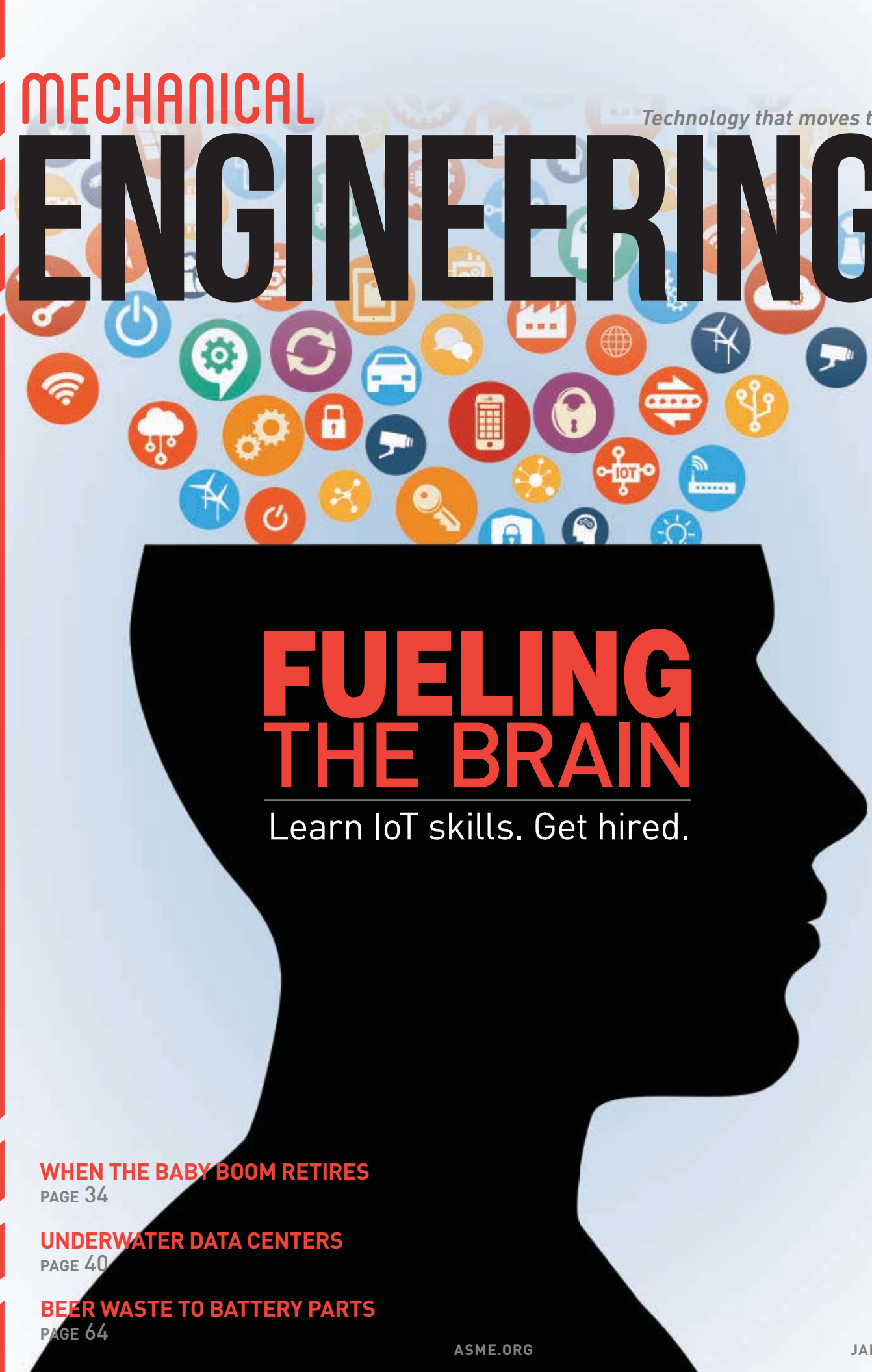

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THE BIO-ARCADE

MICROBES ARE NOT USUALLY CONSIDERED playthings, nor are they easily tamed. But now researchers at Stanford University have made a video game where real microbes become soccer players and Pac-Men that can be directed through a maze. And they've released the blueprints to the general public. With a smart phone, a joystick, an off-the-shelf eyepiece, some LEDs, a handful of 3-D printed parts, and some *Euglena* cells, bio-gamers can be directing a microbe through a maze in a matter of hours.

PLUG-AND-PLAY SOLAR GENERATOR FOR BACKUP POWER

RESEARCHERS AT THE UNIVERSITY of Idaho and a producer of solar generators for outdoor enthusiasts are collaborating on a portable 5-kW plug-and-play system that will power an entire house.

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

WHERE THE ROBOT MEETS THE ROAD

ROADS HAVE GONE FROM SIMPLE, narrow paths to intricate infrastructure systems connecting states, countries, and even continents. Still, though they may look strong, roads age and crack. Filling in those cracks can be a long, expensive challenge. The Georgia Tech Research Institute has been working on a system that travels a different path, and might give the world's roads a healthier future.

3-D PRINTING THE HEART OF THE MATTER

STENTS ARE COMMONLY USED to treat blocked blood vessels. Now a 3-D printing process might just take stents to a different level.

VIDEO: SMALL MODULAR NUCLEAR REACTORS

JOSE REYES, THE CO-FOUNDER and chief technology officer for NuScale Power, talks about the design of small modular nuclear reactors and their future.

NEXT MONTH ON ASME.ORG

MAGNETIC BACTERIA KILL CANCER CELLS
A research team at the Institute of Biomedical Engineering at Polytechnique Montréal has discovered a way to use magnetic fields to direct bacteria loaded with cancer-killing drugs into tumor cells, without damaging surrounding healthy tissue.

VIDEO: THE FUTURE OF NUCLEAR ENERGY
Yoshinobu Shibate, president and CEO of Mitsubishi Nuclear Energy Systems, discusses the future of nuclear energy in the U.S. and globally.

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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

SEARCHING FOR CLUES ON THE FUTURE OF TECH

January is normally a month of change—new calendars, new resolutions. But this month, after a hard-fought presidential race, the inauguration of Donald J. Trump as the 45th President of the United States seems like a step into the unknown. Even Trump's supporters feel largely uncertain about an administration led by a businessman who has never before held public office.

Predicting the positions of a Trump administration, including matters relating to technology, is challenging because the only cues have been often-conflicting comments during the campaign. There are, however, clues to the future of the tech landscape under the new administration found in the early positions on five key areas: manufacturing and related jobs, space exploration, infrastructure, research and development, and the Internet of Things.

For example, Trump's call for the return of manufacturing jobs to the U.S. found widespread support. But the genie may be out of the bottle. As this magazine and others have written, machines are learning to perform jobs previously held by factory workers. The *Washington Post* recently reported on a Boston Consulting Group prediction that, by 2025, the operating cost of a welding robot will be less than $2 per hour, compared to the $25 per hour that a human welder earns today in the U.S. Advanced manufacturing is transforming factory automation and there's no going back.

One technology area where Trump has been specific has been his support for space exploration. Last October, he told a rally in Sanford, Fla., "Human exploration of our entire solar system by the end of this century should be NASA's focus and goal." Trump has supported private-public partnerships to increase space activity and economic growth. A robust space initiative could spur national pride and boost interest in engineering and science careers, much as it did 50 years ago.

A much-discussed infrastructure improvement measure has received general bipartisan support from lawmakers and the public. Infrastructure spending would spur tech and blue-collar jobs. But Trump's trillion-dollar ten-year plan has some lawmakers concerned because the funding model is sketchy and leans on enticing the private sector with tax credits.

Early comments by the new administration on federal funding for R&D portends possible reexamination of government research priorities. Initiatives such as Manufacturing USA, which brings together industry, academia, and federal partners through a network of advanced manufacturing institutes, will be under a microscope. Trump has been on record supporting U.S. manufacturing, so Manufacturing USA's $70 million budget should be safe. Funding for research in other areas, especially those supported by the Department of Energy, may experience a different fate based on the new president's comments on the energy sector.

The fifth area I will be watching is how Trump and his team deal with the complexities of applying the Internet of Things to U.S. industry. Companies such as GE are trying to shed their old, industrial image, becoming instead global IoT providers focusing on delivering software, networks, and artificial intelligence. (GE has become a major proponent of high-tech jobs training. Read about its plans in this month's cover story, "Filling the Talent Gap," beginning on page 28.)

Most candidates who gain elected office trade much of the rhetoric of the campaign for pragmatism imposed by the restrictions of the office they win. Maybe they also discover that the words that got them elected don't make as much sense after Election Day. That's human nature—and also the game of politics. **ME**

FEEDBACK

How do you see the future of technology under a Trump administration? Email me.

falcionij@asme.org

LETTERS & COMMENTS

OCTOBER 2016

Reader Pearl proposes a more level playing field for international trade.

« Three readers pick up arguments from the October 2016 Trending. Another praises an engineering educator.

TARIFF ON TYRANNY

To the Editor: The October 2016 Trending ("By the Numbers: Jobs and Manufacturing" by Jeffrey Winters) misses the point when it suggests that eliminating the trade deficit in manufactured goods won't bring employment in this sector back to pre-2000 levels.

The astonishing growth of American productivity you cite would cause the Unted States to have a tremendous trade surplus, were it not for the competitive advantage gained by totalitarian regimes through forcing their workers into near-slavery.

A carbon tax has been proposed as a means of ensuring that nations can't steal a march via cheap-and-dirty policies; why can't we have a peonage tax to level the playing field regarding human rights? It's perverted for saving polar bears to be all the rage while saving human beings from a race to the bottom is politically incorrect.

Donald Lock, *Bethlehem, Pa.*

FAIR PLAY FOR FAIR TRADE

To the Editor: The October 2016 Trending addressed the issue of the U.S. manufacturing trade deficit and the impact on jobs. But it missed the financial impact of the deficit on jobs.

The U.S. financial debt resulting from the deficit—and the inevitable future increase in interest payments—will stifle funding for research, development, and capital infrastructure budgets. The stifled funding will impact productivity improvements, negatively impact our ability to compete in the world, and result in increasing the deficits further.

The amount of jobs that may be

gained if we increased our manufacturing exports and eliminated our deficits may not be large enough to regain all the old manufacturing jobs, but the need to eliminate the deficit is no less imperative for U.S. financial health.

We can start by imposing the same rules on imports from foreign countries as those countries impose on our exports to balance the playing field.

Sanford L. Pearl, *Palm Beach Gardens, Fla.*

A CAN OF WORMS

To the Editor: While I do not disagree with the conclusions in your October 2016 Trending, you have opened up a vessel of nematodes. I bet you will receive several comments on the article.

However, two glaring omissions deserve mention: NAFTA was signed in 1994, and George W. Bush was elected president in 2000. Some astounding correlations are shown, and others can look at your charts and make whatever conclusions they elect.

Also, I would add that manufacturing productivity did rise, but a lot of the things we "manufacture" are assembled from imported materials, such as electronic parts and steel. So yes, that would lead me to believe we are more productive since the less profitable work has been exported. But as a result did the inflation adjusted wages of floor manufacturing jobs also suffer? In my former factory, I know they did.

Personally, I feel your article is timely, and something that needs to be debated using factual data as you have done.

Patrick Lynch, *Tullahoma, Tenn.*

BIG PRAISE FOR BIG INCH

To the Editor: I thought "Pipelines For War and Peace" (July 2016) to be an interesting and well written piece. It is unusual for engineers to factor in and discuss all the various aspects (other than engineering) that must be considered and dealt with in order to make a major project like this a success. I suspect that Frank Wicks is a great and highly-regarded engineering professor who makes his students aware that engineering solutions are just one part of the puzzle.

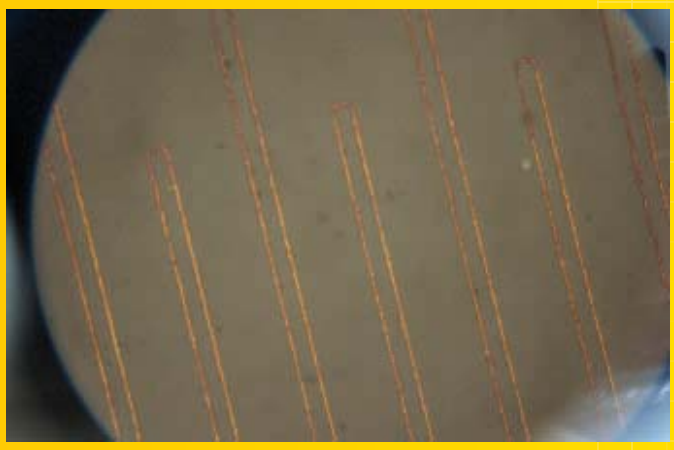
I was fortunate to have a prof like him many years ago.

Bob Balhiser, *Helena, Mont.*

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.

BUILDING BETTER BATTERIES

RESEARCHERS INVENT A BATTERY THAT RECHARGES HUNDREDS OF THOUSANDS OF TIMES. COULD IT MEAN THE END OF REPLACEMENTS?



If Mya Le Thai has her way, the lithium-ion batteries that power your smartphone and other mobile devices will last forever.

Thai, a doctoral candidate in chemistry at the University of California, Irvine, and her team developed a material from gold nanowire that recharged more than 200,000 times with no loss of capacity or power. Most nanowire-based batteries typically die after 5,000 to 7,000 cycles. Thai used her material in a 1.2 volt capacitor, which shares the same chemistry as a battery. The capacitor could have withstood countless more cycles, but she grew tired of running the tests and pulled the plug after three months.

"I didn't want to wait anymore," she said.

Researchers have been probing nanowires, which are thousands of times thinner than a human hair, for years. Nanowires have a higher surface area than films of the same material used in capacitors and lithium-ion batteries, and can therefore handle more power. But heat generated in the devices causes those fragile wires to expand, turn brittle, crack, and delaminate, shortening the life of the device.

Thai drew from her background in materials science and energy storage to build a capacitor with longer nanowire life. She created the capacitor from a gold nanowire to transmit electricity and coated it with manganese dioxide, which is commonly used as a cathode in batteries.

Nanowire-based batteries typically die before 7,000 cycles. Mya Le Thai prolonged the life of the gold wires in her material by covering them with Plexiglas.

To prevent the wires from degrading during thermal cycling and to prolong the life of the capacitor, Thai covered them with polymethylmethacrylate (PMMA), or Plexiglas. In gel form, PMMA is not only strong, it is also an electrolyte.

In a series of tests, Thai discovered that decreasing the gel's viscosity increased its conductivity. Balancing conductivity and protection was key.

"It took two or three tries to get the percentage right," to reach 200,000 cycles, she said.

PMMA is clearly the secret sauce, and Thai is still trying to figure out exactly why. She has several theories. On one hand, the viscous PMMA blocks the manganese dioxide from pulling away from the gold nanowires during thermal cycling. In one experiment, Thai noticed that after several weeks, the gel had permeated the manganese shell, where it acted as a plasticizer. Its elasticity prevents the shell from cracking and breaking down during heating and cooling.

"The packaging of the devices was built in such a way that no material was lost," she said. "If you don't lose the material, you don't lose the charge."

The team is conducting more research to reduce the amount of gel needed without decreasing the capacitor's performance, and to increase its voltage, energy density, and charge. "There's the possibility it will take a lot more engineering work to make this better," Thai said, adding that lithium-ion batteries made from the material could hit the market in five to 10 years. **ME**

JEFF O'HEIR

HOW BOMBS BEHAVE

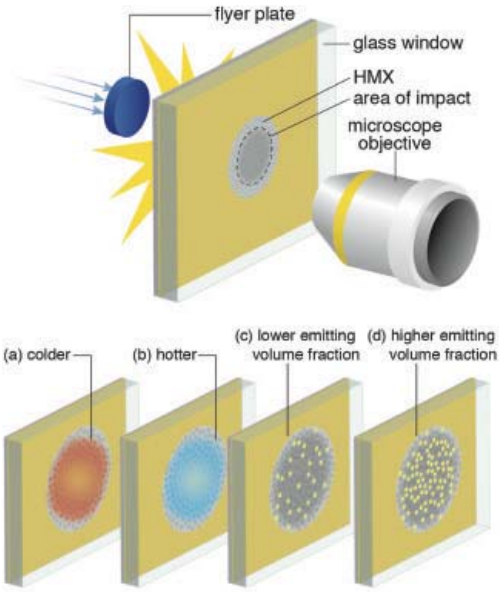
RESEARCHERS WHO WANT TO TEST THE IMPACT of explosions use a huge gun to fire a big plate into an explosive charge inside a protective chamber, usually located at a national laboratory.

The process might be precise, but it's inconvenient and time consuming.

Researchers at the University of Illinois at Urbana-Champaign's School of Chemical Sciences set out to make the process faster and easier by creating a miniature table-top version of the testing process. The method, they claim, achieves new levels of accuracy in recreating the conditions inside an exploding bomb and in measuring how molecules react in an explosion. The testing could lead to the design of safer bombs and other applications.

"Our molecules behave exactly as they would inside a big bomb, but without the rest of it," said Dana Dlott, a laser specialist and chemistry professor at the university. Dlott was referring to the scaled-down apparatus, which is meant to augment traditional impact testing methods, not replace them.

The new apparatus used a pulsed laser—invented by Will Bassett, lead author of the research paper recently published in *Applied Physics Letters*—to fire a tiny flat bullet or plate about 0.5 millimeter in diameter into a thin mirror which was made from glass and tungsten and coated with HMX, a powerful explosive. As the plate smashes through the glass, it explodes the HMX. A high-speed photo Doppler velocimeter measures the speed of the plates and the time of the explosion, enabling researchers to see for the first time what was happening during the millionth of a second while the charge is exploding.



Although the explosion is a million times smaller than one created by traditional methods, the mini-apparatus is up to 100 times more accurate, can be operated up to 1,000 times a day, and is easily replicated, Dlott said.

The heart of the research focused on something called hot spot growth. Hot spots are concentrated areas of energy that cause an explosive to detonate. Picture striking a kitchen match. A few sparks quickly ignite before the rest of the tip explodes in flame. Those initial sparks are the hot spots. Hot spots are important to bomb researchers because they play a key role in controlling explosions and their aftermath.

Dlott's work, funded by the U.S. Air Force, is aimed at helping explosive experts build safer bombs by developing a better understanding of hot

continued on p.19»

MANUFACTURING RELIES MORE ON SOFTWARE

Optima Nonwovens machinery in Germany produces disposable diapers. The company puts all types of engineers on equal footing. *Photo: Optima Nonwovens*

Industrial engineers need to bring products such as complex machinery to market faster and cheaper than ever before—all while maintaining quality. Some engineers have found that adopting systems modeling software can identify and rectify performance issues before fabrication or installation.

In Germany, one manufacturer of high-performance packaging equipment is beginning to see the results of an engineering reorganization that has changed how mechanical, electrical, and software engineers design products.

"There is a great need for industry to go in this direction," said Georg Pfeifer, managing director of Optima Nonwovens, a German firm that produces packaging and filling machines for pharmaceutical, nonwovens, consumer goods, and life-science products. "There is a need to get used to software as a fundamental part of the design of the machine," he said.

Two years ago, Pfeifer and his team began a reorganization they call Engineering 3.0, putting mechanical, electrical, and software engineers on equal footing in early design. They did that because they believe state-of-the-art mechanical engineering is too complex to do otherwise. Basically, Optima turned to mechatronics.

"It is a cultural change," Pfeifer said.

He also pointed out that Optima's first small-scale effort produced software that was ready before machine assembly.

Driving the reorganization was the realization that sequential operations—mechanical calculations followed by electrical engineering input with software development pushed to the end of the line—was not efficient enough. Pfeifer pointed to examples where the software was not developed until machines were nearly completed, and errors not discovered and fixed until they were installed at customers' facilities. That led to delays in production.

Typically, most machines were powered by an electrical drive with mechanical shafts and other parts, Pfeifer said. Calculations on machine movement were performed by mechanical engineers and electrical engineers typically did the wiring.

As machine design has evolved, "software is always hidden in the computer," Pfeifer said. "It is difficult for people to understand how to use it. In the future,

continued on p.21 »

INDIAN COAL POWER BOOMS

Bharat Heavy Electricals Ltd., the New Delhi-based engineering and manufacturing company, commissioned a 660 MW supercritical thermal power plant in the Indian state of Uttar Pradesh in October. The unit, the second of three sections of the 1,980 MW Prayagraj Super Thermal Power Project, located near Allahabad, is owned by Prayagraj Power Generation Company Ltd., a subsidiary company of Jaiprakash Power Ventures Limited.

The plant will burn coal.

According to BHEL, the company has installed more than 70 percent of Uttar Pradesh's power generation capacity, which totals more than 16 GW. Since the start of 2015, the company has added more than 4,300 MW of capacity in the state.

In addition to the plants it has commissioned, BHEL has orders for 36 supercritical boilers and 31 supercritical turbine generators in various stages of completion.

The company says it was responsible for the design, engineering, manufacture, supply, and commissioning of the boiler and turbine-generator package. The key equipment for the project has been manufactured by BHEL at its Haridwar, Trichy, Hyderabad, Ranipet, and Bengaluru works, while the construction of the plant was undertaken by the company's Power Sector—Northern Region.

India is the world's third-largest coal consumer and it is adding coal-fired power plants at a steady pace. The International Energy Agency forecasts that the country's installed coal capacity will reach almost 500 GW by 2040.

The country also has large coal reserves. According to the Ministry of Coal, India has more than 300 billion metric tons of coal resources. Of that total, 126 billion are proved, while the rest is estimated based on geological indicators.

India has the fifth largest coal reserves in the world, and the government expects to use coal-fired power plants to help electrify rural parts of the country. **ME**

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PATENTLY WRONG INTERNATIONAL

OPEN-SOURCE INNOVATION may be the most reliable path to bring health advances to the developing world.

The recent Theranos debacle illustrates the challenge of scaling patented, secretive technologies in healthcare. The company's new Edison blood-testing device was hidden from scientific scrutiny behind a pile of patents. When its problems were finally exposed, it led to the invalidation of two years of blood test results. Lawsuits are now piling up against Theranos and Walgreens, the pharmacy that had used Edison.

Unfortunately, the same Silicon Valley mentality of high capitalization coupled with black-box technology that victimized Walgreens has the potential to be catastrophic for international development. That mentality is infecting the world of social entrepreneurship, which seeks to help the world's poor through market-based approaches.

The risks of rolling out patent-protected healthcare products are more acute for the people of the developing world. Their nations may lack rigorous regulatory agencies and adequate facility inspection capabilities. The inspections that brought the Theranos fraud to light may not have ever taken place in a developing country. When secretive, unproven technologies fail, customers there often don't have the opportunity to seek legal recourse to claim their justified compensation or hold the company that farmed out the technology accountable. So the people suffer and the failed companies move on to their next venture.

Even purely philanthropic efforts such as the donation of outdated medical equipment to hospitals in developing nations can sometimes hurt the recipients. Such donations have surely saved lives in many places. But the World Health Organization estimates that while 80 percent of medical equipment in some countries is donated or funded through foreign sources, only 10 percent to 30 percent of the donations are ever put into operation. Their use of patent-protected custom parts also makes local sourcing of replacement parts difficult or impossible, which means when the devices break they can't be fixed. One way to mitigate that risk to the health—and income—of the world's poorest is by promoting open-source technology.

Choosing to be open source with health-related technology is not about being generous with our knowledge. It's about protecting public health by allowing for appropriate levels of public scrutiny of the products we introduce. This has the effect of flagging poor technologies early, before they scale, and thereby reducing the risk of harm to vulnerable people.

THERE NEEDS TO BE A COMMITMENT TO OPENNESS WITH OUR TECHNOLOGY AND OUR PRODUCTS.

Open source also implies the use of easy-to-find, off-the-shelf components instead of patented or custom-fabricated components. Such access to spare parts makes products locally repairable so they don't end up with broken medical equipment cluttering closets.

Open source also tends to be intuitive to the user. In contrast donated technologies in developing countries often go unused due to a lack of specialized training in operation.

Mission-driven social entrepreneurs are not primarily in the international development business to make a ton of money. (If they are, they might be in the wrong business.) Rather, their focus is first on making long-lasting, positive impacts on the lives of the world's poor.

