MECHANICAL ENGINEERING

THE MAGAZINE OF ASME

No. 08

137

Technology that moves the world

DOES IT ADD UP?

ADDITIVE MANUFACTURING: MORE QUESTIONS THAN ANSWERS

ASME.ORG

AUGUST 2015

LOG ON ASME.ORG

THE SHAPE OF FOOD TO COME

A SCOOP OF ICE CREAM, a wedge of cake, a pat of butter: the shapes of foods can be so pedestrian. But just as no self-respecting, five-star chef would serve up mashed potatoes without at least a tincture of truffle oil—or the marrow of a grass-fed caribou—so the dimensions of yesteryear's food may soon be unfit for the serious eater's table. The folks that make up Robots in Gastronomy are bringing presentation into the third dimension. Their specialized 3-D printer is allowing imaginative gourmets to serve adventurous gourmands latticed pasta, terraced ice cream, and even 3-D printed cocktails.

GAME ON FOR WHEELCHAIR USERS

Engineers are focusing on suitable gearing and increased stability when designing wheelchairs for sports, including basketball, tennis, and handcycling.

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

TAKING A WALK WITH PARKINSON'S

Mark Minor, associate professor of mechanical engineering at the University of Utah, is working on a shoe training system utilizing bladders to improve walking for those with Parkinson's disease.

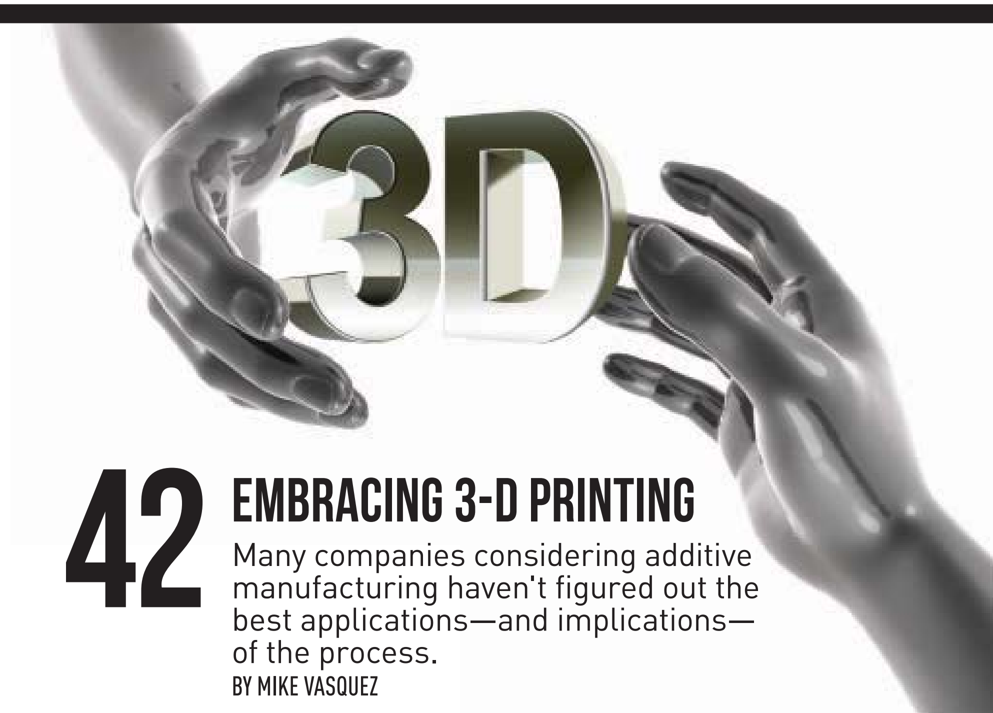
PODCAST: ENGINEERING BIO-HYBRID DEVICES

Rashid Bashir, professor of bioengineering at the University of Illinois at Urbana-Champaign, highlights how the principles of engineering and biology can be integrated to develop devices.

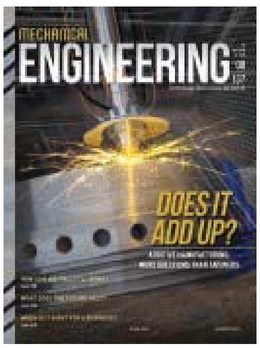
NEXT MONTH ON ASME.ORG

VIDEO: THE FUTURE OF HYDRAULIC FRACTURING: PROPPANT LOGISTICS
Peter Glynn, EVP with Sandbox Logistics, discusses what it takes to keep hydraulic fracturing, and by extension the U.S. economy, flowing.

PODCAST: HOW NANOFLUIDICS CONTROLS CELL MICROENVIRONMENTS
Shuichi Takayama, professor in the Biomedical Engineering Department at the University of Michigan, delves into developing microfluidic systems to control cell microenvironments.



FEATURES



ON THE COVER

DOES IT ADD UP?
Designing for additive manufacturing requires engineers to ask new kinds of questions.

ASME
SETTING THE STANDARD

36

DREAMING IN 3-D

What does the future of additive manufacturing look like?

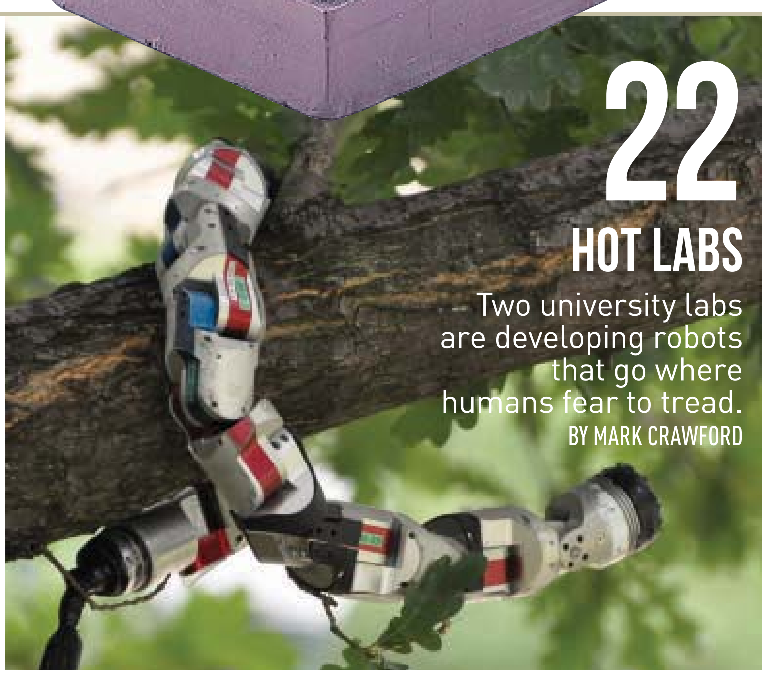
BY ALAN S. BROWN

VAULT

Project Gasbuggy fractured shale with a nuclear detonation.

26

DEPARTMENTS



22

HOT LABS

Two university labs are developing robots that go where humans fear to tread.

BY MARK CRAWFORD

64

A KIDS' KITCHEN

Tulsa engineering students design and build a children's cooking center.

BY JAMES PERO

MECHANICAL ENGINEERING

Contact *Mechanical Engineering*

Mechanical Engineering
memag@asme.org
p. 212.591.7783 f. 212.591.7841
Two Park Avenue, New York, NY 10016

For reprints contact Jill Kaletha
jillk@fosterprinting.com
(866) 879-9144 ext.168

asme.org
on.fb.me/MEMAGAZINE
memagazineblog.org

Published since 1880 by the **American Society of Mechanical Engineers (ASME)**. *Mechanical Engineering* identifies emerging technologies and trends and provides a perspective on the role of engineering and technology advances in the world and on our lives. Opinions expressed in *Mechanical Engineering* do not necessarily reflect the views of ASME.

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

ASME offices

Headquarters
p. 212.591.7722 f. 212.591.7674
Two Park Avenue, New York, NY 10016

Customer Sales & Service
e-mail: CustomerCare@asme.org
f. 973-882-5155
ASME, 150 Clove Road, 6th floor, Little Falls, NJ 07424-2139
In U.S., Mexico & Canada toll-free 1-800-THE-ASME (1-800-843-2763)
International 646-616-3100

Washington Center 202.785.3756
1828 L Street, N.W., Suite 810 Washington, DC 20036-5104

Int'l Gas Turbine Institute http://igti.asme.org
Int'l Petroleum Technology Institute asme-ipti.org
p. 281.493.3491 f. 281.493.3493
11757 Katy Freeway, Suite 380; Houston, TX 77079-1733.

Europe Office dogrum@asme.org
p. +32.2.743.1543 f +32.2.743.1550
Avenue De Tervueren, 300, 1150 Brussels, Belgium

Asia Pacific LLC
p. +86.10.5109.6032 f. +86.10.5109.6039
Unit 09A, EF Floor, East Tower of Twin Towers; No. B12, JianGuo MenWai DaJie; ChaoYang District; Bejing, 100022 People's Republic of China

India Office NehruR@asme.org
p. +91.124.430.8413 f. +91.124.430.8207
c/o Tecnova India Pvt.Ltd.; 335, Udyog Vihar, Phase IV; Gurgaon 122 015 (Haryana)

Mechanical Engineering (ISSN 0025-6501) is published monthly by The American Society of Mechanical Engineers, Two Park Avenue, New York, NY 10016-5990. Periodicals postage paid at New York, N.Y., and additional mailing offices. POSTMASTER: Send address changes to Mechanical Engineering, c/o The American Society of Mechanical Engineers, 150 Clove Road, 6th Floor, Little Falls, NJ 07424-2139. Return Canadian undeliverable addresses to P.O. BOX 1051, Fort Erie, On, L2A 6C7. PRICES: To members, annually $37 for initial membership subscription, single copy $7; subscription price to nonmembers available upon request.

John G. Falcioni
Editor-in-Chief

FLIPPING TO NEW WAYS

I was driving out to the North Fork of Long Island with an old friend who was visiting from Palm Desert a couple of weeks ago when his cell phone rings. He dives deep into his pocket and pulls out a familiar relic that I hadn't seen in some time: a flip phone.

After several minutes of severe ribbing, which included showing off my ultra-smart personal iPhone 6 and work Windows cell phones, he says nonapologetically, "Haven't you heard, flip phones are cool again."

I laughed. But not all that long ago, the flip phone was as uber-cool as, well, Uber is today. And while my friend, Joe, may not feel the need to be connected all-ways-cyber in the way that I do, his cell phone makes and receives calls with no less precision than mine do.

It was clear how out of place the iconography of the flip phone was amidst my mobile gadgetry. In its day, the flip was cutting edge, however, and its design evidently sound enough to withstand years of use. But, as I told Joe, sometimes you have to keep up with the times.

Today, especially in the U.S., old rules of all kinds are transforming—from Constitutional interpretations and laws, to culture and technology. It's not clear how transformative all of the current social and technology disruptions will become, but when it comes to advanced manufacturing, and especially 3-D printing—our editorial focus this month—it won't be long before it's a game changer in certain applications, especially biotechnology, aerospace, defense, and power generation.

One of the most noteworthy examples of transformative innovations is the Model T, circa 1908. It was understood that its design was revolutionary, like the flip phone in its day, but how bravely transformative Henry Ford would be could not have been predicted at first. It wasn't simply about design, but also his manufacturing processes that made Ford unique. The assembly line he shepherded in 1913 was pivotal in mass producing affordably priced cars.

I bring up Ford because he left us three lessons that are valid in today's changing environment. First, design with your customers in mind. Ford grew up on a farm and wanted to make the Model T nimble enough to handle well even on bumpy dirt roads where some of his customers resided. He designed a suspension system with a triangular configuration that allowed the front and rear axles to flex without damaging the engine.

Second, don't overlook what's going on behind the scenes. Even as the assembly line was adopted in other industries, Ford took advantage of this concept and became the first automobile manufacturer to combine precision components with continuously moving assembly to build cars. By 1914 Ford was producing far more cars than any other competitor.

Third, don't be afraid to go against the grain. Having the steering wheel on the left side, as we're used to now, was not standard in the U.S. It was a design decision that changed the entire auto industry. Today's innovators are taking a cue from Ford and are not afraid to do things their way. Those involved in 3-D printing are an example.

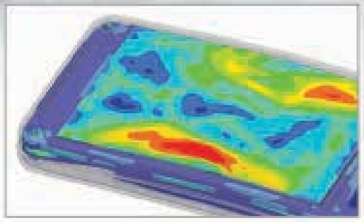
With no disrespect intended to the retro movement, or to the 18 percent of millennials who told the Pew Research Internet Project recently that they don't use a smartphone, the flip phone never hit the high notes of innovation of the Model T. And the flip phone is no longer cool, even if using one today goes "against the grain." **ME**

FEEDBACK

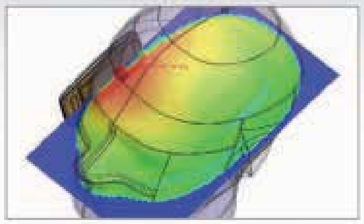
Will 3-D printing become a transformational technology? Email me.

falcionij@asme.org

Been there, dropped that...



Impact Simulation: RADIOSS



Electromagnetic Analysis: FEKO

Structural Analysis: OptiStruct

HyperWorks delivers all the solvers engineers need to make better products, so the next time you find yourself in this situation, you can pick up your phone in one piece.

HyperWorks provides the most comprehensive multiphysics simulation environment with the power of RADIOSS for impact simulation, OptiStruct for structural analysis and optimization, AcuSolve for Computational Fluid Dynamics, MotionSolve for Multi-Body Dynamics, FEKO for electromagnetic (EM) analysis plus solutions from members of the Altair Partner Alliance.

Learn more at altair.com/drop

Altair

INNOVATION INTELLIGENCE®

COMMENT

129 YEARS ... AND STILL UP TO DATE

How do you get two rail cars going in opposite directions to share one set of tracks—with no moving parts? A Swiss engineer solved the problem in 1886, and one of his first installations is set to become an ASME Landmark.

Funiculars are popular transport systems in cases where large vertical heights have to be overcome. They have a history starting in the 15th century but the first larger application was in 1845, the Prospect Park Incline Railway in the city of Niagara Falls.

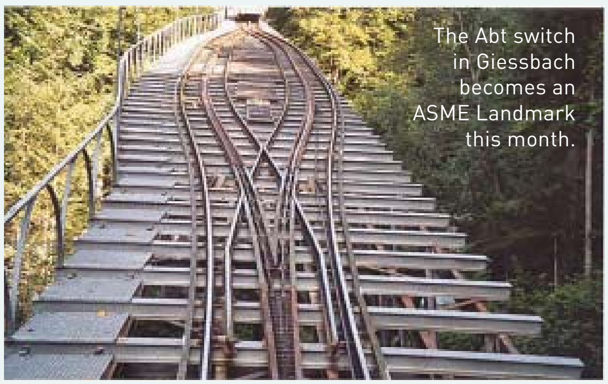
These first installations were driven by water counterbalance. The principle included two cars on an inclined track hanging on a steel cable routed via a deflection wheel at the top end. The counterbalanced cars had to cross each other at half way and this required two parallel tracks with four rails total, two for each car. The speed of the cars was controlled with a friction brake.

Two parallel tracks required a wide right-of-way. Three-rail arrangements came into operation in order to cut down on the width of the right-of-way. But these had still an increased track width on the full length.

Carl Roman Abt invented the final two-rail system in 1879. He built the first installation of this kind in Giessbach, Switzerland, where it is still in operation and has been selected to become an ASME Landmark of Mechanical Engineering on August 27.

Abt's first version with turnout from 1879 used cars with different flanging on their wheels: For one car, the wheels were flanged on the inside, as usual; for the other, the wheels were flanged on the outside. This enabled automatic passing, but it required cutouts in the rails, which made the passage bumpy.

Abt improved upon his invention in 1886 for an installation in Lugano, Switzerland. In this version, both cars had wheel flanges on both sides of the outer wheels, and no flanging on the inner wheel. That arrangement was was so successful that the design has remained unchanged since. This improved version was installed in Giessbach in 1891, too.


The Abt switch in Giessbach becomes an ASME Landmark this month.

The Abt switch ensures an absolutely safe operation. There are no movable parts (except the cars). Access to the turnout is often difficult; indeed, no accident caused by malfunction of the Abt Switch has been reported so far.

The Abt switch opened the opportunity to build long installations greater than 1,000 meters difference in elevation and for moving loads heavier than 200 tons. More than 1,000 installations have been built and there are still new ones under planning or construction.

While the Abt switch principle hasn't changed in 129 years, technical progress has continued. The Giessbach funicular, for instance, has changed its power source to a direct water turbine drive acting on a modified deflection wheel, and then to an electric drive. The updated controls now allow a ride like in an elevator.

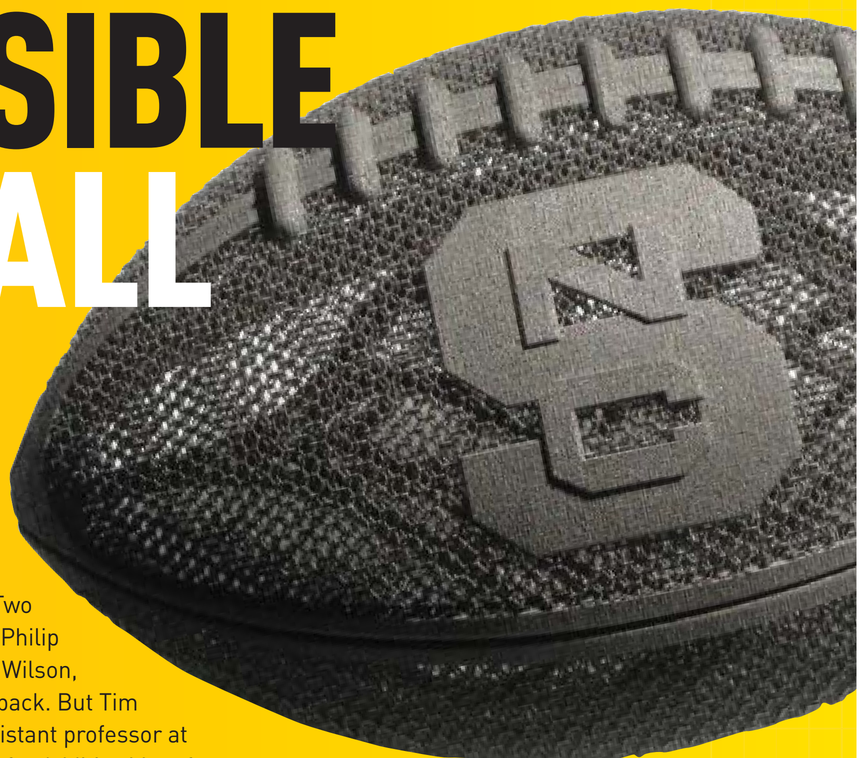
There is an interesting remainder of the first water counterbalance operation phase. This is the cog rail: Initially the speed of the cars was controlled manually with a friction brake acting on the cog wheel of the cars, which is engaged in the rail. After the modification to the turbine drive, this function was obsolete. But the brake acting on the cog wheel is still used as an automatic emergency brake in case the haul cable loses its tension. (Newer funiculars have emergency brakes acting directly to the rails.)

Another visible remainder of the first water counterbalance operation phase is the track arrangement itself. Abt had to design it for a nearly constant inclination in order to avoid excessive braking requirements with one car on a steeper track location than the other. A large part of the superstructure is therefore on bridges. Nowadays changes in inclination are only limited in the concave case by the natural sag of the haul cable in the highest tension case. The reason is that the cable should remain in its guidance pulleys. ME

HANS E. WETTSTEIN works in Zürich and is a member of the Switzerland section.

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.

IMPOSSIBLE FOOTBALL



HOW BEST TO DEMONSTRATE THE ADVANTAGES OF ADDITIVE MANUFACTURING? DESIGN AND BUILD AN OBJECT THAT CAN'T BE MADE ANY OTHER WAY.

North Carolina State University is known for producing quarterbacks: Two current NFL stars, Philip Rivers and Russell Wilson, played for the Wolfpack. But Tim Horn, research assistant professor at N.C. State's Center for Additive Manufacturing and Logistics, likes to point out that the Raleigh-based school is also a major research center for additive manufacturing.

Recently Horn wanted to demonstrate the power of the additive manufacturing processes he teaches to some 300 students taking classes in the center. He designed an object that possesses a number of features that are all but impossible to produce through traditional manufacturing methods such as milling, stamping, or casting.

Tim Horn (right) describes the manufacture of his 3-D printed titanium football to North Carolina State chancellor Randy Woodson.

That the object was a titanium football with the school logo built into the side was just an attention-getting detail.

"It's a demonstration piece," Horn said. "In the context of using additive manufacturing as a true manufacturing tool, not just for prototyping, we teach the students about the traditional design for manufacturing constraints. Then we show them additive manufacturing and how those constraints are different. The students have to think differently about how designs are created and how you can incorporate additive manufacturing along with traditional processes."

According to Horn, N.C. State has been involved in advanced manufacturing for more than 15 years. The Center for Additive Manufacturing and Logistics has partnered with a number of other schools at the university to produce new types of patient-specific medical implants and aerospace components and to investigate different materials for use in 3-D printing.

"We worked with Arcam to develop the titanium alloy process so that we could do our custom implants," Horn said. "The

The one-piece titanium football was made with internal structures that can't be made via extrusion or milling.

original motive for Arcam direct metal additive manufacturing was to produce tooling for injection molds. Implants weren't on their radar. This was something that we were pioneering."

As important as that work is, it doesn't always grab the attention of undergraduates. So the state-of-the-art additive manufacturing machines in the center's lab sometimes produce less useful but more fun objects. Horn said students sometimes toss around 3-D printed softballs and basketballs. "They bounce quite well, actually," he said.

The lab printed two footballs using an Arcam electron beam melting machine, using titanium powder. One of the footballs was presented to school chancellor Randy Woodson, who will display it at the football stadium; the other is staying in the lab.

The footballs are one piece, with a complicated internal structure surrounded by a fine mesh. Horn isn't sure that the balls are the right weight, but they meet the standard dimensions for NCAA footballs. They also have one definite advantage of standard cowhide balls, Horn said.

"They are immune to deflation, I can tell you that." **ME**

JEFFREY WINTERS

NASA SEEKS WIDER USE OF KENNEDY SPACE CENTER

NASA IS ACCEPTING PROPOSALS FROM PRIVATE COMPANIES INTERESTED in using its Vehicle Assembly Building, High Bay 2 at Kennedy Space Center for assembly, integration, and testing of launch vehicles.

