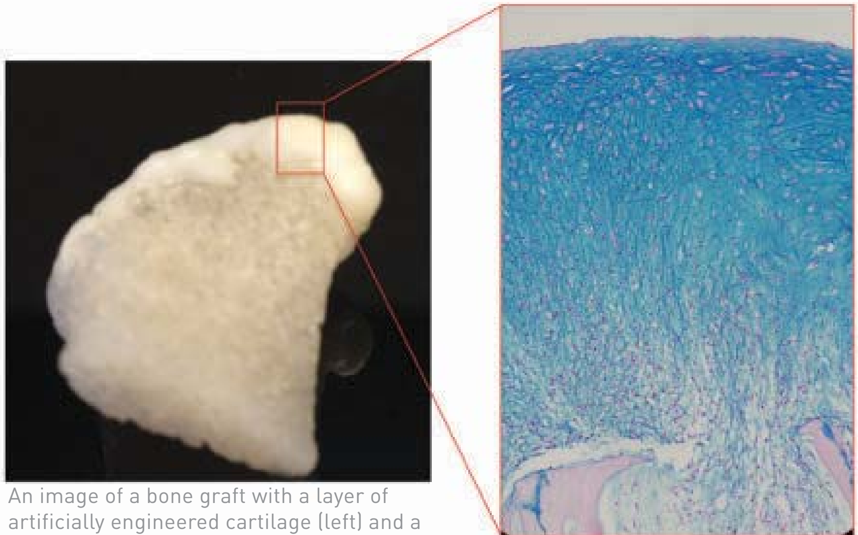
MECHANICAL
ENGINEERING
Technology that moves the world
THE MAGAZINE OF ASME
No. 04
137

THE DIGITAL HEART

ADVANCED SIMULATIONS PROMISE SAFER SURGERY AND IMPROVED MEDICAL DEVICES.


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

LOG ON ASME.ORG



An image of a bone graft with a layer of artificially engineered cartilage (left) and a detail of a cartilage layer (right).
Images: Dr. Sarindr Bhumiratana

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

GROWING FULLY FUNCTIONAL HUMAN CARTILAGE

AFTER DECADES OF TRYING, researchers at Columbia University in New York City have discovered how to grow fully functional human cartilage in vitro from human stem cells taken from fat tissue or bone marrow. Until now, researchers have had success in engineering pieces of cartilage using young animal cells and also in creating synthetic replacement cartilage in the lab. But this breakthrough means a patient's own fat tissue or bone marrow can be the source of cartilage needed to treat a defect.

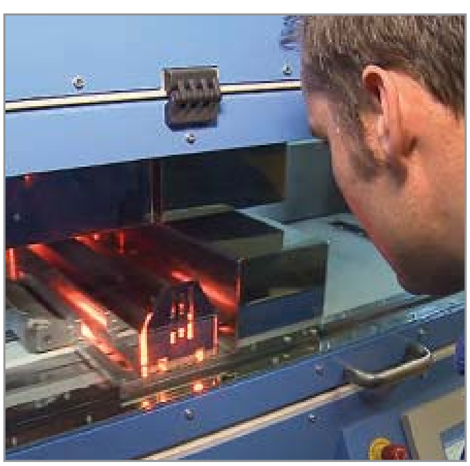
AN INVENTIVE SUMMER CAMP

The Edison Ford Inventor's Summer Camp is helping first through sixth graders use their imaginations and learn engineering skills.

Image: Edison & Ford Winter Estates

PODCAST: INNOVATIONS IN AEROSPACE

Chris Van Buiten, VP of Sikorsky Innovations, discusses how Sikorsky tackles the biggest engineering challenges in the field of aerospace today, including vertical flight and autonomous flying. **ME**



A high-speed sintering 3-D printer at work.
Image: University of Sheffield

3-D PRINTING FOR MASS PRODUCTION

WHEN IT COMES TO MASS PRODUCTION, 3-D printing is not the first choice of most manufacturers, but if additive techniques pick up the pace, the technology can become competitive with anything else found on a factory floor.

NEXT MONTH ON ASME.ORG

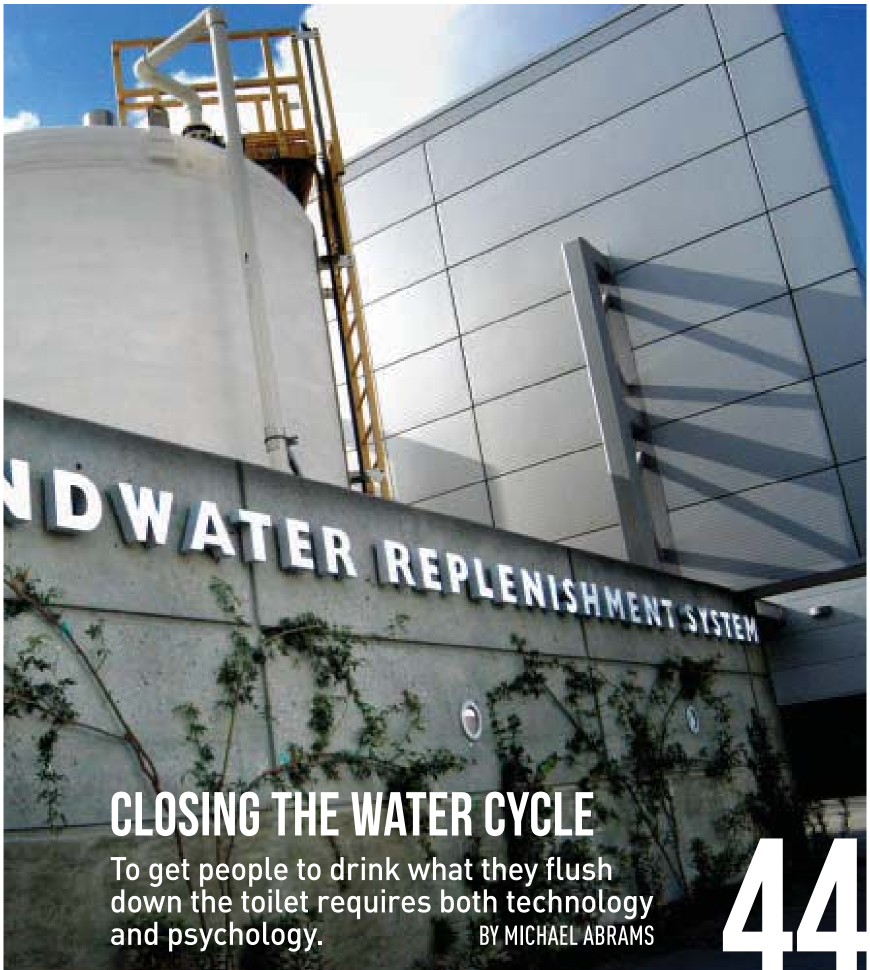
FAUX MISSION TO MARS
After dreaming of being an astronaut as long as she can remember, a young woman prepares as one of six crew members on an eight-month simulated mission to Mars.

NANOPARTICLES KILL CANCER
Treatment for lung cancer may someday involve nothing more than taking a pull from an inhaler. The inhaler would deliver nanoparticles that could kill cancer cells. (Research seeking cures for metastatic cancers is the subject of the feature "Slaying the Dragon" on page 36 of this issue.)

04 137

FEATURES

ASME
SETTING THE STANDARD



DEPARTMENTS

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 technological 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
p. 973.882.1170 f. 973.882.1717
22 Law Drive, Fairfield , NJ 07007
In U.S. toll-free 800 THE ASME
international 973.882.1167

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
p. 404.847.0072 f. 404.847.0151
6525 The Corners Parkway, Suite 115; Norcross, GA 30092-3349

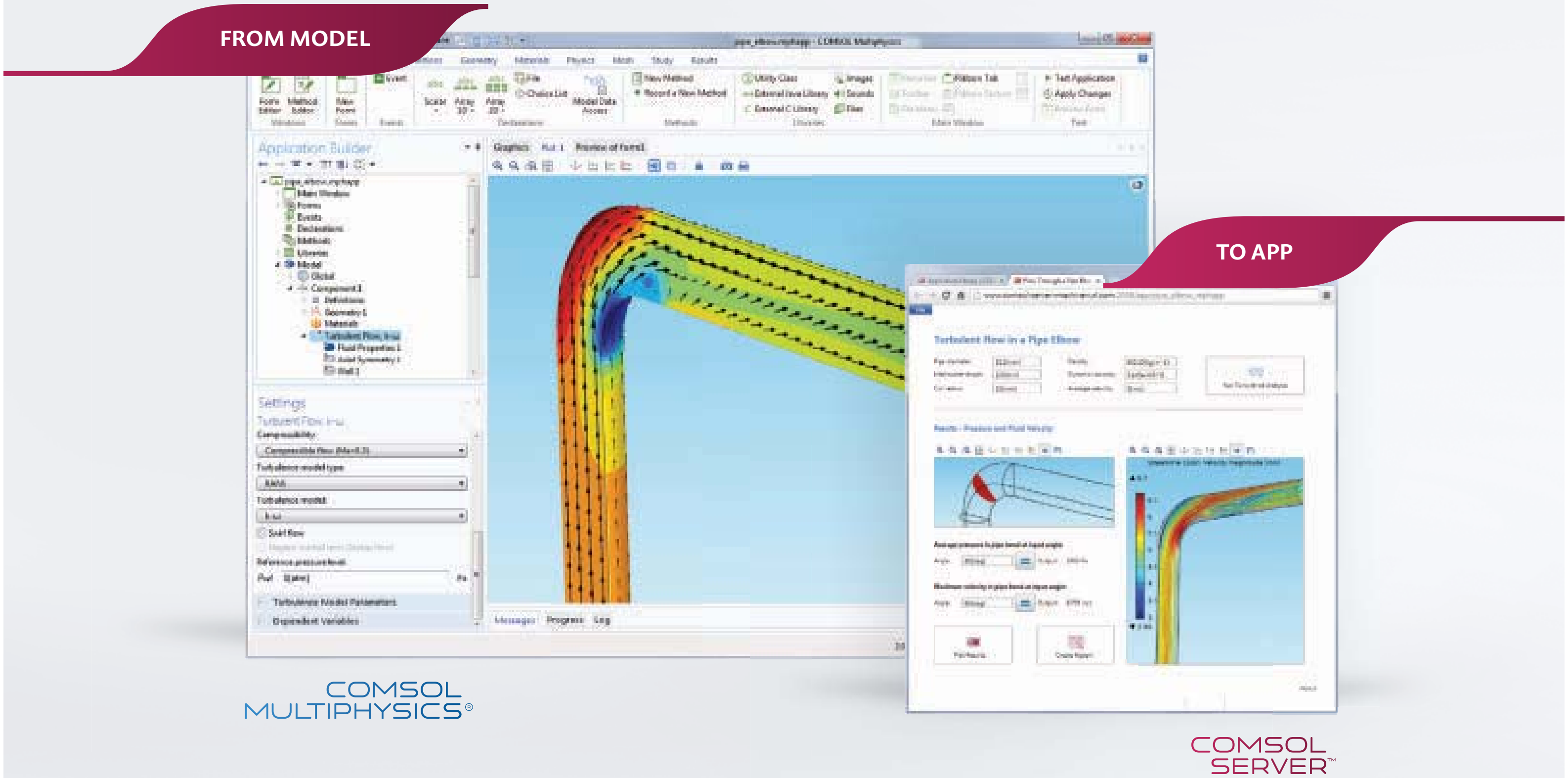
Int'l Petroleum Technology Institute asme-ipti.org
p. 281.493.3491 f. 281.493.3493
11757 Katy Freeway, Suite 380; Houston, TX 77079-1733.

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, 22 Law Drive, Box 2300, Fairfield, NJ 07007-2300. Return Canadian undeliverable addresses to P.O. BOX 1051, Fort Erie, On, L2A 6C7. PRICES: To members, annually $32 for initial membership subscription, single copy $7; subscription price to nonmembers available upon request. Canadian Goods & Services Tax Registration #126148048. Printed in U.S.A.



Verify and Optimize your Designs with COMSOL Multiphysics®

NOW FEATURING APPLICATION BUILDER & COMSOL SERVER™

The Application Builder provides you with tools to easily design a custom interface for your multiphysics models. Use COMSOL Server™ to distribute your apps to colleagues and customers worldwide.

Visit comsol.com/release/5.0

Product Suite

› COMSOL Multiphysics®
› COMSOL Server™

ELECTRICAL
› AC/DC Module
› RF Module
› Wave Optics Module
› Ray Optics Module
› MEMS Module
› Plasma Module
› Semiconductor Module

MECHANICAL
› Heat Transfer Module
› Structural Mechanics Module
› Nonlinear Structural Materials Module
› Geomechanics Module
› Fatigue Module
› Multibody Dynamics Module
› Acoustics Module

FLUID
› CFD Module
› Mixer Module
› Microfluidics Module
› Subsurface Flow Module
› Pipe Flow Module
› Molecular Flow Module

CHEMICAL
› Chemical Reaction Engineering Module
› Batteries & Fuel Cells Module
› Electrodeposition Module
› Corrosion Module
› Electrochemistry Module

MULTIPURPOSE
› Optimization Module
› Material Library
› Particle Tracing Module

INTERFACING
› LiveLink™ *for* MATLAB®
› LiveLink™ *for* Excel®
› CAD Import Module
› Design Module
› ECAD Import Module
› LiveLink™ *for* SOLIDWORKS®
› LiveLink™ *for* Inventor®
› LiveLink™ *for* AutoCAD®
› LiveLink™ *for* Revit®
› LiveLink™ *for* PTC® Creo® Parametric™
› LiveLink™ *for* PTC® Pro/ENGINEER®
› LiveLink™ *for* Solid Edge®
› File Import *for* CATIA® V5

COMSOL

John G. Falcioni
Editor-in-Chief

MENDING A BROKEN HEART

Life has a way of breaking our hearts from time to time. Mine's been broken plenty and I'm sure yours has too.

Some researchers believe that, besides bringing on a lot of misery, in extreme cases a broken heart can have decidedly deadly consequences. Psychologists and medical doctors continue to study whether people can actually die from a so-called broken heart and while there are no definitive answers, there is an ailment known as "broken heart syndrome"—also called stress cardiomyopathy—that can lead to severe cardiac problems and even death.

Deep sorrow brought on, say, by the passing of a loved one is believed to cause such tremendous stress in some cases that it triggers mechanical failures of the body. This syndrome can also be elicited by trauma such as a car accident or by indignities or deep distress. When these types of emotional peaks occur, our bodies unleash chemicals, including adrenaline, that can stun the heart muscle and disrupt its pumping mechanism.

While cases of death by heartbreak are rare, the latest research from the World Health Organization shows that 17.5 million people died from cardiovascular diseases globally in 2012; this represents 31 percent of all deaths. In the United States alone the total medical costs of cardiovascular disease will reach $818.1 billion over the next three decades, according to a report called "Forecasting the Future of Cardiovascular Disease," published by the American Heart Association.

To help stem the tide of cardiovascular disease, a multidisciplinary team of heart experts has launched the Living Heart project, which represents the next frontier in diagnosing, treating, and preventing heart conditions with the use of personalized, three-dimensional virtual models.

In our cover story this month, associate editor Alan Brown takes us on an interesting journey examining the fascinating way this project originated. At the core of the project is Dassault Systèmes' Simulia software, which is used to render a 3-D model that captures the electrical and mechanical behavior of the heart in a realistic manner.

By using input from echocardiograms, MRIs, and CT scans, along with other cardiac data, the Living Heart project has created in virtual reality a representation of chambers, movements, and sounds reflecting the behavior of a human heart. Doctors can maneuver this simulation to reveal detailed behavior of the heart without resorting to invasive diagnostics.

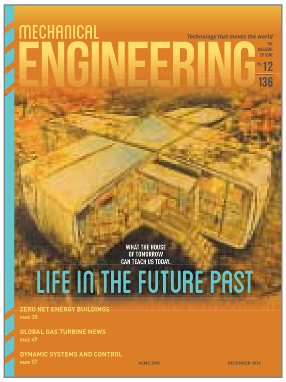
Even though the developers working on the Living Heart make no promise that they will be able to mend a "broken heart," this simulation tool does have the potential to open the door for more research on cardiovascular illnesses, as well as to accelerate regulatory approval cycles for personalized devices and improve patient diagnoses and care.

Besides focusing on the heart in this issue, we also feature a fascinating essay by renowned biomedical and nanotechnology expert—and mechanical engineer—Mauro Ferrari, who discusses how nanomechanics is opening new avenues in the treatment war against metastatic cancer. **ME**

FEEDBACK

How far can 3-D simulations take us in the fight against heart disease? Email me. falcionij@asme.org


Dell recommends Windows.
DELL
Perfection takes time.
Going to market shouldn't.
Screen images simulated. Monitors not included.
Trial and error is the essence of engineering and universal design. The key is to ideate, design, test, make changes and repeat that process quickly and accurately. That's why OXO trusts Dell Precision workstations with Intel® Xeon® processors and their expert design software to accelerate product development. So while it still takes hundreds of iterations to make the perfect water bottle, OXO can now drive their innovative household tools to market faster than ever.
See how companies like OXO partner with Dell to engineer some of the most-loved products at Dell.com/CAD
Big power in a compact, innovative design.
Dell Precision Tower 5810 delivers up to 5.5x higher graphics performance than previous generations on engineering applications like SOLIDWORKS®.*
Built for Pros with Intel Inside®.
intel inside™ XEON®
Intel, the Intel logo, Xeon, and Xeon Inside are trademarks or registered trademarks of Intel Corporation in the U.S. and/or other countries.
*Measured by SPECviewperf 12.0.1 running Windows 7 Professional (64-bit, SP1), comparing sw-03 on the Tower 5810 (Quadro K620, Intel® Xeon® processor E5-1680 v3 CPU, 32GB (8x4GB DDR4 2100) memory) & a T3500 (Quadro 600, Intel® Xeon® processor W3680 CPU, 12GB of memory).
© 2014 Dell Inc. All rights reserved. Dell, the DELL logo, the DELL badge and Dell Precision are trademarks of Dell Inc.



DECEMBER 2014

Reader Krishnamurthy calculates the dangers of water hammer.

« One reader recounts what it took to earn a "P.E." after his name. Another re-examines the potential for autoignition at TMI.

HAMMER AND AUTOIGNITION

To the Editor: This letter is in reference to the December 2014 article "From Water Hammer to Ignition" by Robert A. Leishear. I would like to offer the following comments:

Water and steam present together in any situation is a disastrous recipe for water hammer. Ask any Consolidated Edison steam engineers. This condition has caused many incidents and accidents—all due to improper or malfunctioning trap or liquid level control in the

COMMENT

HOW I PASSED THE P.E. EXAM

I'm a product development engineer in medical devices. I didn't know any engineers in my field who had taken the Professional Engineer exam. Certainly none of my coworkers had taken it. Even though I would never seal engineering work for public and private clients (as many P.E.s do), I still saw the value of becoming a P.E. I decided to take the test.

I first took the P.E. exam in 2009. I studied for months, doing practice problems and practice exams. On exam day, I felt confident entering the exam hall. I didn't feel too confident after the exam, though. After a few months, I received a letter that confirmed my suspicions: I failed miserably. Back to the drawing board.

I retook the exam in 2010. I doubled up my studying efforts, solving even more practice problems and doing even more practice exams. I strode into the exam hall knowing that I would pass this time around. When I left the exam, I again was unsure. Once I got my results in the mail, though, a very familiar letter was staring back at me: I failed again. The only thing that had changed was the date on the letter.

There was never a question in my mind whether I would attempt the exam again. This time around, I took an online P.E. exam prep course. I had access to a professor who was available to answer questions by e-mail and in an online forum. I did all the recommended practice problems and exams. I took the exam for the third time in 2011. Third time's a charm, right? Apparently not. Failed again.

At my wit's end, I started to question whether passing this exam was worth the time and expense. I had spent hundreds of hours studying and over $1,000 of my own money in both prep course costs and exam fees. I didn't even work with any P.E.s. Why was I killing myself trying to pass this test?

I decided to take the exam one last time—my last hurrah. I signed up for an in-class prep course in Walnut Creek, outside of Oakland. The next nine weekends of my life went like this: After work, I flew from Orange County to Oakland, rented a car and drove to Walnut Creek, stayed overnight at a motel, drove to the prep class, and drove back to the airport to fly home. Nine airfares. Nine car rentals. Nine motel stays.

Even though the costs added up quickly, I felt really good about doing a prep course with other students sitting next to me. Having an instructor right in front of me who was able to answer questions in real time made me feel more confident about my chances of passing the test.

In 2012, I took the P.E. exam for the fourth time. My hands were clammy and flop sweat trickled down my forehead as I waited to enter the exam hall. During the exam, I felt my chances of passing slipping away. I left the exam hall absolutely dejected.

A few months later, I was sitting in front of my laptop and a particular e-mail caught my eye. My results were in. Did I pass? I clicked on the email's attachment. There was only one word I remembered from that entire letter: PASS. I had never felt that kind of relief!

For the next 24 hours, I would periodically return to my laptop and read the attachment again to make sure that I had read it correctly. It finally sunk in that, after four tries, I had passed the P.E. exam.

Once reality had set in, I went to my LinkedIn profile to change my name from "Neil Thompson" to "Neil Thompson, P.E."

Now I knew one engineer in my field who was a P.E. **ME**

NEIL THOMPSON, P.E., is a product development coordinator at Biostructures LLC in Newport Beach, Calif.

drain legs of the piping.

In the subject Three Mile Island incident I tried to quantify the magnitude of water hammer pressure spike and relate it to the autoignition pressure and temperature condition for possible hydrogen explosion.

Using the formula (from Tyler G. Hicks, *Power Generation Calculations Reference Guide*, McGraw-Hill):

$V_w = 4{,}720/(1+Kd/Et)^{0.5}$

where V_w = velocity of the pressure wave in the line, in feet per second; K = bulk modulus of water (300,000 lbs./sq. in.); d = diameter of the pipe, in this case the reactor pressure vessel's diameter, 173 in.; E = modulus of elasticity 30×10^6 lbs./sq. in.; t = thickness of RPV, estimated 14.5 in.

I estimated the velocity of the pressure wave at 4,460 ft./sec. I used a typical Westinghouse pressurized water reactor of similar size as TMI. Note that this is just an estimate to get a handle on the magnitude for engineering.

Using the formula for pressure increase (in lbs./sq. in.)

$P1 = (V_w/V)\ (32.2/2.31)$

the increase in pressure is estimated as 3,110 psi, over the uncovered portion between the open fuel elements and the top of the reactor, where the safety valve is located.

It appears reasonable to assume 10 percent hydrogen in this space in the absence of information on the balance of steam and water. This would result in a partial pressure of hydrogen at about 310 psi.

Autoignition temperature of hydrogen under normal ambient conditions is 536 °C (997 °F). Under pressure of 310 psi, the temperature would have easily reached a point causing ignition. My preliminary rough estimate shows 945 °F. Depending on the air-hydrogen mixture's concentration, it would have even become a detonable mix causing a supersonic flame front.

A paper, "Evaluation of Potential Hydrogen Detonation Due to Postulated Hydrogen Pipe Breaks," which Lloyd Nesbitt and I presented to the American Nuclear Society Meeting (Philadelphia, June 1995), includes some basic elements regarding the power potential of the explosion. This paper addressed hydrogen leak issues relating to a leak from an electric generator.

I agree with the author that the cause of the fire may be water hammer, and it may be worth review for future knowledge.

V. Krishnamurthy, P.E., *San Jose, Calif*

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.

NEW MOTOR MAKES FOR A BETTER FAN

A QUIETER, MORE EFFICIENT WAY FOR CIRCULATING AIR BEGINS WITH TAKING AWAY THE GEARBOX.

A manufacturer has introduced a high-volume, low-speed fan with a direct-drive motor and is pitching the product as an environmentally friendly alternative to conventional models.

According to the manufacturer, MacroAir Fans, the new model eliminates the gearbox and variable frequency drive of conventionally driven high-volume, low-speed fans. The company calls the new fan AirVolution-D.

MacroAir said the fan uses less electricity than earlier models in moving the same volume of air. The company is claiming additional efficiency gains for operators because, without a transmission in the fan, there are no gearbox inefficiencies, no oil to leak, and no gears or seals to maintain. MacroAir says the operation of the fan is also quieter than conventional fans and therefore more comfortable for the people near it.