Social-impact investors must be willing to let go of their default closed-source, intellectual property protection requirements for technology startups before they would even consider investing in them. IP protection may make sense when it comes to gadgets and games, but when it comes to products that can potentially boost health or cause great harm, it is just too risky. The right kind of social investor will understand that to have sustainable, positive impact, being open and transparent with your technology is the best way to be accountable to those you are most obligated to serve: your customers.

In April 2016, health experts welcomed the announcement by pharmaceutical giant GlaxoSmithKline that it would stop seeking patent protections in developing and low-income nations, which will allow cheaper generic versions of name-brand drugs to be sold to the public. Those new patent policies make it easier for people in the poorest countries to access medicine, particularly much-needed cancer drugs.

The Institute for Global Health Innovation notes that "frugal technologies that are specifically designed to meet the needs of low-income countries" are the preferred approach to spreading health technology. One example of this is the Jaipur prosthetic foot, which is now used in 22 countries. This rubber prosthesis does not have a patent and can be made locally for just $40.

In February 2016, UNICEF launched its Innovation Fund, which invests in open-source technologies for children. The Fund has raised $9 million so far and offers innovators in developing countries a pooled funding mechanism to help them take their tested projects to the next stage. The Fund brings together models of financing and methodologies used by venture capital funds and the principles of UNICEF'S award-winning Innovation Unit.

These are all moves in the right direction for international development—but

DEVELOPMENT FOR HEALTH

sadly, such open-source approaches are the exception, not the rule. There needs to be a commitment to openness with our technology and our products, in particular when it comes to potentially life-saving technologies. This is the best way to avoid future Theranos-like fiascos.

If you need a cautionary tale, just think of the last few decades of pesticide poisonings that have happened in the developing world. Those patent-protected pesticide products were deemed safe by manufacturers and understaffed regulatory agencies, then they were introduced without public scrutiny due to their legal protections. It often took years, like it did for Agent Orange and DDT, to see their health consequences. In 1990, the World Health Organization estimated three million severe pesticide poisonings occur every year. This figure is likely an underestimate, since most rural poor have no access to healthcare workers, and therefore often fail to recognize and report poisoning cases.

A particularly worrisome development is the looming exportation of gene-edited organisms, using a new technology called CRISPR. That technology enables scientists to quickly alter the genetic make-up of the entire population of a species, such as genetically modified mosquitoes that could eradicate the scourge of malaria in the developing world. A win-win for everyone?

Not so fast. Kevin Esvelt, a CRISPR innovator, told WNYC's On the Media "under science's current culture of secrecy, ensuring that scientists are taking necessary precautions with gene-driven research is next to impossible." He also urged the scientific community to "open all experiments to public scrutiny, beginning with revolutionary and potentially world-changing gene-editing research." Open source is not about intellectual altruism—it's about having an approach that is smart, effective, sustainable and ethical. ME

JASON KASS is a contributing editor at E4C. Kass is an environmental engineer and president and founder of Toilets for People. For more on development engineering, visit **ENGINEERINGFORCHANGE.ORG.**

KEEPING OUR COOL

Refrigeration has **long been a target** for innovators.

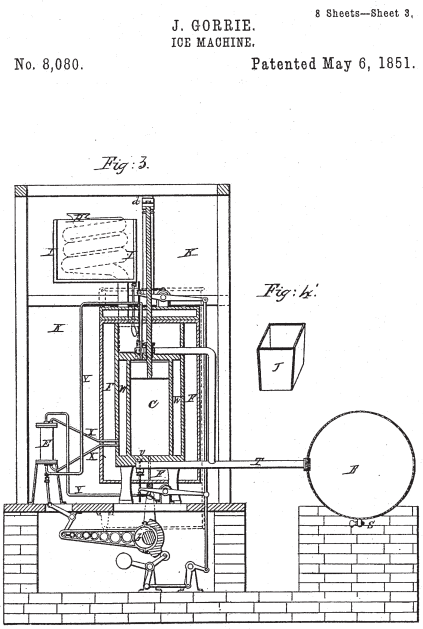
In the middle of winter, it may be hard to appreciate refrigeration and air conditioning. Yet refrigeration is not only a household convenience, but also is vital for certain chemical processing technologies, preserving vaccines and other medicines, and keeping Internet server banks functioning. (See the feature on page 40 for more on server cooling.)

The documentation for the earliest patents were destroyed in a 1836 fire, but we know that Nathanial Wyeth of Cambridge, Mass., was granted several patents in the early 1800's for horse drawn ice cutters and cost cutting improvements in transporting and storing ice. Before that, in 1803, a Maryland farmer named Thomas More patented a "refrigerator" which was reportedly a tin box placed inside a rabbit fur-insulated wooden box, with ice filling the gap between the two.

Icehouses and iceboxes still left refrigeration at the end of a long supply chain. Vapor-compression refrigeration, where mechanical work replaces cold weather to provide cooling and thus can be established anywhere, was invented several times in the 19th century.

Jacob Perkins, an American engineer in London, was awarded a patent in Great Britain in 1835, and John Gorrie of New Orleans obtained U.S. Patent No. 8,080 dated May 6, 1851, for an ice machine. Another notable American inventor, Oliver Evans, has been credited with inventing the vapor-compression refrigeration cycle as early as 1805, but I cannot find any refrigeration patents by Evans.

It took decades for inventors to find ways to bring refrigeration into the household. Patent No. 1,126,605 (January 26, 1915) describes a household refrigerator with the compressor and motor on top of the ice box, while Patent No. 1,276,612 (August 20, 1918) named Rubin Betchtold and Alfred Mellowes as inventors of a household refrigerator with the compressor and motor located underneath the ice box—much like our modern refrigerators.



John Gorrie's 1851 patent for an ice machine was an early attempt to turn mechanical work into refrigeration.

Both of those patents were bought by William Durant, then president of General Motors, who started the Frigidaire Company.

Besides vapor compression, there are other cooling technologies currently being explored, including thermoelectric, thermoacoustic, and magnetocaloric. One example is published Patent Application No. 2012/0273158 (2012) for a promising improvement in thermoelastic cooling, where various mechanisms are used to stress a shape memory alloy such as Nitinol to cool a refrigerated space. The SMA heats up when stressed but cools when relaxed.

The University of Maryland is currently battling with the United States Patent Office over whether this idea is new. In the meantime, the technology has been licensed to Maryland Energy and Sensor Technologies, a start-up founded by one of the inventors named in the patent application.

Nearly two centuries after its invention, perhaps vapor compression refrigeration is ready to be put on ice. ME

KIRK TESKA is the author of *Patent Project Management* and *Patent Savvy for Managers*, is an adjunct law professor at Suffolk University Law School, and is the managing partner of Iandiorio Teska & Coleman, LLP, an intellectual property law firm in Waltham, Mass.

SOUND-POWERED MICRODRONE

How do you drive a microscopic drone with no moving parts—and without introducing potentially disruptive magnetic fields?

Researchers at the University of Pittsburgh's Department of Mechanical Engineering and Material Science believe they've found a way to direct so-called microswimmers through a fluid using nothing more than high-frequency sound waves.

These swimmers are actually nanotubes about the width of a human hair, and may eventually navigate the human bloodstream to deliver drugs, conduct biosensing, and perform microsurgery.

Researchers have been exploring the use of microscopic drones for some time. But because those earlier efforts involved controlling the movements of the drones using magnetic fields, they ran into multiple stumbling blocks in the path of development.

"Other methods are complicated and expensive," said Sung Kwon Cho, an associate professor at Pittsburgh who led the new research effort.

Cho's team created a swimmer that was smaller and less cumbersome, as well as cheaper and easier to produce. They first reported on their results in early 2016, when they described minuscule, test-tube shaped vessels they had built. When submerged in fluid, the tubes trapped a bubble of air that would oscillate when subjected to ultrasonic sound waves. The bubble acted like a piston, drawing fluid through the opening of the tube when the bubble contracted, and forcing fluid out when it expanded. The expulsion of fluid propelled the tube forward at up to 80 body lengths per second.

Cho's team later outlined a design for swimmers that could move in multiple directions. Several tubes pointing in different directions were attached to a raft-like platform, with each tube matched to a particular frequency. The bubbles inside a given tube would oscillate only when excited by a soundwave frequency that matched its size. The frequency matching allows researchers to accurately control the direction of the platform by pulsing sound waves in a way to move it forward or backwards or left or right.

The Pittsburgh team recently received a $724,691 National Science Foundation grant to take its acoustic bubble-powered microswimmers to create "3-D" swimmers that can move in almost any direction. ME

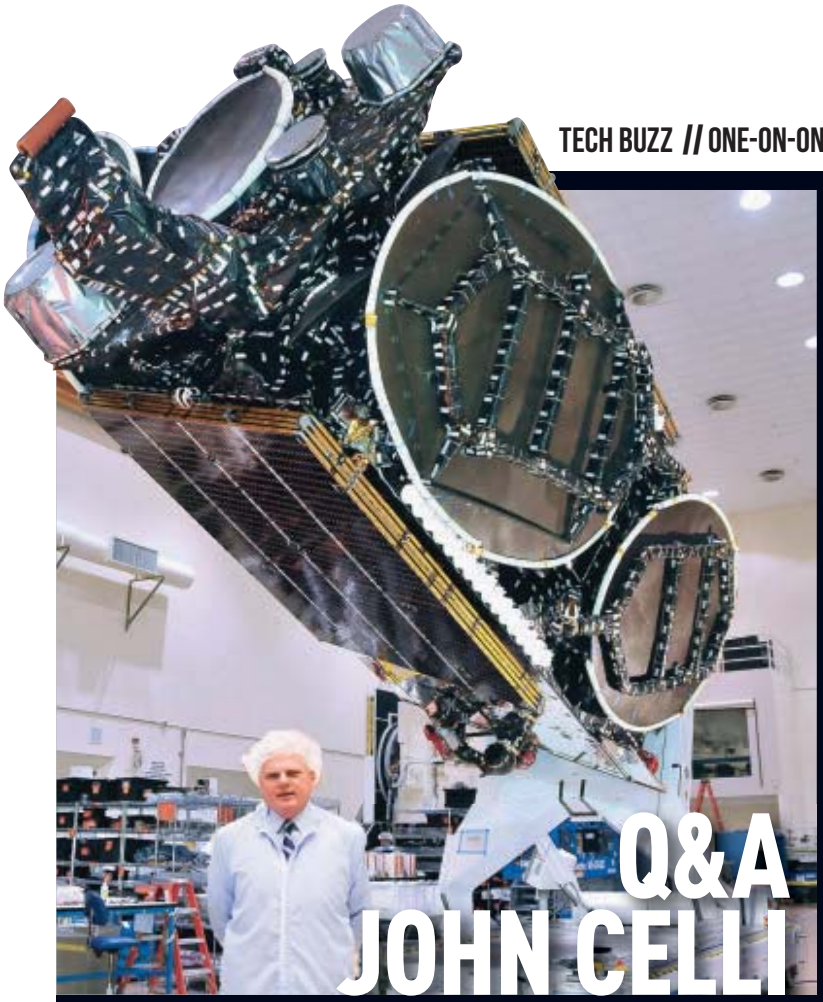


Photo: Courtesy of SSL

Q&A JOHN CELLI

BEFORE JOINING SPACE SYSTEMS LORAL, a leading maker of satellites for both commercial and government customers, John Celli held design and management positions for space products and ground systems at Alenia S.P.A. in Rome, where he attended university. At SSL since 1981, Celli has risen through the ranks, beginning in the antenna department, to become president, overseeing the company's strategic direction. Last year, the Silicon Valley Engineering Council inducted Celli into its Hall of Fame.

ME: What did it mean to be inducted into the Silicon Valley Engineering Council Hall of Fame?

J.C: It was obviously a great honor, but I was also surprised because in the satellite industry, individuals can seldom accomplish a lot. The complexity and the challenges of designing and building satellites are so huge that you need a team to be able to resolve problems and be successful. So I think it was also a recognition of the SSL employees and what they have done with their hard work. We have done something good, and that to me is actually the most important thing.

ME: What's one breakthrough in satellite technology that mechanical engineers are working on?

J.C: An area that will be particularly important for mechanical engineers in the next few years is the packaging. Think of the capability in an iPhone: It's a very small item that is very strong, that is moisture resistant, that is heat resistant, and always works, always performs. Potentially there's going to be a similar breakthrough in the next few years in the design and the manufacturing for packaging of sophisticated electronics and hardware in satellites. It's something that needs to be pushed to reduce the size, the cost, and therefore the cost of launching satellites.

If you look at a satellite today, it probably has 200,000 components inside, maybe more. It will have to be done differently. Everything's going to be either 3-D printed or packaged in a way that the machining will be more complicated. But the result will be much more effective.

ME: What first made you interested in the field of aerospace?

J.C: I was attending the School of Engineering in Rome and living at the top of an apartment building at the top of one of the Seven Hills, so I had a beautiful view of the city. In those days there was no air conditioning, so if it's a hot night, you would sit on the balcony or the terrace and watch your little black-and-white TV. Everyone did. One July night at about one in the morning, I heard an incredible noise coming from below me, a mix of cheers and applause and screams. It's something that I never forgot. Even to this day, I can close my eyes and live it again. It was Neil Armstrong setting foot on the moon. The reaction of the millions of people in the city watching that event is something that still gives me the goosebumps.

I was already in engineering and at that split second, I said, "Well, I'm going to work in aerospace."

ME: What do you think the next moment like that will be? Will it be arriving on Mars someday?

J.C: To be honest with you—and I have expressed this opinion at NASA headquarters—I don't think Mars exploration is going to do it. The younger generation seems to be very focused doing work on things that have a social content. In other words, things that help the environment, that help people, that help the poor, that help developing countries. They're very attracted by that.

We have satellites that helped during the Haiti earthquake and during a cyclone in the Philippines. Our satellites were repointed to cover those particular areas and provide communication and services that otherwise would not have been there. So satellites can do that.

The ultimate social help that space technology can provide, if you think about it, is capturing an asteroid that is coming to the Earth and threatening everybody's life. That is the ultimate social service. And I think that would attract a lot of people and a lot of young engineers. **ME**

DAVID WALSH is the editor of ASME.org.

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HOW BOMBS BEHAVE

spots and how they are concentrated. The applications of the new research extend beyond explosives. Since the process recreates extreme conditions, it can be used to understand how external materials on satellites and spacecraft react to high-speed impacts; how materials behave when used in energy production, such as solar farms, engine pistons, and the interior of nuclear reactors; and how materials far below a planet's surface react to high temperatures and extreme pressure.

"This is indeed a very cool experimental development for high-velocity impact testing," said Veronica Eliasson, an associate professor at the University of California, San Diego, whose research using the traditional testing method was recently featured in *Mechanical Engineering*. "I am curious to see how this could be used for other topics than research on explosives." ME

BIG NUMBER

4,815 lbs

THE AVERAGE CARBON EMISSION EQUIVALENT OF ALL ELECTRIC VEHICLES IN THE UNITED STATES.

Electric vehicles are clean, but in many cases driving an EV simply displaces the emissions from the tailpipe to the smokestack. Last November, the Department of Energy's Alternative Fuels Data Center estimated the annual carbon emissions of battery-electric vehicles in each state, based on the mix of generating stations producing electricity. The average for all states was 4,815 lb. of carbon dioxide equivalent, but in coal-dependent places such as Indiana, it was nearly twice that. The emission for a standard gas-powered car is 11,435 lb.

THERE IS NOT A VIABLE DEFENSE against it for the foreseeable future. IoT adoption is rapidly increasing, while security considerations in connected devices remain largely absent.

— Ted Harrington, executive partner at Independent Security Evaluators, on the potential for remote hijacking of Internet of Things devices. Harrington was quoted by the San Jose Mercury News on October 24, 2016.

BOMB-SNIFFING SPINACH

After years of talking to our plants, it looks like they're finally able to talk back.

MIT researchers recently transformed the leaves of spinach plants into sensors that can detect explosives and other dangerous chemicals in the soil and air, and transmit the information to a smartphone.

Plants are self-repairing, cheap, abundant, and can withstand the elements, which makes them a less expensive and more efficient platform than man-made solutions for certain outdoor applications. They also contain a tremendous amount of information about the environment, and they can use their root systems to help detect chemicals dissolved in groundwater, said Michael Strano, a chemical engineering professor at MIT.

"We're showing how we can get information from a plant's root system to your cellphone," Strano said.

This plant-to-human-communication is the latest phase in Strano's research in plant nanobionics, a new field that the group has pioneered. "The vision is to try to replace the electronic devices we mass-produce with comparably functioning plants," he said.

An MIT researcher infuses simple spinach plants with carbon nanotubes to turn the leaves into sensors. *Photo: MIT*

Two years ago the researchers began engineering different types of plant leaves to detect a variety of chemicals, such as TNT, sarin nerve gas, and hydrogen. They embedded leaves with fluorescent carbon nanotubes that had been coated with a polymer. When molecules of the targeted chemical bind with the polymer, the nanotubes emit a different color of fluorescent light, which the researchers detect with an infrared microscope or camera.

Next, the group gave the bionic plants wireless communications capability, they reported in October in *Nature Materials*. They did this by embedding spinach leaves with polymer-coated nanotubes engineered to detect chemical compounds called nitroaromatics, which are used in landmines and other explosives.

After the nitroaromatics are introduced into the soil, they travel through the plant's roots to its leaves in about ten minutes. The researchers then shine a laser on the leaf, causing it to emit near-infrared fluorescent light, which they detect with an inexpensive camera connected to a $35 Raspberry Pi microcomputer. The microcomputer transmits the signal to a smartphone, which can pick up the signal from about one meter away.

The researchers are working now to extend that range, and they have filed a patent on the technology. One of the paper's lead authors, Win Hao Wong, has started a company called Plantea to develop and market the plant bionic technologies, which potential customers are already inquiring about, Strano said.

The bionic plants—Strano's team also experiments with arugula and watercress—could be planted around chemical, nuclear, or fracking sites to monitor leaks, spills, and security threats, Strano said. They could also detect insect attacks on plants or to predict a drought or other environmental conditions.

Other technologies exist to detect such problems, but many of them are expensive and cumbersome, Strano said. "This is about decreasing the amount of work involved and lowering the economic footprint."

But one thing you can't do with the nanotube-embedded plants is eat them. Now you finally have a good excuse for refusing to eat your spinach. ME

JEFF O'HEIR

CLEAR-SIGHTED ROBOTS, NO DUCT TAPE NEEDED

Jonathan McQueen was ready to buy logistics robots for a factory he managed—until he visited a company using them to move workpieces.

"There was duct tape hanging down everywhere," he said.

It turned out that autonomous logistics robots had a vision problem.

The duct tape acted as warning flags, to keep the robots from crashing into things. Then McQueen did something about it. He helped found Canvas Technology. Its first product is a human-safe logistics robot with an advanced vision system that can map and navigate its workplace autonomously.

"It literally takes 10 minutes to set up," McQueen said. "It works right out of the box."

Canvass' vision system makes this possible. It is based on a technology called simultaneous localization and mapping (SLAM), which was developed over the past decade by company co-founders Nima Keivan and Juan Falquez of Colorado University's Autonomous Robotics and Perception Group.

SLAM uses optical cameras to take high-fidelity pictures of its surroundings. They capture details that other sensors miss, even under dark and dim conditions, McQueen said.

Algorithms are needed to transform those 2-D videos into 3-D maps. The robots update those maps continuously, using on-board accelerometers, local Wi-Fi, and the cloud to pinpoint their location and note changes as they roll through a facility. "There is very little human interaction with that map," McQueen explained. "If you move a table or a machine, the robots update it automatically.

"They also have enough intelligence to react differently to a person than a stack of boxes," he added. "They give more berth to a forklift than a stationary rack of parts."

Canvass supplements its cameras with a "virtual bumper" that uses ultrasound, light, or other sensors to warn if anyone moves into its path.

The ability of Canvass robots to automatically map and adjust to their environments makes them an economical alternative to sophisticated conveyor systems, McQueen said.

"Conveyors are inflexible and you can't walk through them," he said. "Robots deliver goods like a conveyor, and you can reroute them in a minute." ME

continued from page 12 »

PRODUCTION: MODELING

software will be the driver of the system, along with some mechanics."

One of the goals is to have the software ready before the machine is assembled. Optima wants to make the machines more robust from the first day of operations, so Pfeifer said it is essential to identify possible faults and problems early on. He also wants to decrease the time needed to design and manufacture the machines. Finally, the move to accelerate software development is the key to faster production and error-free operation.

Pfeifer said the key is to develop simulation models that can be reused to design its customers' machines.

"If we do this cleverly, we can reuse it in other machines," he said, pointing to Optima's customer base where about twenty companies comprise 80 percent of the market. "Modularization of software allows us to reuse and not reinvent, and it changes the way we work."

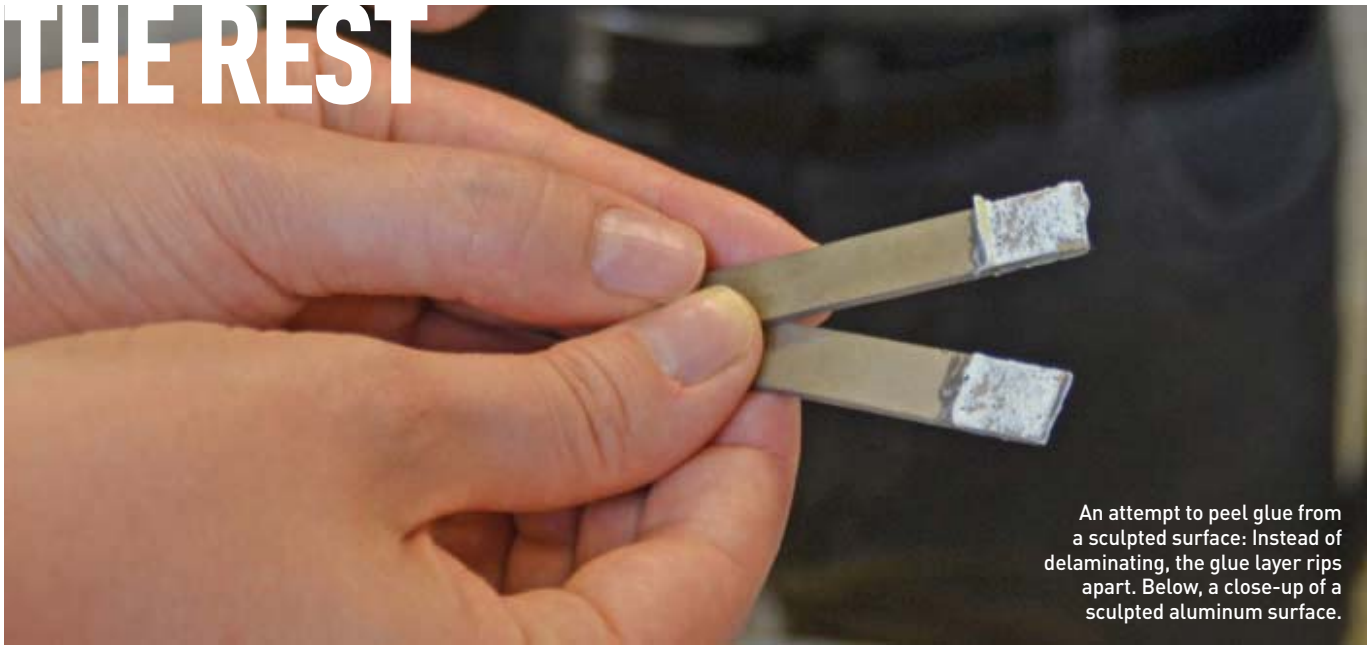
Pfeifer contends Optima is in front of the adaptation curve in industry, and the claim has merit. Research conducted in the U.S. on system-level physical modeling and simulation for mining and off-highway equipment shows those industries lagging. The work, conducted by Ora Research, Raleigh, NC, suggests that adoption constraints include the stubbornness of legacy engineering culture, along with corporate culture.