The center also has three mobile launcher platforms available for commercial space operations.

NASA's 20-year master plan is to develop Kennedy Space Center as a multi-user spaceport.

"Making unique capabilities like the VAB available to commercial companies is yet another step in our evolution to a diverse spaceport that supports government and commercial partners," said Scott Colloredo, director of Center Planning and Development at Kennedy. "The Space Launch System relies on the VAB for assembly and integration, but High Bay 2 will be available in 2016 for commercial users, and we want to fully explore who might have a need for a massive integration facility at Launch Complex 39."

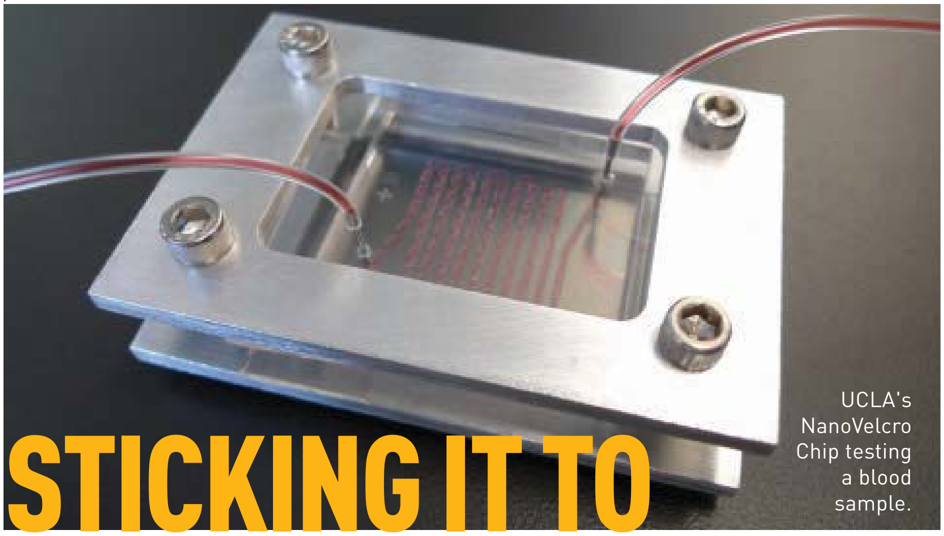
The Vehicle Assembly Building permits stacking of rockets as high as 450 feet tall using its 325-ton cranes.

NASA also has signed a 30-year agreement with Space Florida, the aerospace and spaceport development authority for the state of Florida, which will operate the Shuttle Landing Facility at Kennedy.

Built in 1974 for space shuttles returning to Kennedy, the facility opened for flights in 1976. The concrete runway is 15,000 feet long and 300 feet wide.

According to NASA, the runway already serves several private-sector and government entities. **ME**

NASA's 15,000-foot-long Shuttle Landing Facility at Kennedy Space Center will be operated under a new agreement by Florida's spaceport development authority.


UCLA's NanoVelcro Chip testing a blood sample.

STICKING IT TO LUNG CANCER

Lung cancer is by far the most lethal form of cancer, and lung cancer research is fraught with sticky scientific problems. Catching the disease early and finding the right treatment are the stickiest. But a new nanochip with a Velcro-like grip is grabbing the attention of oncologists eager for a diagnostic breakthrough.

Developed at the California NanoSystems Institute at the University of California Los Angeles, the NanoVelcro Chip is a blood testing device featuring a silicon nanowire substrate that selectively screens out high-purity early traces of cancer. Using about 2 milliliters of blood as opposed to invasive surgical biopsies or complex imaging methods, the chip has implications in a number of cancers. Recent improvements have shown potential in the care of advanced lung cancer, where any life-extending progress is cause for celebration.

The nanowire substrate gets its Velcro-like properties from a coating of special cancer-attracting antibodies. Traces of tumor DNA suspended in a blood sample stick to the substrate, where they are held for subsequent analysis.

The device is one of a number of emerging approaches to noninvasive cancer detection and monitoring based on the analysis of circulating tumor cells (CTCs) in blood. These cellular fragments from a growing tumor carry copies of its mutated genetic material through the bloodstream to new parts of the body, where they can corrupt healthy cells. By catching and analyzing CTCs, researchers are learning to create detailed, patient-specific molecular profiles of a tumor. Several new large-scale studies of these so-called liquid biopsies have recently strengthened many doctors' confidence in using them in patient care. CTCs have potential in early cancer detection, but a nearer-term payoff is likely as a target for molecular characterization and monitoring of cancer cells in response to treatment.

NanoVelcro was developed by an international team of scientists and engineers from UCLA and Japan's Riken Advanced Science Institute. UCLA team leader Hsian-Rong Tseng said the material catches CTCs with killer precision but handles them with kid gloves to ensure they are not physically altered before they are assayed.

Once captured, CTCs must be extracted from the chip without harming them to ensure accurate analysis. The original—and still standard—method for removing CTCs from the NanoVelcro substrate is laser capture microdissection. Although effective, the process is time-consuming and requires specialized equipment. A focus of Tseng's ongoing work is to simplify the process as much as possible while retaining the vital integrity of the CTCs. One answer, it seems, was as close as the nearest Starbucks.

By endowing the NanoVelcro Chip with temperature-responsive continued on p.15»

TIDES TO GENERATE 1.2 MW

A manufacturer plans to install an array of tidal turbines to generate electricity at a key barrier in the Netherlands' water defenses.

The company, Tocardo Tidal Turbines, said it will install five tidal turbines at the storm surge barrier of the Eastern Scheldt Estuary. The structure is one of a series of dams and barriers known as the Delta Works, which protect the Netherlands from flooding from the North Sea.

According to Tocardo, the turbines will be operational this autumn and have a total capacity of 1.2 MW.

The project has received funding from the European Regional Development Fund, the Dutch government, and the province of Zeeland as part of the Operational Program for Zuid-Nederland, a development initiative supporting innovation and a low-carbon economy in the southern Netherlands.

Earlier this year, Tocardo installed three linked turbines with a total capacity of 300 kW in the Afsluitdijk, a 30 km long primary sea defense at the mouth of the Ijsselmeer, near Tocardo's headquarters in Den Oever. The Eastern Scheldt project will be the largest tidal power plant to date in the Netherlands.

The company said it is working closely with a partner, Huisman, the Dutch heavy-equipment maker, which is a shareholder and designed the turbines' suspension structure. Another partner, Struckton, a civil engineering firm, will be in charge of project management.**ME**


IMAGINE DESIGNING
AN 831,000 SQ FT HOSPITAL THAT NEEDS TO BE BUILT IN 30 MONTHS
Meeting the demands of complex projects requires everyone to be on the same page. Learn how Bluebeam® Revu®'s PDF-based collaboration solutions enabled Mortenson and their partners on the Saint Joseph Hospital project to coordinate design changes in seconds – not days.
Imagine the possibilities
bluebeam.com/engineer
bluebeam®
NO LIMITS®
© Copyright 2015 Bluebeam Software, Inc.
Mortenson
construction

SMART PHONE VS. DISEASE

YOU WON'T FIND MANY polymerase chain reaction thermocyclers in rural Kenya, but you will find a lot of people who could use one.

The PCR is a mainstay of disease detection, but it has been frustratingly scarce in the world's hard-to-reach communities. The equipment can be expensive, bulky, and a power guzzler.

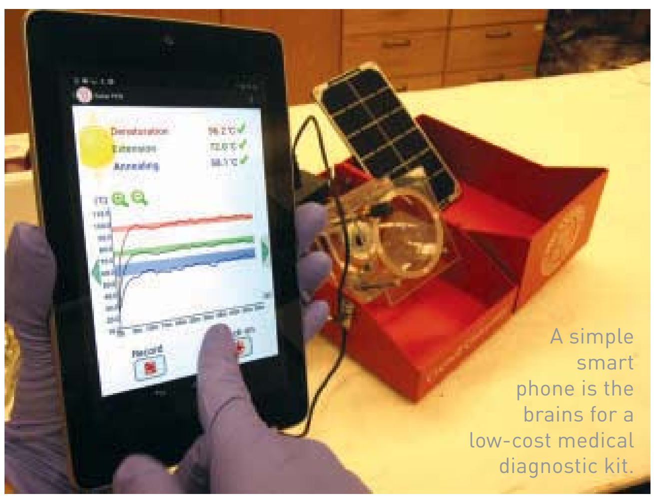
Smart phones might change that. David Erickson and his team from the Sibley School of Mechanical and Aerospace Engineering at Cornell University in Ithaca, N.Y., have built a solar-powered PCR thermocycler that pushes the sample analysis onto a phone with an add-on and an app. The team tested the equipment in western Kenya in 2014 and presented findings in April at ASME's Global Conference on Nanoengineering for Medicine and Biology in Minneapolis.

In Kenya, the rate of Kaposi's Sarcoma is among the highest in the world. The cancer afflicts people with compromised immune systems, including AIDS patients. A test of a biopsy might not be sensitive enough to detect the cancer. But a PCR thermocycler set to detect the cancer's DNA will find and copy it enough times to register on the test that was not sensitive enough for the unaltered biopsy.

PCR starts with two primers, single strands of unzipped DNA that match the thing it is looking for. In Kenya, the primers were from cancer DNA. The process requires three phases, each at a different temperature.

The first step is denaturation, in which the DNA double helix unzips into two single strands at a temperature of 94 °C (201.2 °F).

Next, the sample has to cool to 54 °C (129.2 °F) for the annealing phase, in which the primers glom onto the single strand of DNA that they are set to detect. In this case it's the herpes virus that causes Kaposi's sarcoma. The primer plus the single strands make whole, double-stranded DNA sequences, and the polymerase enzyme goes to work copying them. In the third phase, the sample is heated to 72 °C (161.6 °F) for the extension, in which the polymerase works most efficiently. The enzyme runs along the strand pulling in raw material to copy it. The machine repeats the three steps dozens of times.



A simple smart phone is the brains for a low-cost medical diagnostic kit.

The mechanics of copying the DNA are not technically difficult. As Kary Mullis, the Nobel Prize-winning creator of the technique, wrote in *Scientific American* in 1990, "Beginning with a single molecule of the genetic material DNA, the PCR can generate 100 billion similar molecules in an afternoon. The reaction is easy to execute. It requires no more than a test tube, a few simple reagents, and a source of heat."

Traditional thermocyclers heat and cool the samples with electricity. Erickson and his team fit their off-grid version with a lens that concentrates sunlight to heat the chambers in the thermocycler to the right temperatures. The sample runs through channels carved into a chip. The chambers are temperature regulated by masks that allow only certain amounts of solar heat to enter.

When the DNA is copied, the user places the sample in a mobile-phone accessory. The accessory clips over the phone's camera and acts like a pregnancy test, changing color in the presence of DNA from Kaposi's sarcoma. The phone reads the results through its camera and analyzes it using an app developed for this system.

"The game is how to do something useful without using any infrastructure," Erickson said. An iPhone battery can power the process for 70 hours, Erickson and his colleagues wrote in a paper published in February 2014 in *Nature*. Their field system includes a small photovoltaic panel for the hardware.

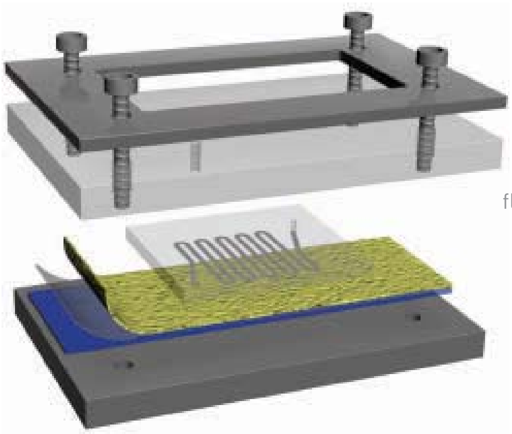
"We tried to build an advanced diagnostics system around a cell phone," Erickson said. "We got it operating off of a 4,000-shilling phone [US$40] I bought off the street."

Readings from the cellphone add-on compared to those from a standard spectrometer, Erickson said in his presentation at the nanoengineering conference. Early data find that the test may have a sensitivity rate, or true positive rate, of more than 90 percent. And it may have a false positive rate of about 5 percent.

For now the researchers are developing the Kaposi's sarcoma test, but a PCR-based test could detect many other kinds of cancers, HIV, tuberculosis, and other bacteria and viruses.

Erickson's cellphone-based system may be a first, but others are working on low-cost PCR. A company called OpenPCR offers an open source thermocycler in kit form at $649.

ROB GOODIER, ENGINEERINGFORCHANGE.COM



When blood flows through a microchannel, cancer cell DNA sticks to a nanowire substrate (shown in yellow).

continued from page 12 »

STICKING IT TO LUNG CANCER

polymer "brushes," Tseng said, the group has achieved good CTC capture-and-release efficiency simply by manipulating the temperature of the blood sample—the way a skilled barista can adjust the properties of a drink to customer specification.

"With our new system, we can control the blood's temperature the way coffee houses would with an espresso machine—to capture and then release the cancer cells in great purity," he said.

At 37 °C, blood-borne CTCs adhere to the thermoresponsive brush material and stay there. To introduce the cells into an analytical instrument or gene sequencer, the researcher lowers the temperature of the blood sample to 4 °C and they are released in a state of high purity.

Tseng said the technology could provide a cost-effective and fast alternative to laser capture microdissection in the care of patients for whom time is of the essence. By combining the NanoVelcro capture approach with mutational analysis, he said, the technology has successfully monitored the disease's evolution at the molecular level in real patients.

Lung cancer claims some 160,000 lives each year in the United States and 10 times more on a global scale. Its lethality rate far surpasses that of breast, prostate, and colon cancer combined. Stealth is its ultimate weapon. The telltale symptoms rarely appear until a tumor is advanced, so the disease is almost always diagnosed after it's already beyond treatment. Among patients diagnosed with stage 4 lung cancers, 96 percent will die within five years.

However, new targeted drugs like Tarceva have been effective against lung cancers caused by specific genetic mutations. Another cause of excitement is a new generation of immunotherapies like the just-approved Opdivo. In many cancers, precision combinations of molecularly targeted and immunotherapeutic drugs like these are fueling new optimism. With the added diagnostic and monitoring support of techniques such as NanoVelcro, doctors and patients have a new source of hope to hang on to.

MICHAEL MACRAE, ASME.ORG

THINK LIKE A GENIUS

Identifying the **basic, underlying principles** of a problem can lead an engineer to a **truly innovative solution.**

Geniuses, by one definition, are luminaries who change the world with extraordinary insight or creativity. We are fascinated by the minds of Alan Turing or Stephen Hawking, featured in recent Oscar-nominated films.

But studies show that even Nobel laureates, universally considered geniuses, don't universally exceed the rest of society in intellect, innate ability, or knowledge. Having the competence to complete an engineering curriculum places one in the same statistical range intellectually as many Nobel winners.

"A formidable IQ promises nothing, and a sub-genius IQ is still an exploitable resource," writes Dean Keith Simonton, a professor of psychology at the University of California-Davis and the author of *Greatness: Who Makes History and Why*.

So why do some achieve genius status? And how can the rest of us, occasionally at least, reach that level in our engineering careers?

Brian Muirhead, chief engineer at NASA's Jet Propulsion Laboratory, relates a story about a junior engineer developing the airbag landing system for the Mars Pathfinder. The program didn't always go well.

"The thing that made him successful," Muirhead said, "was his tenacity, his drive, his energy. [He was] willing to pick himself and his team up in failure after failure, and keep at it."

Steven Kern, a scientist and deputy director at the Bill & Melinda Gates Foundation, says that successful technologists translate knowledge from one field to another. It's something he himself demonstrates. A mechanical engineer with a Ph.D. in bioengineering, Kern uses his engineering know-how to manage diseases on a worldwide scale.

"The control systems theory I learned in the [Penn State] artificial heart program I'm now applying to pharmacological delivery using a control systems approach," Kern said.

Amy Smith, a mechanical engineer and MacArthur Fellow, says that a diversity of perspectives is important, especially when creating or innovating. She co-directs MIT's D-Lab, which is committed to improving the lives of people living in poverty through educational and technology outreach.

The ingredients for success include empathy for people and places. "Contextual knowledge is critical," Smith says. "If you're designing a peanut sheller, spend a few hours shelling peanuts with the local women."

According to Muirhead, leadership and collaboration contribute to genius. "Engineering is a team sport," he says.

But one characteristic of genius stands above all others. Muirhead describes a former JPL colleague, lead mechanical systems engineer William Layman, as a genius because he grasped the basics of a problem. "Oftentimes, problems appear complex," Muirhead says, "but he could boil them down."

According to Kern, geniuses can "see the basics, and say, 'These are the core or key elements of what we have to do.'" They pay great attention to the details that matter.

> **"MOST TRUE GENIUSES (KEPLER, NEWTON, EINSTEIN, AND EVEN STEVE JOBS, TO NAME A FEW) HAVE AN INSTINCT FOR SIMPLICITY."**
> —Walter Isaacson in *The Innovators: How a Group of Hackers, Geniuses, and Geeks Created the Digital Revolution*

Smith admires a retired MIT professor, Carl Peterson, for his "incredible knack" for reducing challenges to basic, underlying principles.

She did that herself to invent a phase-change incubator for labs in the developing world. Seeing temperature control, not power, as the basic problem, she devised an insulated container with a phase-change material that maintains temperature. Heat can come from any source, and electricity is unnecessary.

Geniuses reduce problems to basic principles. This leads them to simple, elegant solutions. That might not be simple for the rest of us, but it is possible. We just need to think that way. ME

JAMES G. SKAKOON is a retired mechanical design engineer and a frequent contributor.

COMPRESSED AIR: DON'T FORGET IT

A two-stage compressor of the sort overworked at the garment factory.

During an energy review at a relatively new health care garment factory in the Southwest, we found that all three of the facility's rotary air compressors, each nominally rated 100 psig, were operating continuously at 115 to 120 psig.

Rotary compressor and dryer equipment designed for 100 psig is not happy when operating at 115 to 120. The compressor runs hotter, and exit air temperature is higher. Exit air carries over a little oil vapor, and the filters that protect the dryer from hydrocarbons begin to foul. Overall dryer performance decreases and pressure differential increases.

The situation begged for an explanation, so we asked the production superintendent if this was normal or if something had recently changed. He explained that initially the plant operated two units. It began running the third unit in trim mode after some converting machines were upgraded. A new, larger converting machine was recently installed, and air pressure quickly became a production issue. Since capital funds were tight, the project engineering team determined that the third compressor had sufficient capacity.

Our preliminary investigation had revealed that all three compressor systems were running at 120 psig (with no crucial operational issues), yet system pressure on the production floor was marginally low and causing intermittent production quality issues. The compressor motors had high amps and high air temperatures, and the dryers were overloaded because of the hot air.

This type of situation occurs occasionally when manufacturing systems engineers manage plant expansion projects. They occasionally have tight project budgets and do not always conduct a thorough assessment of the plant utility equipment. It is the responsibility of site plant engineering to be involved and identify how new loads could impact the utilities: electrical motor control centers, air compressors, process water, HVAC, the steam system, etc.

Our experience is that compressed air is the most often overlooked utility during expansion projects.

The project team apparently had not conducted a thorough due diligence of the entire system to determine if it could adequately supply a relatively higher system demand. Hey, three robust compressors and dryers with a 4-inch air header should work.

But when it comes to standard air dryers, there is a "Three-100s Rule": Operating conditions should not exceed 100 psig inlet pressure, 100 °F inlet temperature, or 100 percent rated flow.

The compressors and dryers had been installed in parallel mode to provide system flexibility; however, piping restrictions (fittings and valves) at the compressors, the in-line filters, and dryer connections were causing downstream pressure problems with all three units in service. More review confirmed that the original design of the system was for only two compressors to be in normal operation. But, since the

continued on p.19 »

Q&A JON SCHULL

JON SCHULL HAS HAD A VARIED background as an academic, entrepreneur, teacher, and, most recently, founder of a volunteer organization that provides crowd-developed prosthetics to young people who have lost their hands or arms. He is a research scientist in the Media Arts Games Interaction Creativity Center at Rochester Institute of Technology. His organization, Enable Community Foundation (e-NABLE), recently won a $600,000 Google Impact Challenge grant that it will use to improve and test its prosthetic devices, as well as the social digital humanitarian infrastructure that brings volunteers together.

ME: How did e-NABLE begin?

J.S: Two years ago, I saw a YouTube video of a South African carpenter who had cut fingers off his hand. He was told a partial hand prosthesis was expensive and hard to come by. By Googling, he found Ivan Owen, a puppeteer who built the first 3-D hand. They created a prosthetic and put the design online.

Many people commented that they wanted to help. So I added a comment, and asked anyone who wanted to make a hand or knew someone who needed a hand to put themselves on a Google map.

Owen's video went viral, and within six weeks, we had 70 members. People starting calling me and asking, "What do I do?" I had no idea, so we began to figure it out. Last week we crossed 5,300 members, and we are growing 1 to 2 percent every week.

ME: Where did you get your original design?

J.S: It was based on a mechanical prosthetic created for a New England sea captain out of ivory more than 100 years ago. It consisted of a gauntlet that wraps around the forearm and a gripper that goes on the remaining palm. Flexing your wrist pulls strings anchored on the gauntlet and bends the fingers.

ME: How do children take to these prosthetics?

J.S: Because they come out in bright colors and look like super-cool robotic hands, they are a total hit. Children feel that they are superheroes. They have a flaw that turns into a super power.

ME: Tell me about your design process. Any surprises?

J.S: When you stir together 5,000 people and 10,000 ideas and posts, the result is a Cambrian explosion of new ideas and designs.

The one that gave me the biggest kick involved Luke Dennison. His dad is an HVAC installer who learned 3-D printing and design from another dad, whose kid had missing fingers.

Luke's father came up with a way for his son [who was born missing fingers on one hand] to hold a light saber toy by putting a second thumb on the opposite side of the prosthetic hand. It makes for a really good grip, and seems so intuitive when you see it. Luke is now known all over the world as Little Cool Hand Luke.

ME: Do engineers and non-engineers approach prosthetics differently?

J.S: It's interesting. Engineers are extremely valuable in developing products. But engineering is about getting it exactly right. What we're about is creating designs that are substantially better than nothing. We sail early and often and share ideas.