The company says it worked with partners to adapt a transverse flux, brushless, sensorless direct-drive dc motor to drive a 24-foot fan. According to MacroAir, the result is more energy-efficient than a comparable fan with an ac motor. The design reduces size and weight, and generates less heat than conventional fan systems.

The transverse flux dc brushless motor uses three copper windings wound radially around the stator and magnets around the rotor. This enables MacroAir to boost the number of poles without increasing the amount of copper wiring, and supports smaller but more powerful motors. The motor has three phases and changes the polarity in each phase as needed to move the motor.

MacroAir said its developmental partners have been able to eliminate the need for sensors, which are needed in conventional brushless motors. Through a proprietary algorithm, they have been able to extract position information from the motor itself, bypassing the need for sensors.

Eliminating the sensors provides a longer service life and the ability to run in harsher environments. MacroAir offers a warranty of 50,000 hours, which translates to more than five years of continuous run time.

The transverse flux motor has three copper windings like the one in the foreground. The complete motor is smaller than the stator of a traditional brushless dc motor (right).

In order to operate the fan without sensors or brushes, the company has developed a custom drive, which is incorporated into the motor housing.

The company ran tests comparing the new fan with others, including its own conventional AirSpan ac model. It found that the AirVolution-D was more efficient than the others over a wide range of speeds. The tests rated its peak efficiency at speeds between 60 and 100 percent of maximum. According to MacroAir, most fans operate at about two-thirds of maximum to provide the most comfort for employees.

The AirVolution-D line of fans includes three different models with list prices from $4,000 to just under $8,000.

The price of the 24-foot AirVolution-D Model 780 is about 6 percent more than that of the AirSpan. The company has estimated that the reduced power consumption of the AirVolution-D can make up the cost difference in as little as one or two seasons. **ME**

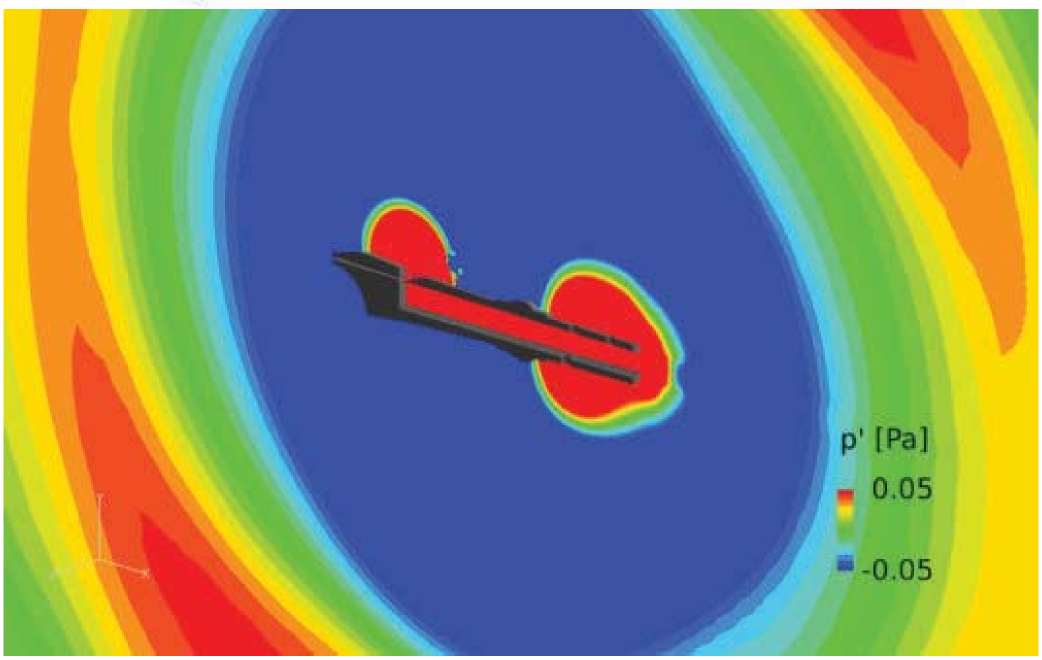
MODELING THE SECRETS OF MUSICAL INSTRUMENTS

Anyone who ever struggled to hit the lowest notes on a flute or recorder will rejoice in a numerical simulation that could help design easier-to-play instruments.

The model was developed by mechanical engineers led by Hiroshi Yokoyama of Toyohashi University of Technology and collaborators at Yamaha Corp.

The simulation, which calculates the flow of air through a Yamaha recorder, took two weeks to run using 100 nodes of a Fujitsu FX10 supercomputer. Yokoyama validated the model by comparing the output with the velocity and sound pressure from an actual Yamaha recorder.

A simulation (below) shows the contours of fluctuation pressure around a Yamaha recorder. *Image: Yamaha.*



There are two reasons why the sound quality model took so long to run. The first is that the simulation used a very fine, three-dimensional mesh, which it solved using compressible Navier-Stokes equations. These are the same equations used to predict weather, ocean currents, and air and water flow.

The second is that the musical quality of recorders involves a variety of complex interactions. They sometimes resemble the interplay of air, vortices, and shear layers along the wing of an aircraft—something that Yokoyama also models.

Unlike an aircraft wing, however, the recorder places the interactions within a pipe-like space that generates resonance, which adds an additional layer of complexity. At the same time, the performer is always changing the velocity of the air blown into the recorder while opening and closing tone holes.

Given these complex dynamics, it should come as no surprise that the best musical instruments have traditionally depended on the skill of the craftsmen who designed them. Relying on a tradition of trial-and-error experimentation, they make decisions based on generations of knowledge about everything from the choice of materials to barrel shape and the size and placement of tone holes.

By modeling the instrument, Yamaha hopes to clarify the relationships among these design variables. The company plans to use that knowledge to build instruments that not only sound better, but also make it easier for musicians to play the entire range of possible notes.

By perfecting this approach on recorders, engineers could improve on the traditional designs of more complex horns, strings, and reed instruments. Perhaps, one day, every child can take lessons on a violin that sounds just like a Stradivarius. **ME**

ALAN S. BROWN

THE POWER OF ONENESS

A no-assembly stapler: A flexible one-piece device has two metal parts that can be insert-molded to eliminate assembly operations. *Photo: Sridhar Kota*

"Design for assembly" methodology has been around for a few decades, and the benefits (and profits) of having a designer consider how things are manufactured have long been obvious. As Geoffrey Boothroyd and Peter Dewhurst put it in their textbook, *Product Design for Manufacture and Assembly*, "The greatest improvements arose from simplification of the product by reducing the number of separate parts."

So, if cutting the part count is key, why not cut that count all the way down to one?

That's just what Sridhar Kota, a professor of mechanical engineering at the University of Michigan and former assistant director for advanced manufacturing at the White House Office of Science and Technology Policy, has long been advocating. He calls his method "design for no assembly."

"When neighboring parts don't have to be a different material, then you should combine them," Kota says. "Even if there is relative motion between parts, you can combine them by exploiting the material's elasticity."

Nearly two decades ago, Kota wanted to show how, by taking advantage of a material's natural compliancy, a complex multi-piece product could be reduced to a single part. So he and two grad students designed and built a flexible stapler that requires no assembly. Two metallic parts could be insert-molded, eliminating the need for assembly operations altogether.

"WHEN NEIGHBORING PARTS DON'T HAVE TO BE A DIFFERENT MATERIAL, THEN YOU SHOULD COMBINE THEM."
— SRIDHAR KOTA, PROFESSOR OF MECHANICAL ENGINEERING, THE UNIVERSITY OF MICHIGAN

Later, Kota attacked another assembly-intensive device, the windshield wiper. His monolithic prototype was meant to show the engineering world how designers could combine flexibility and strength, drastically reduce part count and assembly, and still have a superior product.

Kota has formed a company, FlexSys Inc., which has made injection-molded prototypes of a one-piece device that combines the wiper blade and arm. He says the company has tested it and is in discussions with automakers and suppliers about using the device for a rear-window wiper.

"The compliant wiper performs better than a traditional wiper, with 50 percent of the weight and 75 percent fewer parts, and costs less than half as much as the ones imported from low-wage countries," Kota says. Nearly 100 million wipers are replaced each year, so there is a significant potential market for the product.

FlexSys has put the same methodology to use with a much bigger

continued on p.14 »


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

continued from page 12 »

THE POWER OF ONENESS

part on a much bigger vehicle. This fall, NASA and the U.S. Air Force replaced the multi-jointed rigid flaps on a Gulfstream III with Kota's Adaptive Compliant Trailing Edge. The new system can bend and twist to make the optimal shape for the various stages of flying. In essence, it's a morphing wing and is expected to save 3 to 12 percent of fuel—welcome news for an industry that spends over $200 billion in jet fuel worldwide annually. According to NASA the seamless wing reduces noise by 40 percent.

The Adaptive Compliant Trailing Edge, a hingeless flap, is undergoing tests by the Air Force.

NASA and the U.S. Air Force Research lab began flight tests in November 2014 and everything has worked flawlessly so far.

Instead of turning to stiffness for strength, he looked at how nature combines strength and flexibility: by distributing strain throughout the entire part. "In our load-bearing flexible structures (or joint-less mechanisms), every section of the material shares the load," Kota says. "That wing supports 24,000 pounds of load, bends and twists smoothly to maximize performance under all flight conditions, and yet has no discrete joints in the shape morphing mechanism."

According to Kota, each of the 22-foot-long shape-changing control surfaces, which replaced conventional flaps on both wings, is made of aerospace grade materials. There is no need for new space age materials. FlexSys's proprietary design methods work with common materials like aluminum, steel, titanium, plastics, and composites. The key is to exploit the materials' inherent elasticity.

If wipers and wings can be improved by design for no assembly, what about—you know—all the other things in the world? Indeed, Kota has made medical devices, and MEMS devices.

He says shoe, furniture, automotive, and sailboat manufacturers have approached his company for help in reducing part count or improving performance and reliability. One company, he adds, paid Flexsys engineers to just walk around and identify things that could be redesigned.

To reduce the parts that make up the myriad engineered objects in the modern landscape, designers and manufacturers will need more than just one Kota on the job. To that end, he is currently reworking the software he uses to extend the reach of compliant design.

With the software, and the methodology, twisting its way into more hands, there may be more things in the world with fewer parts. ME

An injection-molded prototype combines a windshield wiper blade and arm in one piece.

MICHAEL ABRAMS, ASME.ORG

CONVERTING FARM WASTE INTO COAL

An entrepreneur aims to improve on traditional methods for making charcoal. *Photo: Center for International Forestry Research/Flickr*

VILLAGE-SIZE TORREFACTION plants can help farmers be more self-sufficient.

IN THE NEAR FUTURE, farms in developing countries could add coal to the list of goods that they produce. And any kind of farm just about anywhere in the world could be eligible.

The trick is to build village-sized torrefaction plants in farming communities. The plants heat waste from the fields to convert it into charcoal, or biocoal. This coal is more energy dense than the raw materials that go into it, and farmers can sell it for cooking and heating. It can even fuel coal-fired power plants.

Torrefaction plants could someday be a common sight in rural villages, if Paul Polak has his way. Polak is a social entrepreneur and founder of the appropriate technology design firms D-Rev, iDE, and Windhorse International who has been instrumental in developing low-cost treadle pumps and solar pumps for farm irrigation. Now he would like to help farmers turn their waste into something with value.

The market for a low-cost torrefaction plant could hardly be larger. Farming is the world's biggest business, employing one-third of people who have jobs. And more than two-thirds of the world's farms are small, at less than one hectare, according to the GlolablAcrgiulture.org website (http://tinyurl.com/small-scale-farming).

Farming is also wasteful. There may be 4 billion to 5 billion metric tons of waste produced on fields every year. Some of it simply rots and some of it burns when farmers ignite their fields to clear them for planting. Polak and his team estimate

continued on p.20 »

INTROVERTS RULE

We may be drawn to the most **charismatic and engaging** among us. But **engineering managers** need to think about how to get the most out of their **introverted** employees.

Extraverts love to hog attention, but recently, introverts have come in for a bit of popularity. The author of a book titled *Quiet: The Power of Introverts in a World That Can't Stop Talking* has given interviews on National Public Radio, written an article for *The New York Times*, and lectured for a TED talk. Susan Cain makes the point, as do others, that today's world has turned almost entirely into an extraverted culture, and the value of introversion is overlooked as a result.

Psychologists' definitions of introversion and extraversion differ from the commonly held notions of being reserved or outgoing. There is some truth in those adjectives, but they are not prescriptive. Introversion is neither shyness nor a fear of public speaking. Introverts, however, do need to prepare and practice a public speech, whereas extraverts can thrive at speaking extemporaneously, even without full knowledge of the subject matter. Neither are introverts averse to socializing, although they prefer small gatherings.

In the work environment, introverts are primarily concerned with concepts and ideas: the inner world. Extraverts find themselves interested in people and things: the outer world. Psychologists have found a link between introversion or extraversion and the level of external stimulation people like (lots for extraverts) or can tolerate (little for introverts). One consequence is that introverts excel at working in an internally focused, reflective manner; extraverts prefer to work by interacting with others. Another is that an introvert's performance can be grossly impaired by distractions that might go unnoticed by an extravert.

Introverts won't show or discuss their work before they themselves are satisfied, while most extraverts share instinctively. Introverts like to communicate—and collaborate—in writing, which involves less personal interaction but lets them reflect more on the content.

Extraversion does have a certain charm. Who isn't drawn to the most charismatic and engaging among us? But our society idealizes extraversion so completely, according to Cain, that no place is left for introverts. "We're told that to be great is to be bold. To be happy is to be sociable," she writes, adding that introversion now falls "somewhere between a disappointment and a pathology." Our society consistently attempts to help introverts overcome an alleged shortcoming. We hear "You should speak up more!" and "Half of your grade will be based on in-class participation." We read books titled *Never Eat Alone* and *Lean In*.

DON'T THINK OF INTROVERSION AS SOMETHING THAT NEEDS TO BE CURED.
—SUSAN CAIN IN *QUIET: THE POWER OF INTROVERTS IN A WORLD THAT CAN'T STOP TALKING*

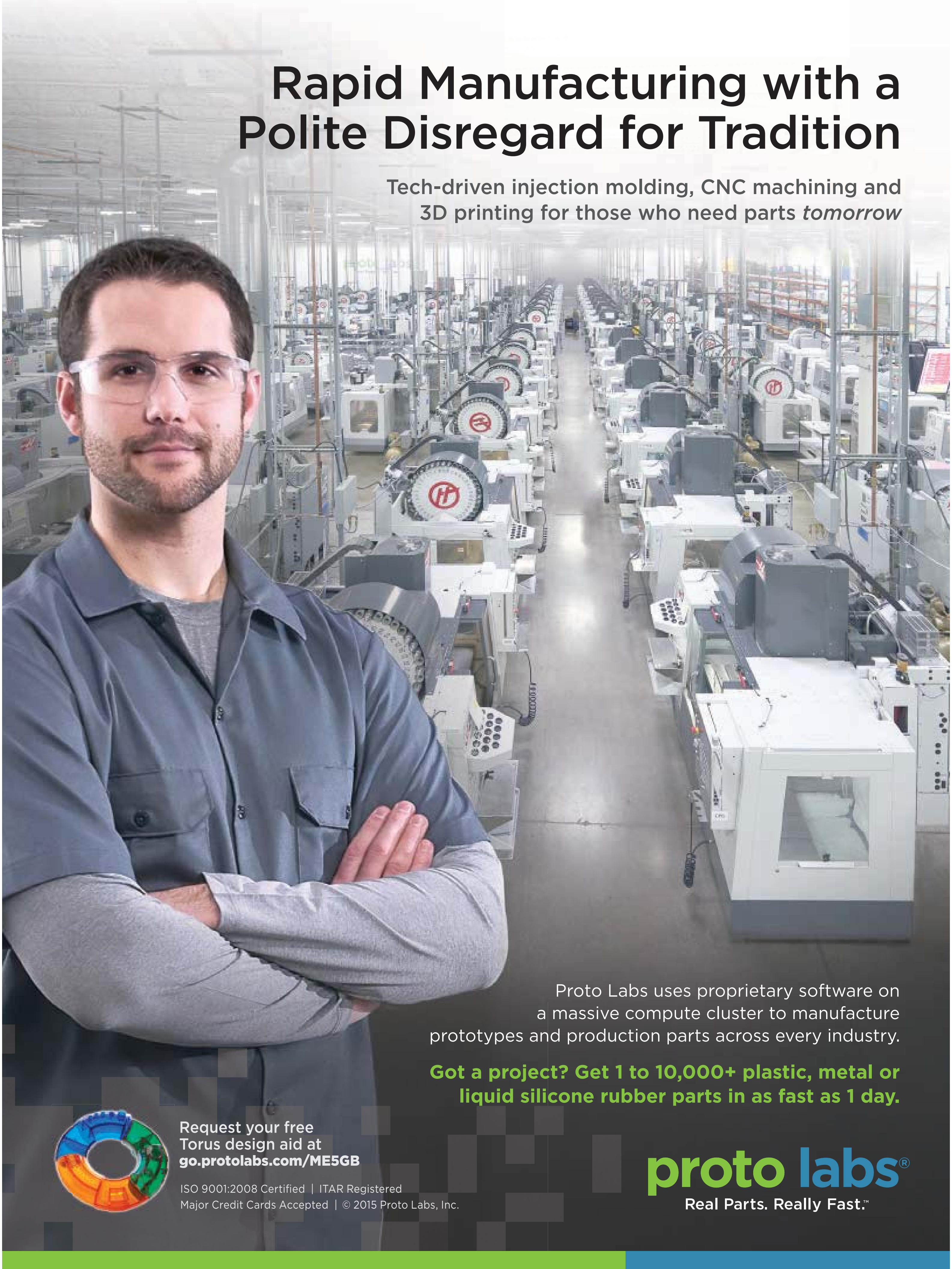
Consider group brainstorming sessions, which are an extravert's dream activity. Despite a widespread acceptance, objective studies prove them sorely lacking if used as the primary source of creative ideas. Absent is the introvert's focused reflection, which has been shown to be more productive. Some experts even suggest that group brainstorming is largely worthless save for its socializing role. Instead, individual idea generation combined with group evaluation and expansion—a hybrid process—appears to work best.

What else can we do for introverts?

Rethink open-plan offices, which studies suggest are counterproductive; provide separate meeting rooms to reduce distractions. Allow ample time for individual thought and action for everyone. Collaborate in small groups as well as in large meetings. Avoid hovering over a colleague's or subordinate's work, and don't hide your own work until you think it's complete; agree to review progress at reasonable intervals. Allow for adequate preparation of formal presentations; don't surprise someone—or be surprised. Recognize peoples' preference for tasks and projects that are deep rather than wide or wide rather than deep. Don't rely solely on oral exchanges; writing and reading stimulate individual thinking.

None of us needs to be a social psychologist to be a good engineer or manager. But we should understand how introverts perform best and take unreserved advantage of that. Engineering managers, for their part, need to encourage and exploit introverted thinking. Nobody should succumb to the social pressure to make this a fully extraverted world. **ME**

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


Rapid Manufacturing with a Polite Disregard for Tradition
Tech-driven injection molding, CNC machining and 3D printing for those who need parts *tomorrow*
Proto Labs uses proprietary software on a massive compute cluster to manufacture prototypes and production parts across every industry.
Got a project? Get 1 to 10,000+ plastic, metal or liquid silicone rubber parts in as fast as 1 day.
Request your free Torus design aid at **go.protolabs.com/ME5GB**
ISO 9001:2008 Certified | ITAR Registered
Major Credit Cards Accepted | © 2015 Proto Labs, Inc.
proto labs®
Real Parts. Really Fast.™

Q&A MARK CONNER

MARK CONNER is a Ph.D. engineer with an unusual job: He teaches engineering at a high school in Alabama. Conner received his doctoral degree from Duke University in 1996. After teaching physical sciences for seven years, he moved to Hoover, Ala., where he founded the four-year Engineering Academy program. The course integrates classroom physics, math, and engineering with lab projects. Through Catapult Engineering Academy, he is now seeking to deliver his program online.

ME: How did an engineer with a Ph.D. wind up teaching high school?

M.C: When I was a senior, our small school had a freshman algebra class with faster and slower students. The school needed to split the class, but we had only one algebra teacher, so they asked the advanced placement calculus students to teach the slower group for two weeks each. I was that smart aleck in the back who thought I could do it better, and I went first. When I saw the light go on when I retaught something, it was really satisfying. It also made me go back and relearn algebra on a deeper level. I was hooked, and taught that class for the rest of the year.

ME: But you didn't go to school for education?

M.C: I knew this is what I wanted to do, but I didn't want to go the teaching route. I was strong in math and science, so I followed my academic strengths and gifts until I ran out of degrees.

ME: What happened after you graduated?

M.C: I started teaching high school physical sciences. After several years, I moved to Hoover High School. It had an assistant principal who thought teaching engineering was cool. We created a four-year course.

ME: What makes it so successful?

M.C: The four teachers who deliver courses are all engineers with graduate-level degrees or research experience. They come at it differently from teachers who learn engineering at a two-week summer course.

ME: Is it hard to engage students?

M.C: I think we lose kids in science and math because of how we teach. When children ask the question, "When will I use this stuff?" no one ever answers them. Our curriculum answers that question. We don't introduce anything without a purpose.

We also do a lot of hands-on work. We may spend a few days or even a couple of weeks teaching a new concept, but then we turn them loose to apply what they've learned. By the time they reach their second year, they realize they're learning a lot.

ME: What about students who have trouble with math?

M.C: Some students can solve any problem in a lab or a shop, but the classroom is a chore. It doesn't engage them. That frustrates me. One of my gripes with how we do education. It's not that they can't do well in math; it's the way we teach math that totally turns them off. If someone showed them the importance of what they are learning, they would grasp it pretty quickly.

ME: You recently started Catapult Engineering Academy to bring your courses to other schools. How will this work?

M.C: We've been piloting online courses at two schools since 2011. We provide all the content. In a classroom, I could throw things on the board, monitor how it was going, and ask students to try things. Our online courses are not real-time, but we want to keep them open-ended and challenging. So we needed a more formal, stand-alone product that we could hand over to a teacher in another school.

ME: If that teacher is not an engineer, how will they teach the course?

M.C: The teacher is responsible for facilitating the class, pacing the lessons, and grading. The teachers who have been with us for a while understand how we assess projects and assignments. For new schools, we are creating online professional development courses that will support each course. We want to hand off grading to the local teacher but support them in the process. **ME**

INDIA TO ADD 15 GW OF SOLAR POWER

INDIA'S HIGHEST-LEVEL DECISION-MAKING body, the Union Cabinet, has approved a plan to establish solar power projects with a nameplate capacity of 15,000 megawatts, according to a report in *Business Line*.

The solar projects will be managed by NTPC, a government-owned energy generator, and a subsidiary, NTPC Vidyut Vyapar Nigam Ltd.

The first phase of the plan is to bundle 3,000 MW of solar power with 1,500 MW of coal-based power. Power will be allocated to states that provide land for the power plants. States that purchase a major portion of the bundled solar power and ensure connectivity will receive priority, the newspaper said.

According to an official statement, "The capacity allotted to each such state will be set up through developers, to be selected through international competitive bidding. ... Both private and government companies would be free to bid for projects."

One-third of the new solar capacity, 1,000 MW, will built on land already identified in the state of Andhra Pradesh. The balance will be allotted in other states that come forward. The first phase is expected to require an investment of more than $2.9 billion, which will be met by project developers, mainly private.

A second phase will add 5,000 MW paid by the government. The third phase, 7,000 MW, will receive no government financing. ME

EPA AWARDS EMISSIONS ANALYSIS CONTRACT

SOUTHWEST RESEARCH INSTITUTE, an independent, nonprofit, applied research and development organization based in San Antonio, was awarded a five-year, $20 million contract by the U.S. Environmental Protection Agency. The contract covers testing and analytical services related to vehicle emissions and fuel consumption.

The contract was tendered by the EPA's Office of Transportation and Air Quality Assessment and Standards Division.

The scope of the EPA-sponsored research includes all types of fuels and additives, including conventional and reformulated gasoline and diesel fuels; alternative fuels such as methanol, ethanol, compressed natural gas, liquefied natural gas, liquefied petroleum gas, hydrogen, and blends of hydrocarbon fuels; and electricity for electric, partial electric, and non-electric hybrid vehicles. ME

NEW DOE OFFICE TO PROMOTE TECHNOLOGY TRANSFER

THE U.S. DEPARTMENT OF ENERGY WILL establish an office to promote technology transfers from the laboratory to the market.