Pfeifer said Optima began changing in small steps about two years ago, putting a team together to work on a small project. But its benefits became apparent swiftly, he said, and the company is committed to furthering changes even if there are some bumps. Even if an employee does not personally feel direct improvement, it could still affect the entire process.

"For example, mechanical engineers are now asked to define parameters such as slider lengths, sensor positions, etc. very early in the process," Pfeifer has said. "These are foundations to make sure that the software engineer can also start simultaneously. So that more mutual understanding develops here, we now communicate more often and more intensively." ME

JOHN KOSOWATZ, ASME.ORG

TOUGHER THAN THE REST



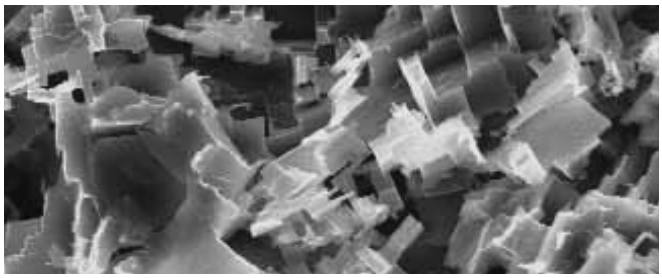
An attempt to peel glue from a sculpted surface: Instead of delaminating, the glue layer rips apart. Below, a close-up of a sculpted aluminum surface.

NEW MATERIALS ARE THE MEANS to create seemingly impossible things. This month, we visit a lab working on a technique to bond metals permanently and without adhesives to virtually any other metal or plastic. And another lab is boosting the toughness of carbon-reinforced composites by encouraging—and then controlling—cracks.

To help materials stick to metals, it's often necessary to rough them up. But a process developed at Christian Albrecht University of Kiel in Germany actually sculpts the surface of metals at the nanoscale, enabling metals such as aluminum, titanium, and zinc to adhere permanently to virtually any other material, even adhesion-resistant polymers such as non-stick fluoropolymers and silicone, as well as incompatible metals.

The process does not require a cleanroom and does not appear to have size limitations. It works even after smearing oil on a treated surface, said Rainer Adelung, who pioneered the work.

The nanosculpting process works with any metal that can form a stable oxide coating. The researchers chemically or electrochemically etch the surface to remove the least stable oxides, which are fortunately also the weakest parts of the metal. This leaves the first 10 to 20 μm of the surface pocked with deep, undercut cavities.



When Adelung's team applies a liquid resin, melted plastic, or molten metal to the surface, it infiltrates the crevices. The undercuts lock it into place mechanically as it solidifies. This is what differentiates it from the roughened surfaces formed by abrasion and other surface treatments.

It is the complex sculpted surface's ability to grip another material that enables it to form permanent bonds even with non-stick polymers. The bond is so strong, it will not peel off. Instead, one of the bulk materials will crack before the bond

BONDING COATINGS MECHANICALLY

THE LAB Functional Nanomaterials, Christian Albrecht University of Kiel in Germany; Rainer Adelung, chair.

OBJECTIVE Creating new functional applications for nanoengineered materials, especially zinc oxide.

DEVELOPMENT Nanoscale sculpting of metal surfaces to create three-dimensional structures that lock coatings or adhesives into place, creating an unbreakable bond that cannot peel off.

fails, Adelung said.

In addition to coatings, the process makes possible some interesting material combinations, Adelung said. It could join a copper surface onto aluminum to increase electrical and thermal conductivity. It could coat cochlear ear implants with silicone—an inert polymer difficult to apply to metals—without using adhesives that might degrade over time.

Etching can also improve the purity of titanium implants. While titanium is inert, its alloys contain small amounts of aluminum that react with the body. Etching removes aluminum oxides, leaving behind a purer, less reactive titanium surface.

Adelung and his collaborators have launched a startup, FUMT, to commercialize the technology. It is currently working with about 10 different companies. ME

Could encouraging composites to crack can actually make them tougher?

It seems counterintuitive, but over the past two years, Imperial College's Silvestre Pinho has used this technique to boost fracture toughness in composites by nearly six times while raising strength by 66 percent.

Several years ago, Pinho created a groundbreaking model to predict the size of cross-ply fractures in composites. The surface created by those fractures looked chaotic, a forest of fibers.

"But when we went back and looked at them again, we realized they were not a mess," Pinho said. "Instead, there were different sized fiber bundles pulling free of the composite matrix in similar ways."

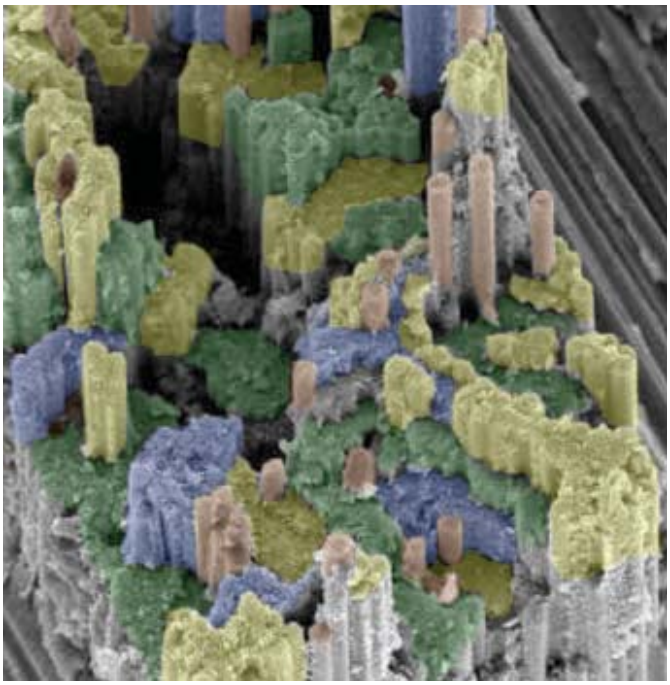
Pinho had seen this before. Natural composites, such as bone, wood, and conch shells, behave the same way.

"Their microstructure is optimized to create fracture paths that dissipate energy and improve fracture tolerance," he explained. "Nature does this with a hierarchy of structures. As cracks propagate from nanoscale to microscale to mesoscale, they take a crooked path. This dissipates more energy than a straight path, and keeps the natural composite from failing catastrophically."

Pinho set out to engineer crooked fracture paths in composites. In one technique, he used a laser to slice a few of the composite's reinforcing fibers. When a load hits those breaks, it transfers energy to the resin matrix surrounding them. The crack dissipates energy as it widens from the nanoscale to the microscale. It loses even more energy through friction when the widening crack hits the notched fibers and pulls them free from the matrix.

"This seems counter-intuitive," Pinho said. "If you cut a bundle of 6,000 fibers, it will severely reduce composite strength. But if you do with only a few fibers, it makes the composite less brittle."

In addition to laser micromachining, Pinho is investigating other ways to slice and align fibers. These include embossing, which is similar to rolling patterns on dough to make ravioli, and combining carbon, aramid, and glass fibers, each with different properties, to create more complex hierarchies.



Controlling how carbon fiber cracks improves fracture toughness and strength.

REIMAGINING CARBON COMPOSITES

THE LAB Mechanics of Composites Lab, Imperial College, London. Silvestre Pinho, Leader.

OBJECTIVE Designing composite structures from the microstructure on up.

DEVELOPMENT Hierarchically structured fibers that make composites nearly six times more fracture-resistant than conventional laminates.

Meanwhile, Pinho's lab is also working on multiphysics models of graphene structures, and partnering with Airbus and SciComp to design more damage-tolerant composite sandwich structures for aircraft. ME

ALAN S. BROWN

APPLICATIONS OF RADIO IN AIR NAVIGATION

J. H. DELLINGER, CHIEF OF RADIO LABORATORY, BUREAU OF STANDARDS, WASHINGTON, D. C.

A leading technologist in the field of radio communication discussed how to get critical information to pilots in mid-flight.

LOOKING BACK

Air travel was still a daring activity when this article was published in January 1927.

Comparing airplane communication with that applicable to marine vessels, it may be stated that aircraft require telephony instead of telegraphy, and that the communication be at higher frequencies, and, generally speaking, over shorter distances than for marine vessels. The use of continuous-wave radiotelegraphy is inherently a more economical method of communication than radiotelephony, and is the natural of communication for ships. This, however, requires the use of an operator trained in the telegraphic code. Most airplanes now have no crew other than the pilot, and this condition will doubtless be true for a long time to come. It is not to be expected that the pilot will also be a telegraph operator, and it therefore follows that radiotelephony rather than radiotelegraphy will be the system used on aircraft.

Higher frequencies will be used than in marine communication because of the relatively small size of an airplane. It is inconvenient and undesirable to use long antennas on airplanes. Short antennas work most efficiently with high frequencies. It is therefore to be expected that relatively high frequencies will become standard for aircraft radiotelephony.

It was stated above that aircraft communication is characterized by shorter-distance work than marine communication. This is true both because of the weight limitation on transmitting or receiving apparatus carried on the airplane, and also because of the interference to reception produced by the airplane-engine ignition system. A shielding system can and should be used on all airplane engines which largely eliminates this interference, but the perfection of this shielding is limited by the additions to the total weight. It may be said, furthermore, that there is no good reason why great distances need to be covered in aircraft communication. Here we have an essential advantage over marine navigation. On the airways of the country radiotelephone transmitting and receiving stations can be placed at convenient and relatively short intervals. These will be advantageous for the aircraft, and incidentally such a system will be more economical than one of a very few stations of great power placed great distances apart. In this respect aircraft communication has an advantage over marine communication.

It is generally agreed that communication to the aircraft is much more important than communication in the other direction. It will add immeasurably to the peace of mind of the pilots and the safety of flying when all airplanes carry radio receiving sets and there is an adequate system of ground stations telephoning information as to weather, landing conditions, etc. As the airways develop and passenger carrying becomes more common, there will be an increasing use of radiotelephony from the aircraft as well. Two-way communication will of course be a great advance. There are a great variety of technical problems involved in this and all the other applications of radio to air navigation, some of them requiring research and engineering work yet to be undertaken. ME

THE LONE EAGLE

Later in 1927, the lack of a radio would be a detail in one of the biggest aviation stories of all time. Just a few months after Dellinger published his article, a fuel-laden monoplane took off from Roosevelt Field on Long Island and headed east. *The Spirit of St. Louis*, piloted by a young aviator named Charles A. Lindbergh, spent the next 33 hours over the Atlantic Ocean. To save weight—and because wireless sets of the era were prone to failure—Lindbergh flew without a radio and navigated by either the stars or dead reckoning. On May 21, Lindbergh completed the first non-stop New York-to-Paris flight, and was welcomed by a crowd of 150,000 Frenchmen.

Lindbergh and his famously radio-less plane.
Credit: United States Library of Congress

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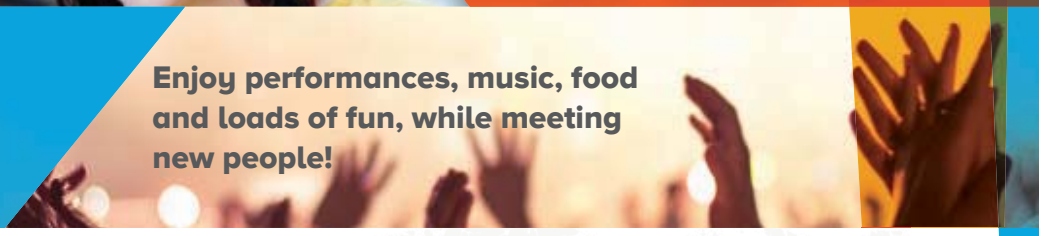

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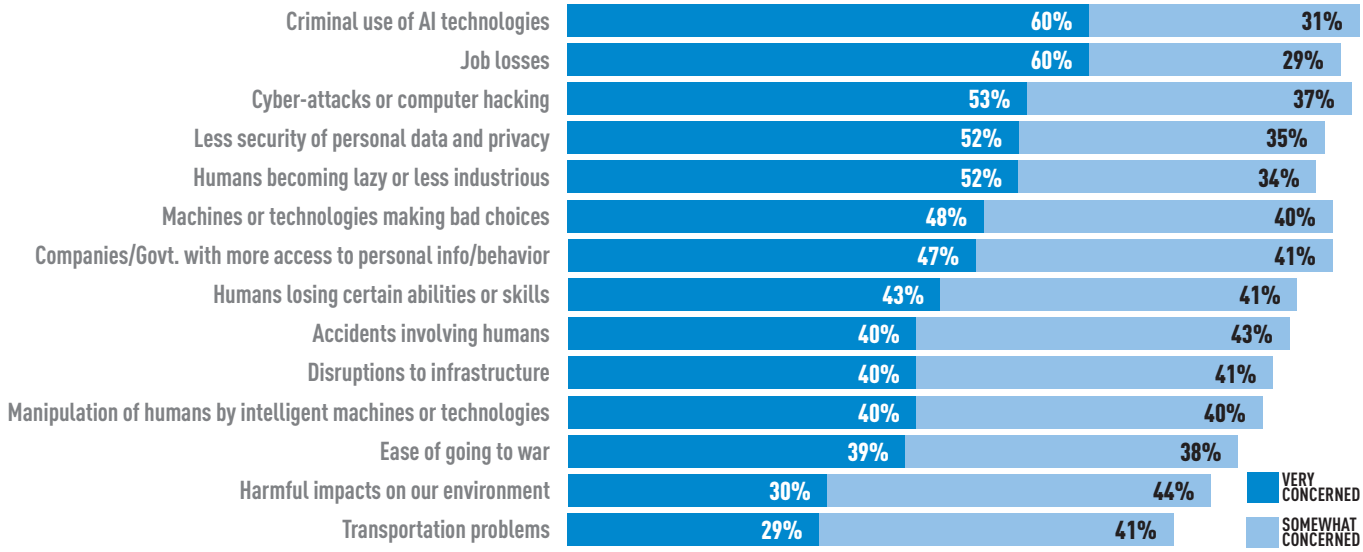
BY THE NUMBERS:

HOW MUCH DO WE TRUST AI?

Technologists have been promoting the promise of artificial intelligence. But consumers don't want to hand every task over to robots.

POTENTIAL OUTCOME CONCERNS OF AI CONSUMERS

PERCENT GLOBAL CONSUMERS



If you listen to Silicon Valley thought leaders, artificial intelligence is poised to make our lives less stressful and more contented. While that message may lead to nods in the crowd at a TED Talk, to the general public, that sunny optimism has to compete with some longstanding skepticism and newly minted concerns.

That's just one of the results that emerged from a recent survey by Weber Shandwick and KRC Research, two public relations firms looking at how best to market AI-enhanced goods and services to consumers. The companies reached out to two pools of respondents: 150 marketing executives in China, the United Kingdom, and the United States, who were surveyed by phone; and 2,100 adults from Brazil, Canada, China, the U.K., and the U.S., who answered an online questionnaire. The findings were published in October as *AI—Ready or Not*.

Marketing surveys have a particular focus—such as how best to sell AI-enabled products—but there are lessons for designers and industrial engineers, as well. For instance, consumers reported having a fairly wide range of trust in the ability of artificial intelligence to handle common tasks. When it came to offering reminders to take medicine, providing travel directions, or supplying entertainment, more than 75 percent of consumers surveyed reported confidence in AI to handle those tasks. But tasks involving larger machines—or higher stakes—left consumers uneasy. Less than 40 percent of those surveyed trusted AI to perform a medical procedure or fly an airplane, and only one in five were comfortable with a robot babysitter. Consumers, it seems, want to keep the most important jobs in the hands of humans.

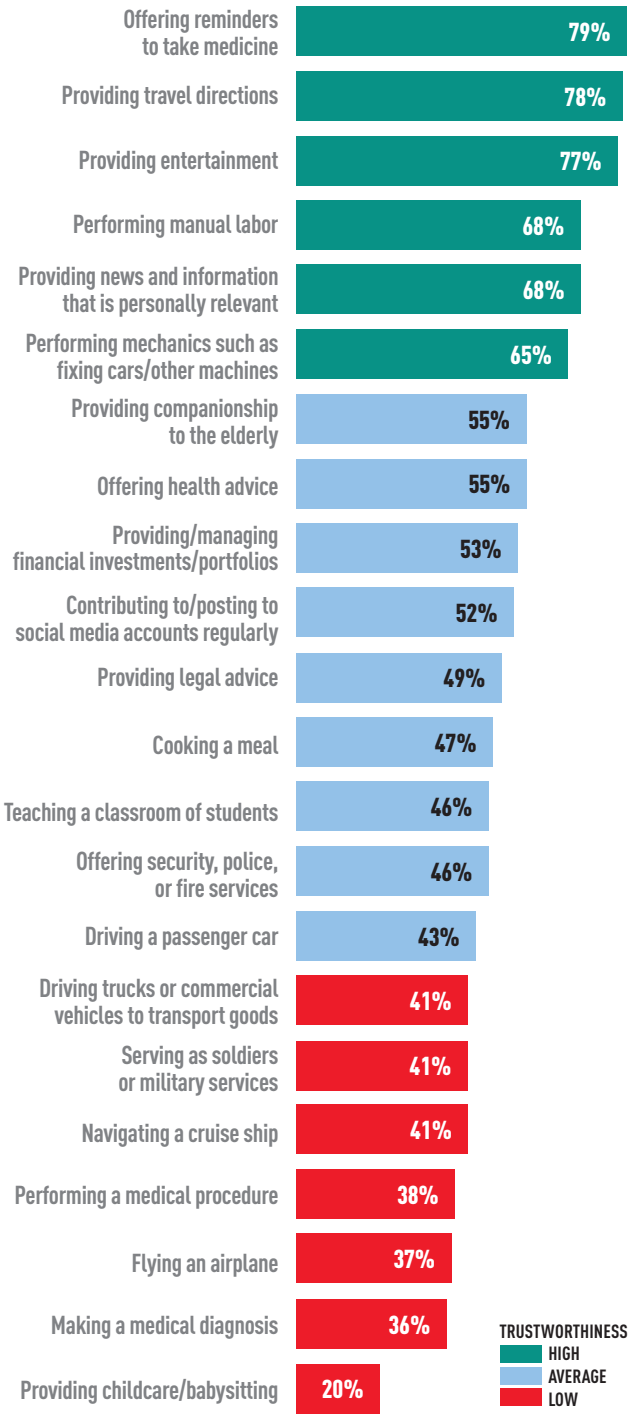
A different sort of divide appeared in the results about hopes and fears. The two of the top-ranked potential benefits of AI for consumers was the ability to do jobs that are difficult or dangerous and freeing up humans to have more leisure time, the kinds of value that new technology has provided for centuries. But when asked about what scared them about artificial intelligence, the respondents listed a host of new concerns, such as hacking and crime, loss of privacy, and humans becoming lazy or less industrious, together with an age-old one: job losses. Indeed, more than 80 percent of respondents from the Millennial generation and 80 percent of parents of children under 18 reported being concerned about the employment impact of AI.

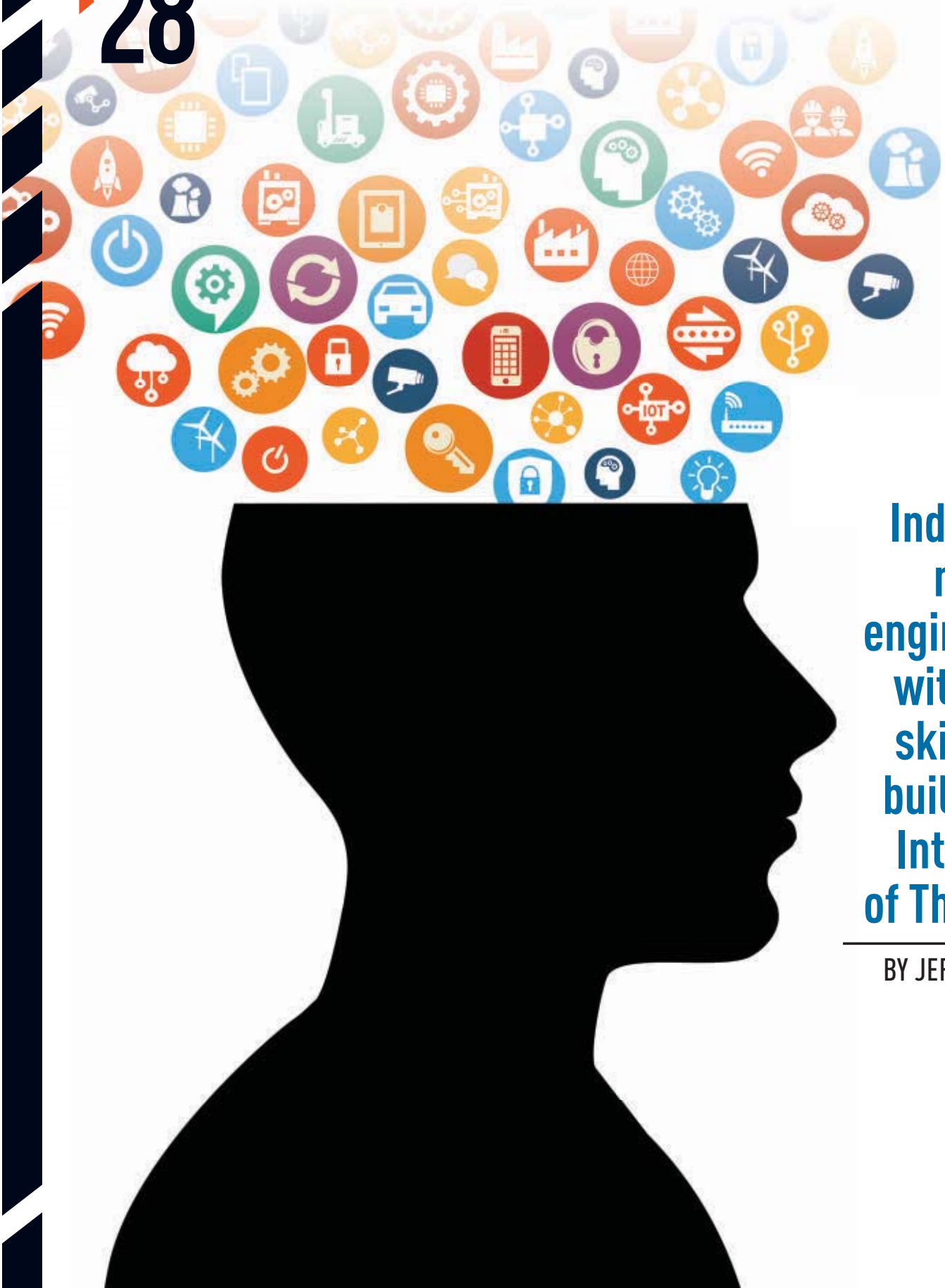
As engineers look to incorporate ever-more powerful artificial intelligence in their devices, they need to make sure not to put in too much, too soon, doing too many jobs. For many critical jobs—from daycare to medicine—people still want the human touch. ME

JEFFREY WINTERS

TASKS TRUSTED BY CONSUMERS FOR AI PERFORMANCE

PERCENT GLOBAL CONSUMERS





Industry needs engineers with the skills to build the Internet of Things.

BY JEFF O'HEIR

FILLING THE TALENT GAP

Will Caldwell was sure he wanted to be a mechanical engineer. The 20-year-old had spent his childhood in Madison, Wis., building models of spacecraft and futuristic vehicles with whatever he could find around the house. He started a mechanical engineering club at his high school. And when he enrolled in the University of Wisconsin-Madison's School of Engineering three years ago, he hoped to someday design cars.

But along the way, he realized that mechanical engineering skills alone would not get him where he wanted to go. His pals who recently graduated with mechanical engineering degrees had landed jobs that required them to program computers and robots, and to perform other tasks that were related more to the computerized world of the Internet of Things (IoT) than to traditional mechanical engineering.

"I met a lot of people who had figured out what IoT was and wanted to do something real with it," he said. But neither he nor his friends had much opportunity in their mechanical engineering classes to learn about IoT-related technologies and how to apply them to real-world solutions.

In the emerging IoT ecosystem, new technologies like embedded sensors make it possible for just about any type of device, machine, or component to collect data and send and receive information over the Internet. Data analytics and cloud computing then turn that data into something valuable.