ME: So what do you see as your challenges going forward?

J.S: We have lots of volunteers, but need better ways to organize them. It's hard to herd cats, and even worse when you put the cats in charge of herding.

We've already moved beyond the typical open-source communities and Wikipedia models, because we're not just tinkering with technology. We're providing direct real-world services with hardware.

To learn more about e-NABLE, go to: www.enablingthefuture.org.

We want to explore this new digital way of organizing ourselves. We want to figure out what iceberg we are the emerging tip of. Are we capitalism? Communitarianism? The post-abundance economy? Or a transition before traditional methods step in and create a product?

ME: You started as a psychologist. How did you end up here?

J.S: I started out in biological psychology, and wrote software to analyze my data. I used those skills to found a company to protect digital IP, and later taught computer-human interaction and innovation at Rochester Institute of Technology.

During that same era, copy encouragement and open source emerged, which was not part of my original recipe. Now, I've gone over to the other side. I've found that letting it go is much more efficient and rewarding than trying to protect and defend IP. ME

continued from page 17 »

COMPRESSED AIR

third unit was not fully loaded, the project team had determined (theoretically) that it should provide the additional capacity for the new converting machine. But, unforeseen piping restrictions were causing compressor performance issues.

These relatively new compressors (150 hp, 750 cfm) were capable of supplying over 2,000 cfm to the plant. However each air dryer line could handle only about 600 cfm before incurring excess pressure loss. In addition, 400 feet of 3-inch main air line to the production area had a nominal capacity of about 1,600 cfm. The new converting equipment (300 cfm air usage) had overloaded the plant piping distribution system. Moreover, additional artificial demand in converting, the use of air hoses to clean the machinery, was out of control.

We recommended changing the valves and fittings at the compressors and dryers from 2-inch to 3-inch size and running a new 2-inch air line from the 4-inch main header (after the flow meter station) to the new converting machine. Pressure storage options were not practical because of the 3-inch header in converting; but, we did suggest 10-gallon surge tanks at the two case-packer machines.

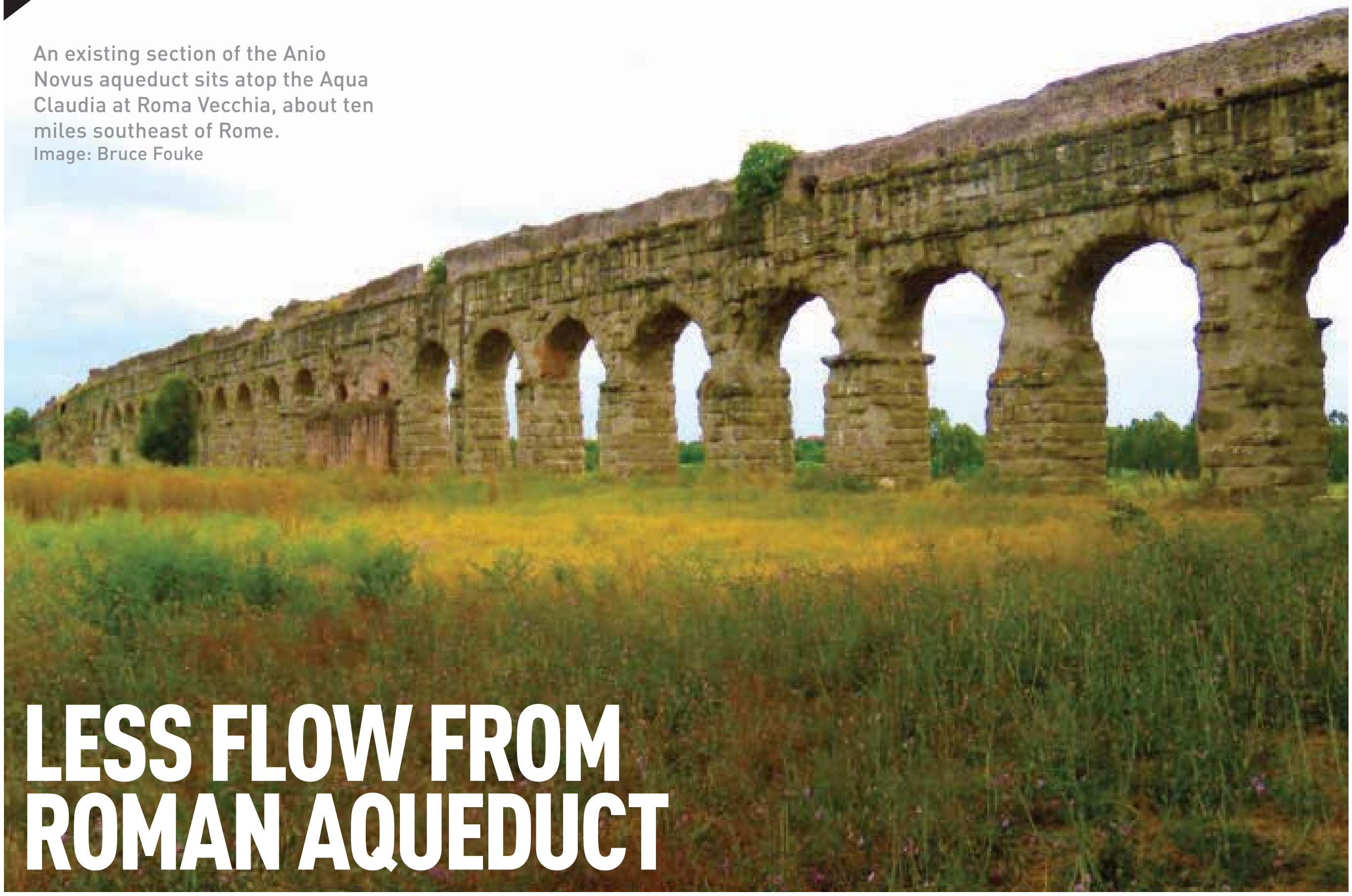
It took a few weeks to get funds approved and make the changes. Some preventive maintenance work also improved dryer performance. Later the compressors were back to operating at 95-100 psig (with 85-90 psig in converting), and production improved.

We recommended that a formal rental compressor delivery plan be established for major maintenance service and emergencies until a fourth compressor/dryer line was installed.

The production issue was resolved. Moreover, every 2 psig drop in the compressor discharge pressure produces a 1 percent reduction of motor power. So 20 psig yielded 10 percent power savings on the 400 hp load. In addition, compressors and dryers operating at 95-100 psig will have a much longer life and fewer maintenance issues than those operating at 115 to 120 psig.

When conducting a problem resolution exercise, be sure to fly your helicopter high enough above the rooftop to get the big picture. It also helps for the "elephant in the room" to have good operational experience. **ME**

GARY WAMSLEY is an engineering consultant at JoGar Energy Services in south Florida with over 40 years of industrial utility systems experience. He can be reached at www.jogarenergy.com.



An existing section of the Anio Novus aqueduct sits atop the Aqua Claudia at Roma Vecchia, about ten miles southeast of Rome.
Image: Bruce Fouke

LESS FLOW FROM ROMAN AQUEDUCT

ANCIENT ROME WAS A CITY DEPENDENT ON IMPORTED water. Beginning in 312 BCE, the city built a series of aqueducts to supply water from the surrounding region to support a population that would reach as high as a million by the beginning of the imperial period.

But for their size and the degree of documentation, there's no agreement on how much water the aqueducts conveyed. A study published in June in the *Journal of Archaeological Sciences* examined the buildup of limestone deposits in the flow channel of one aqueduct supplying Rome and determined that final flow reaching the city was significantly smaller than had been previously estimated.

The researchers from the University of Illinois, Urbana-Champaign, looked at a surviving portion of the Anio Novus aqueduct, which was finished in 52 CE. This expansion of the Roman water system tapped into the somewhat muddy Aniene River more than 50 miles east of the city and delivered it to a large cistern that mixed together water from several sources for distribution across the city. The aqueduct was likely still in service during the reign of the last emperor of the Western Roman Empire in the fifth century.

How much water this or any other aqueduct could carry in ancient times has been disputed. According to the geologist Duncan Keenan-Jones, lead author of the study, and his colleagues, a CE 97 account from Roman water commissioner Sextus Julius Frontinus is riddled with discrepancies and did not account for flow velocity, relying instead on a simple cross section of the water held in the aqueduct in the channels.

To get a better estimate the researchers examined a surviving section of the aqueduct and measured the residue of travertine limestone that remained in the channel. They then modeled how that limestone would have coated the walls of the channel while the aqueduct was operational, and how much water must have flowed over the centuries to have left that much travertine behind.

According to the model, the aqueduct was almost always full of water. But the shallow slope of the aqueduct caused the flow rate to be much less than previously estimated, and the gradual constriction of the channel due to the mineral buildup would have cut the flow rate even further. If the Anio Novus aqueduct as constructed could have provided as much as 3.2 cubic meters a second, by the time the water stopped flowing the rate was down to just 1.4 cubic meters, or about 370 gallons.

What's more, the authors write, even a small coating of travertine on the aqueduct wall could have cut the flow rate by as much as 25 percent.

If other parts of the Roman water system suffered from similar mineral buildup, the gradual reduction in water supply would have put pressure on the city's large population. Even if it took German barbarians to finally kill the empire, the city already may have been slowly dying of thirst. **ME**


ENGINEERS START HERE
Access 500,000 in-stock electronics products, custom services, tools and expertise—all in one place. Plus, count on customer service that goes above & beyond to deliver your needs. Complete engineering solutions start at Newark element14.
1 800 463 9275 | newark.com
Newark
element14

The indoor robotics arena at Easterwood Airport, is the centerpiece of The LASR Lab. *Photo: Texas A&M*

READY ROBOTS

ROBOTS CAN DO JOBS THAT are impractical or dangerous for people—disarming explosives, inspecting critical infrastructure, and exploring space. This month we visit two university labs that are doing groundbreaking research in robotic technologies.

CLEANING UP SPACE

THE LAB Land, Air, and Space Robotics Lab, Texas A&M University, College Station; John L. Junkins, director.

OBJECTIVE Research in robotic sensing and control with an aim to enhance the fields of proximity operations, human-robot interaction, stereo vision, swarm robotics, and autonomous aerial vehicles.

DEVELOPMENT Sensing technologies for proximity navigation and laser detection and ranging (LADAR) systems sensors for high-definition ranging.

Near-Earth orbit is filling with space debris. In addition to countless smaller particles, there are 22,000 objects presently being tracked in orbit, ranging from 10 cm scraps to large derelict spacecraft and spent rocket boosters, which pose the most serious risks for dangerous collision. The International Space Station adjusts its course three or four times per year to avoid debris.

Thanks to his passion for removing space debris from Earth orbit, Texas A&M aerospace engineering professor John L. Junkins has been called a "space junkie."

"Our laboratory experiments focus on methods to remove large dead rocket boosters and satellites in near-Earth orbit," Junkins said. "Over 500 of these launched from the U.S. have a rocket nozzle. We are developing robotic systems that enable docking with the nozzles of dead satellites and driving them onto a trajectory to burn up in the atmosphere or land safely in the ocean."

Research challenges include developing reliable autonomous sensing and control systems, capture mechanisms, and new designs that make the debris removal missions affordable. The key feature of the capture device is a probe that, once inserted into the nozzle, deploys an inflatable bladder in the combustion chamber so the nozzle is firmly locked on.

LASR research has been funded by NASA, the Air Force Research Laboratory, and several industrial partners.

The probability of collision for extremely large satellites is about four impacts per year, according to Junkins. That probability will likely increase to an unacceptable level if more large collisions occur in the near future and create more debris.

"Studies indicate that taking down five to eight dead objects per year can completely arrest the growth of orbital debris and freeze the probability of future collisions at the presently tolerable levels," Junkins said. "Our goal is to make that happen." ME

Studying live snakes yields information relevant to more-efficient motion in robots. *Photo: Carnegie Mellon University*

SNAKES AND MODULES

THE LAB Biorobotics Laboratory, Carnegie Mellon University, Pittsburgh; Howie Choset, director.

OBJECTIVE Reduce complicated high-dimensional problems found in robotics to low-dimensional simpler ones by looking for inspiration from the natural world.

DEVELOPMENT Snake robots for industrial and medical applications and robotic actuators that simplify robot assembly.

Based on his research interests, you wouldn't think Howie Choset has a fear of snakes. After all, Choset, a Carnegie Mellon robotics professor, focuses on the development of snake-like robots. His research includes locomotion mechanics, chassis development, series elasticity, and machine learning for snake robots.

"We have been working with biologists and physicists at Georgia Tech to apply our analytic tools to study the locomotion of limbless animals," Choset said. "We have already developed some novel insights into sidewinder locomotion of real snakes, which have in turn helped us program more efficient motions for the snake robots."

Another key area of research interest is creating new modular robotics architecture that enables the rapid construction of custom-built, state-of-the-art robots. Components include sensor-packed robotic actuators that can be used to quickly assemble robots of various configurations—including, of course—snakes.

"The flexibility and reconfigurability of these tools allow robotic solutions to be more appropriately customized for their tasks, resulting in better robots," Choset said.

Choset is eager to bring robotics technology to the same level as computer technology. He pointed out that, unlike robots, computers have become easy to use, small, low-cost, and highly connected.

"Everyone has a computer in their pockets, homes, and cars, whereas robots are still difficult to use, bulky, expensive, isolated, and of limited use," he said.

One of the reasons for this, Choset said, is the lack of good building blocks to program, integrate, and develop robots.

"We are going to engineer the correct building blocks, which will then lower the cost and increase the flexibility and serviceability of robots," he said. "Perhaps most important, these building blocks will significantly decrease the programming time, and hence the cost, of deploying robots. In fact, we expect that our work will accelerate and transform the entire robotics development process." ME

MARK CRAWFORD is an independent writer based in Madison, Wis.

CRUISE LINE GOES BIG AND GREEN

A company that specializes in sea cruises has placed an order for four ships that aim for record guest capacity and, at least for cruise ships, record low emissions.

The company, Carnival Corp., said it has placed an order worth several billlion dollars with Meyer Werft, the shipbuilder based in Papenburg, Germany, for four "next-generation" cruise ships able to house 6,600 guests each. According to Carnival, they will have the largest guest capacity of any cruise ships in the world.

The ships' propulsion engines will be fueled by liquefied natural gas. Ships of this size conventionally burn diesel fuel.

The four ships will use LNG in dual-powered hybrid engines for power in port and on the open sea. LNG will be stored onboard and used to generate 100 percent power at sea. Carnival expects the use of LNG to power the ships in port and at sea will eliminate emissions of soot particles and sulfur oxides.

Each ship will have a total capacity of 6,600 guests and will feature more than 5,000 lower berths. Vessels will exceed 180,000 gross tons.

The company said the added capacity is largely the result of making more efficient use of the ship's spaces.

The company said two ships will be built for AIDA Cruises, Carnival's line directed at German-speaking vacationers. More information, it said, will be available at a later date.

Meyer Werft will build the two ships for AIDA Cruises at Papenburg. It will build the other two in Turku, Finland.

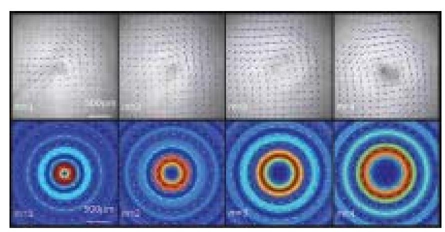
Including these four, Carnival plans to order a total of nine ships to be completed between 2019 and 2022, under a memo of understanding with Meyer Werft and Fincantieri S.p.A of Trieste, Italy. **ME**

TURNING THE SCREW, SONICALLY

In the long-running British television series, *Doctor Who*, the title character carries around a device called a sonic screwdriver. The fictional contraption can do whatever is necessary—from opening doors to breaking into alien computers—to speed the plot along. Now, real-life engineers are using structured sound waves to control particles in fluids. They refer to the system as a micro sonic screwdriver.

The team of researchers recently published a report that they had used small acoustical vortices to grip and spin microscopic particles suspended in water. It's not a screwdriver by any definition but it does open up possibilities.

The research team from the University of Bristol in England and Northwestern Polytechnical University in Xi'an, China, arranged small loudspeakers in a circle within a sample of water containing suspended particles. The speakers were pulsed in a precise manner to create a swirling sound wave. Small particles were not strongly affected by the sound, but larger particles—powders about the size of ground flour—were drawn into the center of the vortex created by the sound waves. Indeed, the larger particles sometimes spun at high speeds within the vortex or separated into concentric rings.



Microparticles twisting in an acoustic vortex. Top row: experimental observations. Below: predicted acoustic energy distributions.
Image: University of Bristol

Such a device may never open doors—one of the researchers, Bruce Drinkwater of Bristol, is quoted calling it the "watchmaker's sonic screwdriver"—but by separating suspended particles of a certain size, it could prove to be the basis of more useful tools. Cells could be separated from medical fluid samples, for example, or contaminants might be removed from water. **ME**

LARGEST SEA PLANE MAY FLY THIS YEAR


An artist's rendering of the AG600.

An amphibious aircraft designed in China to fight forest fires and carry out marine rescues may make its first flight before the end of the year, according to a report in the *People's Daily*.

The newspaper reported that assembly of the main part of the fuselage has been completed in Zhuhai city, in China's Guangdong province. According to *People's Daily*, the AVIC General Aircraft Co. will install wings, tail, landing gear, avionics systems, and airborne equipment on the plane, which will make its maiden flight before the end of this year.

The AG600, intended to be the world's largest amphibious aircraft, will be able to land on sea or land. It has a takeoff weight of 53.5 metric tons. It can collect 12 tons of water in 20 seconds to fight forest fires.

It will have four turboprop engines. Its top speed is expected to be 308 knots and its range 4,500 km.

By contrast, the Hughes H-4 Hercules, also known as the "Spruce Goose," was designed to have a maximum loaded weight of 180 metric tons, but could only take off and land on water. ME

LOOKING BACK

Even in an era of abundant fossil fuels, new production techniques were being explored in August 1965.

PROJECT GASBUGGY: NUCLEAR FRACTURING

ERNEST C. RAIA

An assistant editor of the magazine wrote a brief article about a plan to fracture gas-bearing rock with a nuclear detonation.

Project Gasbuggy involves the nuclear stimulation of a gas reservoir—in this case, natural gas. Exoterically speaking, atomic bombs will be detonated underground to fracture "tight" gas-bearing rock formations.

To see if this can be done, the El Paso Natural Gas Company, the Atomic Energy Commission, and the U.S. Bureau of Mines have recently completed an 18-month study outlining a possible nuclear experiment. Gasbuggy is a part of the AEC's Plowshare Program to develop peaceful uses of nuclear bombs.

Natural gas is found in porous sandstone or limestone rock; an area of such rock formation may include a few or several thousand miles, varying in thickness from a few to several hundred feet. Wells are drilled into the rock to tap the gas.

In sandstone, the gas occupies the spaces (pores) between each grain of sand. The pores of the sandstone may be partially plugged with clay or other similar materials, so that the gas cannot circulate freely from pore to pore on its way up the well bore. Little gas comes out of such wells, and only a small portion of the reservoir is drained. A way to unplug the flow, so to speak, is by a technique called fracturing.

Hydraulic fracturing is the method most often used; a fluid is pumped down the well under high pressure to effect the fracture or crack. The use of nitroglycerin today is not as common as it once was and anywhere from a 1,000 to 2,500 quarts of the delicate explosive are used to free more gas from the plugged reservoir. Both treatments, however, are limited in the extent and number of cracks they make.

In concept, nuclear fracturing is much like "shooting" a well with nitroglycerin; each method relies on an explosion to produce shock waves which fracture the rock. A nuclear explosion would create a cylinder or "chimney" of collapsed rock, with a network of fractures extending beyond the chimney. Even hairline fractures are effective in opening up a tight reservoir.

Calculations based on 160 and 640 acres were made in the study. Pictured Cliffs in the San Juan Basin of northwestern New Mexico was the formation chosen; here the natural gas reserves beneath each acre are estimated at 33 million cu. ft. Using conventional explosives and methods, only about 10 percent of the reserve can be recovered over 20 years from a 160-acre well site. Nuclear stimulation, on the other hand, probably can recover 67 percent of the same gas reserve....

Of course, the gas will have to be tested for radioactivity; so will the site have to be, for a number of years. There are no houses within a five-mile radius of the site; the nearest town, Dulce, is 20 miles away. Rainfall is light and vegetation sparse. The country is open, with low hills and ridges. According to a preliminary survey, there is no real amount of underground or surface water in the immediate area. ME

TOO HOT TO DISTRIBUTE

When Project Gasbuggy was finally carried out in December 1967, a 29 kiloton warhead created a rubble-filled cavern 80 feet wide and 335 high. The gas was radioactive, and a plan to dilute it with conventional natural gas was eventually abandoned. A plaque marks the epicenter of the explosion in the Carson National Forest and excavation is restricted at the site.

Image: Los Alamos National Lab

AncorAM™

Metal Powders for Additive Manufacturing

Hoeganaes Corporation, a world leader in the development of metal powders, has been the driving force behind the growth in the Powder Metallurgy industry for over 65 years. Hoeganaes has fueled that growth with successive waves of technology, expanding the use of metal powders for a wide variety of applications.