The new unit, called the Office of Technology Transitions, will work with the national laboratories and industry to commercialize technology. The aim is to strengthen the global competitiveness of U.S. industries based on scientific and technological innovations.

The DOE is required by the 2005 energy bill to dedicate 0.9 percent of its research and development budget to advance technology transfer and commercialization. The new office will oversee that activity.

It will be managed by the Director of Technology Transfer, a position that has remained officially unfilled since early 2013.

Jetta Wong, a senior official from the Office of Energy Efficiency and Renewable Energy, will be acting director of OTT and is under consideration for the final appointment. The Secretary of Energy, Ernest Moniz, said he hopes to fill the director role within the next few months. ME.

continued from page 15 »

FARM WASTE INTO COAL

that 1 billion tons of that waste is suitable for torrefaction.

Torrefaction plants are huge, expensive beasts that would bankrupt a farming village. But Polak's vision is to design plants that cost as little as $25,000. He explained his vision in an interview that he gave after the ASME International Mechanical Engineering Congress and Exposition in Montreal in November 2014 (http://tinyurl.com/PolakInterview).

"India's having trouble getting good quality coal, so there's a huge, unmet demand for biomass or a substitute for coal," Polak said. "If we can produce that $25,000 torrefaction plant in a village that will do seven tons a day at a value of about $150 a ton, that is one of your so-called disruptive innovations. Once you have 10,000 of those plants, you have enough volume to start being attractive to electricity producers using coal in India."

The technology offers some interesting challenges for engineers. On his site (www.paulpolak.com/four-global-companies), Polak points to a small, do-it-yourself torrefaction system built from two 55-gallon oil drums as inspiration for at least a part of the design his team is developing.

Farm waste, or any kind of biomass, goes into a chamber and is heated. As it heats, the biomass releases gases. Losing gases means that the biomass is losing mass, but one of the interesting things about this process is that it loses mass at a much sharper rate than it loses the stored energy available to burn, so that the charcoal that is left at the end is more energy dense than the raw material that went into the chamber.

Another interesting thing about the gases is that they are combustible. In this home-sized torrefaction unit, the gases are channeled from the biomass chamber around to the fire that is heating it, so that once it is started, the biomass supplies the fuel to continue heating itself until it becomes charcoal.

A torrefaction retort using two 55-gallon drums is an inspiration for part of the design that Polak's team is developing.
Photo: CharcoalKiln.com

Larger plants might employ a similar technique, and they might also try to make use of waste heat to produce hot water, steam, or other products with resale value. ME

ENGINEERINGFORCHANGE.ORG

CARBON-CAPTURE PROGRAM LOSES FUNDING

THE DEPARTMENT OF ENERGY has ended its funding of the FutureGen 2.0 carbon sequestration project, a clean-coal power plant demonstration slated for central Illinois.

The DOE in 2010 offered $1 billion to the project under the Recovery Act. So far it has put about one-fifth of that into the plant. According to published reports, the DOE deemed that the plant could not be operational before the federal funding allocation expires.

The DOE was unable to return phone calls for comment.

In a letter to Energy Secretary Ernest Moniz, the FutureGen Alliance's CEO, Kenneth Humphreys, wrote: "We understand a primary concern that factored into the Department's decision involved commercial financing considerations. FutureGen 2.0 is the only CCS power project with an investment-grade twenty-year power purchase agreement valued at nearly $5 billion."

Gregory Boyce, chairman of Peabody Energy, one of the member companies of the FutureGen Alliance, said, "It makes no sense to pull the plug on $1 billion committed to America's signature near-zero emissions power project at such a critical time for these investments in technology. The administration has pledged $1 billion for advanced coal projects in China, and I urge them to support investments in the United States."

The project would convert a 200 megawatt unit of a coal-fired plant owned by Ameren Energy Resources in Meredosia, Ill. It was to demonstrate two technologies—oxy-combustion, which burns coal with a blend of oxygen and CO_2 instead of air, and storage of captured carbon dioxide in a deep saline geological formation.

Not everyone was in favor of it. A group including Commonwealth Edison and several alternative energy suppliers challenged the legality of a 2012 decision by the Illinois Commerce Commission requiring utilities to sign 20-year contracts for FutureGen power.

The power suppliers argued the commission had exceed its authority in ordering the power purchases. At issue was the increased cost to consumers when utilities were forced to pay above-market rates for FutureGen's power. A District Appellate Court decided in favor of the ICC. The case was later accepted by the Illinois Supreme Court.

Sierra Club challenged the permitting of FutureGen. When the Illinois Pollution Control Board decided against the complaint, the Sierra Club appealed. ME

ONLY HUMAN, BUT ON WHEELS

Christopher Edwards in the driving simulator that helped rearchers test lane drift alert systems.
Photo: Christopher Edwards

TECHNOLOGIES FOR INCREASED AUTO safety—through tailored, intelligent restraint systems or better ways to alert drivers to dangers—are the aims of labs at the University of Michigan and the University of Minnesota.

The HumanFIRST laboratory at the University of Minnesota is working on ways to prevent automobile accidents caused by cars swerving out of their lanes. This sort of accident, which often occurs on rural roads, accounts for one third of all crashes and as many as 55 percent of all traffic fatalities.

The key factor in many of these accidents is human error: speeding, alcohol, fatigue, or driver distraction.

According to Christopher Edwards, a research fellow at the HumanFIRST lab, Minnesota's Local Road Research Board is funding studies of lane departure warning systems to determine their potential effectiveness in assisting drivers. Some systems use stereo visual reckoning to determine when the car has crossed the lane line. Other systems in development use global positioning satellites reckoning against a digital map. When a system determines that a car has drifted out of lane, it warns the driver to make a correction.

HumanFIRST has investigated a number of methods to alert drivers to a number of critical situations, such as a voice or visual alert, but studies have suggested that physical stimulation might result in faster driver responses, especially for lane departures. One option, investigated by HumanFIRST and previous research, was a quick but non-steering jerk of the wheel, but that created an uncomfortable sense that the car wanted control and resulted in overcompensation by drivers.

A TOUCH OF WARNING

THE LAB: The Human Factors Interdisciplinary Research in Simulation and Transportation laboratory, Department of Mechanical Engineering, University of Minnesota, Minneapolis; Max Donath, Director, Roadway Safety Institute.

OBJECTIVE: To improve scientific understanding of driver performance and cognitive functions.

DEVELOPMENT: Evaluating a tactile alert to help drivers avoid lane drift.

Sometimes, the strongest message is an old-fashioned kick in the pants. The lab equipped a simulator with physical actuators on the right and left sides of the seat. They would vibrate each time the simulated car departed the right or left side of the marked lane. This would give the driver immediate feedback not only of lane drift, but also of the direction of error.

The lab ran tests with 60 drivers from the ages of 21 to 65. The scenario simulated wind gusts pushing a car out of lane.

According to Edwards, subjects were assigned to reliability groups and analysis comparisons were conducted between groups. Each subject took a simulated drive during which no warning was given, and the results served as a baseline.

Then each driver took four more simulated drives with 12 simulated wind gusts per drive. The curves and straightaways differed on each simulated course.

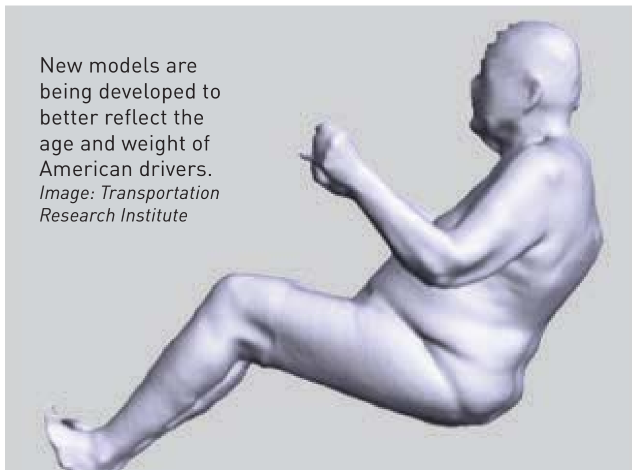
It turns out the system can be too sensitive. Based on records of driver responses, 100 percent sensitivity—buzzing every time the wheel touches the center line—was less effective than setting the system to be a little more forgiving.

When the system sent a warning for 90 percent of lane drift infractions, or even for 70 percent, driver response times were faster. There were also fewer instances of significant lane drift.

Also, drivers—regardless of the condition or the curve of the roadway—did not significantly slow down during lane drift. This reflects the driver training mantra to steer back safely onto the roadway, but suggests additional questions regarding the same behavior for curves and straight sections, Edwards said.

The results supported the findings of previous research in at least one way: A perfectly reliable system may make drivers complacent. **ME**

The University of Michigan Transportation Research Institute is conducting computational crash simulations of human beings to support future vehicle restraint systems that can adapt themselves to different body types and postures during an emergency.



New models are being developed to better reflect the age and weight of American drivers.
Image: Transportation Research Institute

The most commonly used device to study restraints today is the crash test dummy, which is primarily based on male and female percentiles from the 1970s, according to Jingwen Hu, a scientist in the institute's Biosciences Group.

The averages change, however. People have grown heavier, for instance. According to the U.S. Centers for Disease Control, the Body Mass Index, a ratio to measure the obesity level, of 48.8 percent of all adult Americans was in the healthy bracket of 18.4 to 24.9 during the period 1971-74. The percentage has dropped to 29.4 today.

Hu sees the move to mass customization by automakers eventually including vehicle safety restraint systems, which will be tailored to the individuals who will use the car. The auto industry is working on this now, both for safety and comfort, he said.

Hu, whose work is funded by the National Science Foundation, National Highway Transportation Safety Administration, Toyota, Ford, and GM, leads a team developing a mathematical model of the human body that can accurately predict a person's optimal safety restraint based on size, weight, gender, age, and other factors. According to Hu, future car safety restraint systems will become more dynamic as automotive computer systems gain in sophistication, processing power, and storage capacity.

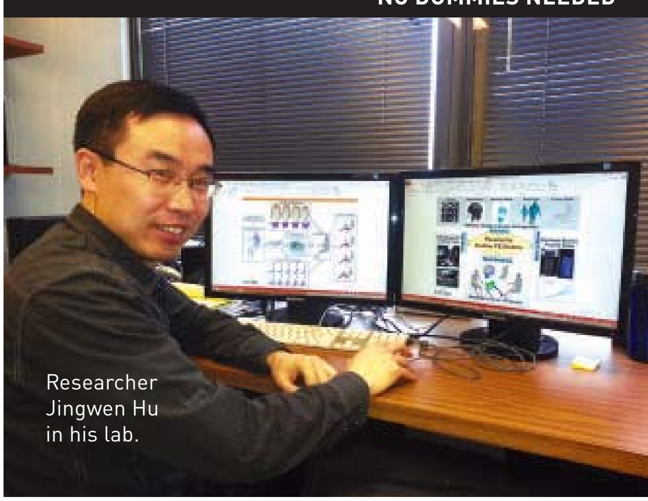
"As cars begin to drive themselves they will begin to avoid many typical accidents, but some accidents will be inevitable," he said, and passengers may be completely unaware of a pending collision because they are not focused on travel.

To protect passengers, restraint systems will have to consider body positions and predict the most likely impact from an impending collision. Software will attempt to minimize injury by adjusting the restraint system of belts and airbags to best protect the passengers accounting for their specific human attributes.

Jonathan Rupp at the university has led the efforts on cadaver experiments that can evaluate the biofidelity of the computational models.

Matthew Reed heads the institute's human body shape research, where volunteers undergo external body scans to catalog body sizes, shapes, and seating postures. In addition, hospitals are providing CT and MRI images to further document the diversity of body types in terms of bone and soft tissue geometries. **ME**

NO DUMMIES NEEDED



Researcher Jingwen Hu in his lab.

THE LAB: University of Michigan Transportation Research Institute's Biosciences Group, Ann Arbor; Matthew P. Reed, head researcher.

OBJECTIVE: Account for human diversity in occupant restraint systems.

DEVELOPMENT: A mathematical model of the human body that can accurately predict a person's optimal safety restraint requirements.

ELLIOT LUBER is an independent writer based in Seaford, N.Y.

COLOR IMAGES FROM FLAT LENSES

LENSES CURVE FOR A REASON: their light-focusing ability comes from the varying angles at which light crosses the air-glass interface. A flat piece of glass isn't a lens, it's a window.

But engineers at Harvard University in Cambridge, Mass., announced in February that they had created a flat, wafer-thin lens made from a glass substrate and nanoscale antennas that concentrate light. The flat lens holds the promise of being able to replace the thick, bulky devices used in cameras, microscopes, and telescopes with miniature systems engineered for high-performance optics.

Physicists have known for some time that flat objects can bend light. Diffraction gratings are used by college students to study light wave phenomena, such as interference. But light passing through diffraction gratings doesn't behave the same way that light traversing a lens does. Light at a given wavelength diffracts away both left and right from normal, while light passing through a prism all bends in the same direction.

Both lenses and diffraction gratings bend light at different wavelengths to different extents, what scientists call "chromatic aberration," that can be overcome in conventional optics through use of a series of lenses that correct for that. Researchers have long hoped to find a way correct the problem in diffraction gratings, since those gratings would be smaller, cheaper, and easier to produce.

A team of researchers from Harvard's School of Engineering and Applied Sciences led by Federico Capasso have devised a means to compensate for the wavelength differences through use of antennas. The team calls the new flat lens an "achromatic metasurface." It uses a nanoantenna made from a dielectric material. The dielectric material shifts the phase of the light passing through the grating so to change the pattern of interference; the nanoantennas can be designed so that certain wavelengths bend in parallel through a regular grating or come to a focus.

The nanoantenna doesn't enable a grating to bring every wavelength to the same focus, but it does allow for a system to be designed that would bend multiple wavelengths by the exact same angle. A color image could be made from focused blue, red, and green light, for example.

In their paper in the February 19 edition of the online journal, *Sciencexpress*, the authors also hint that this sort of optics may one day make 3-D holographic displays practical. ME

STANDARDS VS. ENERGY WASTE

THE AMERICAN NATIONAL STANDARDS Institute is taking aim at energy waste in buildings.

It has issued a report, *Standardization Roadmap: Energy Efficiency in the Built Environment*, which draws attention to published standards that can be used to reduce energy waste and also identifies gaps, where energy-related standards are needed.

The report was prepared by the Energy Efficiency Standardization Coordination Collaborative, an ANSI initiative with participants from a wide range of industries and organizations, including ASME. The collaboration is led by representatives of the Department of Energy and Schneider Electric, the international energy management company.

According to the DOE, buildings account for 40 percent of the United States' energy bill, or about $400 billion a year. About 20 percent of that energy is wasted. Eliminating the waste could save about $80 billion in energy costs.

The *Standardization Roadmap* looks at a variety of subjects including energy and water performance standards, system integration, energy ratings, workforce credentialing, and evaluation, measurement, and verification.

In its next phase, the collaborative will work with groups to encourage efforts to address gaps identified by the roadmap. It also plans to approach research organizations and academia to encourage action on research-related gaps.

The collaborative intends to inform policy makers and others on the use of standards to make the best use of energy and water. It will also work with U.S. technical advisory groups to the International Organization for Standardization and the International Electrotechnical Commission.

Standards-issuing organizations can notify the collaborative by using an online form called the EESCC Standardization Action Form at www.ansi.org/eescc.

The full text of the *Standardization Roadmap* is available at http://tinyurl.com/lgqzh9b. ME.

"The Chinese aid is going into infrastructural development which is a long-term investment that will have a big impact. Once you have built it, then our traders, our business people, tourists can get better roads. Our factories will not work below minimum because there is enough electricity."

Elly Twineyo, economist and author of Why Africa Fails, *in an interview with Xinhua.*

THE MANY-SIDED LASER

LOOKING BACK

Lasers were finding numerous roles in industry when this article was published in April 1965.

COMPILED BY E.C. RAIA, ASSISTANT EDITOR

In 1965, researchers were perfecting techniques to control a device that now has found uses that extend from home entertainment to eye surgery.

The next generation of lasers may be required to seam-weld materials by either continuous welds or by a series of spot welds. With regard to the former, the rate of energy loss by thermal conduction is now an important consideration because of the relatively longer dwell time of the laser beam. Power requirement for continuous welding may well be beyond the capability of present-day lasers, which can produce less than one watt of continuous output power.

On the other hand, a seam weld can be made by a series of successive adjacent spot-welds. This technique, due to an insignificant amount of conductive heat loss, offers more immediate promise.

It can generally be said that the welding speed possible with a successively pulsed laser is dependent upon the thickness and thermal diffusivity of the metal welded and the average power of the laser beam. Materials with high thermal diffusivities, such as copper, require shorter duration pulses to prevent vaporization.

The average power output required for successive spot-seam welding is available in today's lasers. On the other hand, the ability to control precisely the laser pulse duration, repetition rate, and energy content are engineering tasks which need more development effort before the laser can be employed on a production basis for this type of application.

Hole drilling is the most significant advance in laser machining to date. With the laser, holes of very small diameter have been drilled in difficult-to-machine or refractory materials. One possible application for a pulsed laser beam may be drilling holes in ferrite sheets, which are used as magnetic memory elements. At present, the holes are molded with the aid of core pins, which are inserted into the mold before pressing. This method, however, is limited in that the smallest holes feasible are 0.01 in. in diameter. If faster switching speeds and higher element densities are required, smaller holes, approximately 0.001-in. dia., will have to be drilled. The laser may be the only tool for this job. **ME**

'NO, MR. BOND ...'

In the year before "The Many-Sided Laser" was published, the laser made an early, and hard-to-forget, film appearance. In *Goldfinger*, Sean Connery, strapped to a slab of gold as the beam approaches, has an exchange with Gert Fröbe.

Connery (as James Bond): "Do you expect me to talk?"

Fröbe (as Auric Goldfinger): "No, Mr. Bond, I expect you to die."

Image: MGM

BY THE NUMBERS: HOW TO FLY AROUND THE WORLD WITHOUT FUEL

The Solar Impulse team has embarked on its ultimate trip: to fly a solar-powered aircraft around the world. The tour will burn no fuel at all, but will demand plenty of patience.

The Solar Impulse project is led by two Swiss partners, Bertrand Piccard and André Borschberg, who will spell each other in the single-seat cockpit. Piccard has a history of taking unconventional global flights. Fifteen years ago, he and Brian Jones, piloting the *Breitling Orbiter 3*, completed the first non-stop circumnavigation of the globe in a balloon.

Their propane was almost exhausted when they landed. According to Piccard, he realized that the mission would have failed if the gas had run out, so that's when the idea came to him to fly without needing fuel at all.

He floated the idea before the École Polytechnique Fédéral de Lausanne in 2003. Borschberg was chosen to lead a feasibility study and would later join the project as CEO. Piccard is chairman.

The team built a prototype called *Solar Impulse 1*, which proved that a solar-powered aircraft could fly day and night.

The prototype has been replaced by *Solar Impulse 2* for the world tour.

The aircraft is made of carbon fiber and has a 72-meter wingspan, wider than that of a Boeing 747-8I. Its mass is 2,300 kg, or about the same as a family car.

Each day 17,248 solar cells that cover the wings will generate as much as 340 kilowatt-hours of electricity. Part of that electricity will power four electric motors rated at 17.4 metric hp each—about what it takes to run a lawn tractor. The rest of the electricity will be stored in four lithium batteries with a total weight of 633 kg. The batteries are able to store 65.5 kWh of energy.

The strategy is to climb during the day to a maximum altitude of 8,500 meters and then glide for the first part of the night to conserve battery power until the plane reaches its minimum altitude of 1,500 meters.

Crossing the Pacific and Atlantic in the global flight will require one pilot to stay in the single-seat cockpit for five consecutive days. One of the chal-

SOLAR IMPULSE 2 VS. BOEING 747-8I

PRIMARY MATERIAL: *SI2:* Carbon fiber. 747: Advanced aluminum alloy in fuselage; carbon fiber in secondary structures.
WINGSPAN: *SI2:* 72 meters. 747: 68.5 meters.
MASS: *SI2:* 2,300 kg. 747: 447,696 kg.
POWER SUPPLY: *SI2:* 17,248 solar cells. 747: 242,470 liters of jet fuel.
PROPULSION: *SI2:* 4 electric driven propellers @ 17.5 metric hp each. 747: 4 GEnx-2B67 turbo fan jets @ 296 kN thrust each.
ENERGY STORAGE: *SI2:* 65.5 kWh. 747: Not applicable.
BATTERY MASS: *SI2:* 633 kg. 747: Not applicable.
CRUISING ALTITUDE: *SI2:* 1,500 meters. 747: 10,668 meters.
CRUISING SPEED: *SI2:* 70 km/h. 747: Mach 0.855.

THE FLIGHT
PILOTS: Bertrand Piccard and André Borschberg.
AIRPLANE: *Solar Impulse 2*
FUEL: None
DISTANCE: 35,000 km.
DURATION: 5 months.
FLYING HOURS: About 500.
LEGS: Approximately 12.
SUPPORT TEAM: 150 people.

THE PROJECT
DURATION: 12 years of feasibility study, concept, design and construction.
STAFF: 50 engineers and technicians.
SUPPORT: 80 technological partners; more than 100 advisers and suppliers.
PROTOTYPE: *Solar Impulse 1*.

THE COCKPIT
VOLUME: 3.8 m^3.
PRESSURIZATION: None.
OXYGEN: 6 bottles.
EMERGENCY: 1 parachute, 1 life raft.
NOURISHMENT: Food and water for a week.

lenges in building *Solar Impulse 2* was designing a cockpit that could support a lone pilot for that long.

High-density thermal insulation of the cockpit will protect the pilots from exterior temperatures ranging from +40 to -40 °C. Even so, the temperature inside the cockpit may fall as low as -20 °C.

A multi-purpose reclining seat serves as berth, toilet, and exercise platform. The seatback holds a parachute and a life-raft. The seat has an ergonomic inflatable cushion.

Piccard and Borschberg are using self-hypnosis and meditation techniques that will help them rest and retain their powers of concentration.

The pilots will have a balanced diet of 2.4 kg of food, 2.5 liters of water, and 1 liter of sports drink a day. Physicians, including specialists in high-altitude medicine, are available to advise the pilots during flights.

The route begins and ends in Abu Dhabi. The mission control center in Monaco will be in continuous contact and will monitor hundreds of technical parameters via satellite data-link. Specialist teams will watch weather patterns for the best routes and will prepare the way for the airplane to enter controlled airspace and prepare for landings at international airports.

The flight plan includes a path across the continental United States, with stops planned in Phoenix and New York, and also an interim landing somewhere in the Midwest, at a site yet to be determined.

The location will depend on weather conditions.

A solar-powered airplane does not fly fast. *Solar Impulse 2* has a maximum speed of 49 knots, or 90 km/h. On the way back from Morocco a couple of years ago, *Solar Impulse 1* met headwinds greater than its airspeed, and so flew backwards for a while.