Almost every industry is now trying to leverage those technologies to improve business and manufacturing operations, monitor and diagnose how well machines are functioning and forge closer collaboration between humans and machines. This is called the Industrial Internet of Things (IIoT) or Industry 4.0, and companies desperately need a new type of engineer to help them create it.

Until a few years ago, industry expected entry-level mechanical engineers to focus on mechanical engineering. But today almost every job they take on—from designing a medical implant to engineering a turbine jet engine—also requires an IoT-related skill, says Peter Hirst, associate dean of executive education at MIT Sloan School of Management. "IoT is everywhere now," he said. "The job function might not be characterized as IoT, although many of those jobs include some implementation of sensors, data measurements, and connectivity."

Hirst also serves as director of the IoT Talent Consortium, an industry-academic group that develops new ways of training engineers, technicians and others to meet the needs of IoT employers. He's in constant contact with C-level executives from a variety of technology, engineering, and science companies, who say their biggest challenge today is finding the talent to fill IIoT-related jobs.

"It's no longer you and 10 mechanical engineers working on a project, it's you and a designer and a

data scientist and a customer expert," he said. "Those are the kinds of abilities that people historically learned by osmosis and experience over a 10- or 15-year career. Now we're saying we need people to come out of school with those abilities."

But most are not. This has created a gap between the skills that industry needs to develop the technologies, products, and services that make companies profitable and competitive, and the skills that entry-level mechanical engineers typically bring to the table. For these reasons, companies and engineering educators are looking at new ways to train young engineers in the skills needed to bridge the gap.

FINDING A UNICORN

For at least 40 years, mechanical engineering fundamentals have been taught in much the same way. The core classes stuck to the basics every mechanical engineer must know, such as material, fluids, thermodynamics, measurements, and instrumentation. That satisfied industry, and that's what professors on a tenure track had incentives to teach.

While industry has complained over the years about young engineers' lack of job preparation in some areas of technology, most of the skills they needed were closely related to traditional mechanical engineering and could be honed early in a career. Large companies with deep pockets were also able to pick up the slack and teach engineers skills they didn't learn in school. Some still do. GE, for example, looks for candidates with deep knowledge in specific areas and have a commitment for life-long learning, said Stephan Billers, GE's chief manufacturing scientist, who directs a team that develops IoT-related software and hardware to digitize manufacturing processes.

GE also spends billions on ongoing business and technical training initiatives, internship and co-op programs, and online courses. "We hire talent, not skills," Billers said.

But it's difficult for small companies to offer the same opportunities. "Startups don't have the money to burn on training," said Kayla Matheus, a Yale-trained mechanical engineer who invented MOTI, an IoT device designed to help people develop better habits, and founded a San Francisco-based company of the same name to commercialize it.

Many companies, especially those that can't afford to train young employees, expect universities to do a better job teaching mechanical engineering students practical IoT skills. Matheus's startup is no exception. Its namesake product has as much to do with software as hardware. She and her small team develop cloud-based databases, manage firmware, and have created a smart-phone app, and they integrate all these technologies into the device's ecosystem.

Matheus hopes the young engineers who apply to her company will have a working knowledge of

"Startups don't have the money to burn on training"

— Kayla Matheus, a Yale-trained mechanical engineer who invented MOTI (pictured)

these skills their first day on the job. A little marketing, supply chain, and overseas manufacturing experience would also be nice. "We need people who can wear many different hats but who also have focused experience," Matheus said. "We're looking for a unicorn."

REAL-WORLD SKILLS

To prepare for these new jobs, students need a deeper understanding of the cornerstones of IoT, including data analytics, networking, cloud computing, mechatronics (a combination of mechanical, electrical, computer, and controls engineering), automation, and robotics. Young engineers don't need to be crack computer programmers, Hirst and others said, but they need to have enough working knowledge of other specialties to understand what their co-workers or teammates—from designers to data scientists to marketing experts—are actually talking about.

To give them that working knowledge, some companies are taking matters into their own hands.

Siemen's PLM, which sells a suite of software that automates manufacturing processes, donates millions of dollars in IoT-related software, curriculum, and training to more than 3,000 schools, universities and organizations around the world. The company also supports dozens of government, industry, and academic initiatives to provide mechanical and other engineers with the computer-related skills they'll need for IIoT and Industry 4.0 jobs. "More real-world activities will help solve some of those challenges we face," said Dora Smith, Siemens PLM's global director of academic programs.

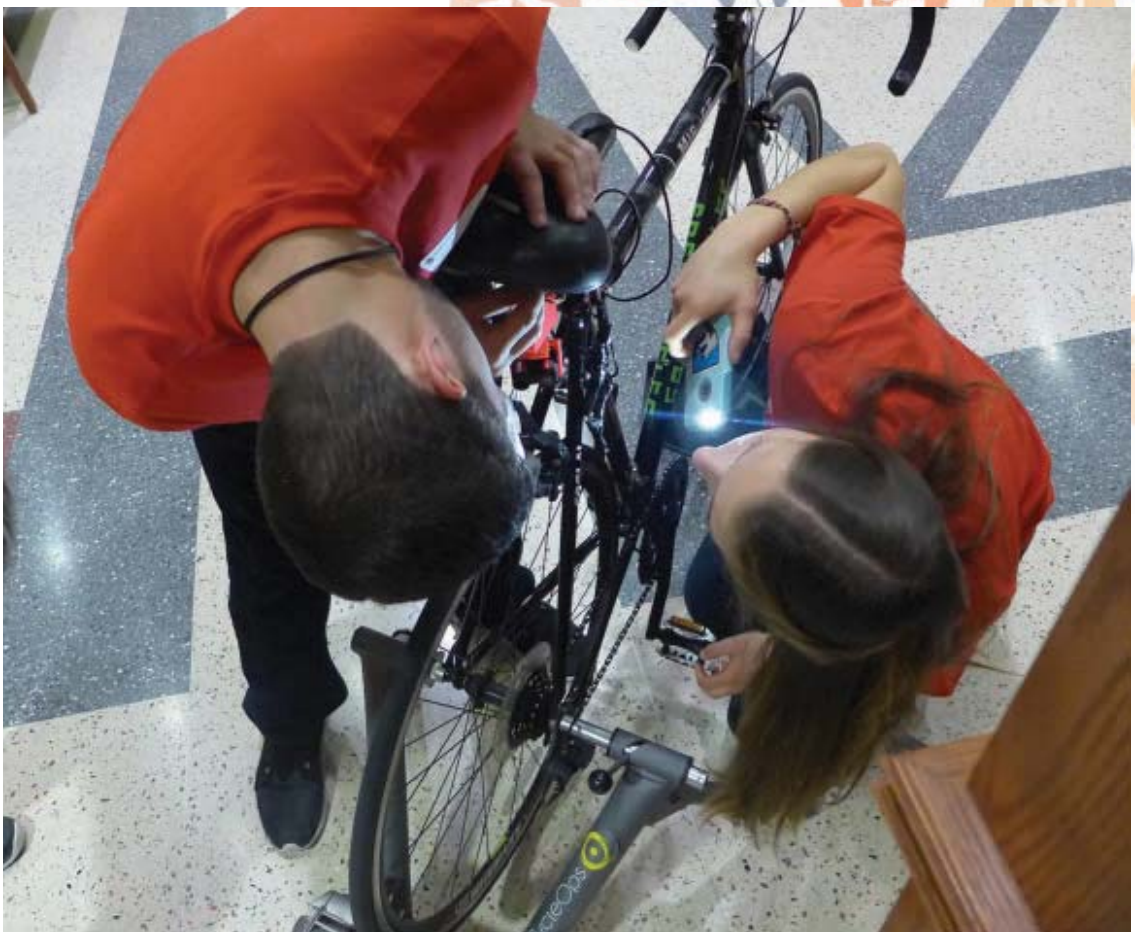
ASME, for its part, hosts a series of global engineering competitions called the IShow, challenging young engineers to design a marketable product that will have a social impact. Each year, more of those projects include sensors, connectivity, cloud computing, and other IoT-related technologies, said Mahantesh Hiremath, a distinguished engineer at Space Systems Loral, a satellite builder in Palo Alto, and an ASME Fellow.

"All those projects on display are very much in tune with what young mechanical engineers will see in the workplace," he said. ASME also offers national and local professional development courses and seminars on IoT-related components like sensors and big data. It also works with academia to shape STEM curricula from kindergarten through university.

Engineers compete in ASME's IShow India. The international hardware competition features many solutions that include IoT-related technologies. Above is Navyo, a Bluetooth-connected smart glove accompanied by a Mobile App that can guide a blind person turn by turn via vibrations.

"All those projects on display [at IShow] are very much in tune with what young mechanical engineers will see in the workplace."

— Mahantesh Hiremath, Space Systems Loral



Will Caldwell and Katie Miller inspect the Safe Cycle, a device they designed to alert a bicycle rider to traffic behind the bike. *Photo: David Tenenbaum/University of Wisconsin-Madison*

THINK DIFFERENT

Training efforts by corporations and organizations can help teach young mechanical engineers how to incorporate IoT technologies on the job. But to properly prepare students for positions created by new IoT technologies, university engineering programs will have to do a better job at contributing, industry and education leaders agree.

Raj Veeramani, a University of Wisconsin-Madison professor in the Industrial and Systems Engineering Department, realized that a few years ago. Since then, he and a handful of other thought leaders have been developing better ways to teach and train young engineers to give them IoT skills.

One of the best is to have students from different majors collaborate on hands-on projects that include IoT components, Veeramani and others say.

"You need to expose [students] to different technologies, designs, disciplines, and business models."

— Professor Karthik Ramani, School of Engineering, Purdue University

For that reason, he and his colleagues launched the IoT Lab two years ago. They saw it as "a tech sandbox" that would bring together students, including those with nonengineering majors, to explore, innovate and engage in problem solving and entrepreneurship with IoT technology.

Veeramani papered the campus with flyers announcing the IoT lab's first informational session, which fell on an incredibly cold January night in 2014. It didn't help that he forgot to mention on the flyer that there'd be free pizza. "I wasn't sure if anyone would show up," he said.

Meanwhile, a handful of other university engineering departments have developed similar initiatives. They're typically set up in partnership with government or industry, which are turning to universities to understand IoT and figure out how to take advantage of the technologies and related business and marketing strategies.

In these programs, students typically pitch an IoT project or build a solution to a problem posed by a company or government agency. The univer-

sity supplies the parts, equipment and guidance the student teams need to complete their projects. The energy, knowledge, and ideas fostered by the environment benefit the corporate or government partners as well. "They bring together a lot of smart people to make the progress you couldn't do alone or with other private companies," said Daryl Erbs, vice president of technology at Manitowoc Foodservices, one of about 25 companies that have joined the IoT Lab's consortium.

Each university adds a few twists to differentiate their program. Karthik Ramani, a professor in the School of Engineering at Purdue University, for example, is developing a set of kits for core mechanical engineering classes with all of the basic components students could use to build an IoT-enabled device related to class topics. He also teaches a popular toy design class where he encourages students to build products and develop business models that fit into the IoT ecosystem. On top of that, Ramani started an IoT product-design contest in his mechanical engineering class.

"If you want to get the best of all worlds, you need expose [students] to different technologies, designs, disciplines, and business models," he said. "That's an interesting concoction that is not found in traditional university settings."

A NEW DIRECTION

Back at the University of Wisconsin-Madison, more than 80 students showed up on that cold winter night for the IoT Lab's open house. Student interest in IoT has blossomed ever since. At a subsequent open house last fall, more than 280 students from a variety of majors showed up. Today, half of the lab's 40 participants are engineers, while the rest are from nonengineering majors, such as computer science and business. About 30 percent are usually women, a much higher percentage than in most engineering-related activities, Veeramani said.

Will Caldwell was one of those participants. His friend—a nutrition major and cycling enthusiast whose friend had been hit by a car—had inspired him to develop a system that would alert bicyclists of a dangerous traffic condition and help them avoid injury. He thought the IoT lab might help him figure out how to go about it. At the open house, Caldwell hit it off with the other students and made a strong pitch to the judges, who accepted his project, which he eventually called Safe Cycle.

The lab, he said, had everything he needed to make his project a reality. "It has the newest, coolest stuff," he said, mentioning an Oculus Rift virtual-reality system; Google Glass; drones; plenty of Arduino boards, Raspberry Pi microcomputers, actuators, motors, and sensors; and a huge RFID container packed with past and present projects to inspire new design and technical ideas.

The University of Wisconsin-Madison IoT Lab is "a tech sandbox" that would bring together engineering and nonengineering students.

During the three months he spent working in the IoT lab, he managed a four-person team that included the nutritionist, along with a mechanical engineering major and an electrical engineering major, both freshman with no project experience. By necessity, each team member did a bit of everything, learning what they needed as they went along. "You ended up doing electrical engineering, computer science, design and marketing," Caldwell said. "I learned so many things in the lab that I couldn't learn in class."

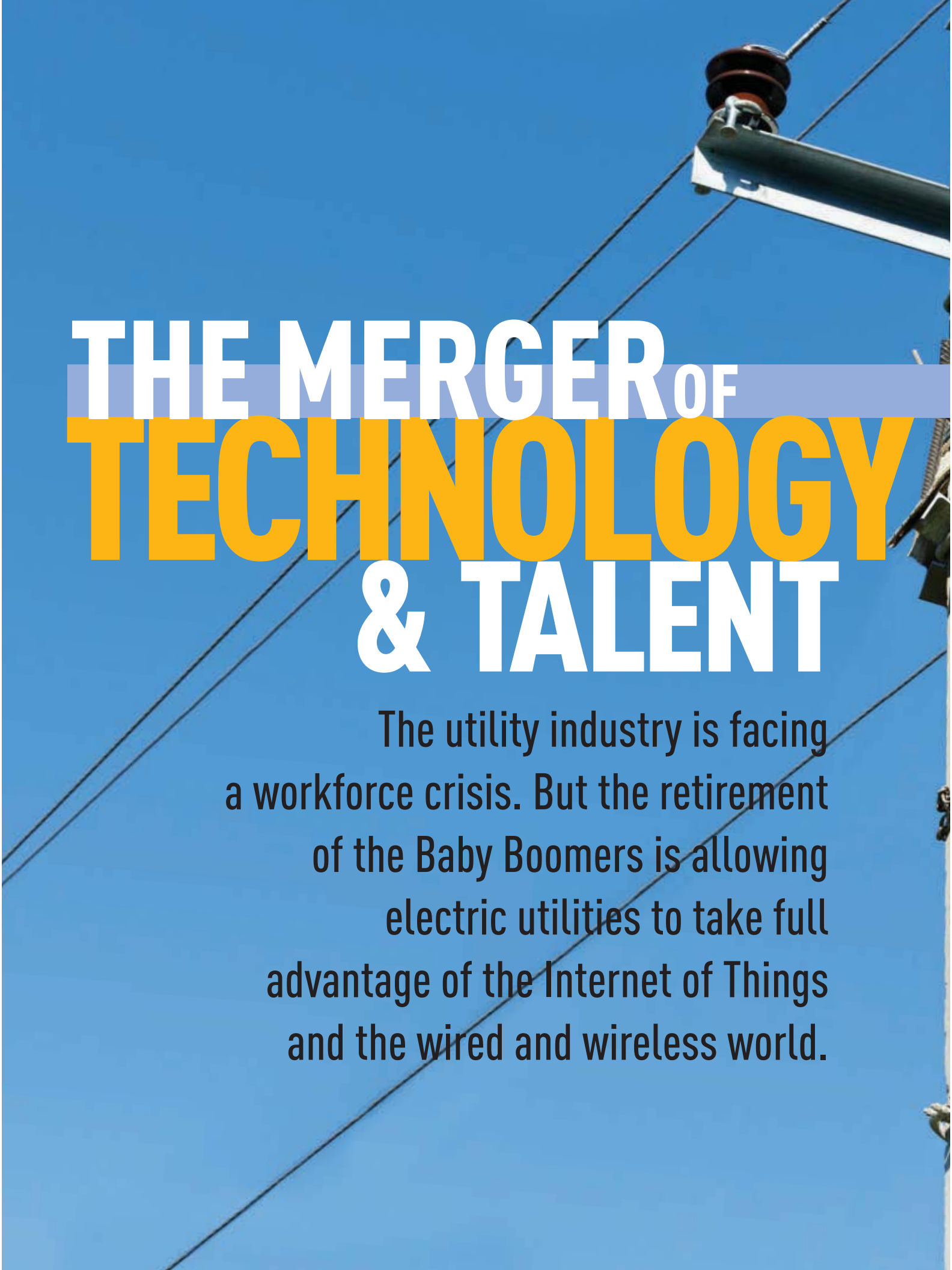
At the end-of–semester open house, Safe Cycle won an award for "Most Potential Impact." And the experience changed Caldwell's career path entirely.

To develop his interest in IoT, he added a computer science major to his mechanical engineering major and tacked on a minor in electrical engineering to build what amounted to a major in mechatronics.

"I was strictly mechanical engineer until the end of last semester. I wanted to build cars," he said. "Now I want to build drones, robots, and other things."

He seems to be on his way. Last summer, Caldwell was hired by a team of UW plant scientists to design and build machines that use connectivity and sensors to capture data on growth patterns of carrot and corn crops. "They were interested in my experience in IoT," he said. "That's what got me the job." ME

JEFF O'HEIR is a contributing writer.



THE MERGER OF TECHNOLOGY & TALENT

The utility industry is facing a workforce crisis. But the retirement of the Baby Boomers is allowing electric utilities to take full advantage of the Internet of Things and the wired and wireless world.

By Marc Goldsmith

By now, you've probably heard plenty of bad reports about the Millennial generation. Supposedly, they are pampered, unmotivated, always in need of praise or the dreaded "participation trophy."

I couldn't tell you if those stereotypes are at all accurate. But I do know that managers in the electric power, transmission, and distribution industry haven't had to worry about catering to Millennials. The bulk of the workforce in the electric utilities is made up of members of Generation X and the Baby Boom.

Now, the Baby Boom generation is starting to retire. In fact, according to a 2013 report by the Center for Energy Workforce Development, more than half of the current utility workforce will retire in the next ten years. As the Boomers retire and leave the business, it isn't just a question of hiring new people. Utilities need to find a way to hold onto critical knowledge and important institutional awareness of these longtime employees while letting go of the obsolete information that they also hold.

But perhaps the more important question isn't how to replace the Baby Boomers, but *whether* to replace them. Some of what these employees are doing already can be replicated by new technology. Advanced Meter Infrastructure—the so-called Smart Grid—and the suite of devices known as the Internet of Things will play a major role in the transition to a new workforce, and change the types of workers utilities employ. This new technology will require new skill sets to construct, operate, maintain, and decommission.

That means that the replacement of older workers cannot be a "one for one" process. New workers will be doing different tasks—most probably at a higher skill level—within the same business process.

The New Utility

When the Baby Boom generation was first hired by utilities in the 1970s and 1980s, the industry was much different from what it has become today. Utilities were adding generating assets—mostly coal and nuclear plants—at a furious pace to meet rapid consumer load growth. The need for new workers was great, so recruiters brought in a surge of fresh faces at every level of power plant operations as well as transmission and distribution.

Deregulation, higher capacity factor operation, energy efficiency, and an economy slowly shifting away from manufacturing meant that utilities could make do with generating assets built decades ago rather than adding more. And that meant that, by and large, they could make do with their existing Boomer and Gen X employees. The great surge in the workforce 30 years ago has moved like the proverbial pig through a python. The average employee has been getting older every year while few new employees were being added.

These longtime employees have been a good deal for utilities and customers alike, since their experience has helped ensure the kind of reliable service customers expect. Indeed, reliability is more important than ever, since our homes and businesses have grown dependent on digital technology that does not happily tolerate interruptions in electrical supply.

While digital technology has upped the customer expectation for reliability, it has also opened up new possibilities for electric utilities. Digital technology, combined with and contained in such devices as cameras, strain gauges, accelerometers, microphones, and the like, can replace the senses of workers. Software coupled with computing power can improve the speed and accuracy of the engineering calculations or better analyze risk. Robots or unmanned vehicles can carry tools and sensors where it is dangerous or uneconomical to send workers.

Utilities could make do with their existing Boomer and Gen X employees. That great surge in workforce 30 years ago has moved like the proverbial pig through a python. The average employee has been getting older every year while few new employees were being added.

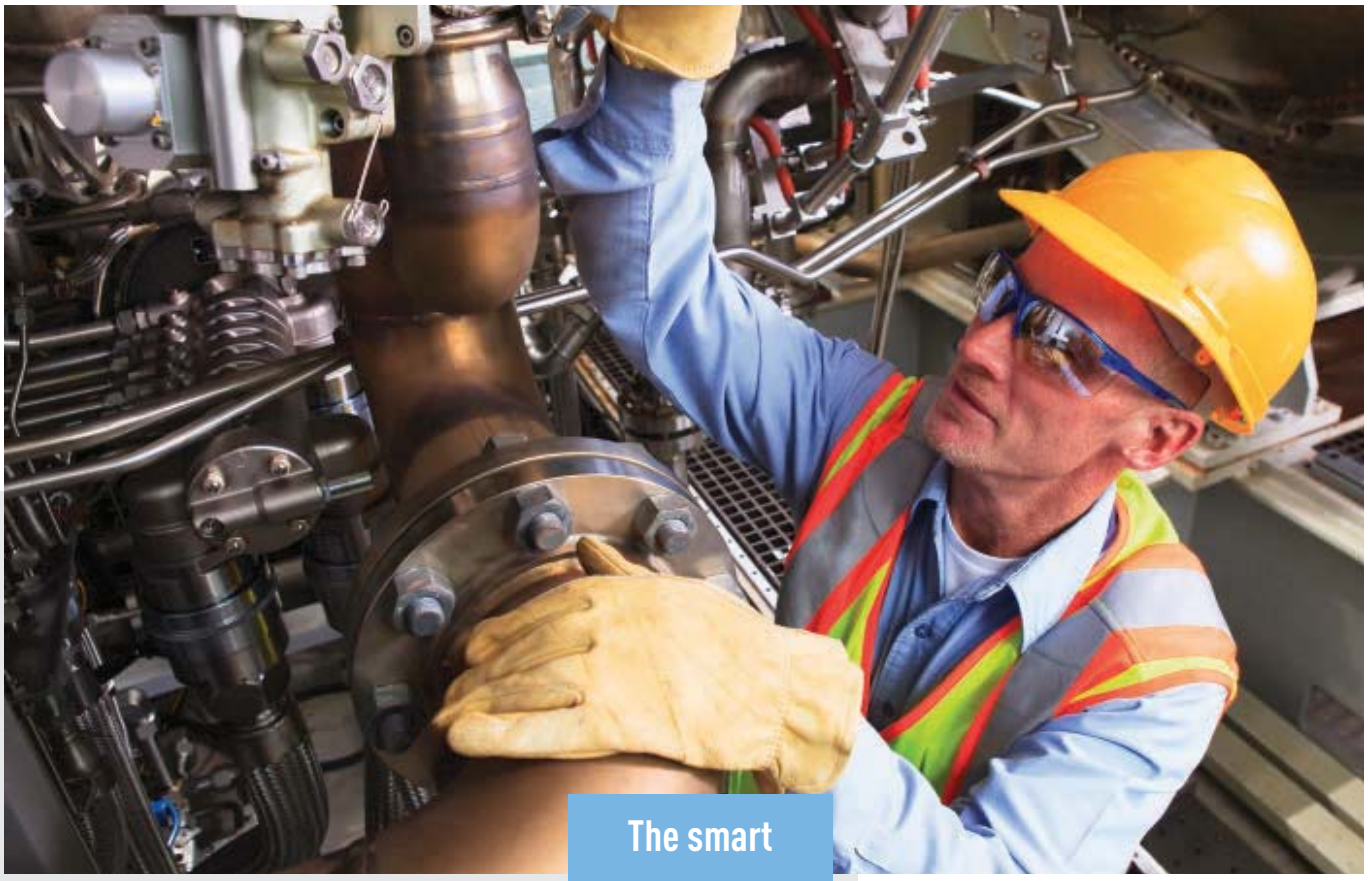
This suit of sensors and automation—including digital meters, advanced two-way communication, meter data management, customer billing software, and customer relationship management software—have enabled utilities to start building out the so-called smart grid. Utilities operating a smart grid are better able to monitor customer demand and in some instances collaborate with the customer proactively to turn off connected appliances and reduce load. The smart grid is also critical for moving utilities from their traditional baseload generation paradigm to distributed generation, which includes intermittent wind and rooftop solar power as well as feed-in from small-scale combined heat and power plants.