AncorTi™

- **Spherical Titanium Powder for Additive Manufacturing**
- **Particle Size Engineered for Selective Laser Melting (SLM) and Electron Beam Melting (EBM)**
- **Rigorous Quality Testing**

HOEGANAES CORPORATION
www.hoeganaes.com

ENGINEERING THAT MOVES THE WORLD

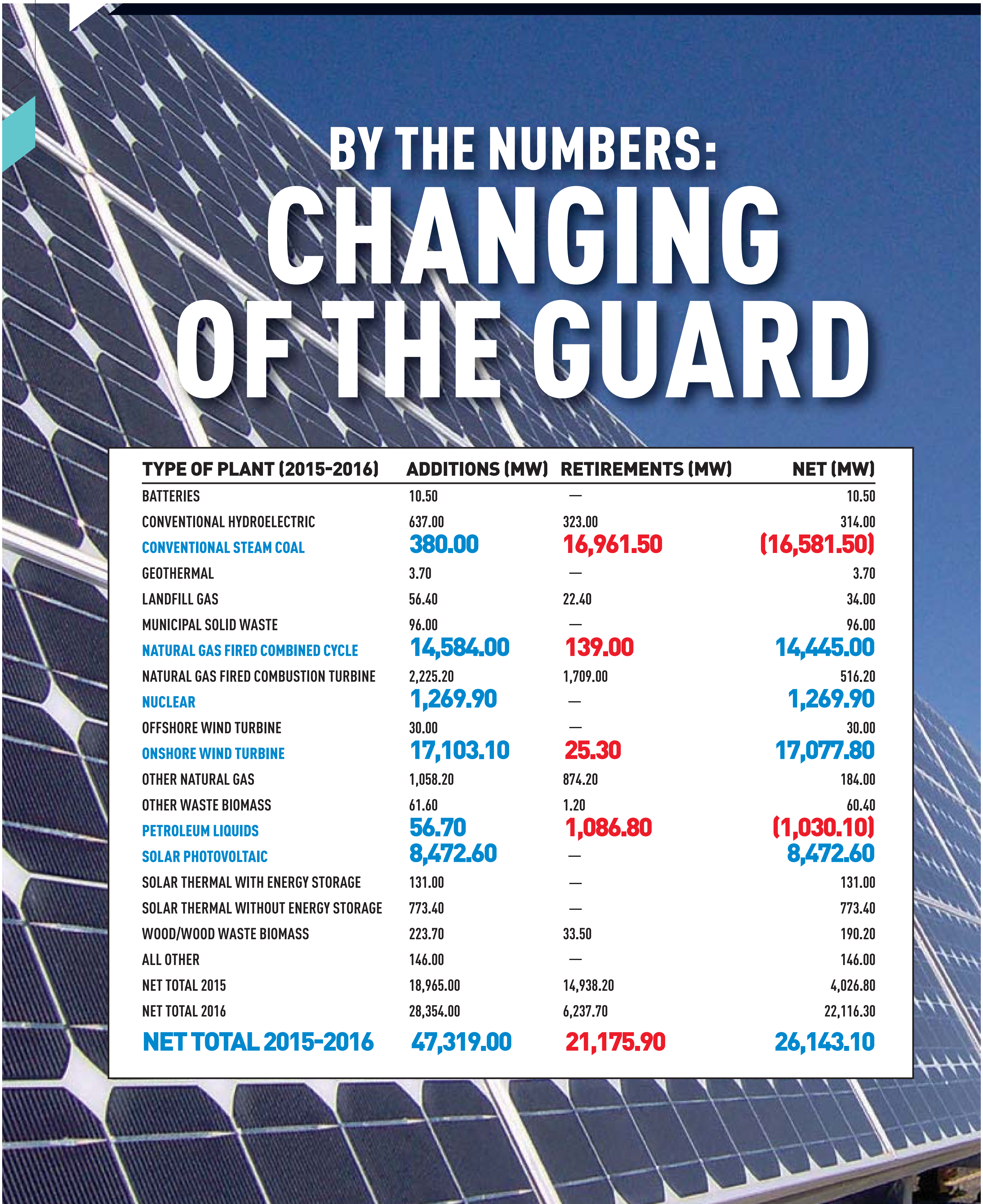
MOBILE DEVICE APPS NOW AVAILABLE FOR DOWNLOAD

App Store Google play

FOLLOW US ON SOCIAL MEDIA AT:

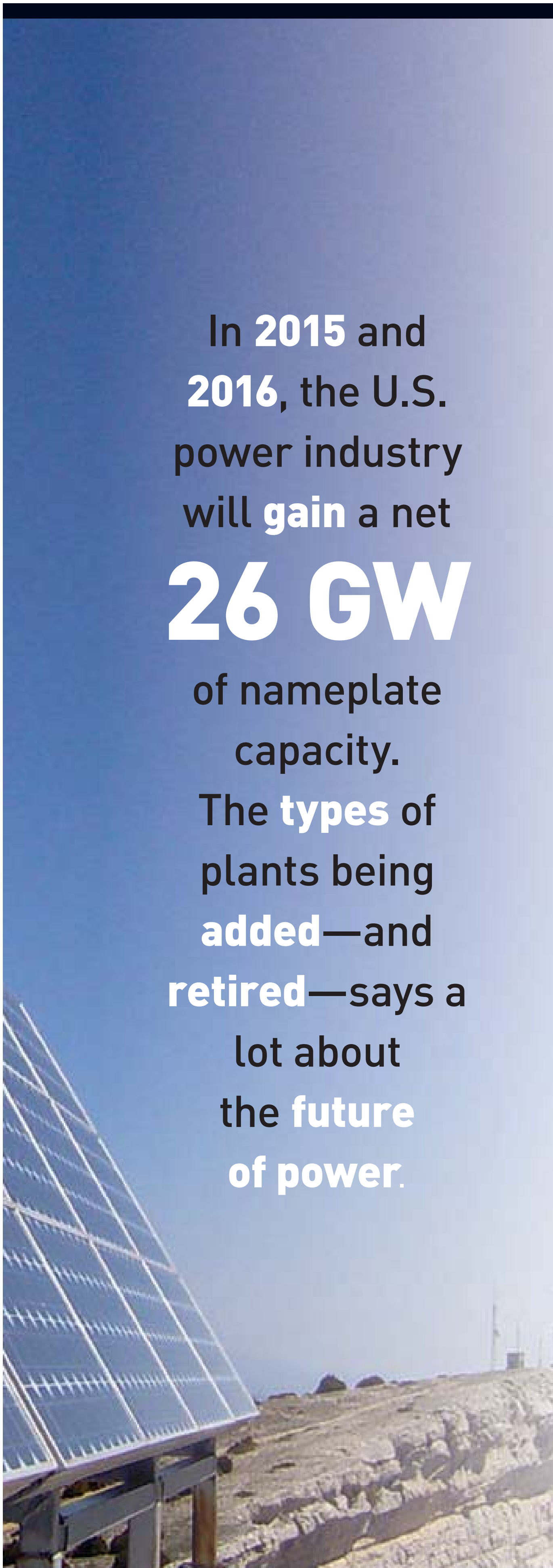
@HoeganaesCorp

YouTube LinkedIn



BY THE NUMBERS: CHANGING OF THE GUARD

TYPE OF PLANT (2015-2016)	ADDITIONS (MW)	RETIREMENTS (MW)	NET (MW)
BATTERIES	10.50	—	10.50
CONVENTIONAL HYDROELECTRIC	637.00	323.00	314.00
CONVENTIONAL STEAM COAL	380.00	16,961.50	(16,581.50)
GEOTHERMAL	3.70	—	3.70
LANDFILL GAS	56.40	22.40	34.00
MUNICIPAL SOLID WASTE	96.00	—	96.00
NATURAL GAS FIRED COMBINED CYCLE	14,584.00	139.00	14,445.00
NATURAL GAS FIRED COMBUSTION TURBINE	2,225.20	1,709.00	516.20
NUCLEAR	1,269.90	—	1,269.90
OFFSHORE WIND TURBINE	30.00	—	30.00
ONSHORE WIND TURBINE	17,103.10	25.30	17,077.80
OTHER NATURAL GAS	1,058.20	874.20	184.00
OTHER WASTE BIOMASS	61.60	1.20	60.40
PETROLEUM LIQUIDS	56.70	1,086.80	(1,030.10)
SOLAR PHOTOVOLTAIC	8,472.60	—	8,472.60
SOLAR THERMAL WITH ENERGY STORAGE	131.00	—	131.00
SOLAR THERMAL WITHOUT ENERGY STORAGE	773.40	—	773.40
WOOD/WOOD WASTE BIOMASS	223.70	33.50	190.20
ALL OTHER	146.00	—	146.00
NET TOTAL 2015	18,965.00	14,938.20	4,026.80
NET TOTAL 2016	28,354.00	6,237.70	22,116.30
NET TOTAL 2015-2016	**47,319.00**	**21,175.90**	**26,143.10**



In 2015 and 2016, the U.S. power industry will gain a net 26 GW of nameplate capacity. The types of plants being added—and retired—says a lot about the future of power.

The completion of Unit 2 of the Watts Bar Nuclear Power Plant in Tennessee has been more than 40 years in the making. Construction began on it and its sister unit in the early 1970s, but work was suspended on Unit 2 in the mid-1980s, even though it was around 80 percent complete. Even after Unit 1 was completed and began commercial operation in 1996, Unit 2 sat unfinished.

Sometime in the next year, however, the Tennessee Valley Authority is expected to put Watts Bar Unit 2 online, after almost nine years of additional construction. Its 1,269 MW of nameplate capacity is part of more than 47 GW of generating capacity to be added to the U.S. power system in 2015 and 2016. And while Watts Bar will certainly buoy the spirits in the nuclear industry, the pattern of additions—and retirements—shows a substantial shift in direction of the power industry as a whole.

According to data from the U.S. Energy Information Administration, which tracks the industry in its *Electric Power Monthly* report, 2015 will see 18,965 MW in new generating capacity balanced by 14,938 MW in retirements. Next year has a planned 28,354 MW in additions and 6,237 MW in retirements, for a net capacity gain of 26,143 MW for the two years. (The EIA reports additions planned out to 2023, for a gas turbine plant in Arizona.)

Within those additions and retirements is the continuation of a major overhaul in the sources of electricity in the U.S. Fifty-three natural gas-fired combined-cycle plants, which run the heat of combusted fuel through two different prime movers, are set to add more than 14,500 MW this year and next. And more than 17,100 MW of nameplate generating capacity is planned to be contributed by onshore wind turbines, though only 87 of the 155 projects are currently under construction.

And solar photovoltaic farms are scheduled to add more than 8,400 MW of nameplate capacity; even with their modest capacity factor, this is significant.

Together, natural gas combined cycle plants, onshore wind farms, and solar photovoltaic facilities are planned to add more than 40 GW of nameplate capacity, or 85 percent of the total.

Scheduled retirements are primarily conventional coal-fired thermal plants: in 2015 and 2016, 16,961 MW worth of coal capacity will close. That's more than 5 percent of the total generating capacity for coal. And another 12,000 MW of coal capacity is already scheduled to be retired after 2016, according to the EIA.

The power industry will have to work furiously to make up for those retirements, plus add capacity to account for growth in electricity demand. Even with the upcoming additions of Watts Bar and a couple of other large nuclear power stations, the mix of sources in the U.S. power industry in a few years will look quite different from the industry today. ME

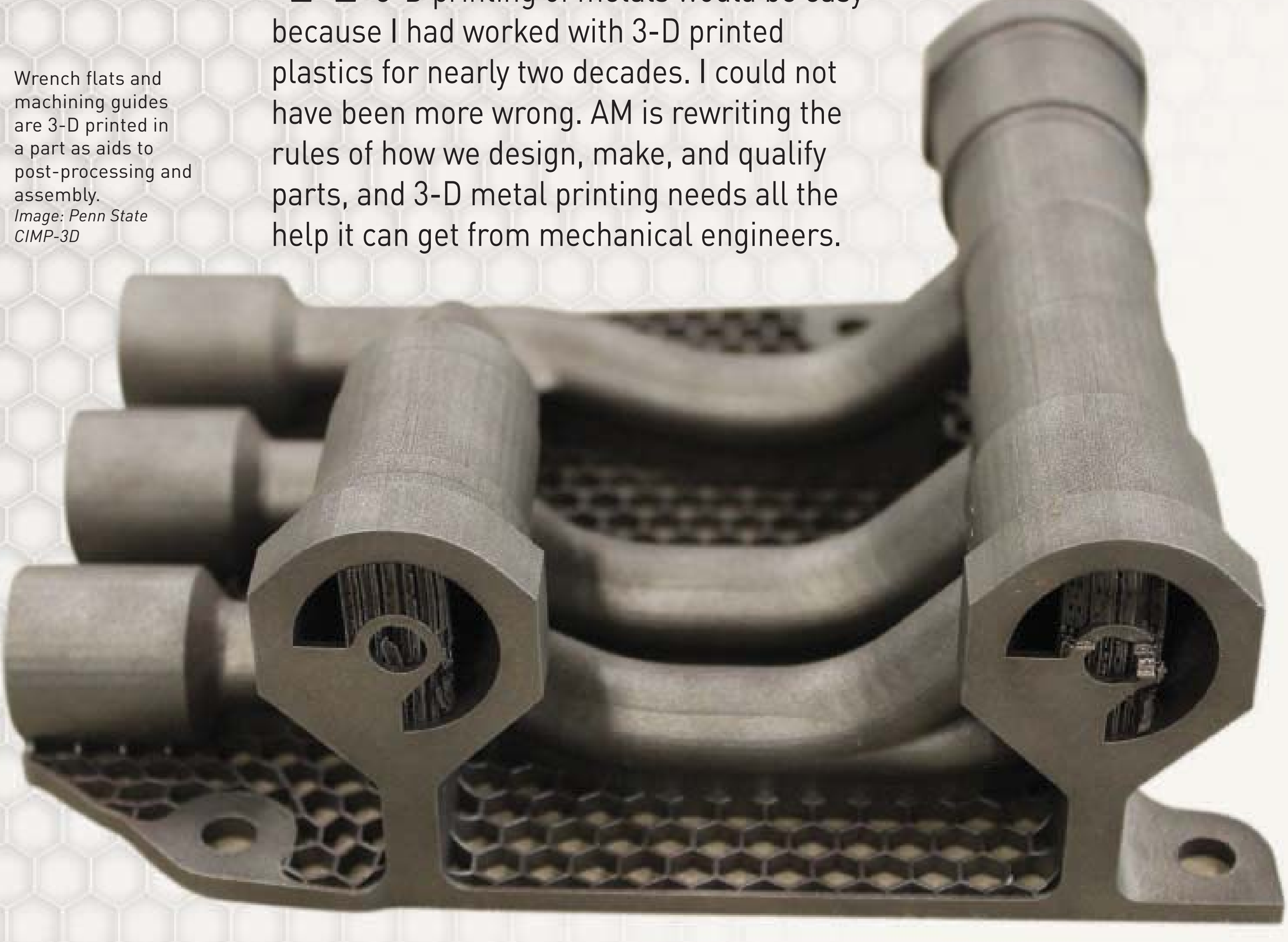
JEFFREY WINTERS

AM Needs MEs

3-D PRINTING OF METALS IS A PROCESS FULL OF UNKNOWNS; MECHANICAL ENGINEERS CAN FILL IN MANY OF THE GAPS.

BY TIMOTHY W. SIMPSON

When I started working in additive manufacturing three years ago, I thought 3-D printing of metals would be easy because I had worked with 3-D printed plastics for nearly two decades. I could not have been more wrong. AM is rewriting the rules of how we design, make, and qualify parts, and 3-D metal printing needs all the help it can get from mechanical engineers.



Wrench flats and machining guides are 3-D printed in a part as aids to post-processing and assembly.
Image: Penn State CIMP-3D

For starters, mechanical engineers have traditionally designed parts by selecting a material with the best known properties (based on how it was processed and heat treated) and then creating the shape they want.

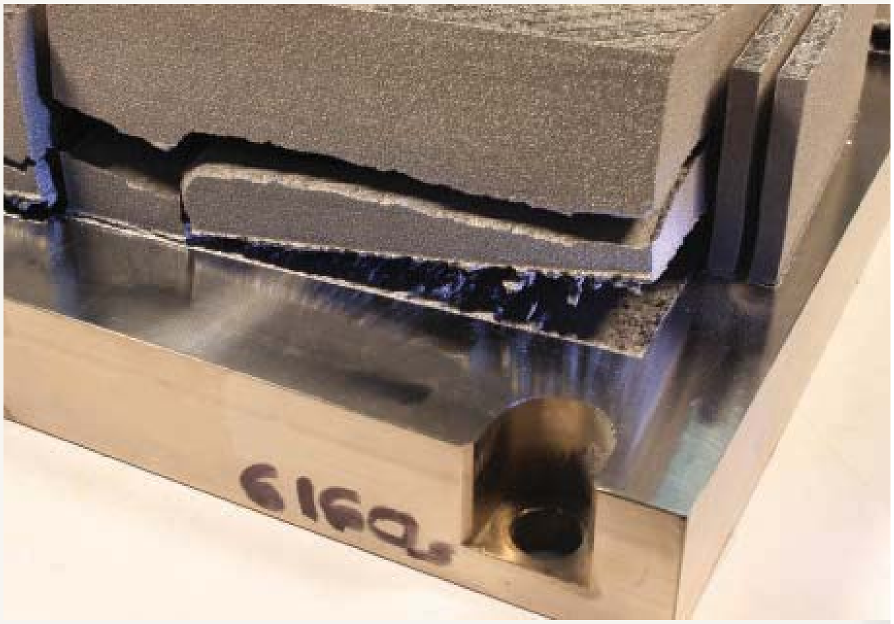
With additive manufacturing, the process is reversed. We print the shape that we want, and then we relieve stress, heat treat, age, or anneal the part until we get the material we want.

The process sounds simple, but it is not. The thermal cycling that 3-D printed metallic parts see during the layer-by-layer melting and fusion process, be it by laser or electron beam, has a huge influence on the microstructure, which in turn affects the material properties. So, the part that we thought we had designed and engineered for specific strength and mechanical properties is not necessarily the part we get—or it may be, depending on how it was made and post-processed. Because there are no good models to predict any of this, companies are currently treating each part as a "one off," which equates to extensive testing and verification for each part made by additive manufacturing, which is neither cost effective nor an efficient use of resources.

So why should we, as mechanical engineers, care about this? The answer's simple: every step of the process has numerous unknowns right now, and the tools, methods, and fundamental understanding needed to answer these questions do not exist. In short, MEs have a lot of work to do to help additive manufacturing reach its full potential.

Even though manufacturers have been selling powder-bed fusion and directed energy deposition systems for several years, we still do not really know exactly what is going on in these machines as the parts are being made. Modeling laser-powder interactions is difficult, especially since the physics and heat transfer phenomena are not fully understood in AM systems, particularly powder-bed fusion systems.

The models and simulations that have been created are computationally expensive and still undergoing validation and verification. Few can simulate a full part through its entire build process. Engineers trying to model and simulate 3-D metal printing using existing finite element analysis packages, such as Nastran or Abaqus, need billions of elements and billions of time steps, which invariably crash the software for even simple part geometries.



Residual stresses accumulated in this titanium part during the build and caused the material to rip itself from the build plate.
Image: Penn State CIMP-3D

Even if you can predict the thermal history the part experiences during a build, that is only half the problem. Models are needed to predict the residual stresses that will result and distortions that will occur, and estimate what the resulting microstructure is going to be—all of which will change for different process parameter settings, build orientations, and metallic alloys and powder parameters including particle size, distribution, and morphology.

Finally, because these AM processes are not well understood, we do not have any good tools for designing build supports in powder bed systems that can "anchor" the part to the build plate and counteract the thermal stresses that develop as the part is built up layer by layer. Based on our experience in the CIMP-3D lab at Penn State, at least 80 percent of build failures in powder bed fusion systems result from poorly designed support structures, yet analytical tools to optimize supports and corresponding build orientation of the part are limited at best. Polymer 3-D printing systems can use supports to counteract gravity and to ensure a successful build, but polymer supports are water soluble and easy to remove. Not so when 3-D printing metals—supports anchoring the part to the build plate must be removed by cutting, grinding, and other labor-intensive processes.

Parts want to curl up (like a potato chip) during a build and have been known to tear themselves from the build plate, particularly titanium parts fabricated using laser-based powder-bed fusion. There are ways to overcome this, but the process requires a lot of trial and error right now, which is expensive and time-consuming.

AIMING FOR SPACE

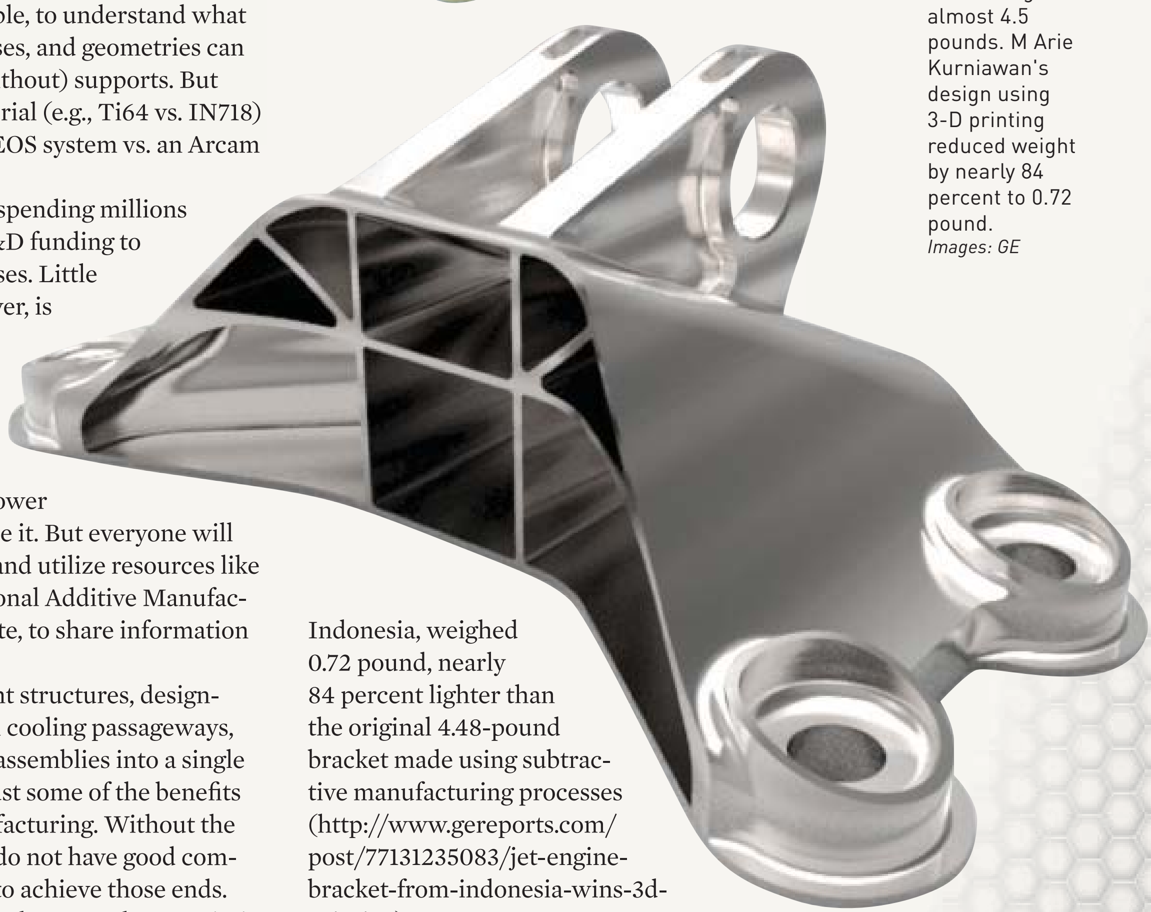
NASA is researching 3-D printing to save time and money on engine parts, including some for the RS-25, the former Space Shuttle main engine that will be used in a future heavy-lift launch system. In 2013, NASA put an injector (right) printed by selective laser melting through a test that generated 20,000 pounds of thrust.