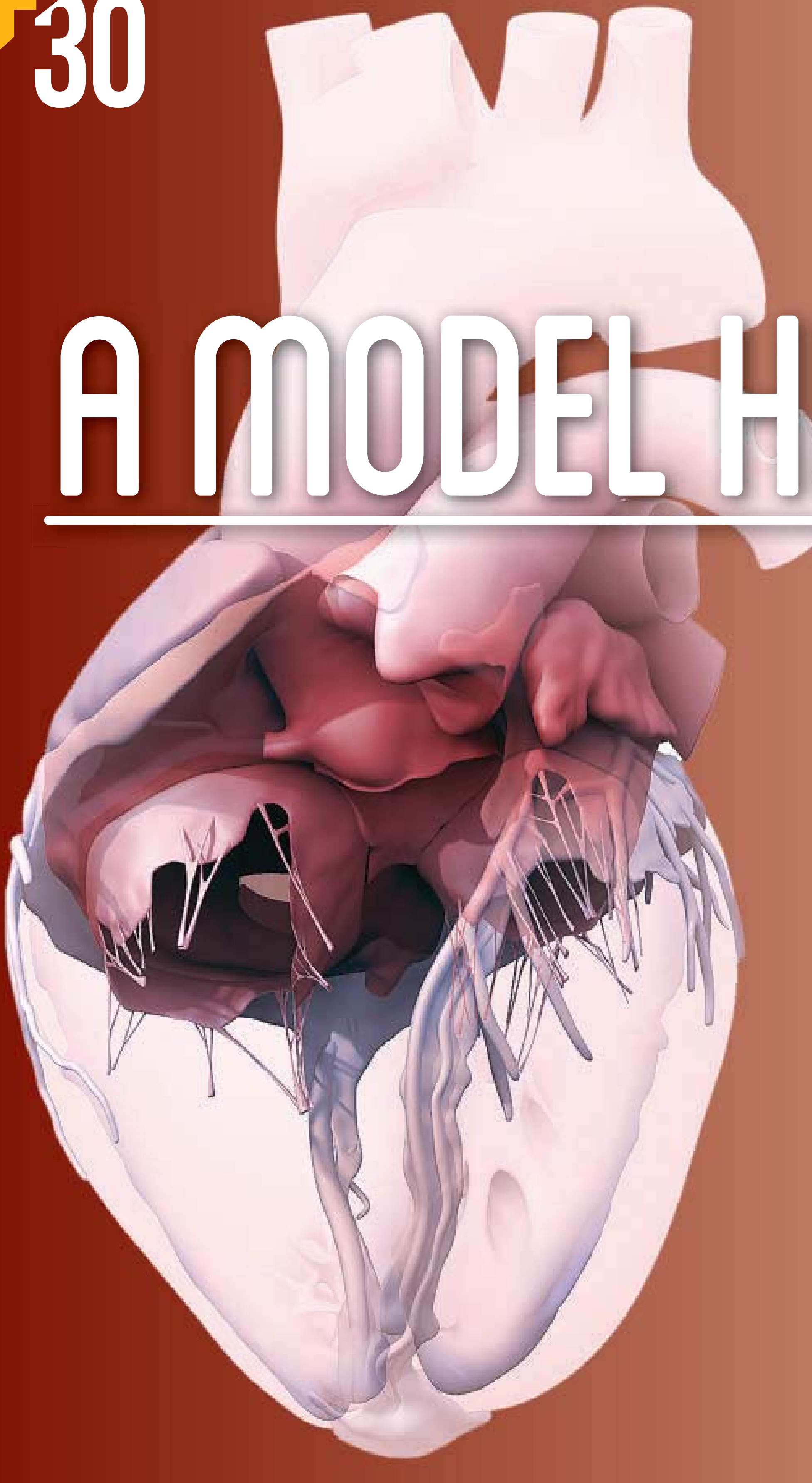
The trip around the world is expected to cover about 35,000 kilometers and take five months. To make headway, the plane will have to avoid rapid headwinds and monsoons. So the exact route and times of arrival are approximate. Weather will be a major influence on the actual course that the plane will take.

But as Piccard once told us, “You can do a lot if you’re not in a hurry.” ME

HARRY HUTCHINSON

F30

A MODEL HEART



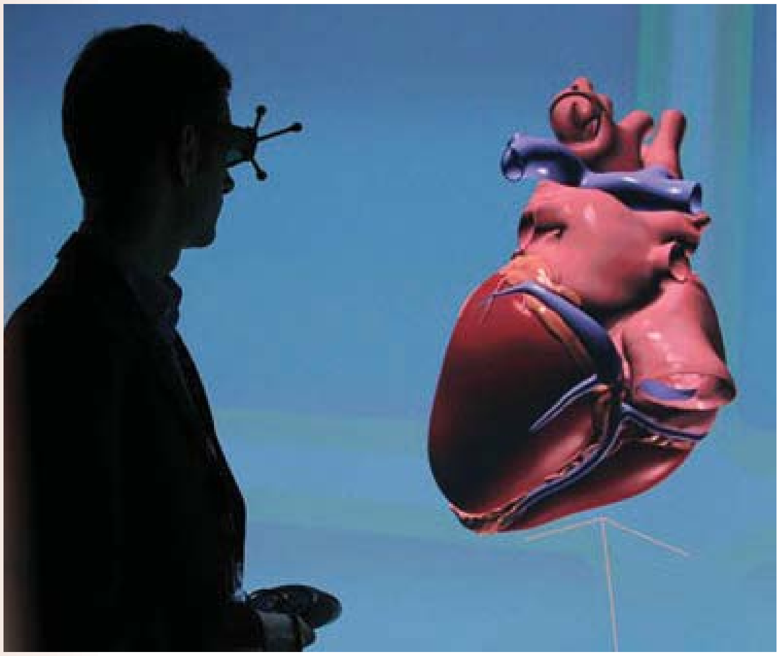
DIGITAL SIMULATION TAKES ON ITS TOUGHEST CHALLENGE

BY ALAN S. BROWN

Steven Levine remembers when the light bulb lit up in his mind.

His daughter had been born with the left and right chambers of her heart reversed. She received her first pacemaker at age two and her fourth at 20. While in medical school, she talked with her cardiologist about future treatments.

"It was clear that he didn't have much data to go on," Levine recalled. "He would have liked her to go into an MRI machine, but there is a risk because she has three broken pacemaker leads still in her body. So they had a negotiation about risk versus the value of the data.



Dassault's Living Heart model is a larger-than-life 3-D representation that enables surgeons, researchers, and engineers to look at the human heart in different ways.

"Then my daughter asked him what he would do with the data. And he said, 'I don't know, but maybe I'll be able to figure something out.' "

After she told Levine, he thought, "This is what I do for a living. If he could get the data, why couldn't I come up with a structural analysis of it?"

To do that would require a realistic simulation model of the heart. It would not only help answer questions about his daughter's treatment, but revolutionize cardiovascular care.

A model might help cardiologists predict how a heart condition would progress. It would provide new ways to design and approve cardiovascular devices, which rarely undergo large-scale human testing before commercialization.

Surgeons could use the model to test new procedures or plan the best intervention for patients. Researchers could use it to develop better ways to image constantly beating hearts.

As chief strategy officer of Simulia, an engineering modeling and simulation software firm, Levine was ideally placed to create that model.

Simulia is part of Dassault Systèmes, which makes a broad range of industrial design and simulation software. Dassault was looking for a highly visible challenge to showcase its multiphysics Simulia software, which let users combine such previously separate tools as finite element analysis and computational fluid dynamics in a single model.

The heart posed that challenge, and more. Its behavior is driven by a complex combination of mechanical, electrical, and fluid properties that called for multiphysics solutions spanning different size scales.

The heart also showed behaviors unlike the purely mechanical components Dassault has modeled in the past. For example, its walls change their stiffness almost instantaneously, depending on whether they are generating or responding to force.

Levine kicked off Dassault's Living Heart Project in early 2013. By May 2014, he had released a beta version of a surprisingly realistic model. Previous simulations, mostly academic, had resembled idealized spheres or heart segments. Dassault's model was a complete heart, with four chambers, valves, papillary muscles, blood vessels, and even some surrounding chest muscles. Future releases will include blood flow dynamics.

"This is an extremely advanced model," said Jose Navia, a cardiac surgeon at Cleveland Clinic in Ohio, who designed a heart valve implant using the Living Heart.

The project came together so quickly because it adapted an open-source approach. Levine reached out to more than 100 people in 30 organizations, including medical device makers, researchers, physicians, and regulators.

In doing so, he tapped into a quiet revolution in understanding and modeling the cardiovascular system. Over the past two years, Levine has been combining this diverse research into a single collaborative engineering platform.

The Living Heart Project is now reaching critical mass, Levine said. Yet one thing is abundantly clear: This is an effort that is being shaped and led by engineers.

Many never imagined doing anything remotely like it.

FINITE ELEMENTS

Ellen Kuhl, an assistant professor of mechanical engineering at Stanford University, was one of them.

Kuhl had trained in finite element analysis in Germany, working on "bridges and dams" types of engineering problems. After she came to Stanford in 2007, one of her graduate students asked to build an FEA model of his mother's heart, which had an irregular heartbeat. A second student wanted to design a new heart valve with a local surgeon.

This drew Kuhl into the orbit of physicians from Stanford's medical campus.

"The cardiac surgeons weren't happy," she said. "They define themselves as plumbers. They fix leaky valves the way plumbers do, by trial and error, but they get only one shot to do it right."

They wondered if they could use something like video game technology to simulate surgical outcomes before they opened a patient. Intrigued, Kuhl began attending surgeries.

The surgeons would test new designs by replicating a condition in large animals, implanting the device to see if it worked, and conducting post-mortems to see if the implant damaged any surrounding tissue.

By placing the heart in a body, Dassault's model enables engineers to envision how medical devices might interact with muscles and bones, as well as with the heart.

Kuhl would arrive at 6 a.m. and help put the animals on heart-lung machines before surgery.

"I could reach into the animal, hold its heart in my hand, and feel the beating. It's very soft when filling, and then, in one millisecond it becomes stiff as a rock as it starts pumping," she recalled.

Her experiences showed the need for a viable heart model.

"These surgeries are incredibly difficult to do in animals," Kuhl said. "They are time-consuming and expensive, and raise ethical questions. We could save so much time and be so much more precise and accurate if we could test these designs on a computer first."

Her team started by incorporating existing data on the heart's electrical behavior into a finite element model. It chopped the complex geometry of the heart into thousands of tiny tetrahedrons. By solving for the electrical response of each small tetrahedron, or cell, and modeling how that change affected neighboring cells, her model could reproduce the sprint of pulses across the heart.

After validating the model against students' EKGs, her team added the mechanics. They used data from researchers who measured the contractions of heart muscle tissue in Petri dishes. By linking FEA cells together into muscle tissue, she could replicate the crisscrossed strands of muscle that reproduce the heart's characteristic twisting pump motion.

The FEA model let her produce a broad range of behaviors.

"By changing the properties of the tetrahedrons, we can make different regions of the heart contract faster, slower, stronger, or weaker, and reproduce different diseases and conditions," Kuhl said.

She could also project how a diseased heart would evolve over many years.

Kuhl's model was very sophisticated but far from perfect. It lacked many features and simplified others. Her modest Living Matter Lab had no way to incorporate all the latest cardiovascular research. So when Levine approached her in 2013, she was happy to join the Living Heart Project. Her model became its FEA core.

As Dassault reached out to other researchers, it upgraded the model. Cleveland Clinic's Navia, who holds joint appointments in surgery and

"THE CARDIAC SURGEONS WEREN'T HAPPY. THEY DEFINE THEMSELVES AS PLUMBERS. THEY FIX LEAKY VALVES THE WAY PLUMBERS DO, BY TRIAL AND ERROR, BUT THEY GET ONLY ONE SHOT TO DO IT RIGHT."

bioengineering, was the first to apply it to design.

Navia worked on an annuloplasty ring, which squeezes together the flaps of a heart valve to keep it from leaking.

Navia used the model to simulate the ring in different types of diseased hearts and measure precisely the stresses the ring puts on the valve and surrounding muscles.

"The model was fantastic, and proved the concept," he said. "We could run simulations under different conditions, including ones we could not recreate in living animals, and change the design to improve performance."

THE LIVING HEART GROWS

Many medical device makers already used Dassault products, and Levine had foreseen a role for the Living Heart in design. As the project began to incorporate the work of other experts into the model, the focus broadened to include surgery and imaging.

For example, Julius Guccione, a bioengineer and professor of surgery in residence at University of California, San Francisco, Medical Center, has been developing heart models since the late 1990s. He was part of a team that pioneered polymer injection, a technique that reduces stress on heart walls by 35 percent.

"When we tried to publish, the reviewers thought the results were too good to be true, and wanted to see our raw MRI images," he said.

His experience shows how models can help innovative surgeons. In the mid-2000s, researchers thought they could treat damaged heart muscle by injecting stem cells, which would grow into muscle cells and strengthen the heart wall. Tests showed noticeable improvements.

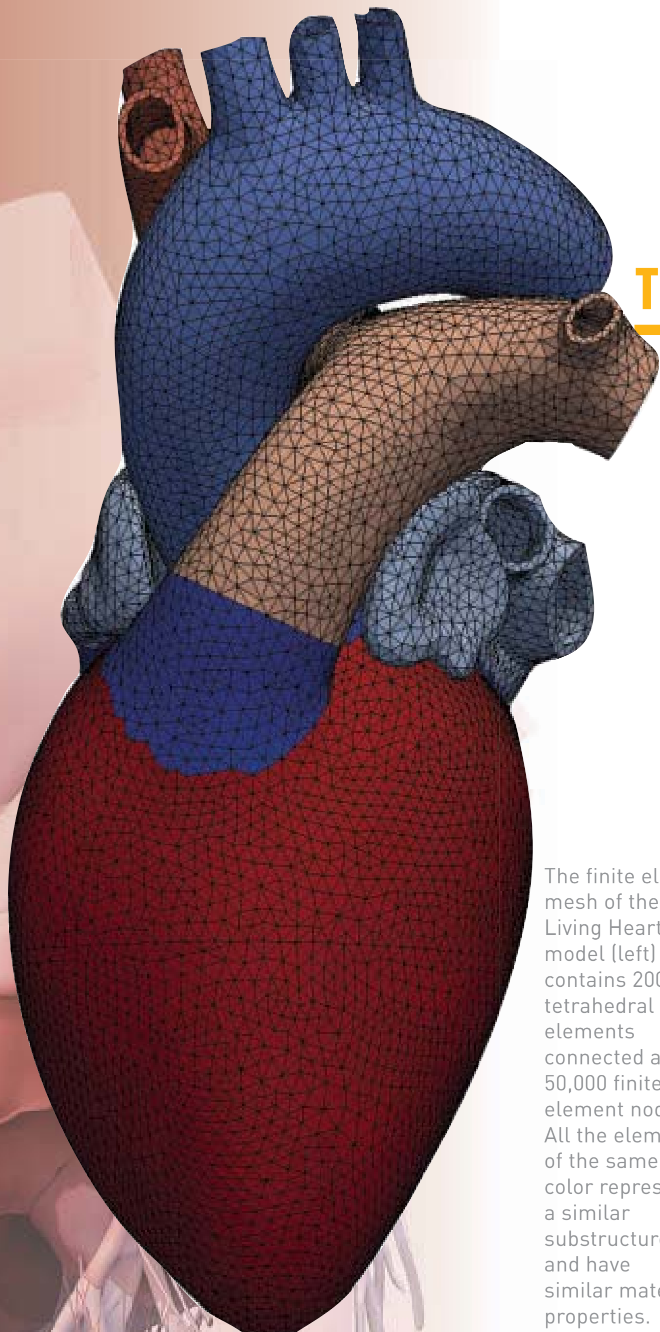
UCSF surgeon Mark Ratcliff and Kevin Healy, a bioengineer and materials scientist at the University of California, Berkeley, thought differently. They argued that injecting any material into the heart would increase the wall's thickness and improve its load-bearing ability

They asked Guccione to model the left ventricle, and use the model to find the right material. They needed an injectable liquid that polymerized quickly. It had to be stiff enough to provide support, but supple enough to flex during pumping.

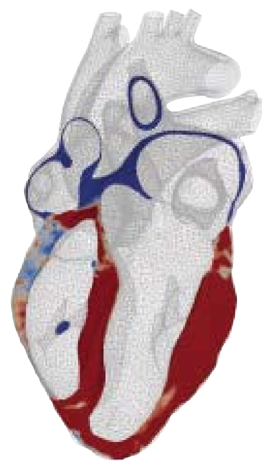
Guccione identified a resin, and also showed that seven injections was the best tradeoff between support and flexibility.

The researchers then reproduced failing left ventricles

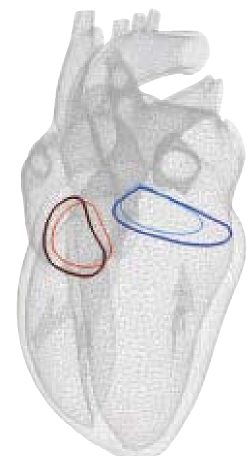
THE FINITE ELEMENT MESH MODEL



The finite element mesh of the first Living Heart model (left) contains 200,000 tetrahedral elements connected at 50,000 finite element nodes. All the elements of the same color represent a similar substructure and have similar material properties.



In the model above, the red regions show that wall thickness increased by up to 50 percent as the heart responded to increased pumping pressure. Cardiologists may soon use similar models to predict how the disease will progress in different patients and, ultimately, design individualized treatment plans.



The left side of the heart in this model has grown too large, and the base of its valve has expanded to the dark blue circumference from the light blue size. Cardiac surgeons typically implant a ring to make the valve smaller and prevent backflow. The model provides detailed stress and strain data that could help them design the rings.

"WE DO WHAT WE THINK IS BEST... BUT THERE IS NO WAY OF KNOWING IF THAT'S RIGHT. "

—JAMES PERRY, HEART SURGEON, RADY CHILDREN'S HOSPITAL, SAN DIEGO.

in dogs. The injections stopped the disease from causing death. The procedure reduced heart wall stress by an average of 35 percent on 11 heart patients in Germany, with no adverse effects.

Guccione's model provided a deeper understanding of how the procedure worked, and shaved countless weeks off materials development and animal testing.

Others are using models to guide treatment. One is James Perry, a heart surgeon and director of electrophysiology and adult congenital heart programs at Rady Children's Hospital in San Diego.

Perry reconstructs the hearts of children born with only one working ventricle. This involves several complex operations, starting in childhood. Some of the children who received this procedure have grown up to be healthy adults, "some as functionally normal as me and you," Perry said.

Yet no two patients are the same, and Perry must decide how to treat each one. “Early on, do we operate or put in a pacemaker? We do what we think is best for that child with that particular defect and that particular cardiovascular physiology,” he said.

“But there is no way of knowing if that’s right. If we could model that procedure, I would know what would be the better choice looking 40 years down the road.”

With no simulation model to give him answers, Perry began developing a mathematical model that analyzed data from several thousand patients with similar conditions. A surgeon could measure a heart’s output and responses, and the model would calculate the most likely outcomes for different treatments.

The model has already given Perry new insights. Some of his patients, for example, have leaky valves. Most surgeons do not want to do open heart surgery until they must. Perry’s model shows that operating early, before leaks grow larger, produces better long-term results.

The Living Heart might also improve the ability of imaging equipment to identify heart conditions, W. Paul Segars said. An associate professor of biomedical engineering and radiology at Duke University, Segars developed a model that simulates how the body absorbs X-rays, ultrasound, and other radiation generated by medical imaging devices.

By modeling the absorption of skin, bone, and organs, Segars can analyze how well a specific imaging device would be able to locate small tumors or other medical conditions in a wide range of patients and positions. Segars and his collaborators use this information to improve image accuracy.

For a beating heart, it remains a challenge.

“The heart beats once each second, so if you were trying to image plaque around a valve, it would get blurred out. You need a way to process this motion to get a clear image,” Segars said.

By recreating the condition in a model, Segars can see how the imaging equipment responds to the challenge. Sometimes, all it takes to remove the blur from the data is a different measurement protocol or a better algorithm. Other times, it may require an equipment redesign.

Segars created his heart model by scanning MRI data into his software. While it is anatomically correct, he has little control over its parameters. He signed on early with the Living Heart Project so he could work with a more realistic model.

“With the FEA model, we can dig deeper and change the size of some features and the blood flow, or place a blockage in the arteries,” Segars said. “We can simulate all types of patient data.”

Segars was attracted to the Living Heart because it offered broader capabilities than his models. That realism opens new doors. The ability to change a wide range of parameters lets researchers access behaviors they cannot replicate with more narrowly focused tools.

TAKING IT TO MARKET

Levine plans to commercialize the Living Heart slowly, in steps.

“We’re systematically targeting problems that are readily addressable by the sophistication of the model at each of its stages,” he said.

For example, the Living Heart model is already suitable for testing pacemaker leads, since it needs to model only mechanical stress during motion. Projecting the progression of heart disease will require a more sophisticated model that incorporates the behavior of the underlying heart tissue.

Dassault is also partnering with the U.S. Food and Drug Administration to test how its model simulates the insertion, placement, and performance of pacemaker leads and other cardiovascular devices. If FDA verifies the model, device makers will be able to use simulations for regulatory approval.

While the FDA relies mostly on bench models, and animal and human tests, it has begun using some computational models, said Donna Lochner, associate director of regulatory science research programs at the FDA’s Center for Devices and Radiological Health.

For example, the FDA uses CFD models to characterize fluid flow through and around cardiovascular devices. Models also play a “significant role” in evaluating how MRI radiation might cause tissue damage by heating implants.

For simulations to play a larger role in regulatory approval, the industry will need more realistic models and a better understanding of how much it can trust the results of those models, Lochner said.

Dawn Bardot agrees. She is senior program manager for modeling and simulation at the Medical Device Innovation Consortium. The group seeks to advance regulatory science, and includes medical device makers, software developers, and such government agencies as the FDA and National Institutes of Health.

Bardot believes the Living Heart Project is breaking new ground.

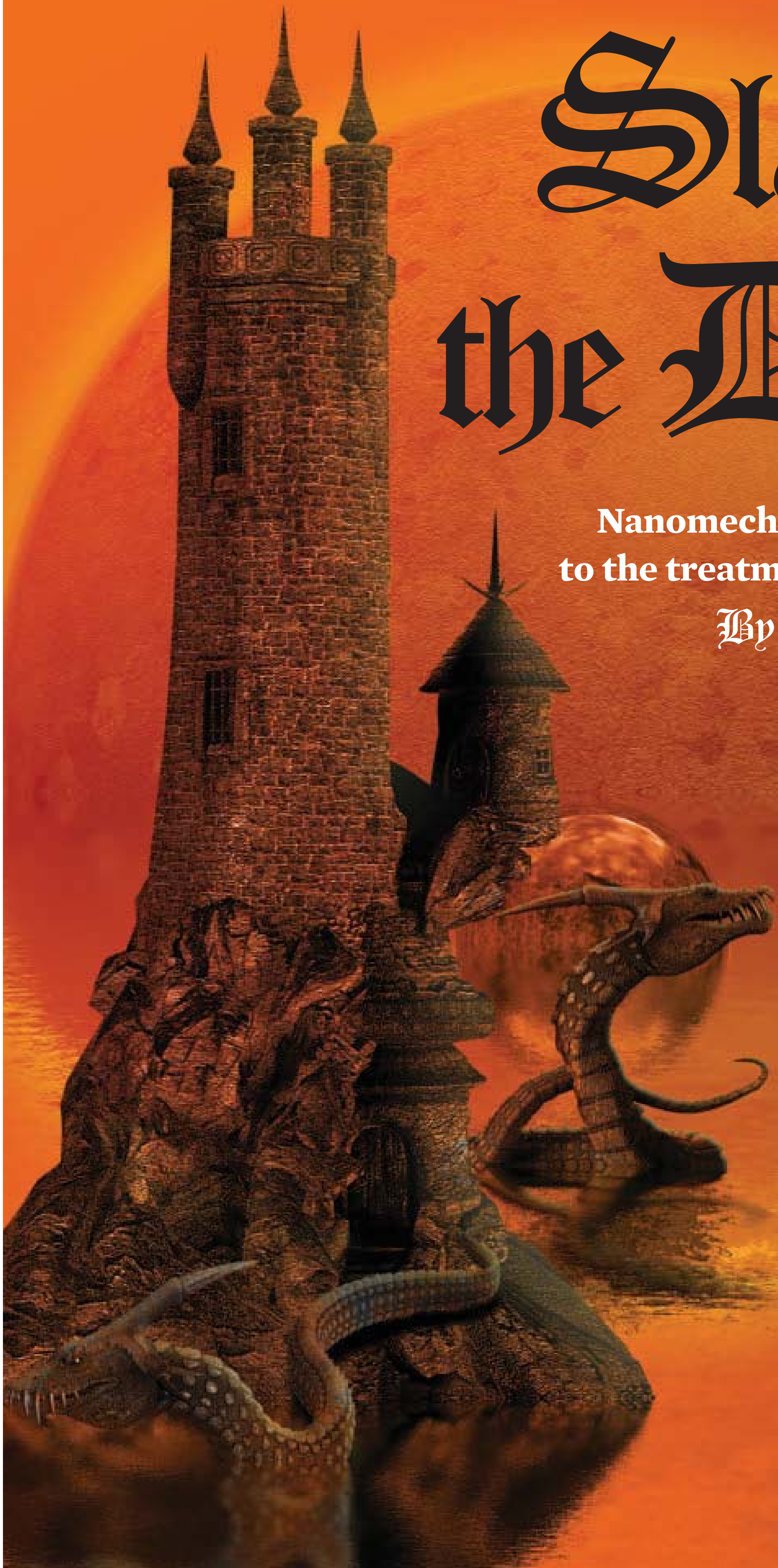
“I think we’re on the cusp of something really big right now,” Bardot said. “When they look at my condition, they are not going to choose the same medical device they used to treat my grandmother. They’ll choose a device specifically for me.