But as the complexity of technology control increases, these changes also shift the workforce.

One example of these changes starts at the customer meter and works all the way forward to the bill payment.

In the past, meter readers walked the street once per month and physically viewed each meter. They recorded the numerical readout on the meter and that monthly reading was carried back to the central office, where a billing specialist would calculate the usage based on the meter reading. A tariff approved by the local utilities commission (known as the rate) would be multiplied by the usage, adjustments made, and a paper bill sent out to the customer. The customer could pay by going to a billing office (in some communities the post office or general store) or mail the money to the utility.

As metering becomes smarter and more automated, meter readers, billing, accounts receivable, cashiers, and similar workers are being replaced not one-for-one, but by end-to-end software that starts at the meter and doesn't stop until the final bill



payment is received.

Now the meter reads itself every 15 minutes or less, and the results are radioed to a central meter data management system (computer plus software) and the usage calculated. That usage is sent to a customer relationship management system or billing system which prepares the bill and transmits it in whatever format the customer desires. The customer can set up automatic payment, or pay by cash or credit card.

Essentially no human intervention is necessary unless a customer calls for a problem.

The system replaces workers with IT and increases the need for programming staff and highly specialized customer service representatives to handle exceptional customer situations. It also increases the demand for engineers to continually add to and upgrade the hardware, software, and systems.

The smart grid and other Internet of Things technologies will require workers to draw from a broader set of skills.

There are other digital and information technologies that are transforming work and the worker at utilities. Supervisory control and data acquisition, or SCADA, systems are used to control the transmission and distribution system and address changes in load, supply, and impacts of weather, failures, and accidents. A control room SCADA system is faster than humans could ever hope to be. It can process a significantly larger amount of information and autonomously communicate and control with sensors, controllers, and displays to open and close breakers, switches, and other equipment. This speed, sophistication, and scope helps improve safety and

increase reliability and system quality.

What's more, SCADA systems are reducing the need for the manual switching of circuits in the field—and with it, the number of line jobs. Anyone hired for a line job today will, however, need to have more digital skills than ever before, as the sensors and controls are all being digitized.

Digital and Analog

New technology is changing the role of engineers, as well. The smart grid and other Internet of Things technologies will require a broadening of the skills needed to service the equipment, the system growth, and the customer expectation.

For instance, the hand calculations that engineers have traditionally performed to estimate electrical loads, wire sizing, relay setting, reverse current, reactive voltage, and numerous other tasks can now be more easily and dependably done by specialized software applications. There are more than fifty software programs available to support electric utility system design. Some of the more common ones are ETAP, AutoCad Electric, MatLab, and EA-PSM.

Software is also assisting the mechanical engineer in sizing new towers, calculating physical loading, and performing a variety of thermal and design tasks.

On the other hand, SCADA systems that are being installed to improve utilities' reliability, costs, and response times also require more engineering to assure that the systems live up to the promised standards and are safe from cyber threats. And while technology is replicating many of the jobs engineers customarily performed, it is also amplifying the speed, productivity, and accuracy of what a single engineer can do.

On balance, then, what does the Internet of Things, digital revolution, and information boom mean for the engineering workforce in the electric utility industry? As the industry becomes increasingly digital, how should it respond to the Baby Boomer engineers who are now retiring and taking with them their analog skill set? Or has that analog knowledge become obsolete?

Technology is replicating many of the jobs engineers customarily performed, it is also amplifying the speed, productivity, and accuracy of what a single engineer can do.

Perhaps the most important question facing utilities and their human resource managers is: Do we need to replace that knowledge one for one?

I think not. But before that engineer goes into retirement we need to capture his or her institutional knowledge of the systems, operations, and maintenance that were never codified and therefore won't be available to the new user. In instances where training and institutional memory is lost, failures go up—and it is far from certain that the new smart grid technologies can make up the difference. Instead, if that knowledge is captured and stored in a systematic way, utilities would have a corporate institutional memory that is available on-demand to every employee.

A variety of new technologies, both used singularly and coupled together, will form the backbone of this knowledge capture. Examples of technology coupled together are helmet cams creating You-tube videos of work examples that train new engineers. Oil companies are using both Artificial Intelligence and virtual reality to both store knowledge and translate it into the engineering space.

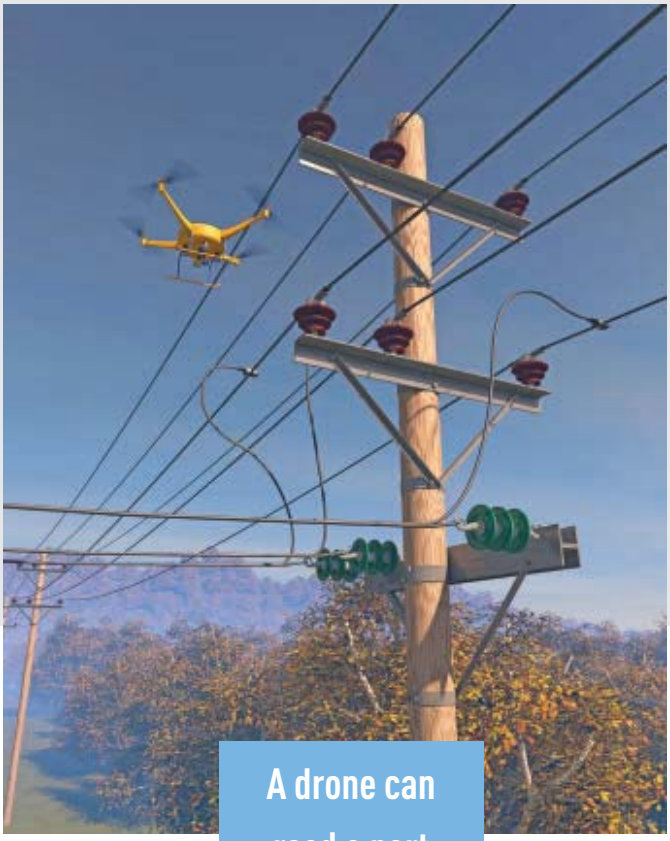
Online tools include the ability to pull drawings, procedures, and other information necessary to effect a field repair to an on-line mobile device.

Navigating Change

For mechanical engineers who are currently in the middle of their careers at electric utilities, there are two distinct areas where new technology is both assisting and

competing with them.

On the one hand, new tools and technologies are making fieldwork safer and more efficient. For example, a drone can read a part number on a high voltage line where before it took three workers. The use of drones in this way is not only faster, safer, and less labor-intensive, but it can also provide more information, such as images of the area surrounding the damaged part that can be sent back to the office for analysis. In New York, Con Edison recently announced it is deploying an aerial drone that can inspect power plant boilers.



For the engineers doing design, operations, and maintenance from the office, the plethora of new software and other tools is amazing. Calculations that used to take days to do and more days to draw now take a fraction of the time—creating significant productivity improvement.

However, the time freed up by automated calculation is now going into analyzing the new big data sets as the information streams multiply and need to be analyzed and acted on. While CAD/CAM and other software reduce stress, static, and dynamic loading—as well as create better as-built drawings—new engineering tasks are created by the need for higher reliability, lower cost, greater cyber-security, and the maintenance of aging infrastructure.

In addition, engineers will need to work with a variety of other disciplines to define the knowledge, new skills, and technologies that will create ongoing value for the utility while maintaining the reliability and service that customers demand.

A drone can read a part number on a high voltage line where before it took three workers—and can also provide more information.

Ultimately, the most important impact of the smart grid and the Internet of Things on the engineering workforce is that utility companies will expect fewer engineers to deal with larger and more complex problems. The engineers who will have the greatest value to utilities are the ones who can best navigate the changing interface between knowledge, technology, and humans.

Given their reputation as savvy users of digital technology, I think engineers from the Millennial generation will be of great value to electric utilities. The Bureau of Labor Statistics expects only small growth in the number of engineers in the utility business in coming years. My take is the increasing reliability, complexity, knowledge needs, ownership of distributed generation, environmental control, and cyber-security (to just name a few of the engineering opportunities) will lead to a much greater need for new engineers in the electric power sector.

I'm still not sure whether engineers will be needed in as great numbers as they were during the great hiring spree of the 1970s and 1980s, but good engineers always can create new value for the electric power sector and are not going away from the utility business soon. ME

MARC GOLDSMITH is the founder of Marc Goldsmith & Associates, a Boca Raton, Fla., engineering consulting firm. He was ASME President from 2012 to 2013.

HEAT SINK

Microsoft lowers its first test underwater data center into the ocean from a pier in San Luis Obispo, Calif.

SUNK

By Alan S. Brown

Big data centers draw massive amounts of power, forcing technology companies to find innovative—and unlikely—ways to remove the waste heat.

Computer scientist Ben Cutler had spent four years at DARPA, the Defense Advanced Research Projects Agency, piloting large programs to develop military battlefield software. Now he was ready to return home to Seattle.

The problem was, he needed a job. So he started reaching out to people he knew in the Seattle area, including Norm Whitaker, a former DARPA deputy director. Microsoft recruited Whitaker from DARPA six months earlier to head up Microsoft Research's Special Projects group, which was dedicated to high risk, high payoff projects.

Whitaker, it turned out, had a job for him. He asked Cutler if he wanted to design and build an underwater data center.

"My first reaction was, 'I'm not going to Microsoft if this is what they're doing,'" Cutler said. "I think I had the same reaction anybody does—it doesn't make any sense."

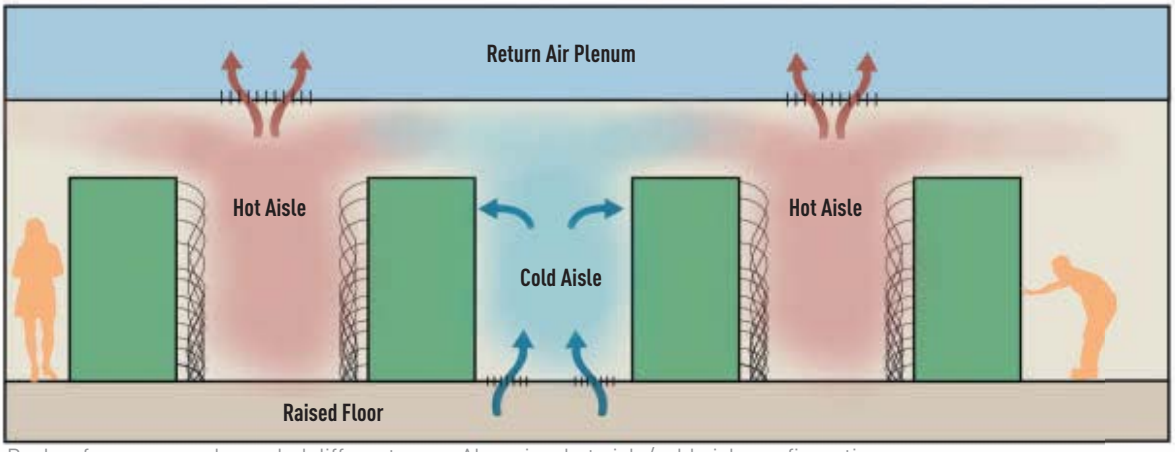
Data centers provide computing power for everything from corporate networks and websites to streaming video and smartphone apps. Submersing racks of electronics in water, where small problems would go unfixed and a single leak could take down the entire system, is not something most engineers would readily embrace.

Cutler rejected the underwater data center out of hand.

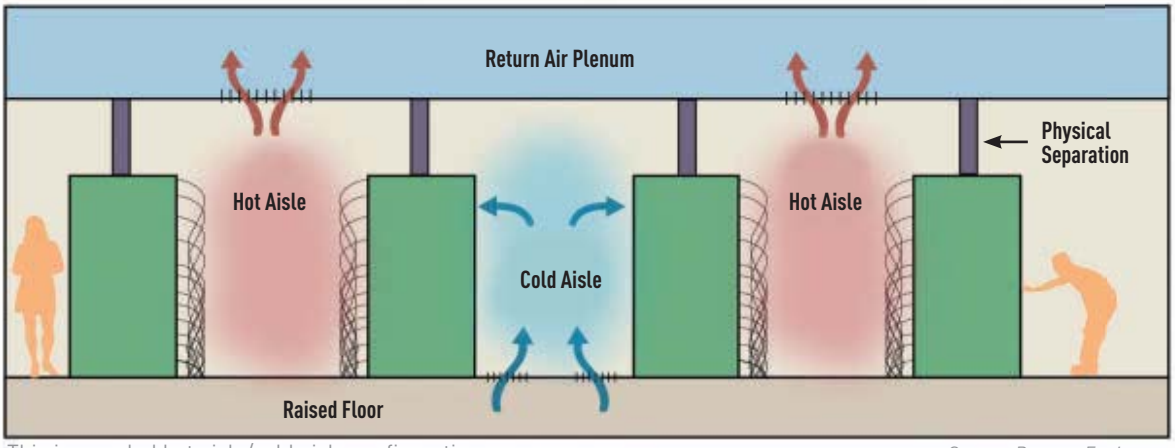
Yet he couldn't get the proposal out of his mind. As he worked through the physics and science, he realized it was not as crazy as it sounded.

For all the downsides of locating a data center underwater, there was one decided advantage. Cold ocean water could provide a cheap source of cooling.

Heat is the enemy of large data centers, which draw and then must shed power by the megawatt. Most data centers spend a significant share of their electrical budget on refrigeration, to keep their circuits from



Racks of servers can be cooled different ways. Above is a hot aisle/cold aisle configuration.



This is a sealed hot aisle/cold aisle configuration.

Source: Rumsey Engineers

cooking. And increasingly, the companies that run data centers are looking for any advantage they can in reducing the cooling costs. Some are building data centers where electricity is cheap and the air is dry and cool. Others have replaced refrigerators with giant cooling towers.

The ocean, however, is an ideal heat sink. Nuclear submarines rely on ocean water to cool heat exchangers used to chill coolant for their nuclear reactors. And submarines have an excellent record of keeping sensitive instruments dry and happy.

In fact, one of the Microsoft employees who first proposed the concept to Whitaker had served aboard a submarine.

Underwater data centers might have power, construction, and performance advantages as well.

Cutler called Whitaker back and they talked some more. In July 2014, Cutler joined Microsoft. One week later, he was leading Project Natick, Microsoft's effort to build a data center that could operate under the sea.

By the next summer, his team was testing out the concept off the coast of California.

Running Full Tilt

Corporations have had data centers for decades, but the Internet and cloud computing sparked their rapid growth.

"Today, everything that we think would normally run on a PC or cellphone is no longer there," said Brent Draney, group lead for networking and security at National Energy Research Scientific Computing Center in Berkeley, Calif. "Those apps and streaming media are running in a data center somewhere else. PC's and phones are really just data movers."

Data center companies of all types struggled to keep up with demand as business took off at the beginning of the decade. Every other priority took a back seat to adding capacity and running it full tilt, 24/7. Anything less and they might lose users—and profits—to faster, more nimble competitors.

That narrow focus could be seen in something as basic as cooling. Most data centers spend a small fortune on chillers, the ton-sized air conditioning units that chill air to cool rack after rack of stripped down computers called

servers. There are ways to economize on this—entraining the cold air directly to the racks, say, or venting the air after it has heated—but instead, many operators let hot and cold air mix, and ran their air conditioners overtime to cool their data center. Data center managers also kept rooms too cold, ran fans too fast, and failed to use their servers' power management features. Nearly half of large companies did not benchmark power use.

In fact, they struggled even to measure electrical efficiency. The industry's metric of choice was something called Power Use Effectiveness, which is total electrical consumption divided by electricity used for computing. According to a 2012 survey by the Uptime Institute, an IT professional organization, the industry's average PUE was 1.8 to 1.9, meaning only about half of the power draw was used for running servers.

But even some of those servers were not being used productively. Most of the time, they were waiting for something to do. Data center managers also kept older, slower units running as backups. Other servers continued to run, even though no one knew what they were being used for. For PUE calculations, power spent running those underused servers counted as computing. An accurate PUE that excluded underutilized servers might have been 3.0 or a less efficient rating.

No one really knew, and as long as the servers kept running, no one really cared.

Harnessing Nature

Today, data center electricity use has been slashed. Servers at the best performers are running at full capacity, and there are no slow units to be found. Google's average PUE is a remarkably low 1.12 and its competitors in the data center business are in the same ballpark. Their costs are so low, they can sell cloud computing services to less efficient IT operations. How did they do it?

One place to study data server best practices is the new 149,000-square-foot facility at Berkeley's National Energy Research Scientific Computing Center. The facility has a lot in common with large data centers run by the best cloud providers. Both consume more than 5 MW of power and use similar technology and similar strategies to manage power and heat.

While most businesses consider data center technology a closely guarded secret, NERSC's Draney is happy to talk about what makes his testbed one of the world's most efficient data centers.

For instance, just like today's best conventional data centers, NERSC runs its large supercomputers as virtual machines. That means that in spite of having hundreds of thousands of processing cores, the supercomputers act as a single unit that can be subdivided into multiple smaller "virtual" computers to run multiple jobs simultaneously. This not only improves utilization, it eliminates the need to run "just in case" vampires.

> **"Today, everything that we think would normally run on a PC or cellphone is no longer there. Those apps and streaming media are running in a data center somewhere else. PC's and phones are really just data movers."**
>
> **— Brent Draney, Group lead for networking and security National Energy Research Scientific Computing Center, Berkeley, Calif.**

To further improve performance, designers packed the processing cores much closer together than in a conventional server. The racks of NERSC's large Cori supercomputer jam two nodes, each with 16 cores, onto a single circuit board. Each rack holds 48 of those circuit boards, and needs two 100-Amp, 480 V feeds for power, Draney said.

The configuration of Cori's second phase will be even denser, with 68 cores per node. Overall, each rack consumes between 65 and 75 kW. That's four to five times more power than a conventional server rack.

That density improves performance—the shorter the path between the cores, the faster they can communicate with one another—but it also increases the amount of waste heat to be bled off. In fact, it's too much heat for air cooling, so NERSC turned to liquids. Water removes heat 1,000 times better than air. Cori uses what Draney calls "nearly liquid cooling." Today, water-cooled heat exchangers chill air before blowing it across the rack. The next phase will use direct liquid cooling, running water through a cold plate on top of the cores, Draney said.

NERSC recycles its chilled water. Most data centers would do that by running the water through a heat exchanger cooled by a chiller, but NERSC does it by tapping one of Berkeley's great natural resources—the cool air coming off San Francisco Bay. "We have the world's greatest cooling system," Draney said.

His data center uses that air to naturally chill a cooling

NERSC's supercomputer center uses bay breezes to cool computers.

tower to remove heat prior to recycling. NERSC also uses air to chill the data center and cooler-running components, such as disk drives, routers, and network servers. By using a combination of cooling towers, inlets, fans, and baffles, Draney can keep building temperature and humidity within the narrow range of conditions best suited for electronics.

Cooling towers are less expensive and far less prone to breakdown than chillers, and they cost less to operate. And water is easier to pipe in and out than air. Those savings make the building less expensive than a similar sized conventional data center.

Most commercial data centers do not have NERSC's enormous heat loads, but they have begun to use similar strategies. Some open their windows to cold desert air at night. Several have located to cooler Scandinavian countries, where they draw cooling water from fjords. One sits deep underground, in an abandoned mine. In Belgium, Google went the other way, and operates at temperatures so high, technicians cannot approach the servers for prolonged periods of time.

And everyone is looking at advanced water cooling.

Cool Runnings

One driver for Project Natick's underwater data centers is access to a great heat sink. "The ocean," as Ben Cutler noted, "is a very cold place."

Cutler's team deployed *Leona Philpot*, Project Natick's first submersible data center, in the cold waters about a mile off the coast of California in 2015. The 10-foot-long by 7-foot-wide capsule weighed in at 38,000 pounds. It carried 300 servers on racks designed to rock gently in the current.

For 105 days, the *Leona Philpot* sat 30 feet below California's ocean surface collecting data from dozens of sensors that measured pressure, humidity, motion, and temperature. Microsoft also installed cameras so it could observe the interior.

Leona Philpot used simple heat exchangers and closed-loop air cooling to bleed off heat. Operating on the sea floor makes it cheap and easy to run data centers at very low temperatures, which lowers the failure rate of its electronics.

With the growing efficiency of data centers, better cooling might not be enough to make underwater operations worthwhile. But cooling is only one of the advantages that Microsoft sees in submerging its data centers. Submersibles also simplify deployment. Today, a data center project takes two years to complete, Cutler explained: In addition to buying land and building and commissioning a facility, companies must line up electrical power, file

environmental permits, and work through tax laws. Even finding a workforce is sometimes difficult in the remote locations where land and power are cheapest.

Submersibles, on the other hand, are prefabricated. Before shipping, technicians have checked every server, wire, and connection. Not only is the ocean a very consistent environment, but once the container is sealed, it is impervious to airborne contaminants and fluctuations in temperature and humidity.

Of course, no one will pay house calls to fix problems either. Microsoft reduces the risk of failure or fire by running cold and substituting nitrogen for oxygen inside the container. Still, equipment will fail.

"Ordinarily, we'd have people running around and fixing things," Cutler said. "Here, we won't do that. We'll let it fail. We accept that capacity will decline over time. And in return, we won't have to pay for people, repairs, parking spaces, or lighting. If you analyze maintenance costs at a granular level, it pays to let some servers fail in place. We can pull the capsule back up to upgrade to next-generation servers every five years."

> "Ordinarily, we'd have people running around and fixing things. Here, we won't do that. We'll let it fail. ... We can pull the capsule back up to upgrade to next-generation servers every five years."
>
> — Ben Cutler, Microsoft

> "Half the world's population lives within 120 miles of the ocean. Putting a data center offshore near population centers reduces the latency and improves the customer experience."
>
> — Ben Cutler, Microsoft

An offshore location also opens up some interesting possibilities for power. Microsoft used an underwater cable connected to the electrical grid to power *Leona Philpot*. In the future, it may reduce costs through renewable energy, combined with on-site energy storage and backup power from the grid.

"We could put propellers in the water and tap tides or currents such as the Florida Gulf Stream, which is 100 kilometers across and moves about 1 meter per second," Cutler mused. "Or we could take advantage of motion from waves, though that is more difficult."

There is one more reason to look offshore, and it is perhaps the most important of all. It is the same reason that has driven data center development since the earliest days of the Internet—performance.

When companies site data centers where land and power are cheap, they are often far from their customers, who more likely than not live in cities and suburbs. That distance creates what is known as latency, a time gap between requests and their fulfillment. Much the way bunching processing cores together improves computer performance, bringing data centers closer to customers reduces latency.

"Half the world's population lives within 120 miles of the ocean," Cutler said. "Putting a data center offshore near population centers reduces the latency and improves the customer experience, whether it's playing a game, watching a video, or extracting files for Microsoft Office."

Leona Philpot was a small step in seeing whether the submersible reality lived up to Cutler's calculations. And Microsoft got some experience working with the marine industry, something new for a land-locked company that has solid ties to academic researchers but not old-line shipbuilders.

"It was the marrying of two mature industries, IT and marine," Cutler said. "It is flip to say that there was nothing really hard about it, nothing that hadn't been done before. But it's a big ocean, and we had some big concerns—could we keep stuff dry? Operate remotely? Keep it cool?"