Engineers at Marshall Space Flight Center placed the part—made of nickel-chromium alloy powder, fused by a high-power laser—in a test stand that simulated an engine environment. Pressures reached 1,400 psi in a vacuum and temperatures were almost 6,000 °F.

The injector had two parts, with a total of 28 elements for channeling and mixing propellants. Current comparable injectors have more than 100 parts each.

Directed Manufacturing Inc. of Austin, Texas, built the part from a NASA design, modified from a conventionally manufactured injector that had already been tested.

Images: NASA/ Marshall Space Flight Center/ Emmett Given



GE and GrabCAD asked designers to improve the bracket shown at top, which weighs almost 4.5 pounds. M Arie Kurniawan's design using 3-D printing reduced weight by nearly 84 percent to 0.72 pound.
Images: GE

Because we do not have a complete understanding of what is going on inside an AM system as a part is being fabricated, design guidelines and design rules for AM are not readily available, or are nascent at best. Studies are starting to become available, for example, to understand what overhangs, wall thicknesses, and geometries can be easily built with (or without) supports. But these values vary by material (e.g., Ti64 vs. IN718) and by machine (e.g., an EOS system vs. an Arcam system).

Private companies are spending millions of dollars of their own R&D funding to create AM knowledge bases. Little of that knowledge, however, is being shared because it provides a competitive advantage for those companies that have it. Since anyone can buy an AM system, the real power lies in knowing how to use it. But everyone will benefit if we collaborate and utilize resources like America Makes, the National Additive Manufacturing Innovation Institute, to share information and advance AM.

Engineering lightweight structures, designing sophisticated internal cooling passageways, or combining multi-part assemblies into a single printed component are just some of the benefits touted for additive manufacturing. Without the design rules, though, we do not have good computer-aided design tools to achieve those ends.

Like 3-D printing technology, topology-optimization tools, for instance, have been around for many decades, yet we only now have the means to fabricate the intricate and organic shapes that provide optimal loading for minimum weight structures. GE's jet engine bracket challenge was a great example of how AM can be used to lightweight components.

GE posted the design specifications and loading conditions for one of its jet engine brackets and crowd-sourced ideas to reduce its weight (https://grabcad.com/challenges/ge-jet-engine-bracket-challenge). Nearly 700 entries from more than 50 countries were submitted within a few months, and the top ten designs were identified, 3-D printed, and then tested. The winning bracket, designed by M Arie Kurniawan from Salatiga, Indonesia, weighed 0.72 pound, nearly 84 percent lighter than the original 4.48-pound bracket made using subtractive manufacturing processes (http://www.gereports.com/post/77131235083/jet-engine-bracket-from-indonesia-wins-3d-printing).

Making the part using additive manufacturing is not straightforward either. A lot can go wrong during the build process. The 3dprintingindustry.com blog carried a three-part entry called, "3D Printing Titanium & the Bin of Broken Dreams." In Part 3, Spencer Wright, a design expert at the organizational consultancy Undercurrent, describes six build failures, which he attributes to various causes, including the stripped-down simplicity of STL files and manufacturing tolerances too generous for larger parts.

Mechanical engineers are salivating at the potential to put any material they want at any position they want in three-dimensional space with additive manufacturing to optimize its performance, but the design tools and analyses do not yet exist—more opportunities for mechanical engineers to help AM.

The interactions between how you design a part and how you build it in an AM system are tightly coupled, yet not well understood. Engineers and designers are used to working with "design allowables" for materials made by known processes (such as casting, forging, and machining), but those design allowables do not yet exist for AM, nor do the "Design for Additive Manufacturing" guidelines that engineers need to successfully design parts for AM fabrication. A forthcoming issue of ASME's *Journal of Mechanical Design* is gathering the current state of best practices, which are far more advanced for polymers than they are for metals.

GE has received FAA approval of a 3-D printed housing for the T25 compressor inlet temperature sensor in the GE90-94B jet engine. The part is being retrofitted on Boeing planes. *Image : GE Aviation*

Even if we can solve the design and material issues, manufacturers are still hesitant to fully embrace the technology. High-end AM systems are still pricey (more than $500,000 in many cases), and machine operation and maintenance are costly. Maintenance agreements can run upwards of $50,000 per year for some systems, putting them well out of reach of many small and mid-size enterprises.

The materials are also extremely expensive. This is particularly important for powder-bed systems as the build height defines the volume of powder needed. We once needed $5,000 of powder to build $200 of parts due to a tall part that we had designed, a mistake we do not want to repeat.

Meanwhile, many AM systems lack the monitoring and sensing capabilities needed to control the processes, making it difficult to qualify equipment for production. It also makes it difficult to determine when and why a defect occurred if the process cannot be monitored. Mechanical engineers with expertise in sensing and controls have a wide-open playing field in this area.

Heat treatment schedules and post-processing considerations for AM-fabricated parts have received little attention to date from the broader mechanical engineering community, yet are crucial for achieving a functional AM part. The question about whether or not to apply hot isostatic pressing (HIP) to a 3-D printed part remains unanswered. Some manufacturers use HIP for all their AM parts to improve fatigue strength and reduce porosity, while others feel it is not needed or too expensive to use on every AM part.

While HIP may reduce internal porosity in some printed parts, it does little to the exterior surface finish, which can vary considerably based on build orientation and material. Identical parts built in the same orientation using two different materials will have two different surface finishes.

This three-way interaction among part features, build orientation, and material choice is difficult enough as it is, but the extent of the interaction also varies by machine. A laser powder-bed fusion system will produce a very different part from that of an electron beam-based powder-bed system, everything else being equal.

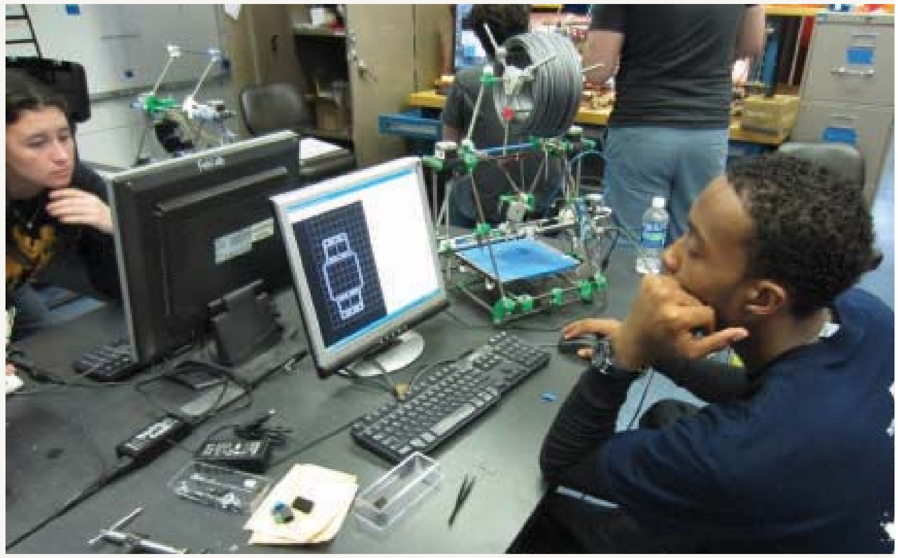
Finally, even though we can now realize complex internal features and passageways for conformal cooling and improved heat transfer, how do we know they printed as we designed them? We can't see them to inspect them; so, new techniques for non-destructive inspection are needed to help certify parts. While X-ray computed tomography (CT) scanning shows promise, part size and material composition limit what this technology can do. CT scanning systems are still rather expensive, and companies certainly do not want to scan every part that they produce using AM.

We need mechanical engineers to help rethink and develop new technology for inspection and certification of 3-D printed parts without having to resort to printing 10 parts, testing nine of them, and keeping the last one for use, hoping it is as good as the ones we tested.

The issues and challenges are far too numerous for one person or team to solve, and so we hope that more MEs will not dismiss AM outright as a new fad for 3-D printing and instead will talk to their colleagues in materials science, metallurgy, industrial engineering, and other fields to see what they can do to help.

Additive manufacturing is poised to become as pervasive as computers—used almost anywhere for almost anything. At home, if a handle or connector breaks, then we will just print a new one. At work, if we want to verify the fit and feel of a part that we designed, then we will just make one on our desktop 3-D printer; we won't have to wait anymore for the prototype shop to make it.

At school, we are already starting see a huge shift in how we integrate 3-D printing into the classroom. Entering freshmen are clamoring to access and use 3-D printing as soon as they come to campus; they do not want to wait until their senior year to use 3-D printers on their capstone design projects. These students have had easy access to these capabilities in middle and high schools, and many mechanical engineering students are bringing (or building) their own 3-D printers and running them in their dorms and apartments. It may not be long before mechanical engineering students may be required to bring their own laptop and 3-D printer to campus their freshmen year.



Freshmen at Penn State use 3-D printers that were made by junior and senior-level engineering students in a technical elective, Open Source 3-D Printing.
Image: Penn State Engineering Design Program

Most mechanical engineering curricula have not yet integrated 3-D printing and additive manufacturing into the classroom. We have a huge opportunity to reinvent how we teach and train mechanical engineers if we embrace AM.

It's all there, and it's never been more affordable and within reach. Low-end polymer 3-D printers now cost about the same as the original 2-D laser printers (which simply drew images on paper) did when they first came out. Prices of metallic AM systems are starting to drop as the field gets more competitive and patents expire, and everyone is trying to reduce material costs and offer a wider palette of materials to 3-D print.

We just have to be willing, as mechanical engineers and educators training the next generation of mechanical engineers, to look beyond the hype to understand what's real, identify the possibilities, and help advance AM technology and education. Only then will additive manufacturing realize its full potential and help revitalize manufacturing in the United States.

Our K-12 students are already doing it. Will we be ready when they go to college and enter the workforce? **ME**

TIMOTHY W. SIMPSON is a professor of mechanical and industrial engineering, and co-director of the Center for Innovative Materials Processing through Direct Digital Deposition (CIMP-3D) at the Pennsylvania State University in State College.

Dreaming in 3-D

Art meets engineering: A face printed with a MoonRay printer.

IF ADDITIVE MANUFACTURING IS THE TECHNOLOGY OF TOMORROW, WHAT DOES THE DAY AFTER TOMORROW LOOK LIKE?

BY ALAN S. BROWN

THREE-D PRINTING IS AT THAT STAGE OF INTEREST WHERE IT HAS BEGUN TO TAKE ON A LIFE—LOADED WITH EXPECTATIONS—OF ITS OWN.

Politicians have proposed 3-D printing as the solution to America's manufacturing problems. Corporations imagine it could slash time in product cycles and improve performance with new designs. Makers envision a future where we will download files and manufacture products (and replacement parts) in our homes.

The technology has been around for more than three decades, but it has come a long way in the past few years. It has established niches in everything from jet engines to oil and gas drilling. It is used to customize such personalized products as orthodontics, hearing aids, and arch and sole supports.

Laboratories have printed small robots that come out of the printer with their batteries in place. Printers have created complete automobiles and turbine engines, and even artificial bones and organs.

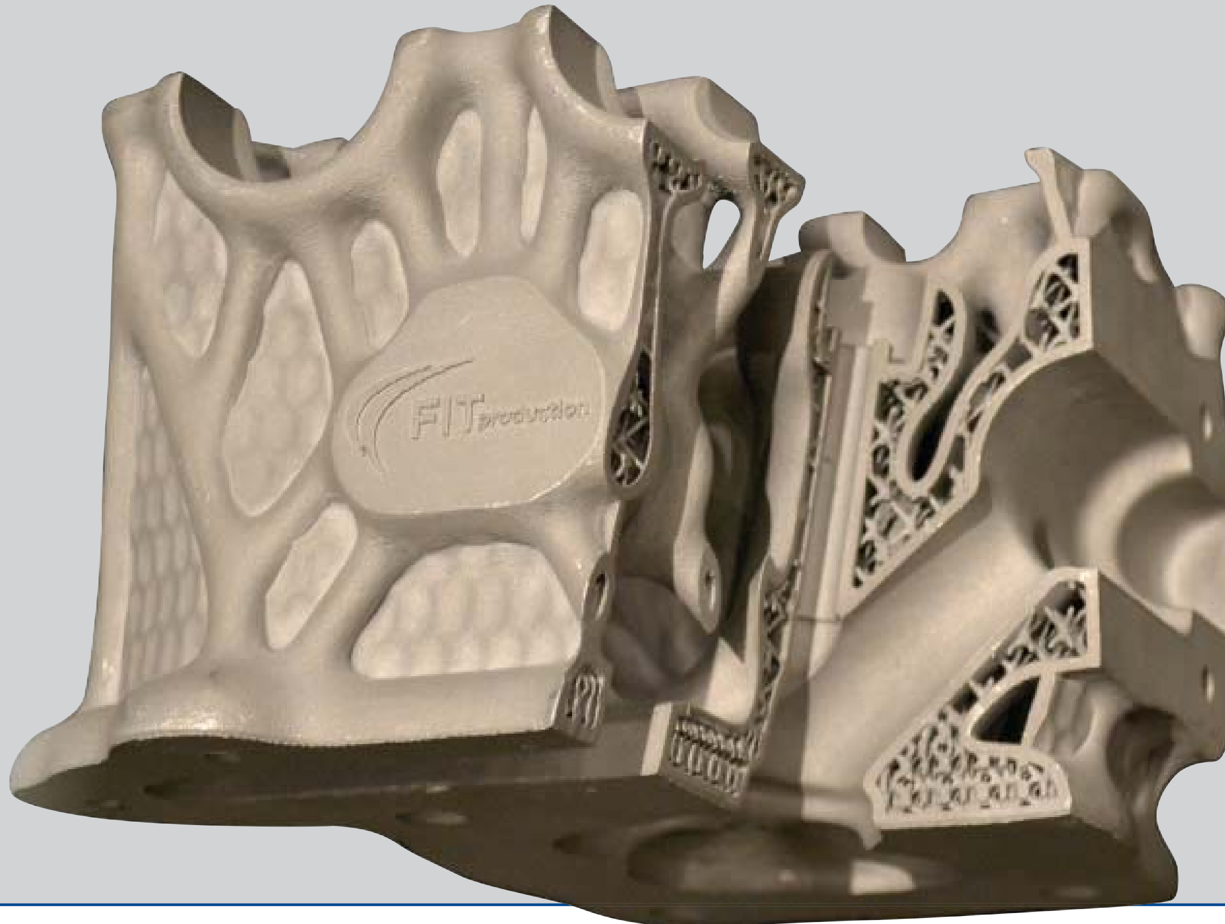
Hobbyists, meanwhile, have developed innovative new ways to use the technology.

This confluence of corporate interest, academic research, and amateur enthusiasm has happened before: It popularized the personal computer.

Could 3-D printers have the same trajectory? It is hard to imagine they will, but something is happening here. To see where it might lead, Mechanical Engineering went to a 3-D printing conference at Javits Center in New York City.

The event included academics, entrepreneurs, industrialists, artists, and makers. We interviewed a few of them. What follows captures some of the breadth—and excitement—in the field today.

ALAN S. BROWN is associate editor of *Mechanical Engineering.*



GEOFFREY DOYLE PRESIDENT, FIT WEST

SANTA CLARA, CALIF.

FIT West is a subsidiary of FIT AG of Germany, which provides engineering, prototyping, and production services, and also develops netFabb 3-D printing software.

There was really no single thing that got me interested in 3-D printing. There were lots of applications that caught my eye, from rapid prototyping to saving weight on products.

It was also a technology that interested me strategically. I am a mechanical engineer and financier, and it was growing 30 percent per year. I wanted to participate in that.

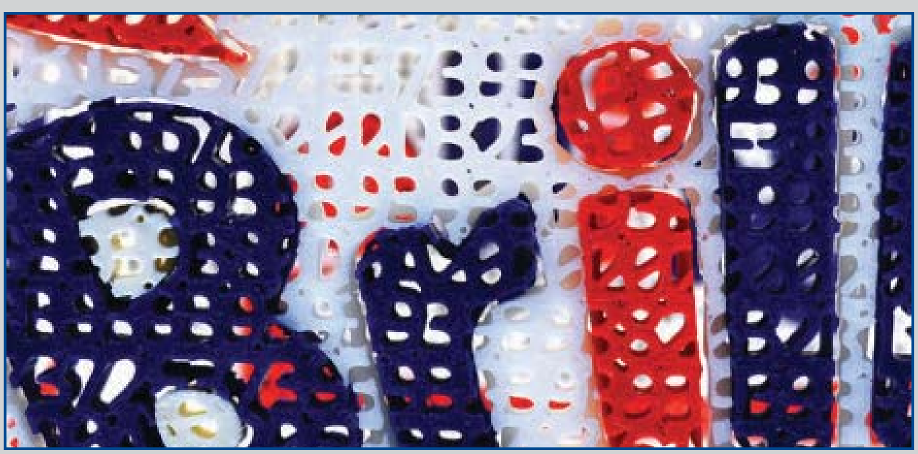
In five years, I think we will be doing higher volume metal parts in additive manufacturing. Right now, metal is not used much outside of defense, aerospace, medical devices, and energy. We are going to be in many more markets in the future.

In the medical field, many problems are personal and require individualized solutions. That's what I would like to see, more personalized products, whether they are implants or accessories, customized for the people who will use them.

I think people get a little too hung up about the hysteria around 3-D printing. We want to do production.

With 3-D printing, Geoffrey Doyle reduced the weight of an aluminum cylinder head (above) by as much as 66 percent.

Ashley Velinskie's remake of Andy Warhol's Brillo Box displays the code used to print the box.



ASHLEY VELINSKIE
CONCEPTUAL ARTIST AND SCULPTOR
BROOKLYN, N.Y.

Ashley Velinskie uses 3-D printing to play with ideas. Her sculptures are covered with the hexadecimal code used to generate the artwork.

I studied glass blowing, and I got really bored with it. It hadn't changed in hundreds of years. What could I start to do that I could never get bored with?

So I got a job at MakerBot, back in the Cupcake and Thing-O-Matic 3-D printer days. They were just starting to take the baby steps of 3-D printing, and I built my own 3-D printer. When I turned it on for the first time and it started moving around and printing something, I realized this was the wave of the future. This was how objects were going to be made. It was my new medium.

Right now, it's hard to scale up sculptures. I did a sculpture garden piece for a U.S. embassy that was five feet long, and had to switch to laser cutout technology because the technology does not exist to make that piece in 3-D printing. I'm hoping that in five years, 3-D printers can make bigger and bigger and bigger and better and better and better parts, so I can make larger and more intricate objects.

I think I already printed my dream object, a life-size chair. In the 1960s, the artist Joseph Kosuth did a piece called, *One in Three Chairs*. It was a chair, a picture of a chair, and a dictionary definition of a chair in a gallery space. It questioned the nature of what's the true chair, the image, the idea, or the object.

I did the same thing, but my one chair is made out of code. So what's the real object, is it the chair or the code that's on the chair? Is it the way a computer sees it or the way a human sees it?

That took me two years on a MakerBot. Then new and better technology came out and I 3-D printed it in larger pieces in just two weeks. I'm just waiting for a technology to catch up with my ideas.

AMIR MANSOURI CO-FOUNDER AND LEAD ENGINEER

SPRINTRAY, REDONDO BEACH, CALIF.

Funded in part through Kickstarter, SprintRay's new MoonRay printer promises 100-micrometer precision at a price under $2,000.

I really got it after I built my first 3-D printer and got my first parts out of it.

It's amazing. As engineers, we're always taught that when we design something, it has to be designed in a certain way so that we can manufacture it. When I saw 3-D printing, I realized that this will change that way of designing things. Right now, I can design anything in my SolidWorks and print it an hour afterwards.

I believe 3-D printing is the future. I want every engineer to have a 3-D printer sitting next to their computer, so they can create their imagination as a source of innovation.

If I could print anything? A flying car. I love cars, I want to be able to 3-D print my own car. Our designer is actually always sketching cars, so I tell him, "You make the body and I'll design the mechanisms to make it work."

They would be electric cars, of course.

Amir Mansouri, co-founder of SprintRay.

SEVERINE ZYGMONT PRESIDENT, BIOMEDICAL DIVISION

OXFORD PERFORMANCE MATERIALS, SOUTH WINDSOR, CONN.

Oxford's biomedical division prints implants, which are mechanically similar to natural bone and support bone cell growth, and are customized for individual patients. It developed one of the first FDA-approved polymeric 3-D printed implants.

I remember seeing a 3-D printer at one of my first trade shows, about 18 years ago, but I thought of it as a gizmo, a little nothing. I never thought I would be using it to make implants.

Severine Zygmont spent years developing customizable 3-D printed implants for surgeons.

What changed my thinking was an article I read years ago, by a surgeon talking about a fantastic synthetic bone material. The surgeon said that the only way to make it was with 3-D printing.

That's when we went to our technical director and asked him if he thought he could do something like that. We started developing our own polymer 16 years ago.

In five years, we're going to be able to change the way surgeons approach medical devices. Right now, they start by thinking about what is available, and then they try to make it fit the patient. They have to work around existing designs.

What is going to happen, I think, is that we are going to be more and more in tune with those surgeons, and better able to give them exactly what the patient needs.

My dream project would be for us to create long 3-D bones that are so good, we no longer have to amputate someone's leg, but can replace the entire bone within it.

Cole Nielsen is printing carbon-reinforced composites and hopes to tackle rocket engines.

COLE NIELSEN CO-FOUNDER

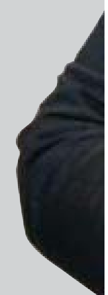
ORBITAL COMPOSITES, SAN JOSE, CALIF.

Orbital Composites is a startup that has patented several print heads that it says will make 3-D printing up to 100 times faster, and that can be used in conjunction with CNC and other conventional production machines.