“We can’t do that now, because we can’t run clinical trials on one thousand Dawns to see which device works best,” she said. “There’s only one of me.

“And that’s what modeling really offers, a way to simulate one thousand Dawns to find the best way to treat my particular condition,” she said.

Or, for Steven Levine, the best way to analyze his daughter’s heart. **ME**

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



Slaying the Dragon

Nanomechanics opens a new route to the treatment of metastatic cancer.

By Mauro Ferrari

Once cancers metastasize, they are almost always fatal. Researchers are looking at the nanoscale mechanics of tumors to discover means to attack—and kill—all kinds of cancer cells. If successful, this will be a cure for even metastatic cancer.

To reach and kill metastatic cancer cells, therapeutic vectors (gray disks) must make it past enzymes (yellow bolts), immune system cells (white globs), and the endothelial layer (blue-gray barrier).

We have been at war against cancer for more than a generation—officially since President Richard M. Nixon signed the National Cancer Act of 1971, and for years before that as well. And there have been many victories over the course of this war: Primary cancers are more and more often completely resolved, largely owing to advances in surgical techniques. But because cancer remains a leading cause of death in the U.S. and other parts of the developed world, many people view the effort against the disease as a failure.

As fearsome as cancers are, cancer cells are easy to kill. All cancer drugs are effective against cancer cells, as are many other substances—even tap water. The problem is that effective cancer drugs are also extremely damaging to the healthy parts of the body, and therefore dosage cannot be increased at will without concern for major, potentially lethal adverse consequences for the patients.

The cancers which we cannot yet cure with any level of confidence are ones that have metastasized. That is, they have spread from the organ in which they originated to other organs. Indeed, the rate at which metastatic cancers, especially those that grow in the lungs, liver, and brain, are cured remains abysmally low and they are responsible for the vast majority of cancer deaths.

Medical researchers have a term, "therapeutic index," which is a measure of how much therapeutic benefit we can achieve for a drug, per unit of adverse effect that the treatment gives to the patient. Simply put, the current treatments that are available to fight metastatic cancers have a therapeutic index so low that they provide only days or weeks of extended life.

And here is where nanotechnology and engineering mechanics come in. My colleagues and I are developing therapeutic drugs that can be tailored specifically to the weaknesses of these metastatic cancer cells and can be delivered to the cells directly, without poisoning the healthy tissues in the rest of the body.

For instance, my colleague Haifa Shen at the Houston Methodist Research Institute has developed a multifunctional particle system that takes advantage of the mechanics of blood flow through capillaries to preferentially attack lung cancer cells. In laboratory trials, Shen has had a 50 percent success rate in curing metastatic lung cancer in mice.

I will describe this approach in more detail, below, but first we need to take a few steps back to frame the problem in fuller detail, and set the stage for nanomechanics-based solution strategies. Perhaps the narrative can be eased by a metaphor—of the human body as a medieval fortress, protected by multiple defensive systems: Its high walls, encircled by a moat, with crocodiles to boot, archers on the walls, cauldrons of boiling oil to be used against attackers scaling the walls (including metaphorical cancer drugs, mistaken for enemies).

You get the idea, the human body comprises a sequence of built-in protections against attack (a.k.a., "biobarriers"), which in biological reality comprise the surfaces lining the blood vessels (vascular endothelium), the trapping organs that selectively filter the content of the blood stream (e.g. liver and spleen, the reticulo-endothelial system), the membranes surrounding the cells of the body, and their inner organelles, and the safety pumps that cells use to expel noxious substances (multi-drug resistance efflux pumps).

In this medieval metaphor, let's imagine the beautiful princess, symbolizing life itself, chained in a room—one among the thousands of rooms in the fortress—and a hideous monster, symbolizing a cancer metastasis, creeping up to her, with deadly intent.

The good news is, the monster is easy to kill: Just about any substance or weapon will kill it, as is true for cancer cells, which can easily be killed with tap water.

The bad news, however, is plentiful. First, we do not know in which room this tragedy is unfolding—and we need to get there quick. Time is ticking away.

Second, the monster has black magic powers, including the ability to modify the biobarriers around itself, so that it will be protected against whatever poisons and weapons we want to use against it. In reality, cancers have the ability to grow protective tissue around themselves (stroma), plus an adverse pressure gradient, and express molecular pumps that push poisons back to where they came from.

Third, the various barriers and protections in health and disease require special biological passwords to get through. Thus, the ability for our "prince charming drugs" to recognize the cancer and kill it on the spot will do the princess no good, unless they come with a sequence of passwords. Drugs without the required complement of carrier passwords will end up in the toilet, or worse, will mostly kill innocent and helpful bystanders in other rooms.

Fourth, the very same poisons and weapons that kill the beast will also kill the princess—though some princesses are indeed a bit stronger than the beasts, by a tiny bit that correlates with the therapeutic index.

Fifth, actually there are many princesses, not only one, and they are all threatened by many different monsters, symbolizing the heterogeneity of metastases deriving from a single primary tumor. If any of the princesses dies, it's game over for all. And, different monsters are vulnerable to different poisons and weapons, while all princesses are harmed by all drugs. And, different monsters can modify the biobarriers around them in different ways, each with new and more complex passwords.

Still surprised that metastatic disease is currently incurable?

So, what approaches have been used to address this horrifying scenario? We have four main lines of attack.

I am optimistic that the day is coming, soon, **when deadly metastatic diseases can be definitively cured.** And the approach that works will be based on the invaluable advances that were recorded in all of the prior approaches, chemo- to bio- to nano-.

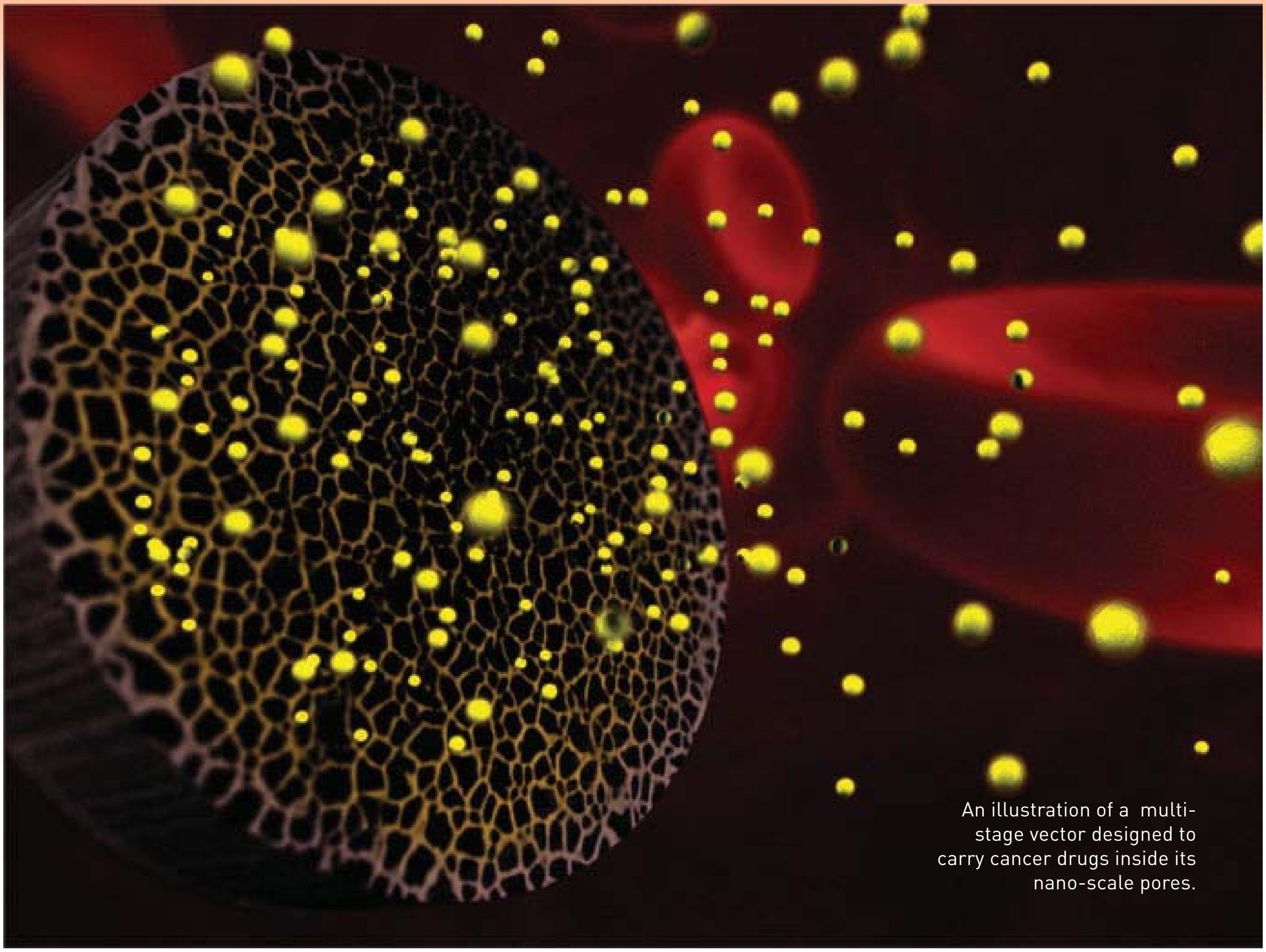
First, the poisons that can get into every room of the human fortress—the classical approach of IV infusion of small molecule chemotherapeutics. They will kill a lot of monsters indeed, but with this approach it is impossible to get them all without executing a princess or two, even though the poisons can be selected to act on processes that are more frequent in cancer than health—such as cell duplication. In short: insufficient therapeutic index.

Second, in the last twenty years or so, all the rage has been on molecularly targeted, biological therapies, mostly monoclonal antibodies. These are really good at recognizing monsters from princesses, and delivering their deadly payload against the captors, rather than the hostages.

Great, but all of the biomolecular equipment they need to carry in order to achieve that bio-sniper capability makes them big and bulky, and generally incapable of making it through the defenses: They are picked up by the biological radars of the body, they are heard stumbling through the vaulted halls, and killed; they are too heavy to swim across the moat with rapidity, and succumb to the metaphorical crocodiles. Result: A modest survival advantage for metastatic patients, on the order of weeks, certainly no cure. Better therapeutic index, but still too low, still needing to flood a patient with drugs to get enough past the crocodiles, and still too much damage to innocent and productive citizens of the body.

Third—here enters nanotechnology! How about packing those chemo-drugs in little tiny nano-containers that will preferentially be collected in the rooms where the princesses meet the beasts? Great idea, but you still need the biological passwords to get there. So, the first generation nanodrugs (starting about 20 years ago) were approved to treat cancers which were so stupid that they did not even lock the doors behind them. These cancers are very permeable to nano-sized agents through the so-called enhanced permeation and retention effect (EPR), which comes with a greater leakiness of their vascular walls.

The nanodrugs use nanoparticle materials such as liposomes (imitation cell membrane) and albumin (a carrier



An illustration of a multi-stage vector designed to carry cancer drugs inside its nano-scale pores.

molecule of the body) as nano-scale drug containers and vectors, to be injected into the bloodstream. Nanodrugs in current clinical use have extended the lives of many metastatic patients on the order of weeks to months, which is good, but not enough.

Thus, fourth came the idea of adding to these nanoparticles a decoration of biomolecular recognition agents on the surfaces, such as antibodies that recognize cancer specifically, on the theory that this would keep the nanoparticle in the princess chambers longer, and away from the healthy parts of the body. Problem is, those metaphorical crocodiles that get the biologically targeted therapies (second approach, above) have a field day against these molecularly targeted nanoparticles, which are much fatter, slower, and juicier!

Then, no surprise that none of these "actively targeted" nanoparticles has ever been approved for clinical use, though several are in clinical trials. Tell you a secret, I am not sure any ever will make to the clinic, and if they do, I doubt they will make much of a clinical impact.

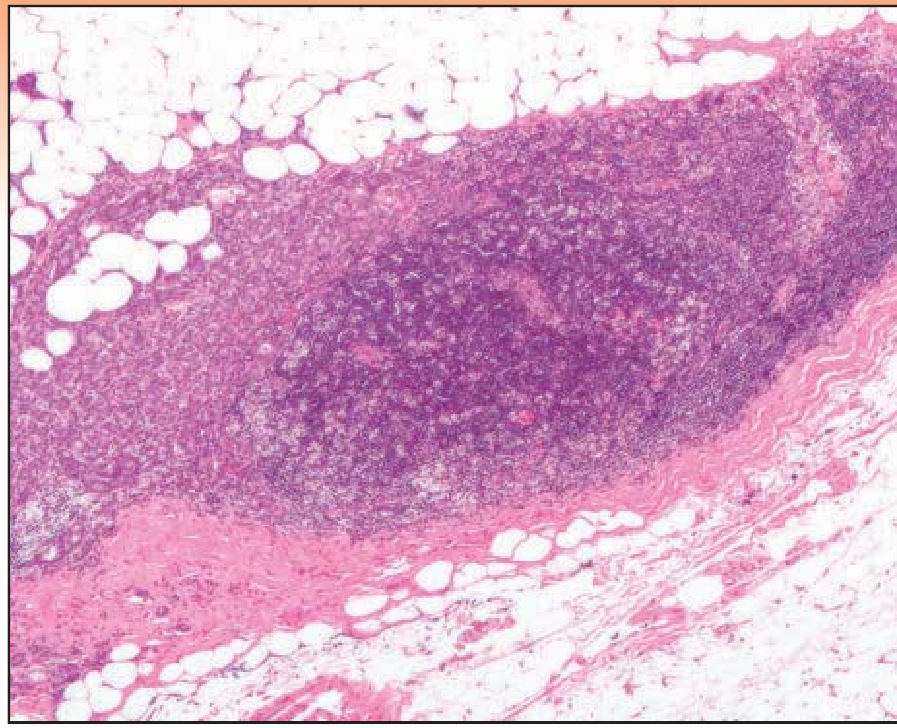
Any impact is good, don't get me wrong—but my only surprise here is that the vast majority of current nanomedicine projects deal with some variant of this ill-fated approach. Different materials, sizes, targeting agents, drugs—but probably the same crocodiles in their future.

Still, I am optimistic that the day is coming, soon, when deadly metastatic diseases can be definitively cured. And the approach that works will be based on the invaluable advances that were recorded in all of the prior approaches, chemo- to bio- to nano-.

Haifa Shen has recently demonstrated that a new, multifunctional therapeutic agent (MSV-pX) can completely cure about 50 percent of animals with breast cancers, metastatic to the lungs, in several different mouse models. For the same situation in the clinic there is no cure, no expectation of survival.

How did he do it? The key word is "multifunctional." In turn, the key foundations of his successes are engineering mechanics and nanotechnology. Let's explore how.

First, the vasculature feeding metastatic lesion is different; it has characteristic flow dynamics, which also reflect the organ in which they are located. Employing mathematical models of multiphase flow, which we have developed over the last 10 years, Shen was able to design particles that, upon reaching the lung cancer capillary bed, tend to accentuate their drift toward the vascular wall, and lodge there, or



Breast cancer cells are shown in dark pink in this micrograph. A nano-based, multi-stage therapy has shown good results.

even penetrate across a line of cancer endothelial cells into the cancer tissue.

This process of drifting (margination), lodging (firm adhesion) and penetration (EPR, transcytosis, and paracytosis) is fundamentally enabled by the shape (disks, resembling platelets), size (3-micrometer diameter, 200 nm thickness), surface charge, and density. It is a physics-based choice of optimal design parameters, obtained in keeping with the principles of engineering mechanics that gives the preferential concentration at the tumor site, or: Mechanics begets therapeutic index. Different choices of physical design variables enable preferential concentration at other crucial metastatic sites, such as liver and bone marrow.

Over a hundred years ago, the Wright brothers tried a few designs to see if any of their contraptions would fly. Now, we design airplanes with the benefit of engineering mechanics and computer simulation for optimal design. Tell you what—I think the time has come that we do exactly the same thing with drugs, designing them for optimal concentration at target sites, based on the quantitative approaches of engineering mechanics.

Tell you more: If different cancers have different vascular and blood flow characteristics, how about we determine these first by radiological imaging (this is easy) and then we design the most suitable drug in a way that will optimize transport to the needed sites? In other words: Personalizing therapy by optimizing the engineering mechanics of its transport?

Alas, concentrate preferentially though they may at desired metastatic lesion sites, the Haifa Shen vectors do not penetrate through the cancer deep enough. They are simply too big. But then—ah-ha!—how about we load them with smaller (second-stage) carriers and molecules?

As we saw, these by themselves if injected in the blood stream would never concentrate at the target site, but the idea here is they can be carried there by the "first-stage" Haifa Shen carrier. Sure, to accomplish this all you have to do is to make the first-stage particles suitably nanoporous (easy, done, patented) and load the "stage two" in the nanopores.

The solution that works against lung metastases is to load a second stage that is a molecule of a polymer (the "p" in MSV-pX), which is linked to a conventional "anti-duplication" chemotherapeutic drug (the "X") by means of a chemical group which is cleaved in high-acidity environments (Don't ask me why now; you will see later). This stage-two molecule is spewed out from the first-stage vector by diffusion, and during the chemical disintegration of the first stage carrier in the body—and by thermodynamic forces it forms nanoparticles, upon exiting the pores.

So, at this point you have a biodegradable microparticle for injection in the bloodstream, which can act as nanoparticle generator, can concentrate preferentially at the target cancer because of its physical characteristics, and upon getting there forms and spews out these drug-carrying nanoparticles – a Multi-Stage Vector (the "MSV").

Why not just carry polymeric nanoparticles to start with, you ask? Too big for the nanopores of the first stage vector.

Why do you need nanoparticles, rather than just the polymer molecules with their linked drugs? Because the polymer with drug simply will not be taken in by the cancer cells.

The nanoparticle, on the other hand, has Trojan horse-like properties, and gets engulfed by the target cells by phagocytic processes. I suspect that the Trojans of old would not have taken into their city just any old, shapeless mass of wood. It had to look like a horse, right? So, we need nanoparticles, not polymeric strands—same idea.

Now, part three of this perilous journey through the cancer jungle swamps, plus crocodiles: Once the nanoparticles are picked up by the cancer cells, what happens to them is what happens to anything (nutrients, signaling molecules, etc.) that is picked up by receptor-mediated endocytosis in cells: They are enveloped in a lipid-bound container (vesicle, phagosome, then transforming into an endosome or lysosome during transport) and carried actively by transporter molecules along train-tracks (microtubules) that direct them toward the cell nucleus.

As this happens, the interior of the vesicles becomes more and more acidic. It's part of the normal garbage disposal processes of our cells. As they get to the immediate vicinity of the nucleus (which is the ultimate target of the anti-duplication chemotherapy drug), the interior of the transporter biovesicle reaches a trigger point of acidity, which results in the pH-sensitive linker to be cleaved, and the therapeutic moiety to be freed from the polymer backbone.

In this free form it can diffuse out of the vesicle, and travel the very short distance to get into the nucleus, where it effectively kills the target cell. Victory. Haifa cured about 50 percent of the animals with lung metastases, which otherwise would have died in days to weeks.

Again, why don't we just inject the drug by itself? Can't reach enough concentration in the right place, resulting in bad therapeutic index. This is the classical chemotherapy approach.

Why not inject the chemo+polymer? Will not enter the cell as effectively.

Why not just find another way to marinate the cancer cells into a large dose of chemo, somehow delivered at the right site, rather than using the polymer backbone-turned nanoparticle to transport across the train tracks of the cells, toward the nucleus? Now, that's a good question to ask! Here goes the explanation—very, very clever of Dr. Shen: Cancer cells, especially those that are hardest to kill and that repopulate the cancer after most of it is wiped out by therapy (these are known as cancer stem cells), have this exceptionally powerful defense mechanism of multi-drug resistance enabled by a great many molecular pumps that sit at or by their outer cell membranes.

The pumps look for toxic agents that may have penetrated the cell, and when they find them, they actively expel them from the inside of the cell, where they can hurt, to the outside, where they can be safely dealt with.

Free chemodrug diffusing into the cell will be spewed out most effectively. Chemodrug inside of polymer nanoparticle, on the other hand, is taken up by the vesicles and ferried far away from these efflux pumps, right by the nucleus where it can carry out its mission impossible, past the defense of the dark-star cancer cell.

Again, all elements of this exquisitely designed multi-component drug—the MSV, the p, the X—are all necessary for its success, and they are all based on the mechanics of transport. And, please do not talk to me about mere "drug delivery systems." What we have here is a new generation of multi-tasking drugs, and any component by itself is incomplete, exactly like those we use every day on thousands of cancer patients.

Other colleagues of mine are exploring further frontiers of multistage pharmaceuticals: Ennio Tasciotti strips some immune cells of their membranes, and uses them to cloak MSV carriers so that they will not be captured as readily by the filtering organs of the body. To use paratrooper analogies, if you are going to be dropped behind enemy lines, you might avoid capture longer to carry out your mission, if you wear the uniform of the enemy.

Elvin Blanco deploys second stages that carry more than one drug, with prescribed concentration ratios, to optimize their synergy. He can even get them to release at different, prescribed times.

Kenji Yokoi, Biana Godin, and Ennio Tasciotti again hijack some cells in the body so that they will carry MSV therapeutics deepest inside of cancers. Carlotta Borsoi uses MSV systems to build a metaphorical road across the cancer jungle, so that conventional drugs can get there with greatest efficacy. Haifa Shen has developed multifunctional MSV cancer therapeutic vaccines. I have been focusing primarily on using MSVs as components of a therapeutic strategy that suppresses the actions of the key driver genes of cancer.

> Cancer cells, **especially those that are hardest to kill** and that repopulate the cancer after most of it is wiped out by therapy, have this exceptionally **powerful defense mechanism of multi-drug resistance enabled by a great many molecular pumps.**

All of these approaches could not succeed without the multi-disciplinary palette of clinical oncology, nanotechnology, cancer biology, mathematics, materials sciences, pharmaceutical methods, physics of transport, imaging technology, chemistry, biotechnology—and the necessary foundations of engineering mechanics!

So, I reckon it's time that engineering mechanics join forces with all of these disciplines, to finally win the fight against metastases. What say you? Haifa Shen and his colleagues have shown the way. There are prairies worth of space for other strategies and designs that will conquer different beasts in different fortresses.

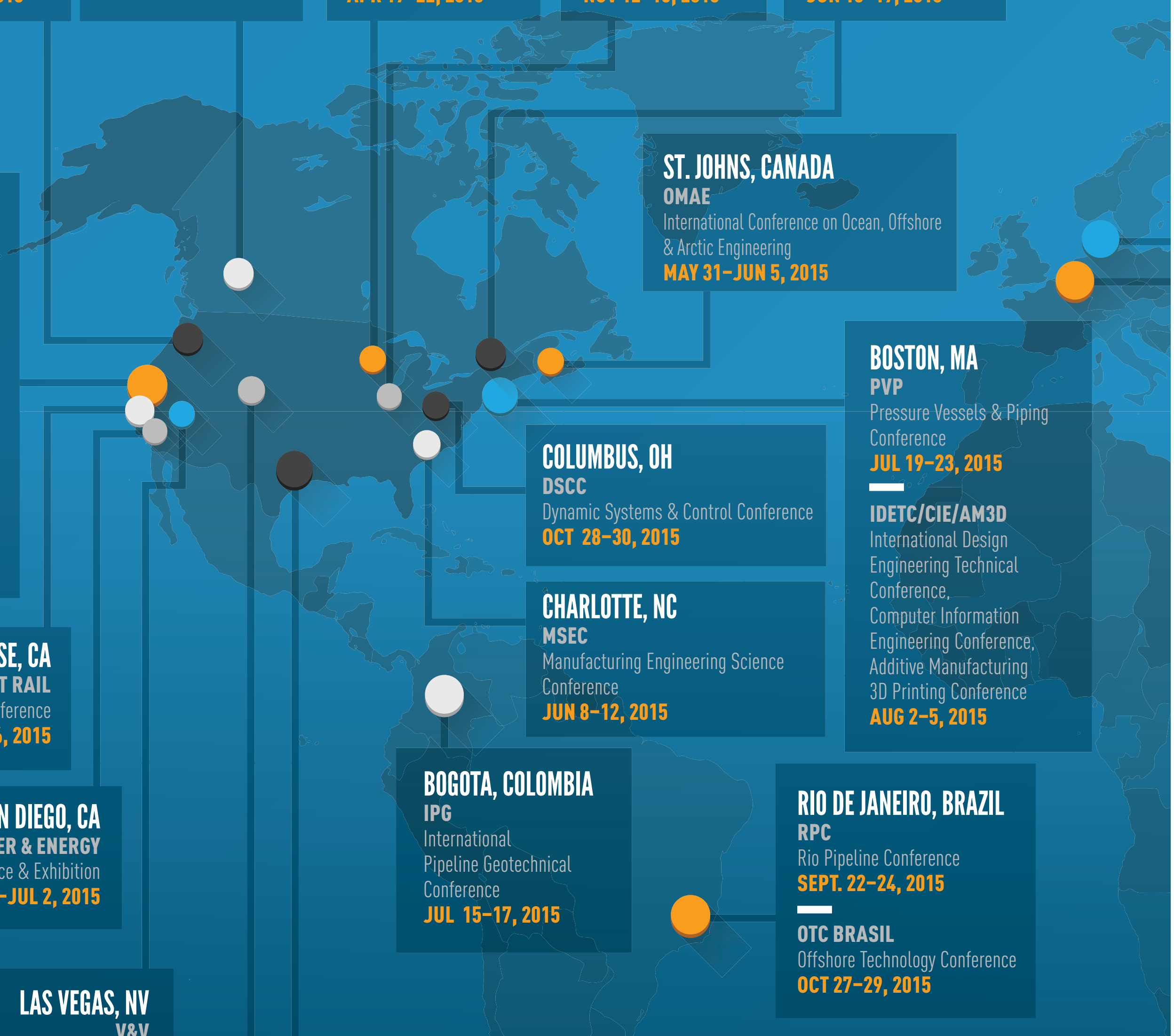
Many lives to save, and we can do it, if we join forces and work together. Let's all get busy! **ME**

MAURO FERRARI, an ASME Fellow, is the Ernest Cockrell Jr. Presidential Distinguished Chair, president, and chief executive officer of the Houston Methodist Research Institute in Texas. He is also the executive vice president of the Houston Methodist Hospital System and senior associate dean and professor of medicine at Weill Cornell Medical College in New York City.