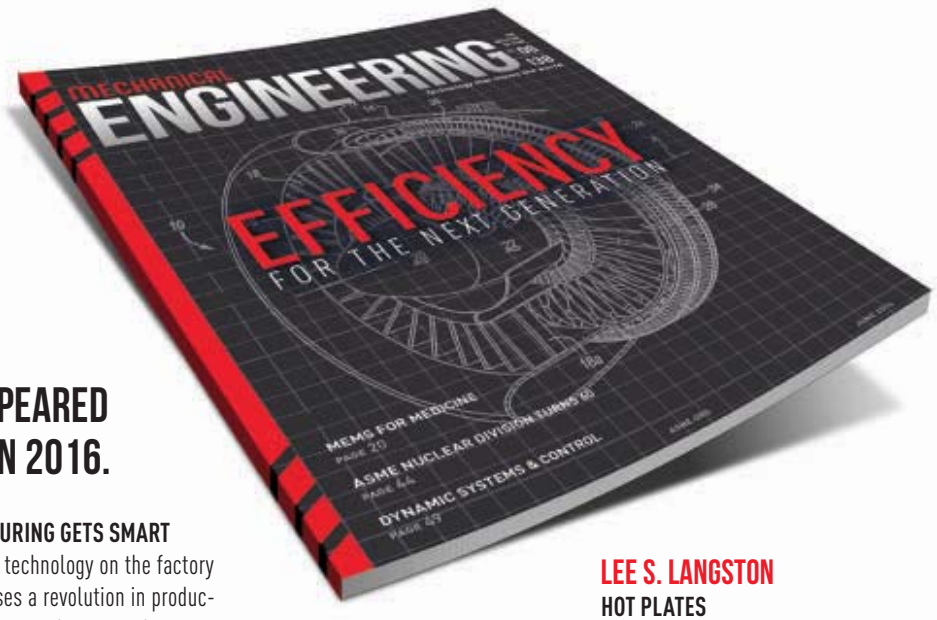
Rather than try to optimize a design, Microsoft simply wanted to prove that the underwater concept would work, and that it would not run into unanticipated problems.

The most surprising element of the *Leona Philpot* experiment was that there were no real surprises. Everything seemed to work. As a result, Microsoft is moving forward on a larger deployment.

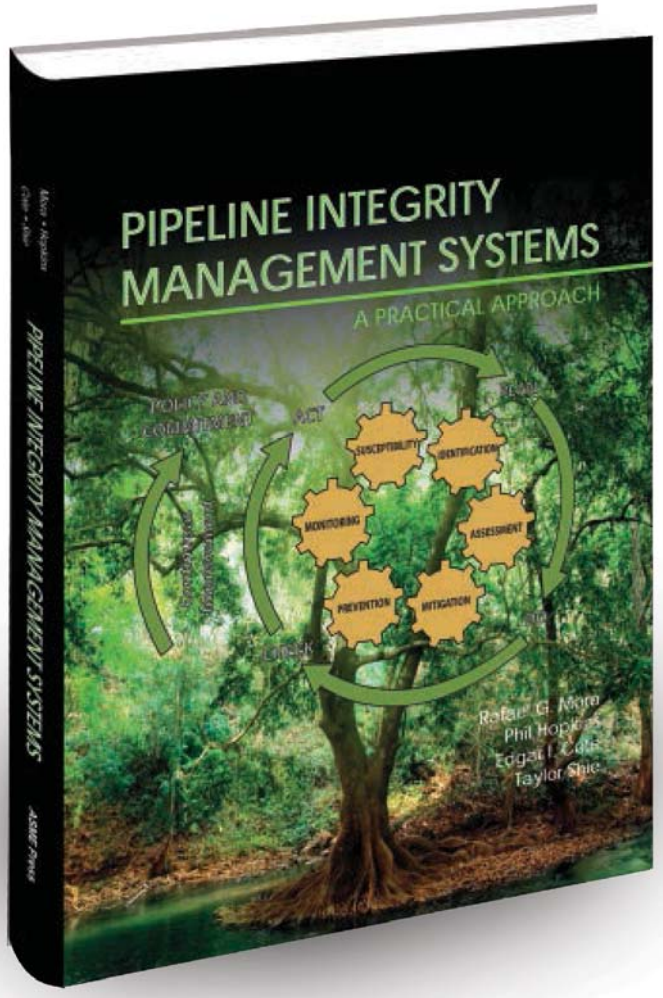
Someday, perhaps, instead of thinking about putting data in the cloud, we'll talk about it living in the ocean. And it won't be a just metaphor. ME

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

2016 ARTICLE INDEX



THE FOLLOWING IS A LIST OF FEATURE ARTICLES THAT APPEARED IN MECHANICAL ENGINEERING IN 2016.



FEATURED

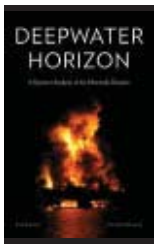
PIPELINE INTEGRITY MANAGEMENT SYSTEMS: A PRACTICAL APPROACH

RAFAEL G. MORA, PHIL HOPKINS, EDGAR I. COTE, AND TAYLOR SHIE

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

When pipelines are working perfectly, they operate out of sight—and mind—of people living nearby. A key to preserving that pipeline integrity is the dynamic linkage and interaction between a management system and an integrity management program. That approach for continuously improving pipeline integrity and sustaining risk reduction is known as a pipeline integrity management system. According to the authors, "The PIMS approach enables organizations to achieve state-of-the-art adequacy, timely implementation, and measured effectiveness of the relentless integrity goals, objectives, and targets toward the safety of employees and the public, the protection of the environment, and a reliable service." Among the topics covered in the book are the engineering concepts that form the foundation for pipeline integrity and methods for performing risk assessments on pipelines, as well as in-line inspection and pressure testing.

350 PAGES. $279; ASME MEMBERS, $223. ISBN: 978-0-7918-6111-0.

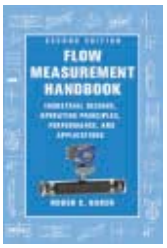


DEEPWATER HORIZON: A SYSTEMS ANALYSIS OF THE MACONDO DISASTER

Earl Boebert and James M. Blossom
Harvard University Press,
79 Garden St., Cambridge, Mass., 02138-1400.
2016.

The 2010 explosion on the floating drill rig *Deepwater Horizon* killed 11 crew members and led to an economic and environmental crisis in the Gulf of Mexico. Boebert and Blossom, both senior systems engineers, sift through the evidence produced by the ensuing lawsuits, to create a comprehensive account of the accident. Contrary to the narrative that arose from contemporary reporting, the authors did not find crew mistakes stemming from cost-cutting pressures to be cause of the accident. Instead, they examined the complex interactions of technology, people, and standard procedures and found that a series of innocuous and understandable decisions led to the disaster.

280 PAGES. $39.95. ISBN: 978-0-674-54523-6.



FLOW MEASUREMENT HANDBOOK, SECOND EDITION

Roger C. Baker
Cambridge University Press,
One Liberty Plaza, New York, N.Y., 10006.
2016.

Now in its second edition, *Flow Measurement Handbook* is a reference for engineers who work on flow measurement techniques and instruments. Baker works to balance laboratory ideas and realities of field experience and strives to provide practical advice on design, operation, and performance of flowmeters. Among the flowmeters discussed are differential pressure devices such as orifice and Venturi, volumetric flowmeters such as positive displacement, turbine, vortex, and electromagnetic, and mass meters such as thermal and Coriolis. This edition includes new chapters covering magnetic resonance flowmeters, sonar and acoustic flowmeters, and verification techniques.

790 PAGES. $135. ISBN: 978-1-107-04586-6.

OPEN-SOURCE CAD

INTELLICAD TECHNOLOGY CONSORTIUM, PORTLAND, ORE.

INTELLICAD 8.2 INCLUDES IMPROVED performance when working with complex blocks, panning and zooming, and exporting to PDF files. The release also features the option to open, save, create, and edit .dgn files in the native DGN format. Integration with Artisan Renderer enables users to create photorealistic images of models using a wide range of pre-set materials and lighting setups, combined with the ability to create custom lights and realistic materials. There is also a new text editor and support for maximizing and minimizing viewports. IntelliCAD 8.2 is supported on Microsoft Windows 10, Windows 8, Windows 7, and Windows Vista, including 32-bit and 64-bit versions.

DATA MANAGEMENT

INNOVYZE, BROOMFIELD, COLO.

Innovyze has released version 5.0 of SCADAWatch, its network data management and business analytics and optimization application for water systems. The new version provides a scalable framework for viewing, sharing, and analyzing water operational information, key performance indicator measures, and hydraulic and water quality data. The application automatically generates comprehensive, high-fidelity performance reports to help utilities develop the optimal course of action based on specific performance objectives. Results are presented on a real-time business dashboard over a standard Internet connection, or on an hourly, daily, weekly, monthly, or year-to-year basis. Users can also graphically select any number of meters for further analysis and display meter readings directly on the map, not only in dashboards. The new version enables data to be shared throughout the organization and sent to mobile devices.

SKETCHING

URBAN DESIGN LTD., SAN FRANCISCO.

Archisketch 2.0 now supports the Apple Pencil, Adobe Creative Cloud, and smart one- and two-point perspectives. The application enables users to import images from their Creative Cloud Library for use directly within Archisketch as well as export Archisketch images to their library. Version 2.0 also provides new dimension lines, a new scrapbook to manage images and receive images from other apps, and the ability to zoom infinitely without losing quality. Also, users can now add text or images, such as a company logo, to an exported file, or print directly from the iPad up to A1 size.

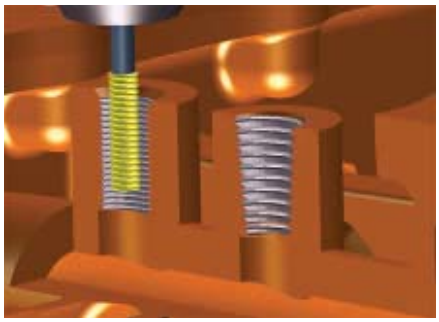
HIGH-SPEED MACHINING

NCG CAM SOLUTIONS, CAMBRIDGE, U.K.

NCG CAM v15.0 includes new functionality to ultrasonic vibration surface machining. It now tries to preserve the original order of surface selection when creating UV machining passes. By selecting the surfaces sequentially to create a chain, the user can minimize retracts and rapid moves. Other enhancements include the ability to use images in the toolsheets and for T-slot cutters to be used in 5-axis mode. When reviewing a plan using the properties dialogue box, users no longer need to use the Ctrl / Shift keys to get extra options, as they are now on the dialogue itself. However, the Ctrl / Shift keys can still be used to set the default options on the dialogue.

CNC PROGRAMMING

3D SYSTEMS, ROCK HILL, S.C.

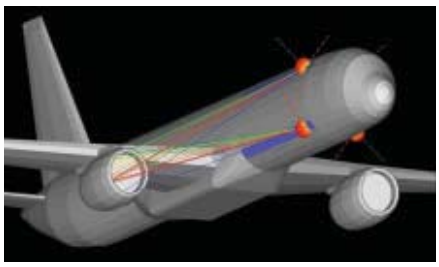


GibbsCAM 2016 builds on universal kinematic machine technology to improve efficiency, accelerate programming speed, and enhance visualization and accuracy for CNC machine programming. The GibbsCAM platform provides a complement to additive manufacturing processes, with the intent of enabling users to transform digital concepts into physical products. GibbsCAM is compatible with a wide range of programming and machining operations, including solid modeling, high speed machining, 2- to 5-axis milling, wire-EDM, and multi-task machining, and is intended to help users eliminate scrap and reduce cycle times. The new

version adds toolpath strategies for 5-axis milling, enabling users to define toolpath direction using the natural flow of a surface with the new flowline option. Toolpaths can also now be extended in width as well as length.

ELECTROMAGNETIC SIMULATION

REMCOM, STATE COLLEGE, PA.



Remcom has released XGtd 2.8, an update to its high frequency ray-based EM simulation software. Version 2.8 adds several new co-site analysis features, which allow users to calculate paths and coupling between transmitters and receivers for EMI/EMC assessment. The addition of transceivers simplifies co-location of functionally independent transmitters and receivers. Different transmitter and receiver properties may be assigned to a common transceiver location, including antenna gain pattern, antenna rotations, and waveform. XGtd 2.8 also supports the import and creation of KMZ and COLLADA geometry files, expediting the import of complex, high-resolution objects to a project, and allowing greater compatibility with industry standards.

NAVAL ARCHITECTURE

SSI, VICTORIA, B.C.

ShipConstructor 2017 is an Autodesk-based CAD/CAM application that now features compatibility with Windows 10. The update lets users attach and view Navisworks models directly inside AutoCAD and snap points to precise locations on an attached coordination model using the standard 2-D endpoint and center object snaps. The WorkShare Model now allows the transfer of individual parts across different projects, which gives users the ability to replicate elements of the 3-D model at a more granular level. According to the company, other performance enhancements include the ability to open weld drawings up to five times faster and to redraw in AutoCAD as much as 27 times faster.

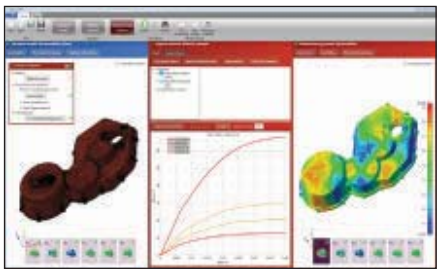
CAD FOR PIPES

PROCAD, CALGARY, ALBERTA.

SpoolCAD-FA is a spool drafting application intended for industrial pipe fabrication companies. It enables the creation of piping isometric drawings and detailed shop fabrication spool drawings for process plant drafting and construction. In many cases, this can be done with minimal CAD or drafting skills. SpoolCAD-FA is built on ProCAD's isometric drafting software and is compatible recent AutoCAD releases, allowing the saving and sharing of drawings in the standard AutoCAD DWG file format.

SCADA

ARC INFORMATIQUE, SÈVRES, FRANCE



PcVue v11.2 offers consolidated support to enable the convergence of SMART Buildings, distributed energy resources, infrastructure, transportation, and industrial automation. It is designed to provide full integration to BACnet equipment, in addition to enhancements for developer efficiency and ease of use. The latest version includes a native KNX and COMMEND SA ICX driver (for Intercom monitoring and control) along with the established LonWorks and Modbus drivers. New BMS libraries include GEZE objects for door, window and safety technology. Drivers for energy management and smart grid interoperability include IEC 61850, 61400-25, 60870-5-104, and DNP3 are built in.

MOLDING SIMULATION

CORETECH SYSTEM, HSINCHU, TAIWAN.

CoreTech has released a new version of eDesignSYNC, the CAD-integrated add-on to its Moldex3D plastic injection molding simulation application. The add-on enables real-time insights into moldability that can flag potential design issues before production. The latest version, eDesignSYNC R14.0, comes with several enhancements to help users identify design problems and make design changes more accurately and efficiently—in particular, the performance of the solver has been improved to yield more accurate simulation analysis results. The new version also offers many post-processing enhancements to make running analysis and result interpretation simpler and more efficient. For instance, the batch run feature adds more flexibility in setting up analyses, to allow analyzing multiple designs with different process settings at the same time.

PRODUCTIVITY BUNDLE

CGS PLUS, CAMAS, WASH.

CGS Civil 3D Tools 2017 is now available for download from the developer, CGS plus. The software bundle is a collection of tools that bring new functionality to AutoCAD Civil 3D, improve workflow, and increase user productivity. The tools are fully integrated with AutoCAD Civil 3D. Among the capabilities provided by the tools is the ability to generate a pipe depth report, swap multiple pipe parts, and to create a pipe network from multiple polylines. Also included are tools for editing points, adding grading, and importing attributes into AutoCAD Civil 3D.

3-D RENDERING

MAXON, FRIEDRICHSDORF, GERMANY.

Cinema 4D Release 18, the 3-D animation, graphics, VFX, visualization, and rendering software application, includes a native feature in the MoGraph toolset in Cinema 4D that works seamlessly with dynamics and enables users to tear down walls and create artistic procedural geometry using spline or polygon objects to define the fractured shape. Interactive knife tools allow the drawing of cutting lines across a model that can be tweaked with an interactive preview. The new release also offers advanced rendering possibilities for creating iridescent surfaces such as bubbles and oil slicks and for capturing shadows for more efficient compositing. The application is available for both macOS and Windows operating systems.

LATHE ATTACHMENT

TORMACH, WAUNAKEE, WIS.

THE TORMACH RAPIDTURN is a 5C CNC chucker lathe attachment designed for use with the company's PCNC 1100 or PCNC 770 mills. The RapidTurn provides CNC lathe functionality without taking up additional shop floor-space, and it can be stored out of the way when not in use. After initial installation, set-up takes just a few minutes. The lathe attachment has a manual index plate with a locking pin. Parts can be securely positioned in 15° increments for secondary work with the PCNC's primary spindle, making it ideal for cutting wrench flats or drilling cross holes on turned parts without additional setups. Tormach offers a complete suite of accessories for the RapidTurn, including quick change toolholders, adjustable tailstock, tooling, and a 3-jaw chuck.

ROTARY ENCODER

LEINE & LINDE, SCHAUMBURG, ILL.

The Leine & Linde 600 and 900 series of absolute rotary encoders use inductive sensor technology designed for environments where temperature, strong magnetic fields, shock, or vibration are extreme. The inductive measurement process involves generating an excitation field in the stator. That field is modulated by conductive patterns on the rotor. Since it is not an optical process, inductive measurement is inherently resistant to contamination from oil or grit. Unlike glass disks which can fracture, plastic disks which can warp or degrade, or magnetic code wheels that can demagnetize, the inductive code disk in these encoders is manufactured using robust fiber-composite construction and printed circuit technology.

SEALS

BAL SEAL ENGINEERING, FOOTHILL RANCH, CALIF.

P78, a high-temperature, high-performance thermoplastic, and P240, a lubricated, fiber-reinforced version of P78, are new product lines in Bal Seal's range of seal materials. The company says P78 and P240 exhibit exceptional heat resistance and minimal wear with excellent load-carrying capabilities at extreme temperatures. Both of the compression-molded materials have a maximum service temperature of 650 °F (343 °C), though effective sealing at even higher service temperatures may be achieved depending on the application. The materials are suitable for applications such as electrical connectors, bearing seals, bushings, and valve seats, and in rotary or reciprocating applications. The company highlights possible applications in the chemical processing and petrochemical industries and those requiring excellent wear resistance at extremely high temperatures.

LINEAR MOTION SYSTEM

LM76, EAST LONGMEADOW, MASS.

Saibo SB-LGC linear motion platform and rail systems, distributed by LM76, are offered in two sizes to meet load requirements up to 6000 N and feature an adjustable preload system to control the required level of precision. SB-LGC platforms have four drilled and tapped holes for mounting tooling, cameras, and test equipment. According to the distributor, the systems offer speeds up to 10 m/s, low weight, and high linear accuracy, and feature sealed rollers and RC60 hardened shafts. They are intended for use in such applications as robotics, assembly, photography, pick-and-place, sorting, packaging, manufacturing, sampling, laser cutting, wafer handling, and other precision applications.

LEVEL TRANSMITTER

VIATRAN, WHEATFIELD, N.Y.

Viatran has introduced the Model 59Y submersible level transmitter series, designed to provide accurate, continuous liquid level measurements of water and wastewater within industrial and municipal environments. The product, which measures hydrostatic pressure of compatible media, features a one-piece design and is available with a choice of PVC, PP, PVDF, or 316L stainless steel material. Units are fully sealed to meet IP68 ratings, and PUR cables are provided as standard. The Model 59Y is offered in submersible ranges from 0-16 inches W.C. to 0-835 feet W.C. The company suggests applications such as use in in-ground and above-ground water tanks, lift stations, and irrigation systems, in addition to inventory tank gauging.

GIMBAL MOUNT

OPTIMAL ENGINEERING SYSTEMS, VAN NUYS, CALIF.

The AU300-XZ motorized three-axis gimbal mount features full 360 rotation of each axis. The rigid black anodized aluminum alloy frame handles loads to 10 kg and has a large enough clearance for mounting lasers, cameras, optics, and instrumentation for pointing, scanning, tracking, and positioning. The footprint of the mount's azimuth-stage rotary table is compact to allow for easy integration into new and existing applications, and the azimuth, elevation, and roll stages all feature powerful bidirectional stepper motors capable of microstepping, together with knobs for manual adjustments. Low backlash worm gear drives and precision "V" groove and cross-roller bearings enable a resolution of 3.6 arc seconds, and repeatability and positional accuracy to 18 arc seconds. The AU300-XZ motorized three-axis gimbal mount can be ordered as a complete plug-and-play system with a multi-axis controller, joy stick, track ball, or keypad, and with a 30 mm thru hole in the roll stage.

LASER SCANNER

KEYENCE, ITASCA, ILL.

The new SZ-V series of safety laser scanners features a system memory plug, network compatibility such as EtherNet/IP, and the ability to receive encoder inputs. Connecting up to three units together in series is also possible with the SZ-V, which greatly reduces the necessary wiring. A camera integrated directly into the unit simplifies installation and may enable the capture of images and video when an object or person enters the protected area. The SZ-V also has a detachable display that provides real-time feedback, protection zone information and even access to historical data, all without interrupting the scanners operation. The manufacturer claims the scanner has a protection range of 8.4 m and has a beam pitch small enough to allow four times the number of beams over the same area as many competing scanners.

BEARING PRELOAD

SMALLEY, LAKE ZURICH, ILL.

Smalley has expanded its SSB bearing preload series, which adds diameters ranging from 9 mm to 13 mm to the product line. The single turn wave spring in the SSB series helps eliminate bearing play and minimizes noise. The constant light-to-medium pressure the wave springs apply removes play between the ball bearings and the bearings' inner and outer races. Preloading can reduce the possibility of bearing damage due to vibration and wear due to repetitive and non-repetitive runout. Thanks to the expansion, Smalley now offers more than 300 SSB springs in carbon and stainless steel.

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.

SERVO ADAPTER

LENZE AMERICAS, UXBRIDGE, MASS.

Lenze Americas has released a new, compact servo adaptor for its g500 gearbox series. The adaptor is offered in a range of standard input sizes for compatibility with most servo motors on the market in the U.S. and Canada. The adapter is intended to provide a more compact and cost-effective solution than using a standard input flange connection from a gearbox to a servo motor. Available as an inline, right angle, or shaft mounted design, the g500 series servo adaptor optimizes available space and reduces the requirement for coupling components.

ABRASION TESTING

PAUL N. GARDNER COMPANY, POMPANO BEACH, FLA.

The Automatic Washability Tester can perform abrasion and washability tests on panels coated with paint, varnish, or related products. Such tests simulate everyday wear such as scratching, wearing and color loss from cleaning actions or general use. The Automatic Washability Tester is driven by a micro-step controlled electronic motor which allows precise and steady speed and sinus wave form control. The machine is operated by means of a jog-dial switch and a multi-lingual menu on a large illuminated display. Two integrated pumps allow the user to test two fluids simultaneously.

SLA PRINTER

KUDO3D, PLEASANTON, CALIF.

Titan 2 SLA-DLP 3-D printer offers print speeds as high as 2.7 in. per hour, and resolutions between 37 and 100 μm. The system is equipped with passive self-peeling technology, which was developed by the company to minimize the separation force between the cured layers and the resin container. Kudo3D says the technology allows features as fine as a strand of hair, and larger objects, up to 10 inches tall, can be printed on the machine. The Titan 2 is Wi-Fi enabled and uses a web-based control system, which makes it compatible with both PCs and Macs, as well as smartphones and tablets such as the Apple iPad, and has its own Raspberry Pi computer built in.

COMPACT PROBE

HEXAGON MANUFACTURING INTELLIGENCE, COBHAM, U.K.

The new HP-S-X1 series of compact probes for 3-D coordinate measuring machine tactile scanning features a new bearing system for better joint repeatability. They also accept longer horizontal styli—up to 225 mm—for improved flexibility. Operators do not need to change modules to tackle different measurement tasks. In addition, magnetic interfaces allow for automated stylus changes on the CMM. The probe range supports all standard inspection modes including dynamic single-point contact measurement, self-centering measurement, and continuous high-speed scanning for quick and precise data acquisition of various surface contours. The probes can be used with most of Hexagon's scan-capable stationary CMMs.

GAS ANALYZER

EMERSON, ST. LOUIS, MO.