Initially, I had another startup. We were going after injection molded products, and we were doing all our prototyping with 3-D printing. We were spending $300 to $800 per prototype. So I bought our own 3-D printers. I wound up logging 10,000 print hours in one year. After 2,000 hours of razor blade work cutting out support material, I almost lost my mind.

In addition, the parts were weak. I thought, if I could use carbon fiber, it would strengthen things up. So after I left my previous startup, I started focusing on the best way to solve my problems with 3-D printing.

One of the things you could do with our technology is create continuous filament, liquid cooled silicon carbide rocket nozzles. These would be many times lighter than you can make now with titanium, and they actually have better thermal and mechanical properties. And the thing is, with 3-D printing you can add in all the little radiator cooling channels that you can't do with any other method. So it's actually like a radiator wrapped around a rocket nozzle, but we're building it out of one piece of ceramic. I think we could start to do that in five years.



By using simple 3-D designs posted online, volunteers can print custom prosthetics for nearby children.

SKIP MEETZE

TANGO PRODUCTS DESIGN INC., ROCHESTER, N.Y.

Meetze retired from Xerox and started his own firm, Tango Products Design. Today, he spends most of his time at e-NABLE, a volunteer organization that uses 3-D printing to create inexpensive prosthetic arms.

After I retired, I used 3-D printing to prototype a good stand for iPads. I didn't realize what a competitive market that was going to be, so I put the code on the Thingiverse website for anyone who wanted to print it.

Inspired by Florida's strangler vine, Veronica Zalcberg created an organic shape for this electric violin.

VERONICA ZALCBERG

PRINCIPAL DESIGNER

MONAD STUDIO, MIAMI, FLA.

Monad Studio adapts new technologies to create organic forms from cityscapes and buildings to installations and product design.

Three-D printing enables us to realize our organic designs. We worked with musician Scott Hall to design a custom two-string piezoelectric violin with a very organic construction. Afterwards, we began receiving a lot of calls from different musicians that want us to design crazy, crazy instruments. Some of them are very interesting.

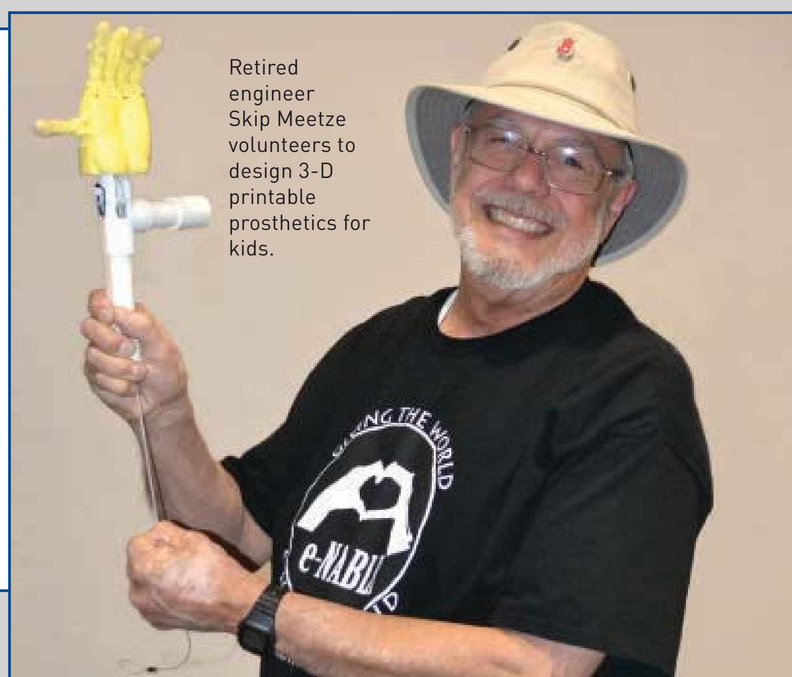
The cost is high because the production is still so complex. Hopefully, costs will decline and these types of designs will be available to more people.

We also work in the construction industry, and create prototypes using different materials and see how we can apply them to architecture. These projects range from inside walls or ceilings to custom-made blocks that can be transformed rapidly to create different shapes and designs. For example, we recently did a sonic art installation, where musicians came with small devices and an electric guitar we designed that let them control the wall to produce music. The wall became the instrument. We want to do more of that in five years.

I built my own 3-D printer from a kit about three years ago, and I've been having fun with that in the meantime.

Last summer, somebody invited me to Rochester Institute of Technology to see Jon Schull putting a prosthetic arm on a young man, and I was just blown away. I couldn't believe you could really do that with a 3-D printer. Since then, I've been making hand designs with a 3-D printer as a volunteer at RIT. [An interview with Jon Schull appears on page 18.]

I've satisfied all my basic needs, like food and shelter, I want to do something that makes you feel good. I don't need to do it, but I want to give back. **ME**



Retired engineer Skip Meetze volunteers to design 3-D printable prosthetics for kids.

EMBRACING 3

A LOT OF COMPANIES REALIZE THAT THEY NEED TO IMPLEMENT ADVANCED MANUFACTURING TECHNOLOGIES, BUT THEY HAVEN'T FIGURED OUT THE BEST APPLICATIONS—AND IMPLICATIONS—OF 3-D PRINTING.

BY MIKE VASQUEZ

It's been almost 30 years since Chuck Hull invented 3-D printing, which he commercialized as stereolithography through his company, 3D Systems. Fast-forward to today, and dozens of companies are now making 3-D printing (also known as additive manufacturing) machines, materials, and software. Some of these systems are small enough to go on a desk while others are scaled to print car housings and entire homes.

However, for all of the hype that the technology has received in the past few years, the industry is still in its infancy and many manufacturing organizations are just starting to grapple with the issue of how (or if) the technology will affect their business.

I talk with business leaders all the time to help them work through that very issue. And what I've found is that while determining what technology is a good match for your business is key, I believe there's a much more important first question: *Does your business even need the technology in the first place?*

There is no doubt that the technology has a rightful place in many organizations, but it hasn't yet matured to a place where it makes sense for every business. And given the investment, it's smart to not just jump into the deep-end.

One challenge for companies figuring out whether they need to invest in 3-D printing is the many different types of printing systems on the market. At a high level, there are seven different families of 3-D printing processes. Each of the seven technologies is differentiated by the materials used and how the materials are fused together to create three-dimensional objects. No single printing technology is right for every need. Instead, successful adoption of this technology requires end users to become smart about the options available to them and to make decisions on the types of applications where they believe the technology can benefit their businesses.

Factors such as cost, materials, resolution, part size, and mechanical properties are vastly different depending on the type of machine used. Some company leaders may be persuaded that they can afford to wait, since the technology continues to improve and evolve, and future advances in 3-D printing may be better suited to their needs.

But many businesses are in a position where implementing the technology—today—could have significant advantages. For that to happen, however, it's essential to have

PRINTING

a realistic understanding of the capabilities that the current technology can offer to you: the cost implications, the material applications, and the final output options.

If all you know about 3-D printing is the hobbyist devices like the MakerBot, the range of possibilities may be a surprise. A 3-D printing machine can run in price to more than a million dollars, depending on its size and the technology it uses. For most businesses that adopt 3-D printing, it's a significant investment.

The good news is that there's a burgeoning industry that allows you to "try before you buy"—3-D printing service bureaus. Service bureaus are companies whose primary business is to print objects on demand for their customers. Oftentimes they have 3-D printers of different types, so a potential purchaser can sample the capabilities of different systems by printing from his own design files to determine which system best suits his needs.

There are other advantages to using service bureaus, including not having to pay for underutilized equipment, more material and machine options than might be possible in an in-house shop, and no need to maintain or develop in-house expertise in operating the machinery. Also, service bureaus can provide additional finishing work—something often needed for 3-D printed parts.

However outsourcing is not without its drawbacks. Companies may discover delays or errors in part delivery, and since they don't maintain control of the model through the entire process, there may be errors in part construction that could lead to designs being compromised. Also, companies may not know the quality of the material being used or whether the part is built in the optimal way. And with no real control on the markups, costs can add up.

Generally, the biggest advantage that companies find in 3-D printing versus traditional, non-additive technologies is the design freedom provided by layer-upon-layer manufacturing techniques. From a product development perspective, 3-D printing eliminates one of the earliest design constraints, which is that added complexity equals increased cost.

For instance, if you are making a part that is to be injection molded, one of the constraints is making sure that the mold is sufficiently simple enough to allow for proper channeling and construction. More complex molds typically result in higher costs, which translate into the need to either sell a lot of the final products or charge a lot of money for each one in order to turn a profit.

For additive manufacturing and 3-D printing, the calculus is different. Design complexity becomes a non-factor: it doesn't make a product more difficult or more expensive to produce. And for now, this is one of 3-D printing's biggest advantages. It allows manufacturers significantly more freedom in design, allows parts to be built together that previously had to be developed separately, and can successfully create anything that can be designed in a piece of software.

In short, to maximize 3-D printing, users shouldn't try to replicate the existing manufacturing of products, but instead should use 3-D printing to enable design improvements to products that would be too costly to do with traditional processes.

So, how does this translate into using the technology in smart and efficient ways?

As I see it, there are opportunities to capitalize on 3-D printing's versatility on several different levels including the way in which different groups work together to manufacture improved and more cost-effective products.

The first—and still most common—is the use of the technology for prototyping. A 3-D printer offers a low-cost way to make small volumes of parts that can be used to test fit, form, and function. Consumer product companies use 3-D printed samples to garner customer feedback in focus groups. Athletic companies are developing prototypes to test things such as a bike's aerodynamic features. Companies which use 3-D printing that way are saving thousands of dollars and employee hours by making their R&D more efficient.

Other companies are using 3-D printing as a platform to introduce concurrent engineering principles in their product development. Specifically, companies can create multidisciplinary teams of engineering, design, manufacturing, and marketing people who work together from the original ideation of a product through the manufacturing rather than sequentially. This close collaboration helps to eliminate problems earlier in the process and avoid costly delays at later phases of development.

For most companies, however, the technology has not yet made the leap to full end-product manufacturing. There are two major factors at play that make adopting the technology in that way challenging.

First, as discussed earlier, is the segmented nature of the available technology, which limits the materials and quality of the end product that can be created using a single 3-D printer.

The second barrier is that most companies have not yet found it viable to put the processes in place to incorporate the change in design, engineering, and manufacturing production that is required. Not only do you need the capital funds to purchase machines, but in order to effectively use the technology to create a sellable product, you need to have a targeted

SEVEN DIMENSIONS OF 3-D PRINTING

3-D printing can be accomplished through many different means. Here's a capsule summary of seven common 3-D printing technologies.

Process	Description	Applications
Material Extrusion	Filament-based technology most commonly associated with desktop plastic printers; also referred to as fused-deposition modeling (FDM).	Plastic prototyping and some functional investment casting molds.
Vat Polymerization	A part is produced from a liquid photopolymer resin cured by a laser; also referred to as stereolithography.	Prototyping and applications that require high-quality surface finish.
Binder Jetting	A powdered material is spread across a build platform and a liquid binder is deposited that glues the material together.	Prototyping and investment casting.
Material Jetting	A photopolymer is deposited on a print bed through ink jets and is cured by a UV lamp that passes over the build area.	Visual prototyping.
Powder Systems	Powder-based materials (metal, polymer, ceramic) are fused together by a laser; common techniques include laser sintering, electron-beam melting, and direct metal laser sintering.	Functional prototypes and end products made from a range of engineering metals and plastics.
Sheet Lamination	A thin sheet of material is layered (glued) with other sheets and then a cutting object removes the designated outline of the 3-D object.	Prototyping and education.
Directed Energy Deposition	Focused thermal energy fuses materials by melting them as they are being deposited; most commonly used with metals.	Repairing metal parts and fixtures.

product line and clear vision of the ways that 3-D printing can help lower material costs, save energy, and simplify manufacturing and assembly, to name a few considerations.

And often companies looking into 3-D printing aren't aware that printing the object is only part of the process. For instance, nearly every 3-D printing system requires parts leaving the printer to undergo some sort of finishing. Part finishing is a big, time-consuming chore and must be considered in estimates of the time needed to complete the production process. Once this extra time is factored in, the advantages of 3-D printing may disappear.

For companies I advise that are evaluating how to start using or efficiently expand their 3-D printing capabilities, I counsel that there are four things—four Ms—they should think about as they start down this path. The four Ms are: *methods, money, measure,* and *message*.

METHODS

Business leaders driving a 3-D printing initiative within their organization need to clearly define the desired outcome, and then very clearly outline the methods that will get you there. The important things to consider in this phase are company-specific and require using knowledge of the organization as well as doing significant homework engaging with various groups to assess their needs.

Business leaders should create a list of potential use cases for 3-D printing and then develop an understanding of what materials and processes those use cases will require. When thinking about these questions, they need do so through the lens of the end customer, meaning the people who ultimately will end up with the final printed product. Do they value customization, large or small volumes of parts, personalization, or something else?

MONEY

Money is an unavoidable topic for two reasons: One needs to know where it is coming from (and ultimately to whom to sell the plan), and one needs to understand all the costs that go into operating a 3-D printing infrastructure. The mistake that many organizations make when looking at costs of 3-D printing is they too narrowly define all the expenses.

The major expenses that almost everyone considers are employees, printers, and materials. This covers about two-thirds of the costs, but what is missing includes training, service contracts, software, post processing tools, and building and construction costs. Those missing expenses add up quickly and should certainly be factored in as you develop your budget.

MEASURE

Even if someone can build a strong case for moving into 3-D printing and has the resources to pursue it, there is still the need to measure whether the initiative is giving the company the results it wants. Many companies do not do this in a smart way when they start deploying the technology, and it makes life more difficult than it needs to be when you want to expand the capabilities.

The best measurement is grounded in what's important to a company's leadership, and then tracks how 3-D printing is making an impact on those objectives. Some common things to keep track of include how many parts are being printed, the number of engaged partners in the organization, products affected, time saved, and manufacturing errors avoided. This way of thinking provides something tangible to benchmark the 3-D printing capabilities against and makes setting reasonable projections easier.

MESSAGING

Building and growing consensus can be challenging. I have seen firsthand how companies have spent $50,000 or more on equipment and hardware, and after a few months that investment has translated into a machine that collects dust on the shop floor. Oftentimes that is because the reality of the technology wasn't aligned to the expectations: The printers were viewed as being too slow; the material was hard to use, or the end-product didn't have the right finish.

Such problems can in large part be addressed by driving alignment very early in the process and ensuring everyone has the same understanding of the capabilities and desired outcomes. When a company begins to incorporate 3-D printing, it should make sure to educate various stakeholders in the organization. This can include holding training seminars or open-lab events to give people an inside look at the machine, and engaging groups in the organization that are involved in taking a product to market and collaborating with them to find ways to use the technology to help them. Finally, company leaders should build a structured process that directs how the lab works, including setting expectations of timing and availability.

3-D printing is going to continue to improve and expand into more applications. At the moment it is not right for every manufacturing company. Sure, for some companies, there are great 3-D printing applications that can save money and drive innovations. But for others, my best advice has been to stay on the sidelines until the technology has further evolved.

The only way to know what's right for any particular organization is to understand where the technology excels, and to map those capabilities against the organization's strategy, budget, and priorities, and to see if there are areas of alignment.

If that advice doesn't sound so different from what's offered for just about any technology, there's a reason. Forget all the hype: 3-D printing is a tool, and not every tool is right for every company. ME

MIKE VASQUEZ runs 3Degrees, a Chicago-based consulting firm for businesses investing in advanced manufacturing technologies.

ASME
SETTING THE STANDARD

Training & Development

Setting the Standard for Workforce Learning Solutions

ASME TRAINING COURSES FOR ENGINEERS AND TECHNICAL PROFESSIONALS

2015 AUTUMN

SEPTEMBER 2015 – CHICAGO, ILLINOIS, USA

MasterClass Series
Pressure Vessel & Piping Technologies at ASME Boiler Code Week

MC110	Application of Piping Flexibility Analysis to ASME B31 Codes	13-14 Sep
MC125	Impact Testing and Toughness Requirements for Pressure Vessels per ASME Section VIII, Divisions 1 & 2 NEW!	14-15 Sep
MC104	Bases and Application of Heat Exchanger Mechanical Design Rules in Section VIII of the ASME Boiler & Pressure Vessel Code	16-17 Sep

Visit go.asme.org/MCsept2015

SEPT. – OCT. 2015 – LAS VEGAS, NEVADA USA

PD391	ASME B31.4 Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids ASME STANDARDS COURSE	28-29 Sep
PD445	B31 Piping Fabrication and Examination ASME STANDARDS COURSE	28-29 Sep
PD570	Geometric Dimensioning and Tolerancing Fundamentals 1 ASME STANDARDS COURSE	28-29 Sep
PD410	Detail Engineering of Piping Systems NEW!	28-30 Sep
PD615	BPV Code, Section III, Division 1: Class 1, 2 & 3 Piping Design ASME STANDARDS COURSE	28-30 Sep
PD763	Centrifugal Pumps: Testing, Design and Analysis NEW!	28-30 Sep
PD184	BPV Code, Section III, Division 1: Rules for Construction of Nuclear Facility Components ASME STANDARDS COURSE TOP SELLER	28 Sep-1 Oct
PD359	Practical Welding Technology	28 Sep-1 Oct
PD448	BPV Code, Section VIII, Division 2: Pressure Vessels ASME STANDARDS COURSE TOP SELLER	28 Sep-1 Oct
PD603	GD&T Combo Course (combines PD570 and PD561) **SAVE UP TO $825!**	28 Sep-1 Oct
PD675	ASME NQA-1 Lead Auditor Training	28 Sep-1 Oct
PD192	BPV Code, Section XI: Inservice Inspection of Nuclear Power Plant Components ASME STANDARDS COURSE	28 Sep-2 Oct
PD432	Turbo Machinery Dynamics: Design and Operation	28 Sep-2 Oct
PD561	Geometric Tolerancing Applications and Tolerance Stacks	30 Sep-1 Oct
PD621	Grade 91 and Other Creep Strength Enhanced Ferritic Steels	30 Sep-1 Oct
PD531	Leadership and Organizational Management	1-2 Oct
PD673	Design and Selection of Heat Exchangers	1-2 Oct
PD692	Communication Essentials for Engineers NEW!	1-2 Oct

Visit go.asme.org/lasvegas8

OCTOBER 2015 – MIAMI, FLORIDA USA

PD100	Introduction to the Maintenance and Inspection of Elevators and Escalators	12-13 Oct
PD475	The Engineering Manager: Engaging Today's Workforce	12-13 Oct
PD567	Design, Analysis and Fabrication of Composite Structure, Energy and Machine Applications	12-13 Oct
PD606	NQA-1 Requirements for Computer Software Used in Nuclear Facilities ASME STANDARDS COURSE	12-13 Oct
PD690	Economics of Pipe Sizing and Pump Selection	12-13 Oct
PD027	Heating, Ventilating & Air-Conditioning Systems: Sizing & Design	12-14 Oct
PD146	Flow Induced Vibration with Applications to Failure Analysis	12-14 Oct
PD467	Project Management for Engineers & Technical Professionals	12-14 Oct
PD633	Overview of Nuclear Codes and Standards for Nuclear Power Plants ASME STANDARDS COURSE	12-14 Oct

CONTINUED, OCTOBER 2015 – MIAMI, FLORIDA USA

PD674	International Business Ethics and Foreign Corrupt Practices Act	12-14 Oct
PD685	The Engineering Manager: Engaging Today's Workforce and Strategic Thinking Combo Course NEW! (combines PD475 and PD676) **SAVE UP TO $450!**	12-14 Oct
PD720	Layout of Process Piping Systems NEW!	12-14 Oct
PD620	Core Engineering Management	12-15 Oct
PD657	HVAC Systems and Chiller Performance Combo Course (combines PD027 and PD387) **SAVE UP TO $440!**	12-15 Oct
PD691	Fluid Mechanics, Piping Design, Fluid Transients and Dynamics NEW!	12-15 Oct
PD602	Elevator and Escalator Combo Course (combines PD100 and PD102) **SAVE UP TO $905!**	12-16 Oct
PD629	Project Management Combo Course (combines 467 and 496) **SAVE UP TO $650!**	12-16 Oct
PD681	International Business Ethics and Foreign Corrupt Practices Act Combo Course (combines PD674 and PD680) **SAVE UP TO $650!**	12-16 Oct
PD686	Layout of Process Piping Systems and Optimization of Plant Layouts Utilizing 3D CAD/CAE Systems Combo Course (combines PD720 and PD721) **SAVE UP TO $650!** NEW!	12-16 Oct
PD676	Strategic Thinking	14 Oct
PD102	How to Perform Elevator Inspections Using ASME A17.2 and ASME Safety Code A17.1 ASME STANDARDS COURSE	14-16 Oct
PD387	Understanding Chiller Performance, Operation and Economics	15 Oct
PD496	Preparing for the Project Management Professional Certification Exam	15-16 Oct
PD680	Understanding the Foreign Corrupt Practices Act	15-16 Oct
PD721	Optimization of Plant Layouts Utilizing 3D CAD/CAE Systems	15-16 Oct

Visit go.asme.org/miami3

OCTOBER 2015 – BARCELONA, SPAIN

PD442	BPV Code, Section VIII, Division 1: Design and Fabrication of Pressure Vessels ASME STANDARDS COURSE TOP SELLER	19-21 Oct
PD635	ASME NQA-1 Quality Assurance Requirements for Nuclear Facility Applications	19-21 Oct
PD645	Code, Section IX: Welding, Brazing and Fusing Qualifications	19-21 Oct
PD720	Layout of Process Piping Systems NEW!	19-21 Oct
PD767	Pressure Relief Devices: Design, Sizing, Construction, Inspection and Maintenance ASME STANDARDS COURSE NEW!	19-21 Oct
PD616	API 579 /ASME FFS-1 Fitness-for-Service Evaluation	19-22 Oct
PD643	B31.3 Process Piping Code ASME STANDARDS COURSE	19-22 Oct
PD644	Advanced Design and Construction of Nuclear Facility Components Per BPV Code, Section III ASME STANDARDS COURSE	19-22 Oct
PD443	BPV Code, Section VIII, Division 1 Combo Course ASME STANDARDS COURSE (combines PD441 & PD442) **SAVE UP TO €800!** TOP SELLER	19-23 Oct
PD686	Layout of Process Piping Systems and Optimisation of Plant Layouts Utilising 3D CAD/CAE Systems Combo Course (combines PD720 and P721) **SAVE UP TO €750!** NEW!	19-23 Oct
PD441	Inspections, Repairs and Alterations of Pressure Equipment ASME STANDARDS COURSE TOP SELLER	22-23 Oct
PD721	Optimisation of Plant Layouts Utilising 3D CAD/CAE Systems NEW!	22-23 Oct