ASME 2015

Experience ASME'S 2015 Global Conferences

INNOVATE. EXPLORE. BENCHMARK.



SEATTLE, WA
MCMAT
Applied Mechanics And Materials Conference
MAY 11–15, 2015

BANFF, CANADA
BANFF/2015 PIPELINE WORKSHOP
APRIL 13–16, 2015

MINNEAPOLIS, MN
NEMB
Nanotechnology in Engineering, Medicine & Biology
APR 19–22, 2015

CHICAGO, IL
FPMC
Fluid Power Motion Control Conference
NOV 12–16, 2015

MONTREAL, CANADA
TURBO EXPO
Turbine Technical Conference and Exposition
JUN 15–19, 2015

ST. JOHNS, CANADA
OMAE
International Conference on Ocean, Offshore & Arctic Engineering
MAY 31–JUN 5, 2015

SAN FRANCISCO, CA
INTERPACK
International Conference on Electronics Packaging
ICNMM
International Conference on Nano-Channels Micro-Channels & Mini-Channels
JULY 6–9, 2015

INTERNOISE
International Congress & Exposition on Noise Control Engineering
AUG 9–12, 2015

BOSTON, MA
PVP
Pressure Vessels & Piping Conference
JUL 19–23, 2015

IDETC/CIE/AM3D
International Design Engineering Technical Conference, Computer Information Engineering Conference, Additive Manufacturing 3D Printing Conference
AUG 2–5, 2015

COLUMBUS, OH
DSCC
Dynamic Systems & Control Conference
OCT 28–30, 2015

CHARLOTTE, NC
MSEC
Manufacturing Engineering Science Conference
JUN 8–12, 2015

SAN JOSE, CA
JOINT RAIL
Conference
MAR 23–26, 2015

SAN DIEGO, CA
POWER & ENERGY
Conference & Exhibition
JUN 28–JUL 2, 2015

BOGOTA, COLOMBIA
IPG
International Pipeline Geotechnical Conference
JUL 15–17, 2015

RIO DE JANEIRO, BRAZIL
RPC
Rio Pipeline Conference
SEPT. 22–24, 2015

OTC BRASIL
Offshore Technology Conference
OCT 27–29, 2015

LAS VEGAS, NV
V&V
Verification & Validation Symposium
MAY 11–15, 2015

HOUSTON, TX
HFC
Hydraulic Fracturing Conference **MAR 17–19, 2015**

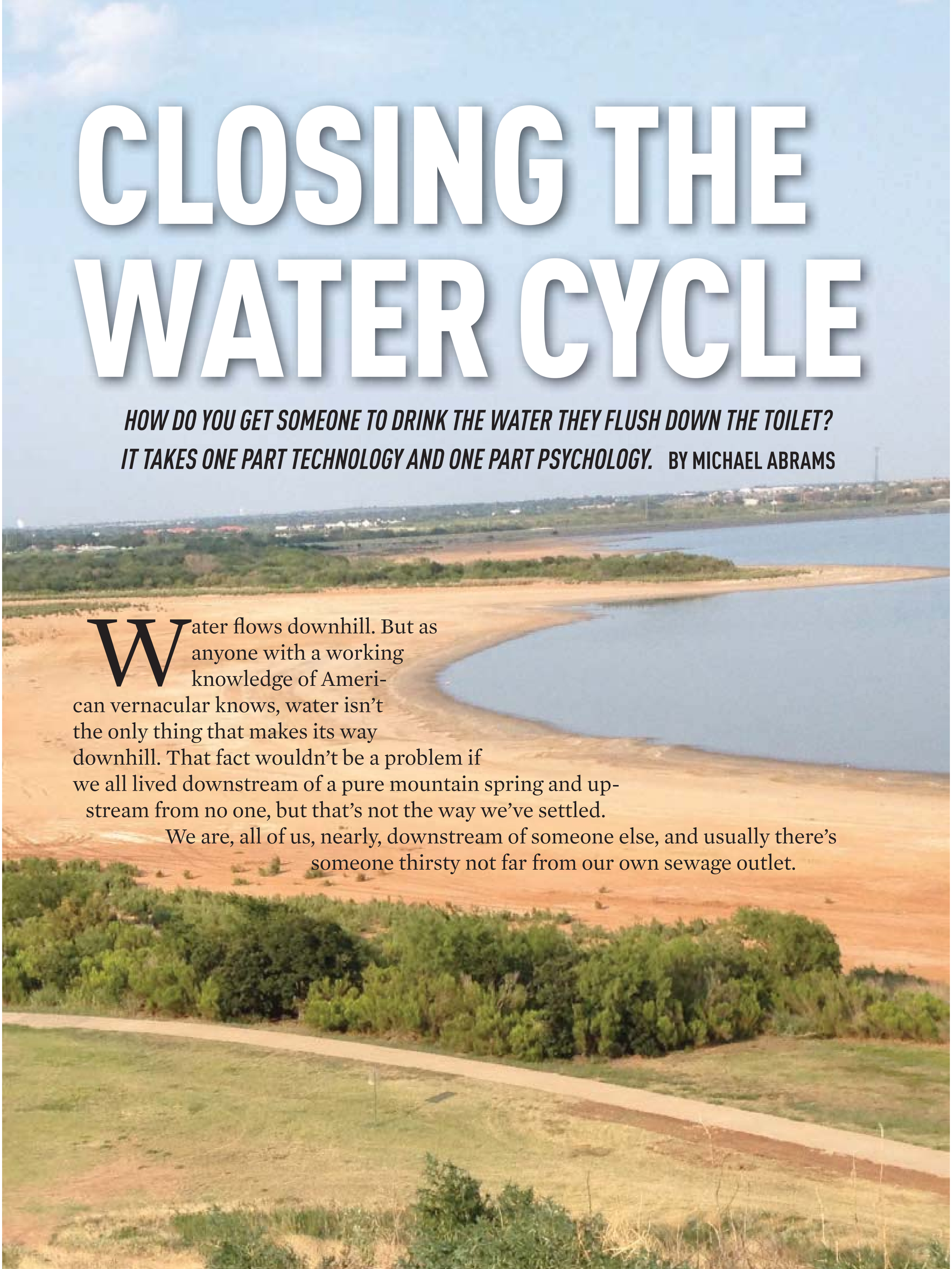
OTC
Offshore Technology Conference **MAY 4–7, 2015**

ICEF
Internal Combustion Engine Fall Conference **NOV 7–11, 2015**

IMECE
International Mechanical Engineering Conference & Exhibition **NOV 13–19, 2015**

COLORADO SPRINGS, CO
SMASIS
Conference on Smart Materials, Adaptive Structures & Information Systems
SEP 21–23, 2015


And Propel Your Organization And Your Career.
NETWORK. IMAGINE. LEARN. SHARE.
COPENHAGEN, DENMARK
ATC
Arctic Technology Conference
MAR 23–25, 2015
BRUSSELS, BELGIUM
ORC
Organic Rankine Cycle
OCT 8–10, 2015
SEOUL, SOUTH KOREA
AJK
ASME – JSME – KSME
Joint Fluids Engineering
JULY 26–31, 2015
CHIBA, JAPAN
ICONE
International Conference on Nuclear Engineering
MAY 17–21, 2015
ASME conferences bring together the world's best talent, organizations and programs to produce an outstanding learning, networking and energizing experience for participants. Discover what ASME has to offer you:
› Technical Research Conferences, Symposia & Industry Forums
› Exhibitions, Sponsorships & Commercial Exchange
› Access To Global Networks
Visit: www.asme.org/events
PUNE, INDIA
AM3D INDIA
Additive Manufacturing+3D Printing
APRIL 20–21, 2015
NEW DELHI, INDIA
IOGPC
India Oil & Gas Pipeline Conference
APR 17–18, 2015
GTINDIA
Gas Turbine India Conference
DEC 15–17, 2015
ASME
SETTING THE STANDARD
ASME 2015
See you there!
CONFERENCES



CLOSING THE WATER CYCLE

HOW DO YOU GET SOMEONE TO DRINK THE WATER THEY FLUSH DOWN THE TOILET? IT TAKES ONE PART TECHNOLOGY AND ONE PART PSYCHOLOGY. **BY MICHAEL ABRAMS**

Water flows downhill. But as anyone with a working knowledge of American vernacular knows, water isn't the only thing that makes its way downhill. That fact wouldn't be a problem if we all lived downstream of a pure mountain spring and upstream from no one, but that's not the way we've settled. We are, all of us, nearly, downstream of someone else, and usually there's someone thirsty not far from our own sewage outlet.

And the water is getting dirtier on both sides. The water that flows from every home to every sewage plant is a potent mix of detergents, pharmaceuticals, leftovers, and, of course, bodily waste. You wouldn't want to drink it. But when fresh water starts drying up and the technology for removing those contaminants is advanced enough, communities start thinking the formerly unthinkable. They start weighing the cost of pumping water to and from treatment facilities, the cost of pumping water against reverse osmosis membranes, the likelihood of reservoirs dipping dangerously low, the difficulty of meeting regulations, and looming large above these, public revulsion.

California's Orange County was faced with just such a reckoning at the turn of the century. After years of debate, county officials decided that the cheapest option available to them was recycling their wastewater.

"It makes sense from an energy point of view," said Mike Markus, the general manager of the Orange County Water District. "Compared to the cost of bringing in imported water from the North Colorado, the energy cost is about half. Compared to using sea water, it's about a third."

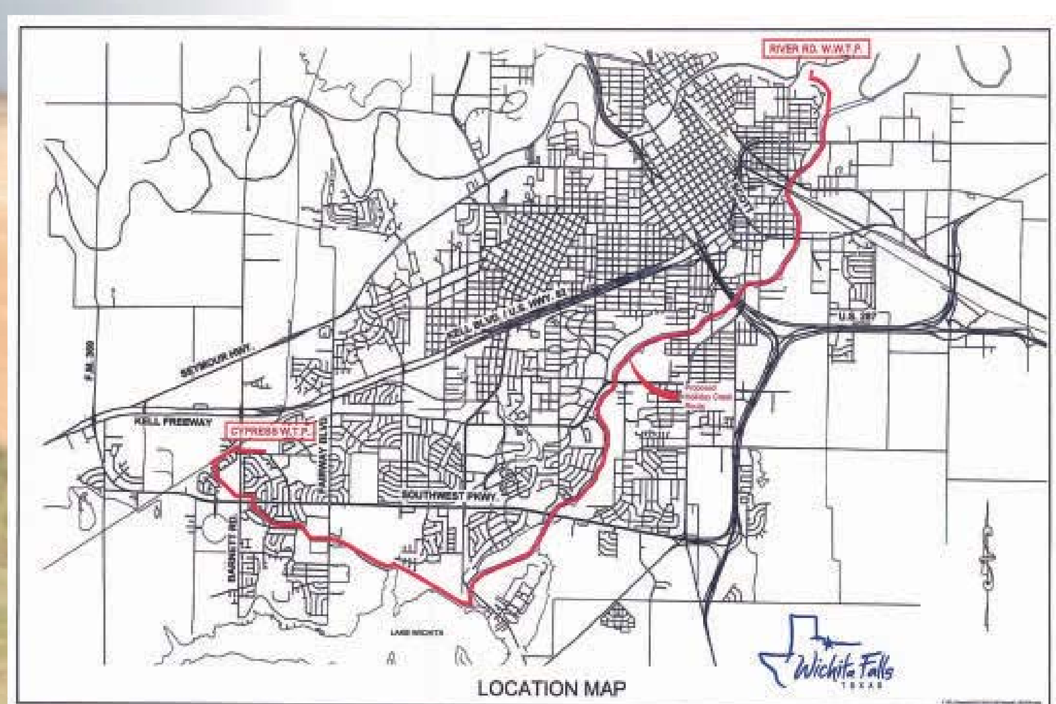
In operation since 2008, the Orange County plant is the largest "indirect to potable reuse" plant in the world. It's "indirect" because that water doesn't flow straight from the plant to the faucet. Instead, after being treated with microfiltration, reverse osmosis, and then ultraviolet light, the water is pumped back into the ground.

There's nothing wrong with the water. It's essentially distilled when it leaves the plant. But regulations do not currently allow it to be sent directly from plant to consumer.

PSYCH JOB

"Ground water is considered an environmental buffer," Markus said. "The water we're putting into the basin is higher quality than the ground water."

Right now, the only thing standing in the way of closing the water cycle that runs from the consumer, the water treatment plant, and back again is the "ick" factor. Many people are repulsed at the thought of drinking toilet



When the reservoirs in Wichita Falls, Tex., started drying out (left), the city ran a pipe (red line on the map) taking water from its wastewater treatment plant to its drinking water plant.

Orange County, Calif., treats 70 million gallons of wastewater (the facility is shown above and left) and pumps it into the ground, where it can then be drawn out for human consumption.

water, however it's been treated. But if water supplies fail to keep up with demand, thirsty populations may learn to overcome their squeamishness.

"What is the purpose of the environmental buffer?" asked Stuart Khan, a civil engineer at the University of New South Wales near Syndey, and author of *Drinking Water Through Recycling: The Benefits and Costs of Supplying Direct to the Distribution System*. "I did a survey of 80 water industry people in Australia and that was the question I asked them. There were probably ten or twelve distinctly different answers that came back. However, no one has really quantified it."

One answer is that the environment adds a buffer, not for contaminant removal, but of time. The water on the other side of a reverse osmosis membrane is measurably, and palatably, pure. But direct use of the water offers no margin for error.

Pumping water to an underground basin gives the county time to react if there's a problem. And, of course, the soil itself would work to remove accidental contaminants.

"If you go direct and you have a problem, it goes right into the water supply," said Markus. "We're trying to find new tools from a control perspective, more online monitoring, so if something arises, the plant immediately shuts down."

The Orange County facility processes some 70 million gallons of water a day, using 14 different reverse osmosis units. Currently, the water is tested—for total organic carbon—at the point where it's all mixed to a single stream.

"What regulators might want is a TOC on each of the units," Markus said. "Then if there were a breakthrough, it doesn't get blended with the other 13."

From an engineering standpoint, the risk of such an accident is extremely low. But need for better testing instru-

"The water we're putting into the basin is higher quality than the ground water."
— MIKE MARKUS, ORANGE COUNTY WATER DISTRICT.

mentation—and the reason for plopping the environment between the plant and the end consumer—has less to do with practicality and more to do with psychology.

"If you can have this water meandering its way down a little stream, bubbling over rocks, with birdies landing in it and drinking from it," said Carol Nemeroff, a professor of social and behavioral sciences at Lewiston-Auburn College in Maine, "it comes across not only as pure, but as living—which is really funny, because the birds that are drinking from that add contaminants."

Working with Markus of the Orange County water department, Nemeroff ran a study that examined people's reaction to the possibility of drinking reclaimed water. She found that people come in three essential types: the first is willing to try it, another sits on the fence until further informed, and a final rejects the concept out of hand. Fence-sitters, she found, could be convinced with reassurances and a little data, but the third group could not be persuaded.

"Nothing will get through, no matter how much effort you put into it," Nemeroff said. Detailed descriptions of the tools, explanations of the necessity for recycling, and elucidation on the results of testing the water have no effect.

To the thoroughly revolted, the water has some kind of homeopathic memory: though it contains not a single molecule of contaminant, it somehow has a memory of where it's been.

What to do about this group? "One school of thought says let them be," Nemeroff said. "Those guys can drink bottled water or whatever."

For everyone else, there's marketing. Singapore, for instance, dubbed its direct-to-potable reuse water system NEWater, replete with ad campaign and smiling droplet mascot (named Water Wally). Others think such marketing can backfire, making the public feel like they're being sold to.

But anyone who still responds to the words "recycled water" with revulsion should have a good look at "Assessment of De Facto Wastewater Reuse Across the U.S.: Trends Between 1980 and 2008." That 2013 paper published in the journal *Environmental Science and Technology* examines 25 different drinking water systems and shows that, on average, 15 percent of the source water is straight waste from somewhere else. And, astonishingly, for many of those systems, in dry years that percentage goes up to 100.

DESPERATE MEASURES

Where drought has increased desperation, municipalities have considered direct potable reuse. But when those same droughts come to an end, the public often seems to forget that another might be around the corner.

In Australia, Brisbane's ticket to fresh water was clearly in the gutter a decade ago. With no rain in sight, the government pumped a good two billion dollars into building direct potable reuse plants.

"Then politics got in the way," Khan said. "Just prior to the election, politicians said they would only flip the switch if the reservoir dipped below 40 percent capacity. Then it started raining. It's not likely to go below 40 percent again for at least 15 years."

Purple pipes carry non-potable water for non-human consumption. Such water can be used to irrigate golf courses or to carry heat away from industrial buildings.

The plants sit unused, and because of the high cost of keeping the facilities in working order, politicians are considering decommissioning them.

Where politics can be minimized, direct potable reuse has proven incredibly effective. Singapore's government, for instance, is "much more nimble than what we have," said Shane Snyder, a professor of chemical and environmental engineering at the University of Arizona. He's also on the World Health Organization's Drinking Water Advisory Panel, and is a visiting professor at the National University of Singapore.

"Singapore is diversified; it's not one system versus an-

Last year the region received the lowest total rainfall since 1869. "Malaysia's reservoirs crashed. They had to truck water in for millions of people. Singapore's reservoirs never fell below 90 percent. That's an amazing story line."

— SHANE SNYDER, UNIVERSITY OF ARIZONA

other," Snyder said. Its recycled water, for instance, is mixed with captured storm water, and desalinated ocean water.

Last year the region received the lowest total rainfall since 1869. "Malaysia's reservoirs crashed," Snyder said. "They had to truck water in for millions of people.

"Singapore's reservoirs never fell below 90 percent. That's an amazing story line."

In Texas, Wichita Falls found that it was easier to get regulatory approval for direct reuse than indirect. In June the city opened the second direct potable reuse plant in the country, thanks to some streamlining of the permitting process by the Texas Commission on Environmental Quality.

Wichita Falls already had a reverse osmosis facility to process the brackish water of one of the three lakes the city drew water from. So when the lake levels sank to a quarter of their capacity, all the city needed to do was run a 13.5-mile pipe from its sewage treatment plant to the reverse osmosis plant. To keep the people of Wichita Falls hydrated, the Texas Commission on Environmental Quality was more comfortable sending the purified water straight to homes than back into a lake first.

"That would require a new discharge permit, something they couldn't provide an exception to," said Mark Southard, Wichita Falls' water source purification superintendent.

"In my opinion we get a better quality of water, because of the amount of treatment, than we would with indirect," Southard said.

PURPLE PROS

Existing facilities, desperation, an absence of regulations at the federal level, and different sources of water all make it impossible to prescribe a single solution for every thirsty county.

"It's very rare that there is a single silver bullet for every situation. Context and social and political support really matter," said Ben Grumbles, president of the U.S. Water Alliance and head of the EPA's Office of Water under President George W. Bush. "You have to use a variety of bullets."

And not all those bullets have to come in a reverse osmosis casing.

"I think reverse osmosis is typically oversold as the panacea," said Ben Stanford, director of applied research at Hazen and Sawyer, an environmental engineering firm in New York. "There are lower-cost, lower-energy alternatives."

Where salinity is not a problem, Stanford and his group recommend a series of mechanisms that will render the water nearly as pure as that produced by reverse osmosis, but without the pumping costs.

This alternative to the "Full Advanced Treatment," or FAT, Stanford calls the "Lo-Fat Diet."

"The beauty of it is that it utilizes a lot of different mechanisms for contaminant removal," Stanford said. These include the addition of coagulants, filtration, oxidation, biologically activated carbon, UV, and chlorine. Individually, each piece is technologically mature. "It's a powerful set of processes lined up that get you the equivalent of the RO process."

But both reverse osmosis and the Lo-Fat treatment are intensive processes considering that less than a percent of the water that ends up in anyone's home ends up in anyone's mouth. Sanitary water is not needed for washing machines, showers, and toilets, to say nothing of lawns and golf courses.

Singapore keeps its citizens hydrated by mixing treated wastewater (the treatment facility is shown below) with captured storm water and desalinated sea water.

Why not send less thoroughly—and less expensively—treated water out for non-consumable purposes?

In California there are plans for distributing such lower-quality water through so-called purple pipes. The problem is that it's "amazingly expensive for a city to retrofit and lay pipes—one of the most expensive things to do," according to Snyder at the University of Arizona.

But for towns that are developing previously unplumbed areas, and have to lay pipe anyway, there are many purple pros. Maricopa, Ariz., was just such an expanding community. The population grew from 500 in 2000 to 50,000 today.

"In order to generate enough water to service a community like that, we really had to think about reusing water," said Graham Symmonds, who was the senior vice president of operations and compliance for the area's utility, Global Water Resources (and is now chief knowledge officer for Fathom, a Phoenix-based water management company).

As the town grew, developers needed permits to lay pipe in the huge virgin tracts of land they had bought up.

"As a utility we were able to dictate the water infrastructure, which is something you don't have everywhere. It's a bit of a luxury," Symmonds said. As a result, Maricopa uses 40 percent less raw water than communities of similar size in the area.

Wichita Falls hopes to benefit by using some of its water for non-potable purposes instead of sending it all through a reverse osmosis membrane. Its utility is working to pipe untreated water for use in a factory cooling system.

The cost of new pipes is not the only disadvantage to an additional purple pipe system: pipes break; mistakes happen; people try their own plumbing.

"My personal opinion is that the water should be safe coming out of any tap in the city, for anyone, for our children to drink and splash in," Snyder said. "To let that system fall apart is just silly."

CLEAR ABOUT WATER

When water is scarce there is no solution without costs and risks. To move forward without public protest, the technology and decisions made need to be as transparent as purified water.

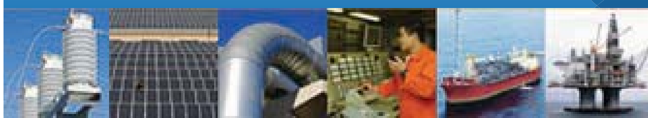
"In the early years of commercial aviation, it was viewed as dangerous to get in an airplane, because you might not come back," said David Sedlak, a professor of mineral engineering at the University of California, Berkeley, and the author of *Water 4.0: The Past, Present, and Future of the World's Most Vital Resource*.

"It wasn't just a question of creating images and wording that got the public to support commercial aviation and consider it a legitimate technology," Sedlak said. "It was a safety culture that responded to accidents, that was transparent about failure, and empowered the people involved to try to take corrective action.