The Rosemount CT5100 continuous gas analyzer is a hybrid analyzer that combines tunable diode laser and quantum cascade laser measurement technologies to conduct gas analysis and emissions monitoring. The CT5100 is the latest offering in the Emerson CT5000 series and provides comprehensive analysis, detecting down to sub-ppm level for a range of components. It operates reliably with no consumables, no in-field enclosure, and a simplified sampling system that does not require any gas conditioning to remove moisture. The device can measure up to 12 critical component gases and potential pollutants simultaneously. Unlike traditional continuous gas analyzers, the CT5100 operates within a single system and meets local, state, national, and international regulatory requirements.

ACTUATOR CONTROLLER

CAMOZZI PNEUMATICS, MCKINNEY, TEX.

The Series 6PF positioning feedback cylinder is designed to increase both precision and control in Camozzi's pneumatic actuators. In compliance with ISO 15552 standards, the Series 6PF is equipped with a potentiometric transducer of a linear position integrated inside the rod. The cylinder operates in standard strokes from 50 mm to 500 mm. According to the company, the Series 6PF makes it possible to constantly control the position of the rod along the entire stroke when it is used with the LRXA4 proportional servo valve. The pistons of the Series 6PF are equipped with specific seals for increased accuracy and a permanent magnet in order to use external end-stroke sensors.

VALVE MANIFOLD

ASCO, FLORHAM PARK, N.J.

ASCO has introduced the capability to integrate multiple safety zones within a single Numatics 503 Series valve manifold. The new zoned safety approach is intended to enable design engineers to satisfy the Machinery Directive 2006/42/EC and comply with ISO 13849-1, while eliminating the components and complexity found in discrete safety circuits. The Numatics 503 Series can create up to three independent electro-pneumatic safety zones, while also allowing independent non-safe sections to coexist within one manifold assembly. The Numatics 503 Series valve manifold can be configured to shut down air and power only to the group of valves that controls the machine's motion in the operator's vicinity.

ASME STANDARDS & CERTIFICATION
TWO PARK AVE., NEW YORK, NY 10016-5990
212.591.8500 FAX: 212.591.8501
E-MAIL: CS@ASME.ORG

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

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

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

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

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

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

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

PUBLIC REVIEW DRAFTS

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

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

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

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

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

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

BAYLOR UNIVERSITY

Two Positions in Mechanical Engineering: (1) Clinical Professor of Practice and (1) Lecturer

The Department of Mechanical Engineering in the School of Engineering and Computer Science seeks dynamic scholars to fill one clinical professor of practice and one lecturer position. Exceptional candidates in all areas of mechanical engineering are encouraged to apply. The two positions are sought to fill specific program areas including (1) mechanics, materials and manufacturing, (2) thermofluid sciences or (3) biomaterials/ biomechanics/ biofluids. Both positions are expected to teach basic mechanics courses and laboratories, a measurements course, and/or engineering design courses. Responsibilities for both positions include teaching and mentoring students, scholarly engagement in engineering education, curriculum development, and professional service. In light of Baylor's strong Christian mission, each successful applicant must have an active Christian faith.

The positions will begin in August 2017. Application materials may be submitted at apply.interfolio.com/38984 and apply.interfolio.com/38902. Review of applicants will initiate January 15, 2017 and will continue until the position is filled.

Baylor is a Baptist university affiliated with the Baptist General Convention of Texas. As an Affirmative Action/Equal Employment Opportunity employer, Baylor encourages minorities, women, veterans, and persons with disabilities to apply.

THE OHIO STATE UNIVERSITY

COLLEGE OF ENGINEERING

Faculty Position in Automotive Systems

The Department of Mechanical and Aerospace Engineering at The Ohio State Universityinvites applications from outstanding individuals for a tenure-track faculty position in thebroad disciplinary area of Automotive Systems. Successful applicants for the positionwill possess expertise in one or more of the following areas: dynamic systems and control; system design; multi-physics modeling; mechatronics; flow of fluids and gases; and experimental methods applied to vehicle systems. The position is for individuals at the assistant professor level. The candidate is expected to develop a robust research program while also creating synergy with existing automotive clusters of excellence such as the Simulation Innovation and Modeling Center, the NSF I/UCRC on Smart Vehicle Concepts, and the Center for Automotive Research.

Research application areas under consideration include, but are not limited to: traditional powertrain design; hybrid powertrains; vehicle electrification; after-treatment systems; fault diagnosis; smart devices; and modeling of complex systems incorporating multiple physical domains.

Candidates must have, by the start date, an earned doctoral degree in mechanical engineering or a closely related field. The new faculty member will be expected to teach core undergraduate and graduate courses in disciplines associated with automotive systems, develop new graduate courses in his/her research area, develop and sustain active sponsored research activities, and provide intellectual leadership in his/her research field. Screening of applicants will begin immediately and continue until the position is filled. The anticipated start date is August 2017.

Interested candidates should apply to the position by submitting a single PDF file containing: (1) complete curriculum vitae; (2) statement of research plans; (3) statement of teaching plans; and (4) the names, addresses, and e-mail addresses of four references. The URL to upload the application file is https://mae.osu.edu/employment/faculty-position-automotive-systems. Questions about the position should be directed to the search committee chair, Prof. Marcelo Dapino at dapino.1@osu.edu.

To build a diverse workforce, Ohio State encourages applications from individuals with disabilities, minorities, veterans, and women. Ohio State is an EEO/AA Employer. The Ohio State University is committed to establishing a culturally and intellectually diverse environment, encouraging all members of our learning community to reach their full potential. Columbus is a thriving metropolitan community and we are responsive to dualcareer families and strongly promote work-life balance to support our community members through a suite of institutionalized policies. We are an NSF ADVANCE Institution and a member of the Ohio/Western Pennsylvania/West Virginia Higher Education Recruitment Consortium. For more information about the Department of Mechanical and Aerospace Engineering at Ohio State, please visit http://mae.osu.edu/.

COLUMBIA | ENGINEERING

The Fu Foundation School of Engineering and Applied Science

School of Engineering and Applied Science
Faculty Position in Civil Engineering and Engineering Mechanics

The Department of Civil Engineering and Engineering Mechanics at Columbia University in the City of New York invites applications for a tenured or tenure-track faculty position. A secondary appointment in the Department of Mechanical Engineering is possible. Appointments at the assistant professor, associate professor and full professor levels will be considered.

Applications are specifically sought in the general field of **Fluid Mechanics**. Representative areas of emphasis include among others: Computational Fluid Dynamics, Experimental Methods, Wind Engineering, Air Pollutant Dispersion, Energy Related Applications (wind turbines), Turbulence, Building Physics (airflow and natural ventilation). Candidates must have a Ph.D. or its professional equivalent by the starting date of the appointment. Applicants at the Assistant Professor and Associate Professor without tenure levels must have the potential to do pioneering research and to teach effectively. Applicants at the tenured level (Associate or Full Professor) must have a demonstrated record of outstanding research accomplishments, excellent teaching credentials and established leadership in the field.

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

For additional information and to apply, please see: https://academicjobs.columbia.edu/userfiles/jsp/shared/frameset/Frameset.jsp?t ime=1478287563454. Applications should be submitted electronically and include the following: curriculum-vitae including a publication list, a description of research accomplishments, a statement of research/teaching interests and plans, contact information for three people who can provide letters of recommendation, and up to three pre/reprints of scholarly work. All applications received by January 15, 2017 will receive full consideration.

Applicants can consult http://civil.columbia.edu/ for more information about the department.

Columbia University is an Equal Opportunity/Affirmative Action employer — Race/Gender/Disability/Veteran with a strong commitment to the quality of faculty life.

School of Engineering

VANDERBILT UNIVERSITY

Faculty Position

Mechanical Engineering Department
Vanderbilt University

The Department of Mechanical Engineering at Vanderbilt University invites applications for a tenure/tenure-track faculty position to begin in the fall of 2017. Applications will be considered for positions at all ranks commensurate with qualifications. Applicants must possess a Ph.D. in Mechanical Engineering or closely related discipline. The Department is particularly interested in candidates with research experience and interests in rehabilitation robotics and/or medical robotics.

The School of Engineering strives for an active culturally and academically diverse faculty of the highest caliber, skilled in scholarship and teaching. The Department of Mechanical Engineering has 15 tenured/tenure-track faculty members with reputations for excellence in research fields including nanoengineering, rehabilitation engineering, and medical robotics, with an annual research expenditure of $7.5 million. The department encourages interdisciplinary research and the faculty is affiliated with 8 cross-campus research centers. The School of Engineering is immediately adjacent to the Vanderbilt University Medical Center, which greatly facilitates collaboration between the schools of engineering and medicine. Successful candidates are expected to (1) teach at the undergraduate and graduate levels, (2) establish vigorous research programs with extramural funds, and (3) contribute to synergistic efforts within the School of Engineering. Applications consisting of a cover letter, a complete curriculum vitae, statements of teaching and research interests, and the addresses of at least three references (include email address) should be submitted on-line at https://academicjobsonline.org/ajo/jobs/8005

Ranked in the top 15 nationally, Vanderbilt University is a private, internationally recognized research university located on 330 park-like acres 1.5 miles from downtown Nashville, Tennessee. Its 10 distinct schools share a single cohesive campus that nurtures interdisciplinary activities. The university has a student body of over 12,500 undergraduate, graduate, and professional students, including over 25% minority students and 1,170 international students from 84 countries. The School of Engineering currently comprises 90 tenured and tenure-track faculty, operates with an annual budget of over $100 million, including $70 million from externally funded research, and serves over 1,400 undergraduate and nearly 500 graduate students. In the 2017 rankings of graduate engineering programs by U.S. News & World Report, the School ranks in the top three among programs with fewer than 100 faculty (behind Caltech and Harvard) and has risen steadily in the rankings over the past decade.

With a metro population of approximately 1.8 million people, Nashville has been named the "It" city by Time magazine, one of the 15 best U.S. cities for work and family by Fortune magazine, was ranked as the #1 most popular U.S. city for corporate relocations by Expansion Management magazine, and was named by Forbes magazine as one of the 25 cities most likely to have the country's highest job growth over the coming five years. Major industries include tourism, printing and publishing, manufacturing technology, music production, higher education, finance, insurance, automobile production and health care management.

SOUTH DAKOTA SCHOOL OF MINES & TECHNOLOGY

DEPARTMENT HEAD AND PROFESSOR
MECHANICAL ENGINEERING

The Department of Mechanical Engineering at the South Dakota School of Mines & Technology invites applications for the position of Department Head and Professor. The desired start date is June 22, 2017. The successful applicant will possess an earned Doctorate in Mechanical Engineering or a closely related field, from an accredited university, with a record of teaching, scholarship, and service sufficient to warrant a tenured appointment, pending SD Board of Regents approval. The successful applicant should also have the vision and ability to lead a faculty representing a diversified range of interests, a balanced perspective on research and teaching, a history of successful research in a field that complements existing departmental strengths, the ability to initiate and implement cross-disciplinary activities, and demonstrated successful administrative skills.

The Department Head reports directly to the Provost/Vice President for Academic Affairs. The primary responsibilities of the department head are to provide visionary leadership; to encourage excellence and innovation in teaching, research, and service; to advance professional development of the faculty and staff; to foster growth in the areas of enrollment, research, and fundraising; to promote productive relationships with students, parents, alumni, industry, and government agencies; to demonstrate a commitment to the cultivation of an ethnically and culturally diverse learning community; and to foster productive interdisciplinary relationships with a variety of entities across the University community and beyond.

The Department of Mechanical Engineering currently has 15 full-time faculty with broad expertise in the thermal sciences, controls, and solid mechanics areas. Department enrollment is approximately 600 undergraduate and 20 graduate students. The Department offers an ABET-accredited B.S. degree as well as M.S. and Ph.D. degrees in Mechanical Engineering. In addition, the ME department is closely affiliated with the Center of Excellence for Advanced Manufacturing and Production (CAMP), the Arbegast Materials Processing and Joining (AMP) Laboratory, and the Composites and Polymer Engineering (CAPE) Laboratory to support student and faculty endeavors.

Individuals interested in this position must apply online at **http://www.sdsmt.edu/employment**. Human Resources can provide accommodation to the online application process and may be reached at (605) 394-1203. Review of applications will begin January 3, 2017, and will continue until the position is filled. Employment is contingent upon completion of a satisfactory background investigation. For more information about the School of Mines and Rapid City, visit: **www.sdsmt.edu** and **http://visitrapidcity.com/**.

SD Mines is an EEO/AA/ADA employer & provider.

UNIVERSITY OF MIAMI

Faculty Position in Mechanical and Aerospace Engineering
College of Engineering at the University of Miami, Coral Gables, FL

The College of Engineering of the University of Miami (UM in Coral Gables, FL) invites applications and nominations for tenured/tenure-track faculty positions at the assistant/associate/full professor level in the Department of Mechanical and Aerospace Engineering. The faculty hires will have expertise consistent with at least one of the following college-wide problem-based research clusters:

- Novel Materials
- Sustainable, Resilient and Smart Systems
- Big Data, Informatics and Cybersecurity
- Cognitive and Brain Engineering
- Health and Healthcare Systems

Applicants must have a strong record of research accomplishments, evidence of leadership and vision, ability to excel in an interdisciplinary environment, and a strong interest in undergraduate and graduate teaching. Applicants must have an earned doctorate in mechanical and aerospace engineering or a related field.

Responsibilities of this position include developing a strong externally funded research program; fostering undergraduate and graduate student development; teaching and developing new courses as well as novel teaching methods; assessing student learning; developing new degree offerings that meet the needs of the community and industry; actively engaging with and participating in professional societies; and strengthening the role of the department and the College in the innovation ecosystem in South Florida.

The University of Miami is a top 50 U.S. research institution committed to attracting a talented workforce to support the common purpose of transforming lives through teaching, research, innovation and service. Faculty hired will have unique opportunities to contribute to the growth of strategic research areas through collaboration within the cluster and leveraging existing strengths at the University of Miami, which include:

- Unique geographical location providing a gateway to the Americas;
- World-class research faculty at the University of Miami, Miller School of Medicine and the Rosenstiel School of Marine & Atmospheric Science;
- Newly formed state-of-the-art "Makerspace" research and teaching facility supported by a major medical devices company;
- A $100 million gift to the College of Engineering together with the School of Arts and Sciences.

Initial screening of applications will begin November 2016, with hires expected to start August 2017. Applications will be accepted until the positions are filled. Applications are to include curriculum vitae, statement of educational philosophy, and the names of three persons who may be asked for letters of reference; these items should be uploaded through the web portal at http://coe.miami.edu/facultyopenings.

The University of Miami is an equal opportunity employer; females, minorities, protected veterans and individuals with disabilities are encouraged to apply. Applicants and employees are protected from discrimination based on certain categories under federal law.

THE UNIVERSITY OF TEXAS AT DALLAS

The Erik Jonsson School of Engineering and Computer Science

MECHANICAL ENGINEERING

OPEN RANK FACULTY POSITIONS

The Erik Jonsson School of Engineering and Computer Science at The University of Texas at Dallas (UTD) invites applications for multiple faculty positions in Mechanical Engineering at the rank of Assistant, Associate, or Full Professor.

Candidates must have a strong commitment to undergraduate and graduate education and strong potential to develop an externally funded research program. Candidates for the positions at the Associate or Full Professor levels must have strong records of scholarly and professional achievements.

Applications will be considered in dynamic systems & control, manufacturing & design innovation, mechanics & materials, and thermal & fluid sciences. Application domains of interest include, but are not limited to: renewable energy and storage, emerging technologies for design and manufacturing with application to health care and nanotechnology, mechatronics and robotics with applications to health care, nano/micro- and bio-mechanics, and thermal transport and management. Applicants with experience in engineering education and the professional formation of engineers are of interest as well.

The Department of Mechanical Engineering is among the fastest growing programs at UTD. The department was established in 2008 and currently has over 1,000 students enrolled, including 184 graduate students. The department has 26 tenured-system faculty members and 6 senior lecturers. The department offers an ABET-accredited BS, as well as MS and PhD degree programs in mechanical engineering. In 2018, the department will be housed in a brand new building with 200,000 square feet for teaching and research.

The research conducted by graduate students and faculty is focused on problems of global significance with regional impact in medicine, energy, and nanotechnology. The department is home to an NSF Industry/University Cooperative Center in Wind Energy. Faculty in the department work in collaboration with the UT Southwestern medical school to solve problems in robotics, assistive devices, and detection of diseases. The junior faculty are highly decorated and include two NSF CAREER awardees, five Young Investigator Program awardees from DoD, and one awardee of the NIH Director's Program.

In addition to Mechanical Engineering, the Erik Jonsson School is home to the Departments of Bioengineering, Electrical Engineering, Computer Science, Materials Science & Engineering, and Systems Engineering, and has interdisciplinary degree programs in Telecommunications Engineering, Computer Engineering and Software Engineering. Opportunities for interdisciplinary research are outstanding.

Located in North Texas, with hundreds of technology, large defense manufacturing, and systems integrations companies, Jonsson School students have ample opportunities for real-world, hands-on experiences. Companies and organizations such as Raytheon, General Dynamics, Medtronic, PepsiCo/Frito-Lay, Texas Instruments, and UT Southwestern Medical Center participate in Mechanical Engineering's UTDesign, the Jonsson School's award-winning and corporate-sponsored capstone senior design program. Opportunities exist to further the relationships developed through UTDesign to develop joint research projects with industry.

Review of applicants will begin immediately and will continue until the positions are filled. Indication of gender and ethnicity for affirmative action statistical purposes is requested as part of the application.

To apply for this position, applicants should submit (a) their current curriculum vitae, (b) letters of research and teaching interests, and (c) letters of recommendation from three academic or professional references via the on-line application form available at **http://jobs.utdallas.edu/postings/6977**. Additional references may be requested if deemed necessary. Applicants must choose one of the following as their main area of technical competence: dynamic systems & control (DSC), manufacturing & design innovation (MDI), mechanics & materials (MM), or thermal & fluid sciences (TFS).

The University of Texas at Dallas is an Equal Opportunity/ Affirmative Action employer and strongly encourages applications from candidates who would enhance the diversity of the University's faculty and administration.

UNIVERSITY of HAWAI'I®

MĀNOA

Assistant Professor (Thermofluids: Micro/Nanoscale Transport Phenomena and/or Biomedical Applications), position number 0085307, University of Hawai'i at Manoa (UHM), College of Engineering (COE), Department of Mechanical Engineering, invites applications for a full-time, general funds, tenure track, faculty position, pending position clearance and availability of funds, to begin approximately August 1, 2017.

The University of Hawai'i is a Carnegie R1 (i.e., highest research activity) doctoral university which is recognized as a Land-Grant, Sea Grant, Space-Grant, and Sun-Grant university. The Department offers B.S., M.S., and Ph.D. degrees in mechanical engineering, and its undergraduate program is ABET accredited.

For more information on college research themes, please visit our college web site at www.eng.hawaii.edu. The department has active research programs in biomedical engineering, boiling and two-phase flow, microscale heat transfer, microfluidics, nanotechnology, CFD, acoustics, multidisciplinary design and analysis optimization, space and ocean science & exploration, robotics, control systems, dynamical systems, corrosion, and high-performance computing.

The applicants should identify potential collaboration(s) with one or more of the following: UHM John A. Burns School of Medicine, Cancer Research Center, Center for Microbial Oceanography: Research & Education (C-MORE), Hawaii Natural Energy Institute (HNEI), College of Tropical Agriculture and Human Resources (CTAHR), Ocean Resource Engineering (ORE), Hawaii Space Flight Laboratory (HSFL), Hawaii Institute of Geophysics & Planetology (HIGP), Information and Computer Sciences (ICS), Information Technology Center, College of Social Sciences as well as other laboratories such as the Laboratory for Advanced Visualization and Applications in Design. This faculty can also contribute to the various COE research areas.

Duties: Teach and develop undergraduate and graduate courses in the area of thermofluids such as heat and/or mass transfer related to thermal or fluid systems as well as design and development of thermofluids systems. Develop externally funded research programs that result in publications in leading scholarly journals; present research work at leading scholarly conferences; supervise graduate students; teach via various distance delivery modes as required; and serve on departmental, college, and university committees.

Minimum qualifications: An earned Ph.D. (All-But-Dissertation, ABD, cases will be considered but dissertation must be filed before start of employment) in Mechanical Engineering or a closely related field. The candidate should have a background in research areas related to design and development of thermofluids systems with expertise in Micro/Nanoscale Transport Phenomena and/or Biomedical Applications. Emerging research areas and cross-disciplinary activities are particularly encouraged. Candidates must also show a strong commitment to teaching excellence and mentoring at the undergraduate and graduate levels.

Pay range: Commensurate with qualifications and experience.

To Apply: Only electronic applications are accepted. Applicants should follow the instructions at http://www4.eng.hawaii.edu/apply for submission instructions (The applicants should submit a cover letter specifying the position and the research area; a statement on their research interests, activities, and plans; a statement on their teaching philosophy, interests, and plan; a curriculum vitae detailing research and teaching accomplishments; copies of up to 4 relevant publications; and the names, addresses, e-mail, and telephone numbers of 4 references). For more information on the Department, please visit our website at www.me.hawaii.edu.

Inquiries: Professor Mehrdad N. Ghasemi-Nejhad, Chair, 808-956-7560, nejhad@hawaii.edu.

Review of applications will begin on February 1, 2017 and will continue until the position is filled.

The University of Hawai'i is an equal opportunity/affirmative action institution and is committed to a policy of nondiscrimination on the basis of race, sex, gender identity and expression, age, religion, color, national origin, ancestry, citizenship, disability, genetic information, marital status, breastfeeding, income assignment for child support, arrest and court record (except as permissible under State law), sexual orientation, national guard absence, or status as a covered veteran.

Individuals with disabilities who need a reasonable accommodation for the application or hiring process are encouraged to contact the EEO/AA coordinator(s) for the respective campus.

Employment is contingent on satisfying employment eligibility verification requirements of the Immigration Reform and Control Act of 1986; reference checks of previous employers; and for certain positions, criminal history record checks.

In accordance with the Jeanne Clery Disclosure of Campus Security Policy and Campus Crime Statistics Act, annual campus crime statistics for the University of Hawai'i may be viewed at: http://ope.ed.gov/security/, or a paper copy may be obtained upon request from the respective UH Public Safety or Administrative Services Office.

THE OHIO STATE UNIVERSITY

COLLEGE OF ENGINEERING

Faculty Position in Applied Mechanics: Mechanical and Aerospace Engineering at The Ohio State University

The Department of Mechanical and Aerospace Engineering at The Ohio State University (OSU) invites applications for a tenure-track faculty position at the Assistant Professor level in the broad disciplinary area of applied mechanics. We welcome applicants from all backgrounds related to applied mechanics. Research areas of particular interest include, but are not limited to, advanced composite materials and material systems, multifunctional materials, lightweight or multi-material structures, micro-nano materials, bio-inspired or biomimetic structures and materials, biomolecular materials, ceramic composites, and advanced manufacturing.

Successful candidates should be able to participate in multidisciplinary initiatives to support the missions of the department and college pertaining to the focus area of materials and manufacturing for sustainability and resilience and/or other broad priority areas of health and wellness or energy and the environment. Applicants must have earned a doctoral degree in mechanical engineering or a related discipline by the start date and should have demonstrated record of excellence in research. The new faculty member is expected to develop and maintain a nationally recognized and externally funded research program at the forefront of their field, collaborate across disciplines, teach and supervise students at the undergraduate and graduate levels, develop and teach courses in their area of expertise, and participate in service to the university.

The sought after colleague will join a vibrant department with 73 faculty members, approximately 1700 undergraduate and 400 graduate students housed in a $72.5 million state-of-the-art teaching and research complex opened in 2006. Ohio State has many additional world-class facilities and established research centers along with government/industrial partners for multidisciplinary collaboration.

Applicants should submit a cover letter, curriculum vitae, research and teaching statements, copies of no more than three representative publications, and contact information for at least four references by applying for this specific position online at:

https://mae.osu.edu/employment/faculty-position-applied-mechanics. Screening of applicants will begin starting Fall 2016 and continue until the position is filled. It is anticipated the appointment will begin Fall 2017.