Visit go.asme.org/barcelona2

- LIVE TRAINING
- eLEARNING
- IACET ACCREDITED
- CEUs/PDHs AWARDED

REGISTER NOW: North America +1.800.843.2763 / Europe +32.2.743.1543 / Middle East +971.4428.0315

OCTOBER 2015 – HOUSTON, TEXAS USA

PD539 Bolted Joints and Gasket Behavior 26-27 Oct

PD190 BPV Code, Section IX: Welding, Brazing and Fusing Qualifications ASME Standards Course Top Seller 26-28 Oct

PD231 Shock and Vibration Analysis 26-28 Oct

PD268 Fracture Mechanics Approach to Life Predictions 26-28 Oct

PD370 B31.8 Gas Transmission & Distribution Piping Systems ASME Standards Course 26-28 Oct

PD395 API 579-1/ASME FFS-1 Fitness-for-Service 26-28 Oct

PD442 BPV Code, Section VIII, Division 1: Design and Fabrication of Pressure Vessels ASME Standards Course Top Seller 26-28 Oct

PD619 Risk and Reliability Strategies for Optimizing Performance 26-28 Oct

PD014 ASME B31.3 Process Piping Design ASME Standards Course Top Seller 26-29 Oct

PD644 Advanced Design and Construction of Nuclear Facility Components Per BPV Code, Section III ASME Standards Course 26-29 Oct

PD679 Selection of Pumps & Valves for Optimum System Performance 26-29 Oct

PD764 Introduction to Hydraulic Systems New! 26-29 Oct

PD443 BPV Code, Section VIII, Division 1 Combo Course ASME Standards Course (combines PD441 and PD442) **SAVE UP TO $680!** Top Seller 26-30 Oct

PD581 B31.3 Process Piping Design, Materials, Fabrication, Examination and Testing Combo Course (combines PD014 and PD457) **SAVE UP TO $575!** ASME Standards Course Top Seller 26-30 Oct

PD601 Bolting Combo Course (combines PD539, PD386 and PD577) **SAVE UP TO $1,275!** 26-30 Oct

PD386 Design of Bolted Flange Joints 28 Oct

PD766 Post Weld Heat Treatments in ASME Codes New! 28-29 Oct

PD441 Inspections, Repairs and Alterations of Pressure Equipment ASME Standards Course Top Seller 29-30 Oct

PD575 Comprehensive Negotiating Strategies®: Engineers & Technical Professionals 29-30 Oct

PD577 Bolted Joint Assembly Principles Per PCC-1-2013 ASME Standards Course 29-30 Oct

PD457 B31.3 Process Piping Materials Fabrication, Examination and Testing ASME Standards Course Top Seller 30 Oct

Visit go.asme.org/houston8

NOVEMBER 2015 – DUBAI, UNITED ARAB EMIRATES

PD618 Root Cause Analysis Fundamentals 1-3 Nov

PD715 Principles of Welding and BPV Code, Section IX: Welding and Brazing Qualifications ASME Standards Course 1-3 Nov

PD723 B31.4 and B31.8, Liquids and Gas Pipelines New! 1-3 Nov

PD726 API 579-1/ASME FFS-1 Fitness-For-Service Evaluation 1-3 Nov

PD642 ASME B31.1 Power Piping Code ASME Standards Course 1-4 Nov

PD675 ASME NQA-1 Lead Auditor Training 1-4 Nov

PD725 BPV Code, Section VIII, Division 1: Design and Fabrication with Inspections, Repairs and Alterations of Pressure Vessels ASME Standards Course 1-5 Nov

Visit go.asme.org/dubai5

NOVEMBER 2015 – ATLANTA, GEORGIA, USA

MasterClass Series

Pressure Vessel & Piping Technologies at ASME Boiler Code Week

MC104 Bases and Application of Heat Exchanger Mechanical Design Rules in Section VIII of the ASME Boiler and Pressure Vessel Code 1-2 Nov

MC111 Piping Vibration Causes and Remedies - a Practical Approach 4-5 Nov

MC117 Piping Failures - Causes and Prevention 6 Nov

Visit go.asme.org/MCnov2015

...and more to be announced – visit go.asme.org/MasterClass

NOVEMBER 2015 – SAN DIEGO, CALIFORNIA USA

PD107 Elevator Maintenance Evaluation 9-10 Nov

PD382 How to Predict Thermal-Hydraulic Loads on Pressure Vessels and Piping 9-10 Nov

PD077 Failure Prevention, Repair and Life Extension of Piping, Vessels and Tanks ASME Standards Course 9-11 Nov

PD146 Flow Induced Vibration with Applications to Failure Analysis 9-11 Nov

PD389 Nondestructive Examination-Applying ASME Code Requirements (BPV Code, Section V) ASME Standards Course 9-11 Nov

PD410 Detail Engineering of Piping Systems 9-11 Nov

PD506 Effective Management of Research and Development Teams and Organizations 9-11 Nov

PD513 TRIZ: The Theory of Inventive Problem Solving 9-11 Nov

PD515 Dimensioning and Tolerancing Principles for Gages and Fixtures 9-11 Nov

PD702 Process Safety and Risk Management for Mechanical Engineers New! 9-11 Nov

PD359 Practical Welding Technology 9-12 Nov

PD448 BPV Code, Section VIII, Division 2: Pressure Vessels ASME Standards Course Top Seller 9-12 Nov

PD013 B31.1 Power Piping Code ASME Standards Course Top Seller 9-13 Nov

PD665 BPV Code, Section I: Power Boilers ASME Standards Course 9-13 Nov

Visit go.asme.org/sandiego3

NOVEMBER 2015 – ATLANTA, GEORGIA USA

PD391 ASME B31.4 Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids ASME Standards Course 16-17 Nov

PD449 Mechanical Tolerancing for Six Sigma 16-17 Nov

PD595 Developing a 10-Year Pump Inservice Testing Program 16-17 Nov

PD624 Two-Phase Flow and Heat Transfer 16-17 Nov

PD706 Inline Inspections for Pipelines 16-17 Nov

PD618 Root Cause Analysis Fundamentals 16-18 Nov

PD683 Probabilistic Structural Analysis, Design and Reliability-Risk Assessment 16-18 Nov

PD711 ASME NQA-1 and DOE Quality Assurance Rule 10 CFR 830 ASME Standards Course New! 16-18 Nov

PD394 Seismic Design and Retrofit of Equipment and Piping 16-19 Nov

PD622 BPV Code: Plant Equipment Requirements ASME Standards Course 16-19 Nov

PD632 Design in Codes, Standards and Regulations for Nuclear Power Plant Construction ASME Standards Course 16-19 Nov

PD583 Pressure Relief Devices: Design, Sizing, Construction, Inspection and Maintenance ASME Standards Course 18-20 Nov

PD596 Developing a 10-Year Valve Inservice Testing Program 18-20 Nov

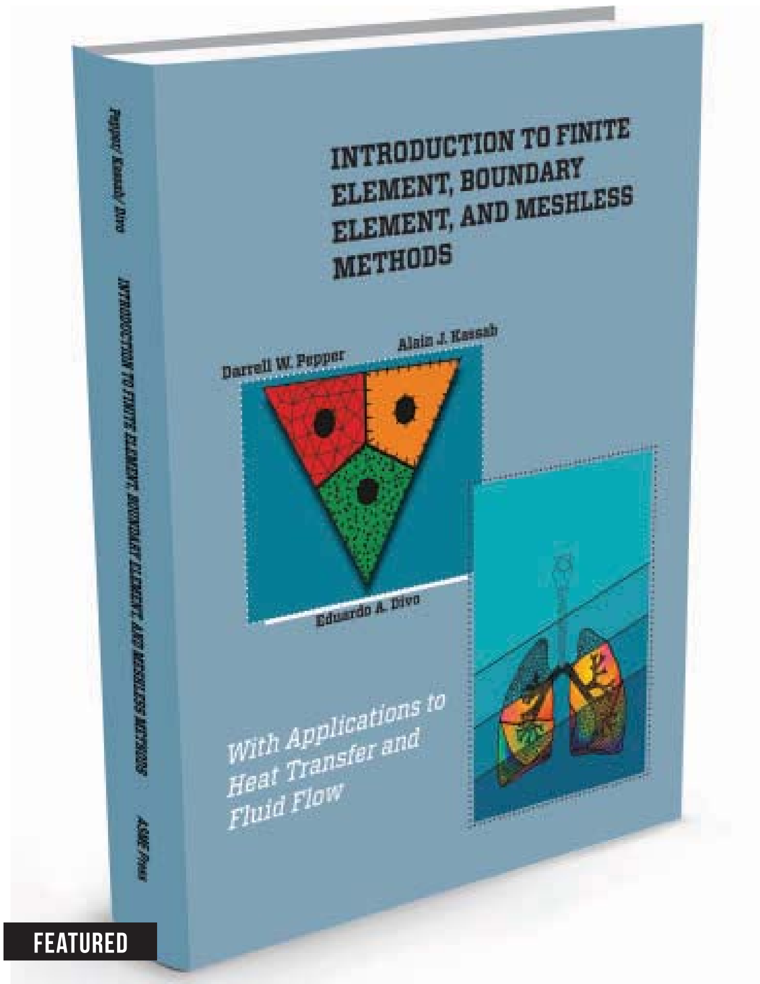
PD591 Developing Conflict Resolution Best Practices 19-20 Nov

Visit go.asme.org/atlanta6

Free ASME Training & Development Autumn 2015 eCalendar Now Available

Download the FREE Autumn 2015 ASME Training & Development eCalendar listing dates and locations of Live Course offerings in North America and Europe through December 2015, as well as eLearning Courses available worldwide from a PC with Internet access, any time.

Visit:
go.asme.org/autumntraining
or scan with a smart device:



FEATURED

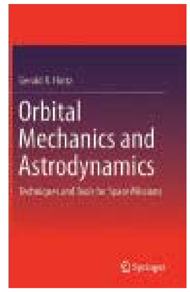
INTRODUCTION TO FINITE ELEMENT, BOUNDARY ELEMENT, AND MESHLESS METHODS: WITH APPLICATIONS TO HEAT TRANSFER AND FLUID FLOW.

DARRELL W. PEPPER, ALAIN KASSAB, AND EDUARDO DIVO

ASME Press Books, Two Park Avenue, New York, N.Y. 10016-5990.

The authors have structured this book in four sections. An introductory section provides the method of weighted residuals development of finite differences, finite volume, finite element, boundary element, and meshless methods along with 1-D examples of each method. The following three sections of the book present a more detailed development of the finite element method, then progress through the boundary element method, and end with meshless methods. Each section serves as a stand-alone description, but it is apparent how each leads to a discussion of other techniques. It is recommended that the reader begin with the finite element method, as this serves as the primary basis for defining the method of weighted residuals.

300 PAGES. $129; ASME MEMBERS, $103. ISBN: 978-0-7918-6033-5.



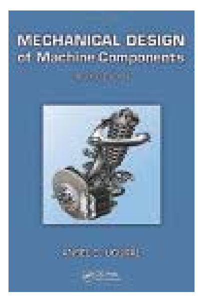
ORBITAL MECHANICS AND ASTRODYNAMICS: TECHNIQUES AND TOOLS FOR SPACE MISSIONS.

Gerald R. Hintz

Springer Science + Business Media LLC, 233 Spring Street, New York, N.Y. 10013-1578.

This textbook, directed toward both practicing engineers and graduate students, covers fundamental and advanced topics in orbital mechanics and astrodynamics to expose the student to the basic dynamics of space flight. The author's intent is that readers will gain knowledge that they can apply to mission design and navigation of space missions. Topics include methods for designing interplanetary and orbital trajectories and information on astronautical techniques and tools. The publisher recommends the book for graduate students in astronautical or aerospace engineering and related fields of study, researchers in space industrial and governmental research and development facilities, and researchers in astronautics.

386 PAGES. $99. ISBN: 978-3-3190-9443-4.



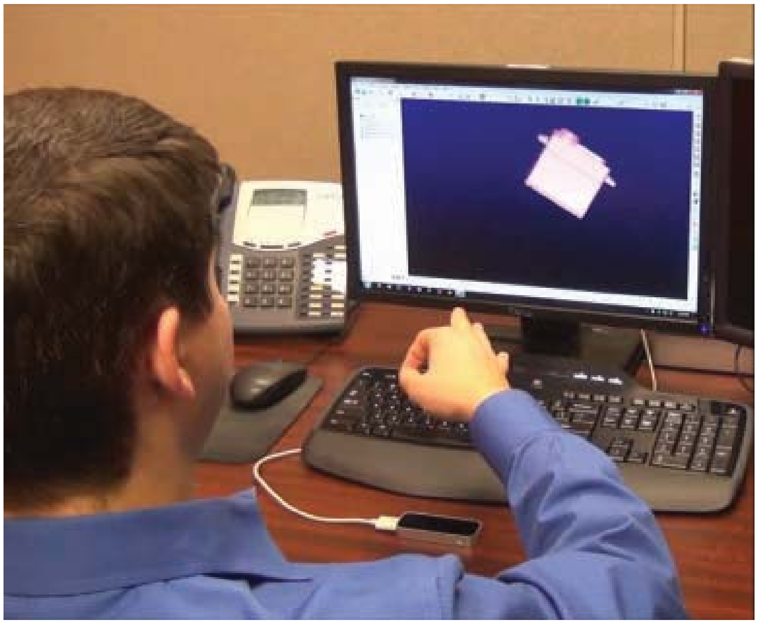
MECHANICAL DESIGN OF MACHINE COMPONENTS, SECOND EDITION.

Ansel C. Ugural

CRC Press, 6000 Broken Sound Parkway NW, Suite 300, Boca Raton, FL 33487.

Mechanical Design of Machine Components is intended to strike a balance between theory and application, and to prepare students for more advanced study or professional practice. It outlines the basic concepts in the design and analysis of machine elements using traditional methods, based on the principles of mechanics of materials. The text combines the theory needed to gain insight into mechanics with numerical methods in design. It presents real-world engineering applications, and reveals the link between basic mechanics and the specific design of machine components and machines. Divided into three parts, this revised text presents basic background topics, deals with failure prevention in a variety of machine elements, and covers applications in design of machine components as well as entire machines. Sections treating special and advanced topics are also included.

1,034 PAGES. $119.96. ISBN: 978-1-4398-8780-6.



CFD MESHING

POINTWISE INC., FORT WORTH, TEXAS.

The second release of Pointwise version 17.3, the computational fluid dynamics meshing software, comes with enhanced overset grid generation capabilities. The new release is compatible with the Leap Motion Controller. This compact USB device from Leap Motion senses your hand gestures and can be used with Pointwise to pan, zoom, and rotate the mesh.

TEST AND ANALYSIS

HBM INC., SOUTHFIELD, MICH.

HBM NCODE 11.0 INTRODUCES speed improvements that enable users to rapidly process large amounts of data and state-of-the-art methods for designing and validating components subjected to vibration excitation. The functionality of the vibration fatigue solver in nCode DesignLife has been improved in several areas including new types of loading, new conditions, and new calculations. Added methods such as multiple simultaneous PSDs, Sine on Random, and Sine Dwell loading enables improved simulation of real-world conditions and offers benefits for engine and powertrain applications.

WATER NETWORK MODELING

INNOVYZE, BROOMFIELD, COLO.

GENERATION V5.5 OF IWLIVE PROVIDES new capabilities and enhancements for comprehensive real-time water network modeling. The latest release delivers major advancements for operating and sustaining safe, reliable, and more efficient water supply and distribution systems. A complete solution for real-time network hydraulic and water quality modeling, monitoring, forecasting, and SCADA integration, IWLive equips water utilities with powerful, mission-critical tools that are both predictive and reactive. It continuously assesses system performance and alerts operators to problems that may arise in the coming minutes, hours, and days.

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.

CAE SYSTEMS

BETA CAE SYSTEMS SA, THESSALONIKI, GREECE.

THE RELEASE OF V15.2.4 of ANSA/μETA pre- and post-processing suite focuses on the correction of identified problems and issues for ANSA and μETA. This release of v15.2.4 implements enhancements and code corrections on the v15.2.x branch. Connection Lines realization performance has been optimized. Improvements in ANSA correct issues in the Seamwelds and Femsite-Spotweld functions, and in the import of NX files. Improvements in μETA include correction of issues involving Abaqus and ANSYS files.

ENGINEERING DESIGN

BRICSYS INC., MERRIMACK, N.H.

THE BRICSCAD V15.2 IS AN UPGRADE that offers new and improved features. The function of the quad cursor is extended so that it now also draws entities. Users bring up the quad by clicking the right mouse button to not only modify selected entities, but also place new ones in drawings. An improvement to the sheet metal design facility creates junction features automatically, with BricsCAD supporting several types of junctions.

3-D INSPECTION

AMETEK CREAFORM, LEVIS, QUEBEC.

VXINSPECT 3-D INSPECTION software includes all the tools for first article inspection and quality control. VXinspect provides simple integration for probing and scanning measurement in numerous manufacturing applications. The dimensional inspection software is designed to be used in combination with the company's HandyPROBE, MetraSCAN 3D and HandySCAN 3D portable measurement devices. The software features all the functions required to set up a high-efficiency measurement sequence to inspect parts.

SPOOL VALVES

ASCO NUMATICS, FLORHAM PARK, N.J.

The 362 and 562 stainless steel spool valves are for control valve automation in upstream, mid-stream, and downstream oil and gas applications. The 362 and 562 series valves offer low-power solenoid versions that consume only 1.4 watts. An option of a 0.55-watt solenoid is in development for remote applications requiring alternative energy sources. The 562 is a four-way spool valve designed for double-acting process valves.

ROD CLAMP

ADVANCED MACHINE & ENGINEERING CO., ROCKFORD, ILL.

The Hydraulic Series RCH rod clamp provides power-off clamping of rods and shafts. The clamps are actuated by a spring/collet mechanism and unclamped by hydraulic pressure. These rod clamps are designed to clamp components after motion has stopped and to hold the position securely as long as the forces do not exceed the table values. For braking and pneumatic applications, contact the factory.

BLUETOOTH TRANSMITTERS

OMEGA ENGINEERING INC., STAMFORD, CONN.

The UWBT Bluetooth transmitter combines the accuracy of an industrial sensor/transmitter with the convenience of smartphones and tablets. It measures different sensor inputs such as thermocouple, RTD, relative humidity, and pH, and transmits the data via wireless Bluetooth to a smart phone or tablet. The UWBT app running on an iOS or Android smart phone or tablet is free. The app has many features including the ability to be configured in nine different languages.

MATRIX DRIVE

YASKAWA AMERICA INC., WAUKEGAN, ILL.

The new U1000 industrial matrix drive uses a system of nine bidirectional switches that are arranged in a matrix to convert a three-phase ac input voltage directly into a three-phase ac output voltage. This eliminates the need for a rectifying circuit and dc smoothing circuit that are used in traditional ac drive inverters. The result is a compact drive with full regenerative capability and reduced harmonic distortion.

TOOLS//HARDWARE

AC DRIVE

SIEMENS INDUSTRY INC., ELK GROVE VILLAGE, ILL.

Single-axis Sinamics V20 ac drives are available in five sizes, with power ratings ranging from 1/6 to 40 hp at 480 V ac. The devices are designed to be compact and rugged. They are recommended for operating pumps, fans, compressors, and conveyor belts as well as for basic drive applications in the process and manufacturing industries. Drives can be connected and installed by wall mounting or, optionally, mounted with heat sinks pushed through the enclosure wall.

HARSH-DUTY PHOTOELECTRIC SENSORS

AUTOMATIONDIRECT, CUMMING, GA.

Harsh-duty photoelectric sensors are IP69K-rated sensors in three-wire NPN or PNP styles and are available in 27 washdown models. Good for food and beverage applications, the 10-30 V dc rectangular sensors are fitted with 316L stainless steel housings and are available in diffuse, diffuse with background suppression, and polarized retroreflective styles. The sensors have either an attached two-meter output cable, or an M8 or M12 quick-disconnect. All models have a selectable light-on/dark-on output setting.

PRESSURE AND TEMPERATURE TRANSMITTER

GP:50, GRAND ISLAND, N.Y.

The Model 7500-9000 is a high-performance pressure and temperature transmitter suitable for subsea use. It offers accurate, reliable pressure and temperature process measurements up to 25,000 psi (1,724 bar) and +392 °F (+200 °C) with seawater submersibility to 30,000 ft. (9,144 m). Series units feature all stainless steel housings; SAE-AISI 4130 flange material; 718 Inconel wetted parts with optional Inconel or Hastelloy inlay; 4-20 mA outputs; ±0.2% FSO static accuracy (±0.1% FSO optional); and an API rated flanged process connection, in sizes ranging from 2 1/6 to 4 1/16 in.

LINEAR ENCODER

MICRONOR, NEWBURY PARK, CALIF.

With 100 μm resolution and 50 μm accuracy, the MR303 linear sensor is designed for applications where position and speed must be precisely monitored, and electro-magnetic immunity and invisibility are required. The sensor works in conjunction with the MR302-2 OEM controller which enables it to integrate with conventional PLC controllers and servo drives. The position sensor is immune to electromagnetic interference, such as magnetic fields, lightning, high voltage and radiation.

SIGNAL CONDITIONER

KNICK USA, MORGAN HILL, CALIF.

Common signal conditioning requirements call for the galvanic isolation and conversion of a wide range of input signals. Featuring 480 uniquely switchable inputs, the Knick ProLine P27000 signal conditioner can greatly simplify these tasks across multiple measurement types within a single device. Onboard transformer isolation and a digitally controlled range selection provide repeat-able signal transmission.

ELECTROMAGNETIC SHIELDING

LEHVOSS NORTH AMERICA, PAWCATUCK, CONN.

Luvocom ES is a new generation of thermoplastic compounds to shield against electromagnetic waves at smaller wall thicknesses. The compounds are engineered for the housings of electric and electronic devices such as computers, radios, phones, and laboratory equipment. A shielding effect is achieved by making the housings of the electronic components electrically conductive. Luvocom ES has high electrical conductivity and small contact areas for electrical grounding.