"I think it's a very similar story with potable water recycling. Everyone involved needs to think about it in those terms. Here we are in a new era of water and we need to think about how to make our institutions more adaptable and proactive to avoid the mistakes that sometimes happen when a new technology is rolled out." **ME**

MICHAEL ABRAMS is a writer based in New York City. He is a frequent contributor to *Mechanical Engineering* magazine.

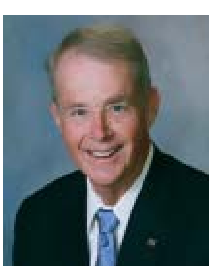
Energy Sources and Processing



ASME & OTC: A Partnership Based on Sharing Knowledge and Leading-Edge Technology

The character of the Offshore Technology Conference (OTC) is a true reflection of the industry it serves. The worldwide oil and gas industry is dependent upon a wide variety of scientific and technical disciplines. OTC, its flagship conference, is the result of the cooperative effort of 12 professional societies and organizations, including the American Society of Mechanical Engineers (ASME) and its international industry segment — Energy Sources and Processing (formerly IPTI) — and its four divisions, the Petroleum Division, the Pipeline Systems Division and the Ocean, Offshore and Arctic Engineering Division, and the Pressure Vessels and Piping Division. ASME was, in fact, one of the conference's founding societies.

According to Joe Fowler, Vice President and Co-Founder of Stress Engineering Services and Chair-Elect of



the OTC Board of Directors, and long-time ASME member and Past Chair of the Petroleum Division and the South Texas Section, many ASME members have been involved since the early days of the conference back in 1969 with members on the Executive Committee (now the Board) and on various program committees.

"OTC is a great example of the power of inter-society cooperation," remarked Mr. Fowler, "All offshore projects are interdisciplinary and a conference that mirrors that dynamic is quite useful to attendees."

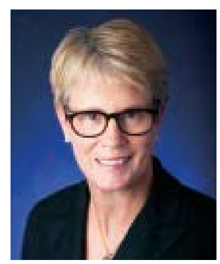
THE VALUE OF THE TECHNICAL PAPER

Speaking from his many years of experience as the organizer of the Arthur Lubinski Best Technical OTC Paper

competition, Jean-Francois Saint Marcoux, past chair of the ASME-OTC Programming Committee and former Engineering Expertise Director for Subsea 7, elaborated on ASME's participation.

"Typically, ASME organizes up to a dozen sessions, thus providing a series of well-written technical papers that help define the state-of-the-art on major, noteworthy projects. This effort gives us the opportunity to build sessions in our fields of expertise while interacting with other specialists in other disciplines... in a free exchange of knowledge not bound by contractual restrictions."

Another committed OTC participant is Barbara Thompson, Senior Vice President Front End Spectrum at Aker



Solutions. She has given the ASME OTC Subcommittee more than a decade of her time and now serves as its Program Chair. She believes that ASME has been a leader in driving safety through design specifications in pressure vessels, pipelines and other offshore equipment.

"The art of mechanical engineering is to design equipment and systems that perform efficiently, accurately and safely for both the operators and the public, and the benefit of working in OTC technical session committees is partnering with key thought leaders in our industry to help bring their ideas and innovations forward to benefit the integrity of the industry," she explained.

INSPIRING THE NEXT GENERATION OF MECHANICAL ENGINEERS

Bobby Voss, Chief Consulting Engineer–Subsea Production for GE Oil & Gas, who is involved in OTC-Brasil as ASME subcommittee chair, said that ASME's professional development infrastructure is also key to maintaining focus on building the next generation of mechanical engineers who will positively contribute to industry innovation through participation in conferences such as OTC.

"It's where we can disseminate mechanical engineering subject matter to the energy industry, leverage member knowledge and professional experience to the benefit of both industry and society, stay current with the latest technology, and give back to our industry while networking with professional associates," he stated.

But most importantly, ASME's commitment to OTC benefits both the energy industry and ASME's current and future members.

As Joe Fowler explained, "OTC is about technology. Participants get to experience the latest developments through technical papers, exhibits and networking. The latest safety advances and products are on display and the 'Spotlight on Technology' contest is conducted to recognize the most innovative and important technologies and products exhibited at OTC. In addition, manufacturers, service companies, oil exploration and production companies, educational institutions and government agencies are all participants."

So his advice to young mechanical engineers is shared by his fellow ASME-OTC subcommittee members and summarized best by Barbara Thompson.

"Meet as many people as you can, see as many paper presentations as your schedule and interests allow. Ask lots of questions of those who have been around. And have fun doing it."

The OTC organization currently consists of four major conferences – the Offshore Technology Conference (OTC), the Arctic Technology Conference (ATC), OTC Brasil and OTC Asia. Each event is tailored to the needs of the offshore energy professional and supported by the core 12 non-profit sponsoring organizations in addition to regional and supporting organizations worldwide. ■

ABOUT OTC

- Founded in 1969
- One of the largest 200 tradeshows & conferences held annually in the United States
- Named one of the top 100 "Gold Standard" shows of 2014 by Trade Show Executive
- 108,000 attendees (2014)
- 2,500 exhibitors (2014)
- More than 120 countries represented (2014)

2015 OTC Events

March 23-25
OTC-Arctic Technology Conference
Copenhagen

May 4-7
Offshore Technology Conference
NRG Park, Houston

October 27-29
OTC-Brasil
Rio de Janeiro

March 22-25, 2016
OTC Asia
Kuala Lumpur, Malaysia

CONTRIBUTORS TO THIS ARTICLE:

Joe Fowler
Vice President and Co-founder, Stress Engineering Services, Inc.
OTC Board of Directors, Chair-Elect
ASME IPTI Petroleum Division, South Texas Sector, past Chair

Barbara Thompson
Senior Vice President Front End Spectrum, Aker Solutions, Inc.
ASME-OTC Subcommittee, Program Chair

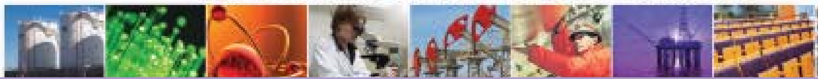
Bobby Voss, Jr.
Chief Consulting Engineer – Subsea Production, GE Oil & Gas
OTC-Brasil Program Committee
ASME Subcommittee Chair

Jean-François Saint Marcoux
Engineering Expertise Director (retired), Subsea 7
ASME-OTC Programming Subcommittee, past Chair
ASME Petroleum Division Executive Committee

ASME
SETTING THE STANDARD

Training & Development

Setting the Standard for Workforce Learning Solutions



TRAINING COURSES FOR ENGINEERS AND TECHNICAL PROFESSIONALS — 2015 SPRING

APRIL 2015 – CHICAGO, ILLINOIS USA

PD107	Elevator Maintenance Evaluation	20-21 Apr
PD539	Bolted Joints and Gasket Behavior	20-21 Apr
PD583	Pressure Relief Devices: Design, Sizing, Construction, Inspection and Maintenance ASME CODE COURSE	20-21 Apr
PD077	Failure Prevention, Repair and Life Extension of Piping, Vessels and Tanks ASME CODE COURSE	20-22 Apr
PD349	Design and Applications of Centrifugal Pumps	20-22 Apr
PD395	API 579-1/ASME FFS-1 Fitness-for-Service	20-22 Apr
PD618	Root Cause Analysis Fundamentals	20-22 Apr
PD674	International Business Ethics & Foreign Corrupt Practices Act	20-22 Apr
PD702	Process Safety and Risk Management for Mechanical Engineers NEW!	20-22 Apr
PD711	ASME NQA-1 and DOE Quality Assurance Rule 10 CFR 830 ASME CODE COURSE NEW!	20-22 Apr
PD014	ASME B31.3 Process Piping Design ASME CODE COURSE TOP SELLER	20-23 Apr
PD394	Seismic Design and Retrofit of Equipment and Piping	20-23 Apr
PD448	BPV Code, Section VIII, Division 2: Alternative Rules - Design and Fabrication of Pressure Vessels ASME CODE COURSE TOP SELLER	20-23 Apr
PD622	BPV Code: Plant Equipment Requirements ASME CODE COURSE	20-23 Apr
PD581	B31.3 Process Piping Design, Materials, Fabrication, Examination and Testing Combo Course ASME CODE COURSE SAVE UP TO $575!	20-24 Apr
PD601	Bolting Combo Course SAVE UP TO $1,260!	20-24 Apr
PD681	International Business Ethics and Foreign Corrupt Practices Act Combo Course SAVE UP TO $635!	20-24 Apr
PD386	Design of Bolted Flange Joints	22 Apr
PD410	Detail Engineering of Piping Systems	22-24 Apr
PD631	Manufacturing, Fabrication and Examination Responsibilities in Codes, Standards and Regulations for Nuclear Power Plant Construction ASME CODE COURSE	22-24 Apr
PD575	Comprehensive Negotiating Strategies®: Engineers and Technical Professionals	23-24 Apr
PD577	Bolted Joint Assembly Principles Per PCC-1-2013 ASME CODE COURSE	23-24 Apr
PD606	NQA-1 Requirements for Computer Software Used in Nuclear Facilities ASME CODE COURSE	23-24 Apr
PD680	Understanding the Foreign Corrupt Practices Act	23-24 Apr
PD690	Economics of Pipe Sizing and Pump Selection NEW!	23-24 Apr
PD692	Communication Essentials for Engineers NEW!	23-24 Apr
PD457	B31.3 Process Piping Materials Fabrication, Examination and Testing ASME CODE COURSE TOP SELLER	24 Apr

Visit **go.asme.org/chicago1**

APRIL-MAY 2015 – COLORADO SPRINGS, COLORADO USA

MasterClass Program at ASME Boiler Code Week

MC104	Bases & Application of Heat Exchanger Mechanical Design Rules in Section VIII of the ASME Boiler & Pressure Vessel Code	26-27 Apr
MC110	Bases and Application of Piping Flexibility Analysis to ASME B31 Codes	27-28 Apr
MC107	Design by Analysis Requirements in ASME Boiler and Pressure Vessel Code Section VIII, Division 2 – Alternative Rules	28 Apr
MC113	Techniques and Methods Used in API 579-1/ASME FFS-1 for Advanced Fitness-For-Service (FFS) Assessments	29 Apr
MC111	Piping Vibration Causes & Remedies - A Practical Approach	29-30 Apr
MC114	Repair Strategies and Considerations for Pressure Vessels and Piping	30 Apr
MC112	Structural Materials & Design for Elevated to High Temperatures	30 Apr-1 May
MC117	Piping Failures - Causes and Prevention	1 May

Visit **go.asme.org/MCseriesApr2015**

MAY 2015 – LAS VEGAS, NEVADA USA

PD100	Introduction to the Maintenance and Inspection of Elevators and Escalators	4-5 May
PD313	Fundamentals of Fastening Systems	4-5 May
PD456	Tools and Methods of Finite Element Analysis	4-5 May
PD370	B31.8 Gas Transmission and Distribution Piping Systems ASME CODE COURSE	4-6 May
PD389	Nondestructive Examination - Applying ASME Code Requirements (BPV Code, Section V) ASME CODE COURSE	4-6 May
PD513	TRIZ: The Theory of Inventive Problem Solving	4-6 May
PD515	Dimensioning and Tolerancing Principles for Gages and Fixtures	4-6 May
PD571	The Taguchi Design of Experiments for Robust Product and Process Designs	4-6 May
PD621	Grade 91 and Other Creep Strength Enhanced Ferritic Steels	4-6 May
PD683	Probabilistic Structural Analysis, Design and Reliability-Risk Assessment	4-6 May
PD632	Design in Codes, Standards and Regulations for Nuclear Power Plant Construction ASME CODE COURSE	4-7 May
PD644	Advanced Design and Construction of Nuclear Facility Components Per BPV Code, Section III ASME CODE COURSE	4-7 May
PD675	ASME NQA-1 Lead Auditor Training	4-7 May
PD679	Selection of Pumps and Valves for Optimum System Performance NEW!	4-7 May
PD432	Turbo Machinery Dynamics: Design and Operation	4-8 May
PD598	Developing a New Inservice Testing Program	4-8 May
PD602	Elevator and Escalator Combo Course SAVE UP TO $635!	4-8 May
PD665	BPV Code, Section I: Power Boilers ASME CODE COURSE	4-8 May
PD102	ASME A17.1 Safety Code and ASME A17.2 Inspection Requirements ASME CODE COURSE	6-8 May
PD584	Centrifugal Compressor Performance Analysis	6-8 May
PD619	Risk and Reliability Strategies for Optimizing Performance	6-8 May
PD445	B31 Piping Fabrication and Examination ASME CODE COURSE	7-8 May
PD567	Design, Analysis and Fabrication of Composite Structure, Energy and Machine Applications	7-8 May

Visit **go.asme.org/lasvegas7**

MAY 2015 – DUBAI, UNITED ARAB EMIRATES

PD583	Pressure Relief Devices: Design, Sizing, Construction, Inspection and Maintenance ASME CODE COURSE	10-11 May
PD720	Layout of Process Piping Systems NEW!	10-12 May
PD645	BPV Code, Section IX: Welding, Brazing and Fusing Qualifications ASME CODE COURSE	10-12 May
PD643	B31.3 Process Piping Code ASME CODE COURSE TOP SELLER!	10-13 May
PD686	Layout of Process Piping Systems and Optimization of Plant Layouts Utilizing 3D CAD/CAE Systems and 3D Laser Scanning Technology Combo Course NEW!	10-14 May
PD725	BPV Code, Section VIII, Division 1: Design and Fabrication with Inspections, Repairs and Alterations of Pressure Vessels ASME CODE COURSE	10-14 May
PD577	Bolted Joint Assembly Principles Per PCC-1-2013 ASME CODE COURSE	13-14 May
PD721	Optimization of Plant Layouts Utilizing 3D CAD/CAE Systems and 3D Laser Scanning Technology NEW!	13-14 May

Visit **go.asme.org/dubai3**

The American Society of Mechanical Engineers (ASME)

- 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

MAY 2015 – ATLANTA, GEORGIA USA

PD387	Understanding Chiller Performance, Operation and Economics	18 May
PD475	The Engineering Manager: Engaging Today's Workforce	18-19 May
PD531	Leadership and Organizational Management	18-19 May
PD673	Design and Selection of Heat Exchangers	18-19 May
PD146	Flow Induced Vibration with Applications to Failure Analysis	18-20 May
PD190	BPV Code, Section IX: Welding, Brazing and Fusing Qualifications ASME CODE COURSE	18-20 May
PD231	Shock and Vibration Analysis	18-20 May
PD395	API 579-1/ASME FFS-1 Fitness-for-Service	18-20 May
PD410	Detail Engineering of Piping Systems	18-20 May
PD442	BPV Code, Section VIII, Division 1: Design and Fabrication of Pressure Vessels ASME CODE COURSE TOP SELLER	18-20 May
PD523	Quality Assurance (QA) Considerations for New Nuclear Facility Construction ASME CODE COURSE	18-20 May
PD633	Overview of Nuclear Codes and Standards for Nuclear Power Plants ASME CODE COURSE	18-20 May
PD685	The Engineering Manager: Engaging Today's Workforce and Strategic Thinking Combo Course SAVE UP TO $465!	18-20 May
PD184	BPV Code, Section III, Division 1: Rules for Construction of Nuclear Facility Components ASME CODE COURSE	18-21 May
PD620	Core Engineering Management	18-21 May
PD657	HVAC Systems and Chiller Performance Combo Course SAVE UP TO $475!	18-21 May
PD672	BPV Code, Section XI, Division 1: Inservice Inspection 10-Year Program Updates for Nuclear Power Plant Components ASME CODE COURSE	18-21 May
PD443	BPV Code, Section VIII, Division 1 Combo Course ASME CODE COURSE SAVE UP TO $645!	18-22 May
PD027	Heating, Ventilating and Air-Conditioning Systems: Sizing and Design	19-21 May
PD676	Strategic Thinking	20 May
PD690	Economics of Pipe Sizing and Pump Selection NEW!	20-21 May
PD441	Inspections, Repairs and Alterations of Pressure Equipment ASME CODE COURSE TOP SELLER	21-22 May
PD634	Comparison of Global Quality Assurance and Management System Standards Used for Nuclear Application ASME CODE COURSE	21-22 May

Visit **go.asme.org/atlanta5**

MAY 2015 – LONDON, UNITED KINGDOM

PD445	B31 Piping Fabrication and Examination ASME CODE COURSE	18-19 May
PD577	Bolted Joint Assembly Principles Per PCC-1-2013 ASME CODE COURSE	18-19 May
PD615	BPV Code, Section III, Division 1: Class 1, 2 & 3 Piping Design ASME CODE COURSE	18-20 May
PD714	BPV Code, Section VIII, Division 2: Alternative Rules–Design and Fabrication of Pressure Vessels ASME CODE COURSE	18-20 May
PD643	B31.3 Process Piping Code ASME CODE COURSE TOP SELLER	18-21 May
PD675	ASME NQA-1 Lead Auditor Training	18-21 May
PD684	BPV Code Section III, Division 1: Rules for Construction of Nuclear Facility Components ASME CODE COURSE	18-22 May
PD621	Grade 91 and Other Creep Strength Enhanced Ferritic Steels	20-22 May

Visit **go.asme.org/london2**

JUNE 2015 – HOUSTON, TEXAS USA

PD391	ASME B31.4 Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids ASME CODE COURSE	1-2 Jun
PD539	Bolted Joints and Gasket Behavior	1-2 Jun
PD570	Geometric Dimensioning and Tolerancing Fundamentals 1 ASME CODE COURSE TOP SELLER	1-2 Jun
PD583	Pressure Relief Devices: Design, Sizing, Construction, Inspection and Maintenance ASME CODE COURSE	1-2 Jun
PD467	Project Management for Engineers & Technical Professionals	1-3 Jun
PD597	Risk-Informed Inservice Testing	1-3 Jun
PD711	ASME NQA-1 and DOE Quality Assurance Rule 10 CFR 830 ASME CODE COURSE NEW!	1-3 Jun
PD014	ASME B31.3 Process Piping Design ASME CODE COURSE TOP SELLER	1-4 Jun
PD359	Practical Welding Technology	1-4 Jun

CONTINUED, JUNE 2015 – HOUSTON, TEXAS USA

PD448	BPV Code, Section VIII, Division 2: Alternative Rules - Design and Fabrication of Pressure Vessels ASME CODE COURSE TOP SELLER	1-4 Jun
PD603	Geometric Dimensioning and Tolerancing Combo Course SAVE UP TO $380!	1-4 Jun
PD192	BPV Code: Section XI: Inservice Inspection of Nuclear Power Plant Components ASME CODE COURSE	1-5 Jun
PD581	B31.3 Process Piping Design, Materials, Fabrication, Examination and Testing Combo Course ASME CODE COURSE SAVE UP TO $575!	1-5 Jun
PD601	Bolting Combo Course SAVE UP TO $1,260!	1-5 Jun
PD629	Project Management Combo Course SAVE UP TO $635!	1-5 Jun
PD386	Design of Bolted Flange Joints	3 Jun
PD496	Preparing for the Project Management Professional Certification Exam	3-4 Jun
PD561	Geometric Dimensioning Tolerancing Advanced Applications with Stacks and Analysis TOP SELLER	3-4 Jun
PD115	The Gas Turbine: Principles and Applications	4-5 Jun
PD577	Bolted Joint Assembly Principles Per PCC-1-2013 ASME CODE COURSE	4-5 Jun
PD593	FRP Pressure Piping Construction Process NOW 2 DAYS!	4-5 Jun
PD617	Design of Buried High Density Polyethylene (HDPE) Piping Systems	4-5 Jun
PD692	Communication Essentials for Engineers NEW!	4-5 Jun
PD457	B31.3 Process Piping Materials Fabrication, Examination and Testing ASME CODE COURSE TOP SELLER	5 Jun

Visit **go.asme.org/houston7**

JUNE 2015 – MILAN, ITALY – SPECIAL EVENT

Public Courses

PD577	Bolted Joint Assembly Principles Per PCC-1-2013 ASME CODE COURSE	22-23 Jun
PD410	Detail Engineering of Piping Systems	22-24 Jun
PD442	BPV Code, Section VIII, Division 1: Design and Fabrication of Pressure Vessels ASME CODE COURSE TOP SELLER	22-24 Jun
PD615	BPV Code, Section III, Division 1: Class 1, 2 & 3 Piping Design ASME CODE COURSE	22-24 Jun
PD635	ASME NQA-1 Quality Assurance Requirements for Nuclear Facility Applications ASME CODE COURSE	22-24 Jun
PD645	BPV Code, Section IX: Welding, Brazing and Fusing Qualifications ASME CODE COURSE	22-24 Jun
PD616	API 579 /ASME FFS-1 Fitness-for-Service Evaluation	22-25 Jun
PD644	Advanced Design and Construction of Nuclear Facility Components Per BPV Code, Section III ASME CODE COURSE	22-25 Jun
PD672	BPV Code, Section XI, Division 1: Inservice Inspection 10-Year Program Updates for Nuclear Power Plant Components ASME CODE COURSE	22-25 Jun
PD679	Selection of Pumps and Valves for Optimum System Performance NEW!	22-25 Jun
PD716	BPV Code, Section 1: Power Boilers ASME CODE COURSE	22-25 Jun
PD192	BPV Code: Section XI: Inservice Inspection of Nuclear Power Plant Components ASME CODE COURSE	22-26 Jun
PD443	BPV Code, Section VIII, Division 1 Combo Course ASME CODE COURSE SAVE UP TO €800!	22-26 Jun
PD441	Inspections, Repairs and Alterations of Pressure Equipment ASME CODE COURSE TOP SELLER	25-26 Jun

MasterClasses

MC121	Design by Analysis Requirements in ASME Section VIII, Division 2 – Alternative Rules	22-23 Jun
MC116	Techniques and Methods Used in API 579-1/ASME FFS-1 for Advanced Fitness-For-Service (FFS) Assessments	24 Jun
MC104	Bases and Application of Heat Exchanger Mechanical Design Rules in Section VIII of the ASME BPV Code	25-26 Jun
MC112	Structural Materials and Design for Elevated to High Temperatures	25-26 Jun
MC124	Inspection Planning Using Risk-Based Methods	25-26 Jun

Visit **go.asme.org/MilanTraining**

HIGH SPEED MACHINING

DELCAM LTD., BIRMINGHAM, U.K.

The new 2015 release of PowerMILL programming software includes improvements in tool path simulation and verification, area clearance and drilling, plus more options for customization. Complete verification can be undertaken of a project for machine-tool issues such as collisions without the need to undertake a verification of each individual tool path in turn. Comprehensive verification is performed, including ensuring that the machine tool is capable of running the proposed strategy, as well as checking for both machine-tool collisions and tooling collisions.

PowerMILL enables users to verify the machine tool against the model.

CFD MESHING

POINTWISE, FORT WORTH, TEXAS.

The latest release of computational fluid dynamics meshing software, V17.3 R1 now features direct integration with overset grid assembly software. Overset gridding is a technique that avoids the topological complexity of generating abutting point-to-point connected multi-block grids by allowing the component grid blocks to overlap. The price paid for that flexibility is the need to ensure a sufficient degree of overlap so the CFD solver can accurately share data between the component grids. The overlap is computed using overset grid assembly software.

GEOMETRIC SEARCH ENGINE

3D SEMANTIX, MONTREAL, QUEBEC.

A search engine for parts, 3DPartFinder, is available in version 5. The software uses proprietary geometric shape search technology that can seek out the closest matches and display them in a ready-to-use CAD form. The software will also rank parts according to their similarities, to allow for further analysis and design decisions. Purchasing teams can identify suppliers for a new part and compare costs for similar designs. The software can also be used to search for parts in a company's own product database or PLM system to identify duplicates and near-duplicates. The software is also available in a desktop version for all users, including employees who do not have access to a CAD system.