To build a diverse workforce, Ohio State encourages applications from individuals with disabilities, minorities, veterans, and women. Ohio State is an EEO/AA Employer. The Ohio State University is committed to establishing a culturally and intellectually diverse environment, encouraging all members of our learning community to reach their full potential. Columbus is a thriving metropolitan community and we are responsive to dual-career families and strongly promote work-life balance to support our community members through a suite of institutionalized policies. We are an NSF ADVANCE Institution and a member of the Ohio/Western Pennsylvania/West Virginia Higher Education Recruitment Consortium. For more information about the Department of Mechanical and Aerospace Engineering at Ohio State, please visit http://mae.osu.edu/.

EMBRY-RIDDLE Aeronautical University

PRESCOTT, ARIZONA

EMBRY-RIDDLE AERONAUTICAL UNIVERSITY'S COLLEGE OF ENGINEERING in Prescott, Arizona, invites applications for a tenure-track position in our Mechanical Engineering Department.

The position is available in Spring 2017 at the Assistant/Associate Professor level. The department is particularly interested in interviewing candidates with design experience in rocket propulsion and/or energy systems. A PhD in ME or AE and related experience is desired, but candidates with significant industry experience and a MS Degree are strongly encouraged to apply. Additional information regarding these positions may be found at http://prescott.erau.edu/college-engineering/propulsion-energy-faculty-openings/index.html. Materials may be submitted in electronic form through careers.erau.edu

UNIVERSITY OF MIAMI

Department Chair Position in Mechanical and Aerospace Engineering

College of Engineering at the University of Miami, Coral Gables, FL

The College of Engineering at the University of Miami (UM in Coral Gables, FL) invites applications and nominations for the Professor and Department Chair position in the Department of Mechanical and Aerospace Engineering (MAE).

Applicants must have an outstanding record of research accomplishments, evidence of leadership and vision, and a strong interest in undergraduate and graduate teaching in mechanical and aerospace engineering. Applicants must have an earned doctorate in Mechanical Engineering, Aerospace Engineering or in a related field.

In addition to maintaining his/her research portfolio, the candidate will provide departmental leadership that cultivates excellence in teaching, research, innovation and service; will develop strategic collaborations with colleagues across Colleges and Schools; and will promote the department to reach new levels of excellence. The candidate will serve as an advocate for the department, college, university and community. Responsibilities of this position will include fostering faculty, staff and student development; assessing student learning, developing new degree offerings that meet the needs of the community and industry; strengthening the role of the department and the college in the innovation and commercialization ecosystem, strategic planning and other department related management duties.

The University of Miami consistently ranks among the nation's top universities and has recently been infused with an extraordinary gift of $100M targeted at engineering and sciences. The new department chair will be presented with an unusual opportunity to define strategic directions and significantly grow the MAE department by leveraging tremendous internal opportunities, as well as building on its strengths, which include:

- Excellent, innovative, ABET-accredited undergraduate programs;
- MS and PhD programs, which have very high-quality graduate students and can be quickly expanded;
- Eleven tenured/tenure-track faculty with recognized expertise across four areas:
  1. Novel Materials and Applied Mechanics (spanning biomedical, aerospace, energy, and environmental applications)
  2. Clean Energy and Sustainability
  3. Green Aviation and Aerospace systems
  4. Simulation-Based Engineering
- Unique geographical location providing a gateway to the Americas and providing opportunities for innovative education and research programs;
- Opportunities to hire new faculty talents through college-wide cluster-hire initiatives;
- Opportunities to strengthen and develop collaborations with world-class researchers and educators at the University of Miami, including the Miller School of Medicine and the Rosenstiel School of Marine & Atmospheric Science;
- Newly formed state-of-the-art "Makerspace" research and teaching facility supported by a major medical devices company;
- Growing network, emphasis and infrastructure to support and promote entrepreneurship, innovation and commercialization for faculty and students.

Initial screening of applications will begin in November 2016, with an expected starting date of August 2017. Applications will be accepted until the position is filled. Applications include curriculum vitae, a statement of educational and administrative philosophy, and the names, phone number and email addresses of three references should be uploaded through the web portal at http://coe.miami.edu/facultyopenings.

The University of Miami is an Equal Opportunity Employer - Females/Minorities/Protected Veterans/Individuals with Disabilities are encouraged to apply. Applicants and employees are protected from discrimination based on certain categories protected by Federal law.

POSITIONSOPEN

THE GROVE CITY COLLEGE DEPARTMENT OF MECHANICAL ENGINEERING seeks a new faculty member at the assistant or associate level. Grove City College is a Christian liberal arts college with strong science and engineering programs. For additional info please visit: http://www.gcc.edu/about/employment/Pages/Mechanical-Engineering.aspx.

THE UNIVERSITY OF CALIFORNIA – SAN DIEGO, Department of Structural Engineering (http://structures.ucsd.edu) has opened a search for a faculty member at the Assistant Professor level with demonstrated potential to achieve excellence in teaching, scholarship, and professional activity. Specializations in any of the primary research areas within the Department will be considered, which include: (1) Geotechnical Engineering, (2) Advanced Composites and Aerospace Structural Systems, (3) Computational Mechanics, (4) Structural Protective Systems Against Extreme Events, and (5) Structural Health Monitoring and Damage Prognosis, as well as (6) New Areas in Creative and/or Sustainable Design. A successful candidate will be required to teach undergraduate and graduate courses, develop an active and well-funded research program, and form synergistic connections with other areas in the department and university. An earned doctoral degree or advancement to candidacy in the relevant field is required at the time of application. For inquiries specific to the Department of Structural Engineering, contact the Chair of the Search Committee, Prof. John McCartney (mccartney@ucsd.edu). The Department of Structural Engineering houses unparalleled large-scale testing facilities, including the NHERI@UCSD Large High-Performance Outdoor Shake Table, a blast simulation facility, a composite and aerospace structures laboratory, a geotechnical centrifuge, two 9-m deep soil pits for foundation testing, a rail defect testing facility, a high-bay structural systems laboratory, a structural components laboratory, a large Caltrans 6-DOF shake table for testing structural response modification devices (SRMD), and multiple non-destructive evaluation/structural health monitoring (NDE/SHM) laboratories. UC San Diego is an affirmative action/equal opportunity employer, and the Jacobs School of Engineering is committed to building an excellent, diverse, and inclusive faculty, staff, and student body (http://www.jacobsschool.ucsd.edu/diversity/). Candidates with experience with or willingness to engage in activities that contribute to diversity and inclusion are especially encouraged to apply. For applicants interested in spousal/partner employment, please visit the UCSD Partner Opportunities Program website (http://academicaffairs.ucsd.edu/aps/partneropp/). **SALARY:** Level of appointment commensurate with qualifications; salary based on UC pay scales. **CLOSING DATE:** Applications received by January 16, 2017 will be given full consideration; however, the position is open until filled. **TO APPLY:** The application (curriculum vitae, including a complete publication list, a list of four professional references' contact information, a cover letter which identifies the Department of Structural Engineering as the department to be considered for, a statement of research and teaching interests, and a separate statement describing past experience and activities that promote diversity and inclusion and/or plans to make future contributions), should be submitted electronically to the Jacobs School of Engineering at (https://apol-recruit.ucsd.edu/apply/JPF01289). For further information about contributions to diversity statements, see: http://facultyequity.ucsd.edu/Faculty-Applicant-C2D-Info.asp

POSITIONSOPEN

ASSISTANT, ASSOCIATE OR PROFESSOR MECHANICAL ENGINEERING

THE DEPARTMENT OF MECHANICAL ENGINEERING at the **SOUTH DAKOTA SCHOOL OF MINES & TECHNOLOGY** invites applications for nine-month, tenure-track faculty position(s) at the Assistant, Associate or Professor level. Rank is dependent on qualifications and the record of the successful candidate. We anticipate hiring multiple positions. An earned PhD in Mechanical Engineering or a closely related field is required by the anticipated August 22, 2017 start date. The ideal candidates will have excellent communication skills, both verbal and written, teaching and research experience at the university level, and a strong background in one or more of the following areas: controls and robotics, thermal-fluid sciences, or solid mechanics. The successful candidates will each be expected to teach at the undergraduate and graduate levels, develop an externally funded research program in his/her area of expertise, participate in service related activities, and supervise student design projects. Salary is commensurate with qualifications. For more information regarding the Mechanical Engineering Department visit http://me.sdsmt.edu. Individuals interested in this position must apply online at http://www.sdsmt.edu/employment. Human Resources can provide accommodation to the online application process and may be reached at (605) 394-1203. Review of applications will begin January 12, 2017, and will continue until the position is filled. Employment is contingent upon completion of a satisfactory background investigation. For more information about South Dakota Mines and Rapid City, visit: www.sdsmt.edu and http://visitrapidcity.com/. SD Mines is an EEO/AA/ADA employer & provider.

INSTRUCTOR, LECTURER OR SENIOR LECTURER MECHANICAL ENGINEERING

THE DEPARTMENT OF MECHANICAL ENGINEERING at the **SOUTH DAKOTA SCHOOL OF MINES & TECHNOLOGY** invites applications for nine-month, non-tenure-track, term Instructor, Lecturer or Senior Lecturer position(s). We anticipate hiring multiple positions. An earned MS in Mechanical Engineering or a closely related field is required; a PhD in Mechanical Engineering or a closely related field is preferred. Excellent communication skills, both verbal and written, are required. The ideal candidates will have practical industry experience in Mechanical Engineering or a closely related field, prior teaching experience at the university or college level, and a strong background in one or more of the following areas: controls and robotics, thermal-fluid sciences, or solid mechanics. Expectations will include teaching courses, supervising student design projects, and department service. The anticipated start date is August 22, 2017. For more information regarding the Mechanical Engineering Department visit http://me.sdsmt.edu.Individuals interested in this position must apply online at http://www.sdsmt.edu/employment. Human Resources can provide accommodation to the online application process and may be reached at (605) 394-1203. Review of applications will begin January 12, 2017, and will continue until the position is filled. Employment is contingent upon completion of a satisfactory background investigation. For more information about South Dakota Mines and Rapid City, visit: www.sdsmt.edu and http://visitrapidcity.com/. SD Mines is an EEO/AA/ADA employer & provider.

POSITIONSOPEN

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

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

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

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

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

The American University of Beirut is an Affirmative Action, Equal Opportunity Employer. For general information consult the AUB's home page www.aub.edu.lb.

FACULTY POSITIONS IN MECHANICAL ENGINEERING, UNIVERSITY OF SOUTH CAROLINA

The University of South Carolina College of Engineering and Computing will be hiring a substantial number of new faculty members in the next four years (10 or more per year). As part of this hiring initiative, the Department of Mechanical Engineering is accepting applications for tenure track positions at the Assistant and Associate Professor levels. Though preference will be given to candidates in the following areas: (a) thermo-fluids, (b) materials (c) mechanics of materials, and (d) advanced manufacturing (broadly defined), highly qualified candidates from all areas of Mechanical Engineering will be considered. Applicants must possess a Ph.D. in Mechanical Engineering or a closely related field. Applications should be submitted by email to odonnemc@cec.sc.edu, in the form of a single PDF document, containing: 1) vitae, 2) statement of research plans, 3) statement of teaching interests, and 4) contact information for three references. The selection process will begin on February 15, 2017 and will continue until the positions are filled. The University of South Carolina is an Equal Opportunity/ Affirmative Action Employer. Minorities and women are encouraged to apply.

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RECRUITMENT

NEXT MONTH IN MECHANICAL ENGINEERING

THORIUM POWER

Around the world, researchers and entrepreneurs are racing to build breeder reactors that could jump start the nuclear industry.

STUDENTS SUPPORT ASME AT GOOGLE STREET FAIR

For the second year, a team of engineering students from New York City College of Technology in Brooklyn and their advisor represented ASME at the annual New York City Geek Street Fair. The event, held this year in Manhattan's Union Square, featured science exhibits from more than 20 universities, museums, nonprofit organizations, and technology companies from the New York area. The event drew more than 5,000 students, teachers, and tourists.

The engineering students from City Tech, along with professor **Andy S. Zhang**, demonstrated devices they had designed and built in the school's Mechatronics Technology Center. These devices included a robot that could scan and recognize the faces of visitors to the booth, a basketball hoop that generated electricity using gravity, and a crane that children could use to pick up bags of candy.

Julio Mejia is a 38-year-old former U.S. Marine who is currently president of the school's mechatronics club and a mechanical engineering student in his senior year at City Tech. Mejia brought a unique perspective to the event. "My nieces just finished junior high school and they had robotics clubs available to them. But we didn't have these types of opportunities that the kids have now."

With Mejia at the ASME booth were **Luca Scarano**, **Devon Paul**, **Zahra Elfatimi**, **Ehab Amed**, and **Tristen Canchig**.

Zhang, an ASME member and advisor to the City Tech mechatronics club, said events like the Google Geek Street Fair are important not only for younger students who are visiting the events, but also beneficial for the university students who participate.

"It's very important to get young people to know science and technology early on, especially in grade school and middle school," Zhang said. "When they're in high school, it's too late.

ASME Student member Luca Scanrano sits on City Tech's human powered vehicle while controlling the *Twisted Sister* rover.

"It's also a good opportunity for our students to get involved and sharpen their hands-on skills," Zhang continued. "Your first design doesn't always work. That's why it's important to get hands-on experience. If you make your mistakes while you're in school, then you won't make a big mistake at your company." ME

APPLY FOR A 2017-2018 ASME CONGRESSIONAL FELLOWSHIP

Applications are now being accepted for the 2017-2018 ASME Congressional Fellowship through the ASME Federal Government Fellowship Program.

Since 1973, ASME has sponsored more than 100 Federal Fellows, providing them with an opportunity to serve a one-year term in the executive branch or U.S. Congress.

Fellows serve as independent, non-biased advisors in engineering, science and technology, bringing a nonpartisan, pragmatic approach to analysis and input that has a profound impact on the decision-making process. The result is effective and technologically appropriate public policy based on sound engineering principles.

Applicants for the Fellowship must have a strong energy background.

ASME will be accepting applications for the 2017-2018 Congressional Fellowship until Jan. 31, 2017.

This ASME Congressional Fellowship is sponsored by ASME Government Relations, the ASME Foundation, and the ASME Petroleum Division.

A recent webinar, "ASME Federal Government Fellows: Technology Intersecting Policy and Politics," featuring ASME's former Congressional Engineering Fellows, **Briana Tomboulian** and **Stephen Lehrman**, discusses the Congressional Fellows program.

For more information on this opportunity, visit the ASME Congressional Fellowship page on ASME.org. ME

ASME, CHINESE INDUSTRIAL ORGANIZATION SIGN AGREEMENT

A delegation from the China Chemical Industry Equipment Association journeyed to ASME's headquarters in New York to formalize the decade-long relationship between the two groups.

The memorandum of understanding, which was signed by ASME Executive Director **Thomas Loughlin** and CCIEA's Director General **Zhao Min** in October, covers the promotion of information exchange, cooperation in standards development and training, standards committee participation, and potential cooperation in workshops and seminars with a special focus on conformity assessment and personnel certification.

Zhao Min (left) and Thomas Loughlin at ASME headquarters in New York.
Photo: Wil Haywood, Public Information

The CCIEA is a group of more than 500 Chinese manufacturers involved in fields such as petroleum, machinery, agriculture, and light industry, in addition to chemicals and petrochemicals.

Founded in 1989, the CCIEA interacts with a variety of government agencies and large state-owned enterprises. The group is responsible for appraisal and evaluation in pressure vessel design and manufacture, pressure piping components and related equipment, as well as associated training and personnel certification. About 200 CCIEA member firms have their quality assurance programs certified by ASME, and many more are expected to become certified. ME

WARNING AGAINST CHANGES

The Licensing That Works Coalition, an ASME-led coalition of engineering societies representing thousands of engineers in New Jersey and more than 300,000 engineers across the United States, recently urged the New Jersey State Board of Professional Engineers and Land Surveyors to oppose any legislative or regulatory proposals requiring anyone seeking licensure as a professional engineer to obtain a master's degree in engineering or its equivalent first.

The coalition supports a four-year bachelor's degree from an EAC/ABET accredited college or university bachelor's degree program as the mandatory baseline educational requirement for PE licensure as a professional engineer. Continuing education throughout an individual's career is supported to supplement an engineer's degree and experience with current technological and regulatory information and training.

The coalition's position is that there is no evidence that the present requirements for licensure are in any way inadequate. Additional mandatory requirements would only serve to deter students from considering engineering as a career—particularly one connected to public service and infrastructure.

New Jersey saw a similar effect when it passed legislation raising the educational requirements for obtaining a land surveying license. The state saw a significant drop in students entering the profession.

To read the full letter, please visit: http://bit.ly/2eDqXa7. ME

ASME, GERMAN ENGINEERS TALK ADVANCED MANUFACTURING

Early career engineers from ASME and the Association of German Engineers (known by its German acronym, VDI) recently met in New York to take part in a three-day workshop focusing on additive manufacturing. During the visit, the engineers took part in tutorials covering additive manufacturing topics, and visited two area universities that have active AM research facilities.

The event in New York City was held as part of the ASME-VDI Early Career Engineers Program, which stemmed from an agreement the two organizations signed two years ago. Eleven engineers took part—five representing ASME and six from VDI.

The delegations met at ASME's 2 Park Avenue headquarters to talk with **John Koehr**, managing director of technology advancement and business development for ASME, and **Claudia Rasche**, VDI's project coordinator for the ECE initiative. **Israr Kabir**, ASME's program manager for emerging technologies, gave the group a demonstration of the MakerBot Replicator 3-D Printer that is housed at ASME headquarters.

The delegations also visited two university labs specializing in advanced manufacturing research. At New York University's Tandon School of Engineering, they toured a maker space that provides students with access to rapid prototyping technology.

They also visited the Columbia University Creative Machines Lab, a robotics laboratory encompassing researchers from various disciplines including engineering, computer science, physics, math, and biology. While there, they heard a presentation from **Hod Lipson**, professor of mechanical engineering and co-author of the recent book, *Fabricated: The New World of 3D Printing*.

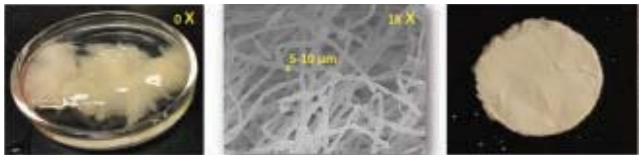
For more information on the ASME's strategic interest in manufacturing or the ASME-VDI Early Career Engineering Program, contact **Raj Manchanda**, Emerging Technologies, by e-mail at manchandar@asme.org. ME

FROM BEER TO BATTERIES

Using fungus to harvest carbon for industrial applications

Beer drinkers aren't the only ones that produce lots of wastewater after processing their favorite beverage. Breweries do, too—up to seven barrels of it for every one barrel of beer. But while the drinkers are left to handle the end result on their own, a team of engineers is helping brewers lower their wastewater treatment costs, improve the environment, and provide lithium-ion battery manufactures with an inexpensive and sustainable form of carbon.

Those claims might sound like the hopeful ravings of an inebriate, but they're based on the sober work of Tyler Huggins, an environmental engineer who specializes in wastewater treatment and resource recovery.



The *Neurospora crassa* fungus grows (left) after 48 hours and forms a mat of fibers (center and right). That biomass can be baked into carbon chips (top) to be used in batteries.

As a doctoral candidate at the University of Colorado in Boulder, Huggins began turning *Neurospora crassa*, a fast-growing fungus, into a biomass that he hoped to use as a carbon electrode in batteries and other applications. While hanging out at one of Colorado's many breweries, it dawned on him that the sugar-rich wastewater breweries produced, already an ideal environment for growing yeast, would be a perfect breeding ground for the fungus.

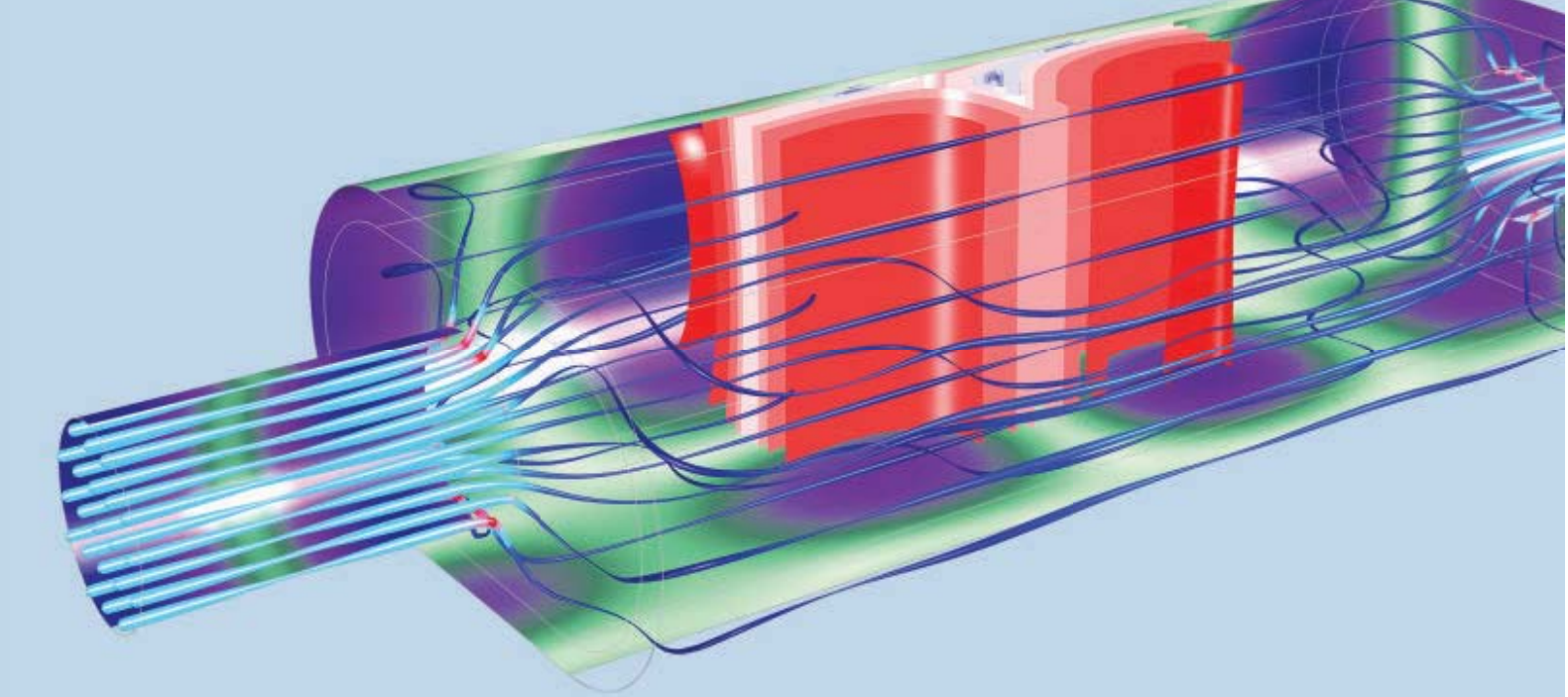
The process, he realized, could also save breweries thousands of dollars in water treatment costs. Brewery wastewater contains high amounts of alcohol, sugar, and other solids, such as proteins and hops, that most municipal treatment facilities can't handle. Some breweries, depending on their size and location, have to build expensive wastewater treatment systems or hire an outside firm handle the task. "We can take away about 90 percent of the wastewater treatment costs," Huggins said. Along with his business partner, Justin Whiteley, a mechanical engineer and UC Boulder alumnus who focuses on battery technologies, Huggins recently started Emergy, a company that's commercializing the process.

Emergy has partnered with Boulder's Avery Brewing on a pilot program. The process is quite simple. In this case, Avery collects wastewater in a separate tank and Huggins adds fungal spores, which feed on and remove carbon from the wastewater that has been heated to about 77 °F. The fungus grows into a solid mass within about 48 hours. It's then scooped out of the water and baked at 800 °F, until it's a charred piece of carbon that's ready to use as a raw battery material.

Emergy is still working on its business model and billing structure, Huggins said.

One of the main benefits of the process is that Emergy can fine-tune the fungus' chemical and physical characteristics to create a product that fits a specific need. "We like to think of it as a living 3-D printer," Whiteley said. "We can manipulate it and grow whatever we want." ME

JEFF O'HEIR



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