FLANGE FACERS

CLIMAX PORTABLE MACHINING & WELDING SYSTEMS, NEWBERG, ORE.

Climax FF1200 CE-certified, OD-mount flange facers are engineered for safety. The feed control is located on the outside of the machine, keeping the operator's hands away from moving parts. Machining time for small flanges can be decreased by as much as 30 percent because of productivity enhancements built into the machine's design. Automatic feed comes standard for both radial and axial feed. Feed rates are adjustable while the machine is running.

SHAFT COLLARS

STAFFORD MANUFACTURING CORP., WILMINGTON, MASS.

Mounting collars provide a flat mounting surface with multiple attachment options and are available with or without a flange. Square to assure smooth operation, the mounts can be easily repositioned and are suitable for use with a wide range of components including gears, lever arms, pulleys, and sprockets. Offered in steel, stainless steel, and aluminum, the mounting collars can be supplied with various mounting hole patterns. Accu-Mount has a centering hub and comes in one- and two-piece designs from 1/2 to 2 in. interior diameter. Accu-Flange is available in 1/4 to 3 in. bores; with or without keyways.

HIGH-TEMPERATURE ACCELEROMETERS

PCB PIEZOTRONICS INC., DEPEW, N.Y.

Accelerometer models 357D92 and 357D93 are accurate to 1,000 g and operate at temperatures up to 649 °C. They are designed to avoid the pyroelectric noise of ceramic sensors used in gas turbines, automotive engines, and other hot mechanical environments. The sensitive axis of model 357D92 is in the direction of the mounting screw. The axis of 357D93 is 90 degrees to the mounting screw.

AIR-OPERATED CONVEYORS

EXAIR CORP., CINCINNATI.

The new aluminum 3/8 NPT and 1/2 NPT Threaded Line Vac air-operated conveyors convert ordinary pipe into a powerful conveying system for parts, scrap, trim, and other bulk materials. Their small size makes them efficient for fitting in the cramped spaces and tight confines of many production lines. The Threaded Line Vac is designed to attach to plumbing pipe couplers, making it possible to build a complete system using ordinary pipe and fittings available from a home center, hardware store, or plumbers' supply.

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.

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 (accreditation, registration, and certification) programs, visit the Standards and Certification website at http://www.asme.org/kb/standards/certification---accreditation.

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=1.

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.org

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 and Accreditation
Chains
Controls
Conveyors
Cranes and Hoists
Cutting, Hand, and Machine Tools
Dimensions
Drawings, Terminology, and Graphic Symbols
Elevators and Escalators
Energy Assessment
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 and Calibration of Instruments
Nondestructive Evaluation/ Examination-Nuclear
Operator Qualification and Certification
Performance Test Codes
Piping & Pipelines
Plumbing Materials and Equipment
Post Construction of Pressure Equipment and Piping
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
Welding & Brazing

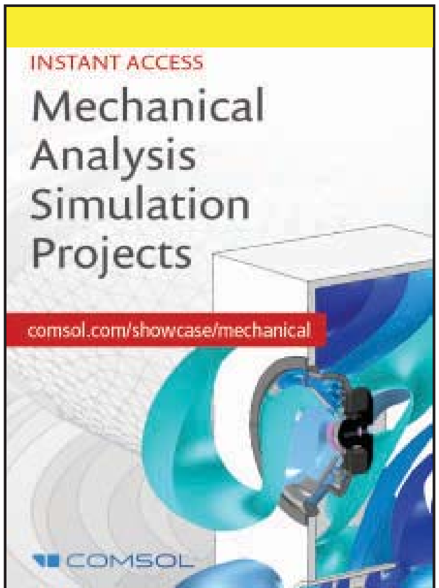
The ASME Standards & Certification section is published as submitted to Mechanical Engineering magazine by ASME's Standards & Certification Department.

RESOURCEFILE

- Instrumentation & Control
- Power Transmission & Motion Control
- Fluid Handling
- Materials & Assembly
- Engineering Tools
- Other Products & Services

A bimonthly listing of the industry's latest technical literature and product information available FREE to *Mechanical Engineering* readers.

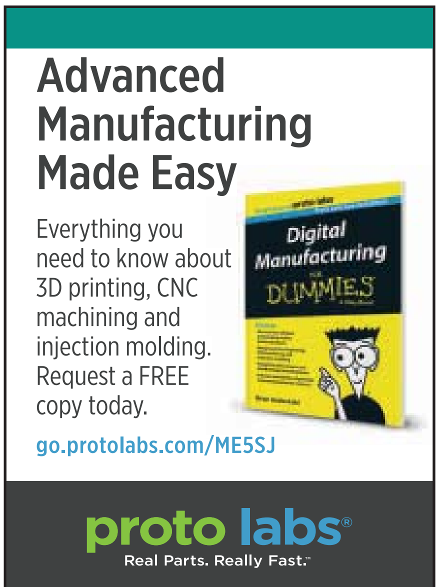
Receive an item by visiting **http://mecheng.hotims.com** and click on the company name.



COMSOL

CEI

WWW.MASTERBOND.COM



PROTO LABS

OMEGA

SPG MOTOR

TORMACH

TSUBAKI

DYNATECT

Faculty Director Search
Jerome Fisher Program in Management & Technology

The School of Engineering and Applied Science (SEAS) and the Wharton School at the University of Pennsylvania have initiated a search for an outstanding scholar to serve as the Director of the prestigious Jerome Fisher Program in Management & Technology (M&T).

The M&T Program (http://www.upenn.edu/fisher/) combines academics from two phenomenal Penn assets, Penn Engineering and the Wharton School, into one unique educational experience. Founded in 1977, it has attracted some of the brightest undergraduates in the world. With over 1,900 alumni worldwide, graduates from the M&T Program are corporate leaders and innovators in a number of industries and fields, including investment banking, the technology sector, hedge funds and private equity, venture capital, aviation, medicine, biotechnology, consulting, law, and more. The M&T community in general is highly entrepreneurial, working on their own ventures or collaborating on start-up enterprises. With eight regional groups across the globe, M&T alumni love to stay connected, and frequently recruit fellow graduates and current students for internships and full-time positions.

The Director of the Jerome Fisher Program in Management & Technology should be an individual with an exceptional record of:

- A world-class scholar in a relevant area of engineering, management, innovation or related field with a broad understanding of issues across domains
- An international leader and educational innovator that has a vision for the future of the program in an era of growing innovation
- An institution builder that will work with faculty, students and leadership across SEAS and Wharton as well with an extremely deep alumni base in executing the vision.

Candidates must hold a Ph.D. in engineering, management, or related area. The academic appointment of the Director is expected to be at the level of tenured Full Professor holding the Jeffrey A. Keswin Professorship, and could be in any relevant department in SEAS, Wharton, or across schools, depending on the applicant. Diversity candidates are strongly encouraged to apply. Interested persons should submit their application here: http://tinyurl.com/mandtsearch-upenn. Questions regarding this unique opportunity should be directed to mandtsearch@upenn.edu. Review of applications will begin August 1, 2015.

The University of Pennsylvania is an affirmative action/equal opportunity employer. All qualified applicants will receive consideration for employment and will not be discriminated against on the basis of race, color, religion, sex, sexual orientation, gender identity, creed, national or ethnic origin, citizenship status, age, disability , veteran status, or any other characteristic protected by law.

POSITIONS OPEN

DIRECTOR OF OPERATIONS & ENGINEERING - NOVA VENTURES GROUP CORP. (WOBURN, MA). REQS BA/BS OR FOREIGN DEGREE EQUIV IN MECH ENGG OR CLOSELY REL. SUCH AS ENGG (OR REL.), in addition to 1 yr exp in job offered or rel. role such as Dvlpmt Engr, Mech Engr, or rel. Also reqs following, knowl of which may be gained either thru work exp, internships or academic study at or during Bachelors or Masters degree level program: prior exp in dvlpmt & production of ultrasonic transducers & non-destructive testing instruments; Ability to & some past exp designing piping syss; Ability to & some past exp testing components for Boiler & Pressure Vessel Code as well as aircraft components; Ability to & some past exp performing quality inspections & test executions on prototypes; Good knowl of Macola ERP sys & ability to generate reports; Ability to & some past exp performing safety analysis by means of Hazard & Operability Method; Background in or knowl of Proj Mgmt & Lean Manufg principles; Working knowl of Microsoft Office & Engg Equation Solver (EES). If interested, pls send resume to: Janet Barbookles, VP/General Counsel, Nova Ventures >> Group Corp., 600 Unicorn Park Drive, Woburn, MA 01801

PENNSTATE

1 8 5 5

NEW FACULTY SEARCHES IN MECHANICAL ENGINEERING

Through strong support from the Provost and Dean, The Department of Mechanical and Nuclear Engineering at The Pennsylvania State University is pleased to announce there will be a significant growth of faculty over the next several years. In 2015/16, the Department is seeking excellent applicants to fill six tenure-track positions in ME. The areas of interest include, but are not exclusive to: advanced manufacturing and materials processing, energy systems, computational fluid dynamics, intelligent systems and sensors, autonomous systems, and other emerging areas. Applicants should have demonstrated outstanding scholarly research and teaching interests in mechanical engineering or a related field.

The Department is home to 55 faculty, 280 graduate students, and 1100 undergraduate students. The faculty conduct in excess of $25M per year of funded research across a broad spectrum of traditional and emerging areas. Penn State actively encourages and provides resources for interdisciplinary research collaboration through university-level institutes primarily focused on materials, health, and energy. In addition, many faculty in the Department work collaboratively with scientists and engineers in our Nuclear Engineering Program, the Applied Research Laboratory and the Center for Innovative Metal Processing by Direct Digital Deposition (CIMP-3D, http://www.cimp-3d.org/). The Department offers separate B.S., M.S., and Ph.D. degree programs in both mechanical engineering and nuclear engineering. The Department also offers online graduate degrees in both mechanical and nuclear engineering. Further information on the Department can be found at: http://www.mne.psu.edu/.

Qualifications for these positions include a doctorate in engineering or a related field. The successful candidates will be expected to teach courses at both the undergraduate and graduate levels, to develop an internationally-recognized externally-funded research program, and to contribute to the operation and promotion of the department, college, university, and profession through service.

Nominations and applications will be considered until the positions are filled. Screening of applicants will begin on September 15, 2015. Applicants should submit a statement of professional interests, a curriculum vitae, and the names and addresses of four references. Please submit these three items in one pdf file electronically to job 57752 at https://psu.jobs/job/57752

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

Penn State is an equal opportunity, affirmative action employer, and is committed to providing employment opportunities to all qualified applicants without regard to race, color, religion, age, sex, sexual orientation, gender identity, national origin, disability or protected veteran status.

ADVERTISER INDEX

To purchase or receive information from our advertisers, go to **http://me.hotims.com**, visit the advertiser's website, or call a number listed below.

RECRUITMENT

CONSULTING

GUERRERO BEGINS TERM AS ASME PRESIDENT

K. Keith Roe (left) and Julio Guerrero share the stage at the President's Dinner.

Julio Guerrero, an R&D and business development lead at Draper Laboratory in Cambridge, Mass., kicked off his yearlong term as ASME President at a ceremony during the ASME Annual Meeting in Jacksonville, Fla.

During the President's Dinner held on June 9, the ASME Nominating Committee also announced the selection of ASME's president-nominee, K. Keith Roe, and three Board of Governors members who will begin their three-year terms in 2016.

Guerrero, who joined Draper Laboratory in 2011, had previously been employed for 12 years as a principal research scientist at Schlumberger Research where he initiated research collaborations with the Massachusetts Institute of Technology's mechanical and electrical engineering departments, and the Woods Hole Oceanographic Institute Center for Marine Robotics for subsea and land oil operations. Guerrero has also taught engineering courses as a senior lecturer at MIT, and served as a member of several doctoral committees at MIT and the University of Texas at Austin.

Guerrero has been a member of ASME for more than 20 years and served as a member of ASME's Board of Governors from 2011 to 2014, as well as vice-chair of the Society's Industry Advisory Board from 2008 to 2010. He is the Society's 134th president.

His other Society activities include serving as chair of the Sector Management Committee, reviewer for the ASME *Journal of Mechanical Design,* and working with the steering committee that proposed the ASME Innovation Showcase in 2006.

Roe, the president-nominee, retired last year as chairman, president, and chief executive officer of Burns and Roe Group Inc., an international engineering, construction, and operations services company based in Oradell, N.J. The company had been founded by Keith Roe's grandfather, Ralph Coats Roe, for whom an ASME medal is named.

Prior to joining Burns and Roe Group as a design engineer in 1974, Roe had served in the United States Navy, ultimately advancing to the rank of lieutenant.

An ASME Fellow, Roe was the founding chair of the ASME Industry Advisory Board from 1987 to 1996, and a member of the Board of Governors from 2008 to 2012. Roe has also been a dedicated supporter of the ASME Foundation, having served as member of the foundation's Board of Directors from 1991 to 2008 and board chair from 1994 to 2007. He is currently the foundation's chair emeritus.

Roe received a bachelor's degree in mechanical engineering from Princeton University in 1968. He earned both a master's degree and engineer's degree in nuclear engineering from Massachusetts Institute of Technology in 1974.

The Nominating Committee also announced the names of three candidates for the Board of Governors for 2016-2019. The three nominees—Karen Ohland, Mahantesh Hiremath, and William Wepfer—will begin their terms as board members at next year's Annual Meeting, following membership approval by proxy ballot this autumn. **ME**

ROSE-HULMAN AND MISSOURI S&T WIN TOP HUMAN POWERED VEHICLE HONORS

Perennial powerhouses Rose-Hulman Institute of Technology in Terre Haute, Ind., and Missouri University of Science and Technology in Rolla picked up victories in the annual Human Powered Vehicle Challenge events.

Rose-Hulman Institute of Technology took top overall honors at HPVC West, hosted by the ASME Santa Clara Valley Senior Section. The event took place from April 24 to 26 in San Jose, Calif. One of 29 teams competing, the Rose-Hulman team finished first in the men's speed race, and second in the design, innovation, and women's speed categories.

Although it was the overall runner-up at HPVC West, the Missouri S&T team was the overall winner at the HPVC East competition hosted by the University of Florida in Gainesville two weeks later. One of 31 schools competing at the event, Missouri S&T, finished first in four categories—women's speed, men's speed, endurance, and innovation—and placed third in design.

The University of Alabama, meanwhile, took second place in the overall competition, having placed second in both the women's speed and endurance events. The University of Akron finished third overall and second in the men's speed category.

For complete results from the ASME Human Powered Vehicle East and West Challenges, visit https://community.asme.org/hpvc/w/wiki/11346.results.aspx. **ME**

NEW EDITION OF BPVC SECTION I ADDRESSES LOCOMOTIVE REQUIREMENTS

In July, ASME released the 2015 edition of Boiler and Pressure Vessel Code Section I, *Rules for Construction of Power Boilers*. This new edition of Section I marks the first time in more than 60 years that ASME has published a stand-alone code addressing requirements for locomotive boilers.

Section I of the Boiler and Pressure Vessel Code, which is maintained by the ASME Boiler and Pressure Vessel Committee on Power Boilers (BPV I), outlines the rules relating to pressure integrity governing the construction of power boilers and high-pressure, high-temperature water boilers. Following a request from locomotive boiler stakeholders, BPV I formed the Subgroup on Locomotive Boilers in February 2010. Chaired by Linn Moedinger, president of the heritage Strasburg Rail Road, the subgroup was assigned the duty of developing a new Section I Part addressing locomotive boiler construction rules.

Some may wonder why a modern code would address locomotive boiler technology, which could be considered an arcane art.

The simple answer, according to the Subgroup, is that steam locomotives continue to operate in densely populated environments where the need to ensure safe boilers is paramount.

Millions of people throughout the world ride behind and stand near steam locomotive boilers every year. Moreover, real working knowledge of what these boilers experience while operating and how their various structures work together while bouncing down the track is not widely prevalent.

Since the late 1950s there has been a growing knowledge base on locomotive boilers in preservation railroad circles, but it has been outside the mainstream boiler industry. Over time it had become quite possible—if not probable—that a perfectly reputable boiler shop could have the best of intentions and still legitimately build an unsatisfactory steam locomotive boiler in accordance with the Boiler Code.

In an attempt to rectify this situation, the ASME Subgroup on Locomotive Boilers has taken the approach of codifying both best practices and Code material from the early steam days of the locomotive, melding modern technology into the process where that technology has been tested and proven.

The process of fine-tuning this new Section I Part will continue as long as people continue to tinker with the "iron horse" worldwide.

The timing of this publication coincides with a generational change in the steam railroading world. The new Part captures and codifies the knowledge gained by a generation of railroaders over the past 50 plus years since the last ASME Locomotive Code was published.

The result of the Subgroup's efforts, Part PL, *Requirements for Locomotive Boilers*, was included in the 2015 Edition of BPVC Section I, *Rules for Construction of Power Boilers*, which was published on July 1.

This new locomotive code section can truly be looked at as a beginning for the technology, as new materials and methods will now have a place to be vetted within the unique perspective of steam locomotive operation so as to ensure safe steam locomotive boilers for centuries to come. **ME**

Linn Moedinger, chair, Subgroup on Locomotive Boilers (BPV I), and **Umberto D'Urso**, secretary, BPV I.

VERMONT ENGINEERS REJECT MOE REQUIREMENT

The Vermont Board of Professional Engineering struck down in May a motion to revise the state's statutory requirements to specify a master's degree as the minimum education standard for engineering licensure in Vermont.

The decision makes Vermont the third state to forgo adopting the master's degree or equivalent as the educational requirement for engineering licensure at the state level, following unsuccessful efforts to introduce the requirement in Nebraska and Montana.

The vote, 4 to 1 against, followed approximately two years of discussion among members of the Vermont Board, as well as concerted public outreach efforts by the board to gauge the engineering community's opinion on the subject. After evaluating feedback provided through presentations at board meetings, public comment sessions, and letters from groups and individuals, the board determined that there "was not sufficient reason or evidence to support any proposed legislation to increase the minimum education required for licensure to a master's degree or equivalent."

ASME has been a vocal opponent of the MOE requirement since its introduction nearly a decade ago. The ASME Board of Governors issued a position statement opposing the MOE proposal in April 2008. Later that year, ASME established the Licensing That Works coalition of engineering societies, which endorsed the position statement.

The coalition represents more than 300,000 engineers from 12 professional engineering societies including the American Institute of Chemical Engineers, ASHRAE, the Institute of Industrial Engineers, and the Society for Mining, Metallurgy, and Exploration.

"I applaud the action of the Vermont Board of Professional Engineering not to endorse the proposed legislation," said ASME President J. Robert Sims. "We will continue to be vigilant because ASCE has made increasing the education requirements for the licensure of engineers of all disciplines one of its three strategic initiatives. No evidence has ever been presented that MOE will have a positive impact on the public's health, safety, and welfare, which is the basis for licensure."

To learn more about the Licensing That Works coalition, or to learn more about the MOE debate, visit www.licensingthatworks.org. **ME**

Tulsa engineering students designed and constructed a kids' cooking center for the Little Light House. Team members included (left to right) Mohamed Ghori, Sam Carr, David Gogolakis, Christopher Butler, Joe Meier, Khristen Thornburg and Salman Hassan Al-Ali.

A KIDS' KITCHEN

FOR 25 YEARS, UNIVERSITY OF TULSA ENGINEERING students have used their talents to address the special needs of Oklahoma residents with physical and developmental disabilities.

The program is called Make a Difference Engineering—MADE at TU—and students from all departments in the College of Engineering and Natural Sciences are invited to participate.

This year seven seniors designed and built a small portable kitchen as an educational tool for developmentally challenged children. The kitchen allows children to participate in food preparation ranging from mixing and chopping to slicing and dicing.

Christopher Butler, Sam Carr, Mohamed Ghori, David Gogolakis, Salman Hassan Al-Ali, Joe Meier, and Khristen Thornburg worked directly with staff from the Little Light House, a tuition-free Christian center for preschool-age children with special needs.

Molly Smith, the Little Light House's director of development, said, "The goal of the center is to provide hope for families of children with special needs and improve their quality of life."

John Henshaw, chair of the university's Department of Mechanical Engineering, is the MADE at TU advisor. "TU's goals are broad—to use the engineering talents of students to make life better for people with disabilities," Henshaw said. "This program not only helps the students develop comprehensive technical skills, but it also helps them gain the experience of client interaction."

According to David Gogolakis, the team leader on the kitchen project, "The Little Light House pitched the project to us as a potential customer for our senior project and collectively seven of us put about 1,400 hours in on creating the Mobile Cooking Center."

The modified kitchen is designed to be safe and friendly for the children, who will use it under supervision of a therapist or aide. The cooking center is a completely functional mini kitchen with upper and lower cabinets for storage, two fold-down tables for counter space, an induction stovetop where the surface area around the pan doesn't get hot, a cutting board, mixer, a mechanical arm to help pour ingredients into bowls, and a slicer and dicer.

The project features cooking tools that children can control with supervision.

The kitchen has options to accommodate different children, many of whom have mobility and sensory challenges.

The TU students purchased a Ninja slicer and dicer and then built stands for it, so it can be operated by remote control. After the therapists plug the machine into a specific outlet, the children can push a button, allowing them to watch the process in action.

The kitchen has plastic knives that are safe for the kids to use with assistance.

Therapists can attach different spoons or measuring cups to the pouring arm, which functions similar to a desk lamp. The arm can be repositioned to pour ingredients into a second bowl.

The design team helped the children make pancakes in the mobile kitchen the day it was delivered.

According to Meier, a remote control device was used to operate the mixer to mix pancake batter. All of the kitchen's components can be operated both manually and by remote control.

"The mechanical engineering students have listened to our needs of making all their projects accessible to all of our children," said Dede Flately, physical therapist at the Little Light House. "They have provided projects that help the children with different aspects of their development by providing a fun activity that will not seem to be work to them." ME

JAMES PERO

UPTIME TIME

– THE EXPERTS AGREE –

INTELLISENSE®

WINS THREE PRESTIGIOUS AWARDS
FROM LEADING INDUSTRY TRADE PUBLICATIONS

PNEUMATICS 2.0™ HAS ARRIVED

Introducing IntelliSense®, a one-of-a-kind technology platform that delivers real-time performance data on standard Bimba pneumatic devices for maximum uptime. Never before has such a wide range of industries been able to move from emergency repair to proactive maintenance, thus optimizing plant efficiency and production as a whole.

bimba.com/smarter