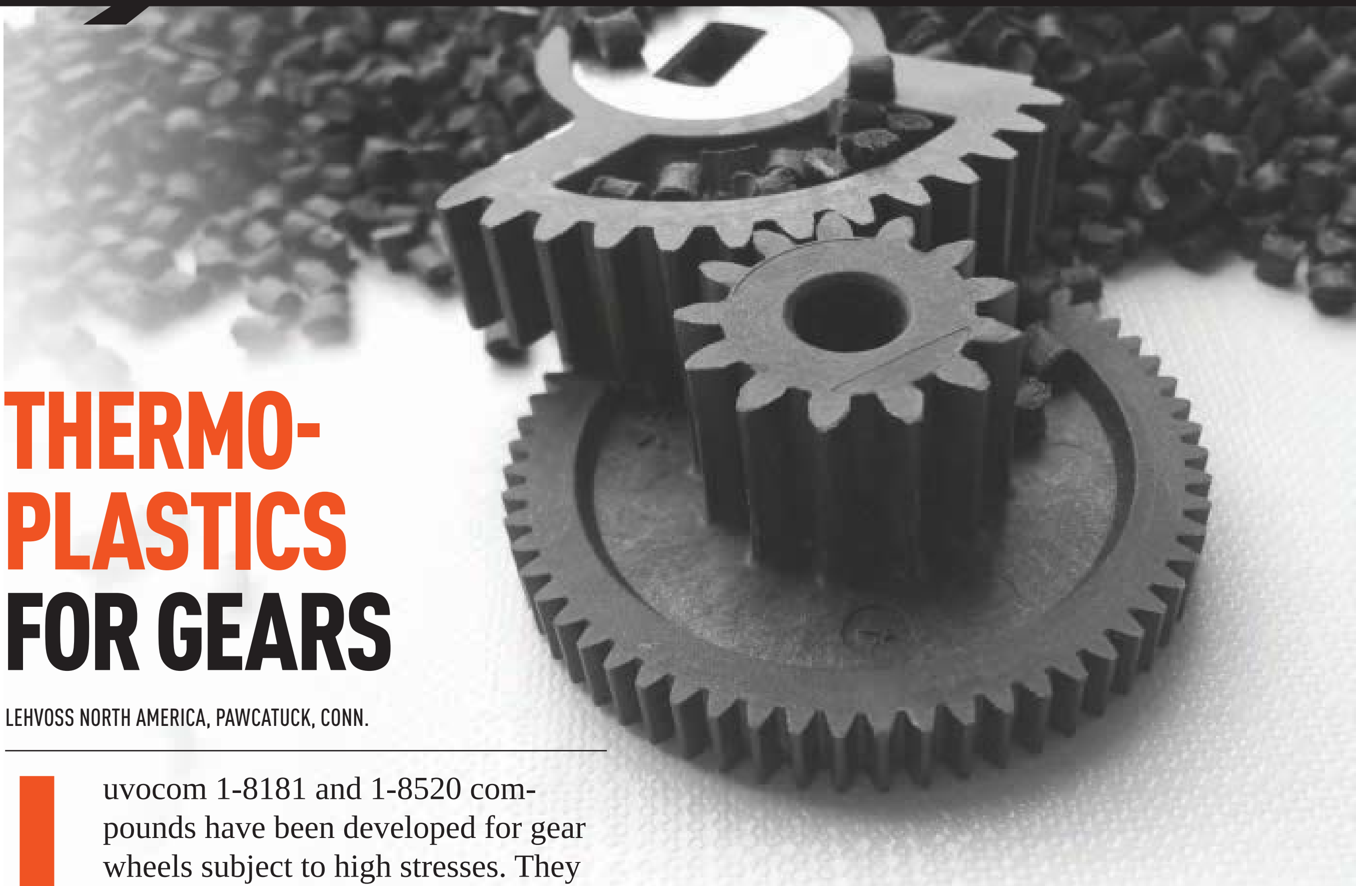
ASSET MANAGEMENT

BENTLEY SYSTEMS INC., EXTON, PA.

The AssetWise APM version 7.3 is an enhanced edition of asset performance management. It offers an all-in-one analysis and information management software platform for asset reliability and asset integrity. Version 7.3's new process safety features help users manage the integrity of safety systems and hazardous processes, thereby preventing failures and catastrophic incidents and keeping people, assets, and the environment safer. Capabilities include safety instrumented function analysis, safety instrumented systems, safety integrity level, and safety provisions, overrides, and incidents.

SUBMISSIONS

Submit hard copy or e-mail memag@asme.org, using subject line "Software Exchange." *ME* does not test or endorse software described here.



THERMO-PLASTICS FOR GEARS

LEHVOSS NORTH AMERICA, PAWCATUCK, CONN.

Luvocom 1-8181 and 1-8520 compounds have been developed for gear wheels subject to high stresses. They consist of polyamide 66 fortified with carbon fibers and impact modifiers. According to the manufacturer, the compounds at room temperature and at 120 °C (240 °F) are approximately 80 percent stronger than standard polyamide 66 compounds.

TWO-COMPONENT EPOXY

MASTER BOND INC., HACKENSACK, N.J.

This two-component epoxy has a flowable paste consistency that enables alignment with minimal fixturing. It cures at room temperature or more quickly with the addition of heat. This system is notable for having a low coefficient of thermal expansion of 9-12 x 10^{-6} in./in./°C. With a tensile lap shear strength of over 1,200 psi, it bonds well to a wide variety of similar and dissimilar substrates, including metals, composites, ceramics, glass, and many plastics.

CAPPING HEAD

CHR. MAYR GMBH + CO. KG, MAUERSTETTEN, GERMANY.

The rustproof ROBA hysteresis capping head has a wear-resistant plastic/stainless steel linear guide, which is lubricated for the entire lifetime of the product. The top part of the capping head can be dismantled without tools. This ensures reduced standstill times and high plant availability and productivity. The capping heads also feature a high torque repetitive accuracy of +/- 2 percent. The limit torque can be easily and continuously adjusted, and can be read directly.

COLLET CHUCK

WIDIA, FORT MILL, S.C.

The new Widia universal high-precision collet chuck is available with pull-out protection. Helical grooves are ground into the shank of the milling tool that, together with the respective pin drivers in the chuck, prevent the tool from spinning or being pulled out of the holder under extreme machining conditions. The helical path of the grooves also allows for adjusting tool length, meaning tools can be reground and pre-set as usual.

LOW-EMISSION POLYPROPYLENE

RTP CO., WINONA, MINN.

Low emission PP VLF compounds are designed for structural use and to provide exceptional strength, stiffness, and dimensional accuracy. They have been tested and authenticated by approved outside laboratories according to German Automotive Industry (VDA) test methods for odor, fogging, and total volatile organic compound emissions. Results from VDA tests show that PP VLF products meet or exceed the OEM requirements in all three categories.

SUBMISSIONS

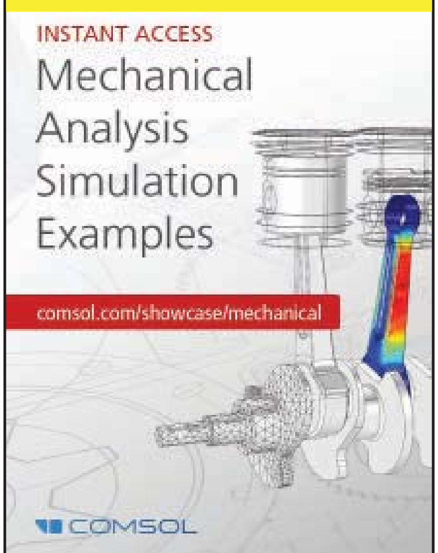
Submit electronic files of new products and images by e-mail to **memag@asme.org**. Use subject line "New Products." *ME* does not test or endorse the products described here.

RESOURCEFILE

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

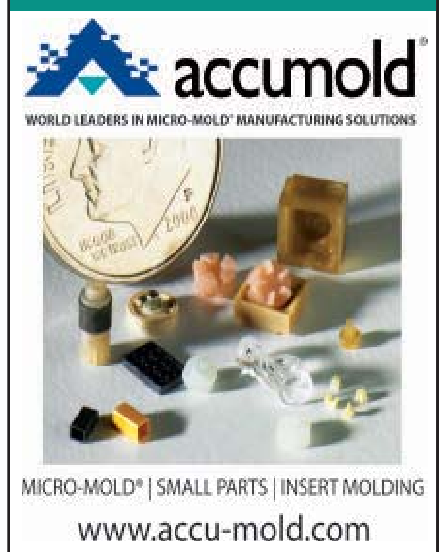
A bimonthly listing of the industry's latest technical literature and product information available FREE to *Mechanical Engineering* readers.

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



COMSOL

TORMACH



ACCUMOLD

MASTERBOND

OMEGA

PROTO LABS

SPG MOTOR

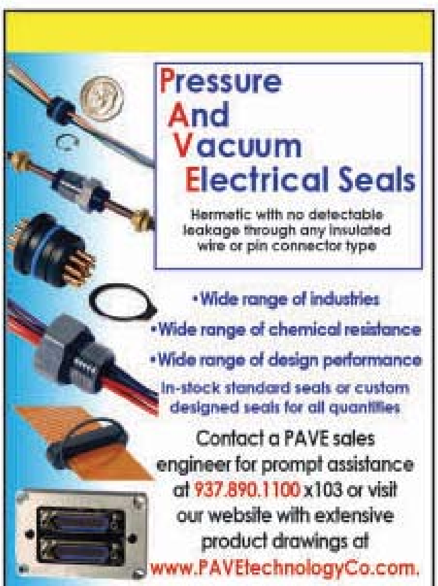
CEI

SMALLEY

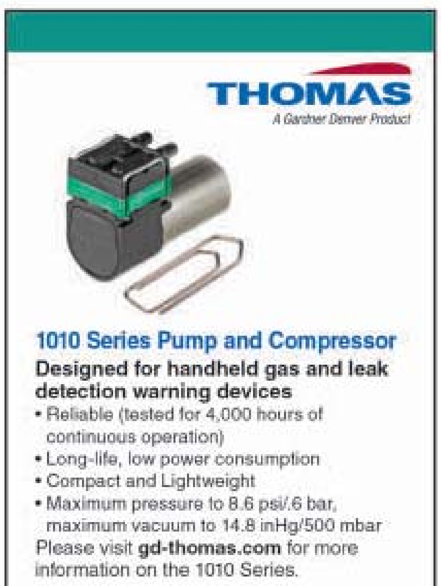
DYNATECT

OMEGA

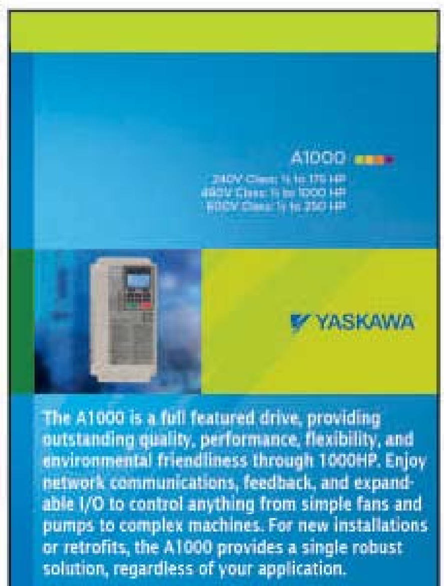
NEWARK



PAVE TECHNOLOGY



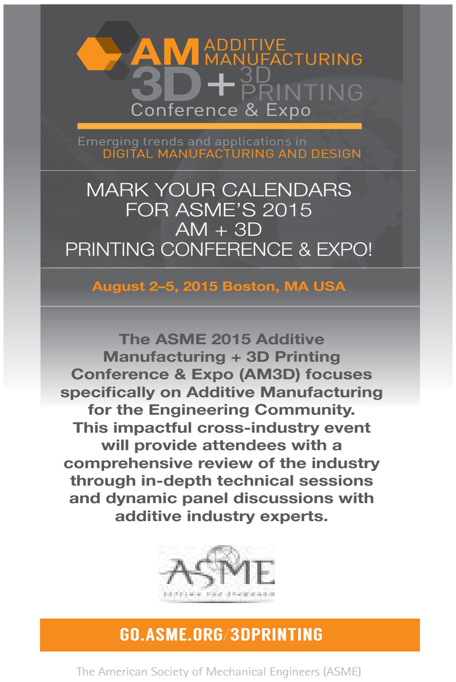
THOMAS



YASKAWA

POSITIONS OPEN

THE UNIVERSITY OF SOUTHERN MAINE invites applications for a **FULL-TIME LECTURER POSITION IN MECHANICAL ENGINEERING** to begin in September 2015. See the complete notice at https://usm.hiretouch.com/view-all-jobs.



The Ohio State University

COLLEGE OF ENGINEERING

FACULTY POSITION - ASSISTANT PROFESSOR OF PRACTICE
DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING

Academic Field(s): Mechanical Engineering or related field with expertise in the design of mechanical and thermal/fluid systems.

Job Description: The Department of Mechanical and Aerospace Engineering seeks a full time Assistant Professor of Practice. The position's primary responsibility is for the teaching and ongoing development of the Mechanical Engineering Senior Capstone Design course sequence, but would have broader responsibilities involving other undergraduate courses. The Capstone Design duties include instruction and leading of exercises in design methodology, project management, overview of computational and solid modeling for use in engineering analysis, technical communications, ethics and professionalism, and overseeing, advising and evaluating group design/build/test projects. Continual development of either in-house or industrially sponsored projects for the course is also expected. Responsibilities also include teaching other courses as needed such as engineering mechanics and machine design; developing curriculum; preparing lecture materials for presentation; developing projects, exams, quizzes, and homework assignments; advising M.S. and undergraduate research; holding office hours; and curriculum committee duties as assigned.

Interested candidates must have at least an M.S. in Mechanical Engineering or a closely related field and at least ten years of design and engineering analysis experience with mechanical and thermal/fluid systems in an industrial or research organization. Expertise is sought in the broad range of the undergraduate mechanical engineering curriculum, complemented by a strong background in engineering design and analysis of machine elements. Experience in teaching design and other undergraduate mechanical engineering subjects is desirable. Candidates must also demonstrate an ability to develop and plan student projects and interact with industry sponsors of projects, and must have excellent communication skills. Successful candidates will also have a strong interest in guiding MS level research in an independent capacity, but working in collaboration with faculty members as needed.

The anticipated start date is May 2015. Screening of applicants will begin immediately, and will continue until the position is filled. Interested candidates should send curriculum vitae, a 2-3 page statement of teaching interests and goals, a 1-2 page statement of research interests and goals, and names and postal/email addresses of three references electronically to mendelsohn.1@osu.edu, or http://www.mecheng.osu.edu/faculty_positions/.

The Ohio State University is an equal opportunity employer. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, sexual orientation or identity, national origin, disability status, or protected veteran status. Columbus is a thriving metropolitan community, and the University is responsive to the needs of dual career couples.

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.

	PAGE	WEBSITE	PHONE
ACCUMOLD	58-59	accu-mold.com	
AM3D India	27	go.asme.org/am3dindia	
AM3D Printing	64	go.asme.org/3dprinting	
ASME Event Map	42-43	asme.org/events	
ASME Power & Energy	C3	go.asme.org/powerenergy	
ASME Smart Brief	60	go.asme.org/smartbrief	
ASME Training & Development	52-53	go.asme.org/training	800-843-2763
ATI Industrial Automation	20	ati-ia.com/mes	919-772-0115
Bimba Manufacturing	C4	bimba.com/smarter	
Bluebeam Software	C2	bluebeam.com/engineer	
Computational Dynamics (CD-Adapco)	24	cd-adapco.com	
Computer Engineering, Inc.	58-59	THINKCEI.COM/DC	
COMSOL Inc.	5, 58-59	comsol.com	
COMSOL Webinar	57	http://goo.gl/yAF917	
DELL	7	Dell.com/CAD	
Dynatect	58-59	dynatect.com	800-298-2066
Evapco	19	EVAPCO.com	
Forest City Gear	56	forestcitygear.com	815-623-2168
Fotofab	9, 58-59	fotofab.com/free	773-463-6211
Master Bond	58-59	masterbond.com	201-343-8983
Nanoscribe	54	nanoscribe.de	49 721 60 82 88 40
NEMB 2015	14	asmeconferences.org/nemb2015	
Newark/element14	13, 58-59	newark.com	800-463-9275
Omega Engineeirng, Inc.	15, 58-59	omega.com	888-826-6342
Pave Technology	58-59	PAVEtechnologyCo.com	937-890-1100 x 103
Proto Labs, Inc.	17, 58-59	protolabs.com	
Smalley Steel Ring, Inc.	25, 58-59	smalley.com/getcatalog	847-719-5900
SPG USA, Inc.	58-59	sales@spgmotor.net	847-439-4949
Vibration Test Systems	55	VTS2000.com	330-562-5729
XYZ Scientific	21	trugrid.com	925-373-0628

RECRUITMENT

Ohio State University........61

CONSULTING

Design Engineering Analysis........61
Pipeline Safety Trust........61

CONSULTING

Pipeline Safety TRUST

Credible.
Independent.
In the public interest.

RFQ OPPORTUNITY

We're looking for pipeline safety technical experts to provide assistance to local governments and communities related to on-shore oil and gas pipelines in the US and Canada. More information is available and submissions are accepted through our website:

http://pstrust.org/rfq

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.

EWEEK PUTS ENGINEERS IN THE SPOTLIGHT

The annual Engineers Week threw a spotlight on engineers all over the world.

The festivities kicked off a few days before the official start of Engineers Week with the championship round of the Future City Competition, which was held Feb. 17-19 at the Capital Hilton in Washington, D.C.

Leah Schroeder, Abby Dayton, and Emily Abramczyk (front row, left to right) at the Future Cities finals.

Teams of sixth-, seventh-, and eighth-graders from across the U.S. were asked to design and build a model of a futuristic urban farm community. Forty thousand middle school students from 1,350 schools were involved.

A team of students from St. John Lutheran School in Rochester, Mich., won the grand prize with an entry they called "Lekol-la-fre." The students on the team were **Leah Schroeder**, **Emily Abramczyk**, and **Abby Dayton**. The school won last year's competition as well.

Second place went to West Ridge Middle School from Austin, Texas, and the Academy for Science and Foreign Language from Huntsville, Ala., took third place.

Other events associated with EWeek included "Introduce a Girl to Engineering Day" on February 26. Workshops, lab tours, online discussions, and hands-on projects at companies, universities and other locations gave young women the chance to learn about engineering careers from women who work in the profession.

The Family Day event, held at the National Building Museum in Washington, D.C., featured nearly 30 exhibitors presenting hands-on activities exploring basic science and engineering principles. The daylong event, which attracts thousands of attendees each year, is designed to introduce grade school students to the importance of technological literacy.

In early March, DiscoverE, the non-profit group that organizes EWeek, presented the 2015 Global Marathon, a free, online event for women in engineering and technology worldwide. The three-day event, which coincided with International Women's Day, consisted of a globally connected group of live webcasts as well as locally organized, in-person satellite events taking place throughout the world.

Each of the three days focused on a specific theme: "New Horizons for Women in Engineering and Technology" on March 9, "Your Horizon: Finding Perspective" on March 10, and "Explore Your Next Horizon" on March 11.

ASME ISSUES PIPELINE STANDARDS COMPENDIUM

ASME has published a pipeline standards compendium designed to link relevant technical documents to passages in the U.S. pipeline safety regulations.

Within the United States, federal regulations governing pipelines are administered by the U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration. The federal agency relies on numerous private-sector standards and guidance documents—including those developed by ASME—to establish a robust and relevant technical basis for its regulations.

The new compendium is intended to facilitate an understanding of the relationship between the regulations and the ASME standards. The compendium has been organized to aid users of the pipeline safety regulations promulgated by Parts 192, 193, and 195 of Title 49 of the U.S. Code of Federal Regulations. It identifies the ASME standards relevant to the regulatory language, describes each referenced ASME standard in plain language, and also provides relevant technical excerpts.

The compendium, which will remain a copyrighted work of ASME, is available as a free digital product in ASME's online catalog at https://www.asme.org/shop/standards.

WEBINAR DISCUSSES WATER SYSTEMS

Billions of aid dollars have been spent on rural water systems in the developing world. But according to follow-up studies, an average of 40 percent of those systems stop working within a few years after they are built. **Susan Davis**, executive director of the aid agency Improve International, presented a webinar on February 18 that focused on one of the common reasons that rural water systems in developing countries do not function as expected: the lack of preventive maintenance.

The webinar was part of the Engineering For Change series, and an archived version of the event is now available for viewing. Please go to http://www.engineeringforchange-webinars.org/ to view that webinar and register for upcoming events.

EIBECK TO OVERSEE NCAA ACADEMICS

ASME Fellow **Pamela A. Eibeck**, president of University of the Pacific in Stockton, Calif., has been appointed to serve on the National Collegiate Athletic Association Division I Committee on Academics. She will serve as vice chair of the committee, which will focus on advancing the association's mission of supporting student-athlete success in the classroom and on the playing field. The new committee replaces two previous NCAA bodies: the Committee on Academic Performance and the Academic Cabinet. Eibeck also serves as chair of the executive committee of the Association of Independent California Colleges and Universities, an organization that represents the state's 77 private nonprofit colleges and universities.

SUPER SCIENCE

Comic-Tanium: Suveen Mathaudhu with Captain America's vibranium shield.
Photo: The Minerals, Metals, and Materials Society

SUVEEN MATHAUDHU SAYS HE ALWAYS had an interest in science fiction and fantasy comic books—long before he became assistant professor of mechanical engineering at the University of California, Riverside's Bourns College of Engineering. Mathaudhu, who is also on the university's materials science and engineering faculty, has found that a comic turn of science fiction can help drive home a point of science fact.

He put together a workshop for the U.S. Army Research Laboratory in December 2013, titled "Materials in Extreme Environments." He represented various extreme conditions by conjuring up his childhood heroes. The embodiment of high-pressure, for instance, was the Hulk, and for temperature, the Human Torch.

About 10 years ago, Mathaudhu started collecting panels from comic books that depicted some aspect of science—or in many cases pseudo-science—that supports a hero. Fantasy science has "limited accuracy," Mathaudhu said. For example, the "adamantium" that coats Wolverine's skeleton and claws has properties that surpass any metal known.

Even so, Mathaudhu said, the fundamental idea of engineering super-strong metals and coatings is a goal of real science and engineering. And the connection of comics with reality can inspire curiosity, in groups of kids and sometimes among his colleagues.

He was in Pittsburgh for an engineering conference when he visited the ToonSeum, a museum dedicated to comic and cartoon arts where he met Joe Wos, who was the executive director.

The two discussed Mathaudhu's academic background and interest in comics, and then Wos asked him if he would be interested in curating an exhibit that would combine engineering and comics. The Comic-Tanium was born.

Comic-Tanium (tms.org/comictanium) combines the real world of materials science with the fictional worlds of comic book heroes. The exhibition includes panels from Mathaudhu's collection, as well as vintage comic books, movie props, and other artifacts with science fiction themes. Its lessons link the fictional with real-world engineering.

Visitors are told that Captain America's shield, for instance, is made of "vibranium," the "strongest material in the universe." Then they learn that Suveen Mathaudhu and a team at North Carolina State University "achieved the highest strength in a magnesium alloy"—a material that can replace heavier metals to reduce weight in vehicles.

Before the show opened at the ToonSeum it made its debut in San Diego at the Minerals, Metals, and Materials Society Annual Meeting and Exhibition in February 2014. The society, also known as TMS, was a co-sponsor of Comic-Tanium.

In April the exhibit traveled to the USA Science and Engineering Festival in Washington, D.C. This is the largest festival for science, technology, engineering, and mathematics education in the world. It draws more than 350,000 children and adults.

The Comic-Tanium closed at the ToonSeum in January, but will continue in a new form. Mathaudhu is working with the TMS and the TMS Foundation to create a version of Comic-Tanium that will provide video and instruction modules for elementary and high school teachers.

He says the goal of the Comic-Tanium is to get kids interested in science and engineering. "They typically don't think of engineering that is something cool or interesting," he says. "But when you make the connection that Spider-Man and Hulk are scientists, kids start connecting to what scientists and engineers do."

Did comics influence Mathaudhu's career choice? He says no. His main influence was his father, an ME. But early on Mathaudhu saw superheroes as engineers.

"I suppose this viewpoint, in a way, made me feel that being an engineer was cool, even if society, pre-The Big Bang Theory sitcom, didn't necessarily see it that way." ME

JAMES PERO

Keynote Speaker Announcement at ASME's 2015 Power & Energy Conference!

BOOK EARLY AND SAVE! Register online today and receive **$100 OFF**

2015 ASME POWER & ENERGY

JUNE 28-JULY 2, 2015

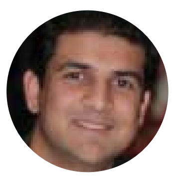
SAN DIEGO CONVENTION CENTER | SAN DIEGO, CALIFORNIA | GO.ASME.ORG/POWERENERGY

In 2015, four of ASME's major conferences (ASME Power Conference, ASME Energy Sustainability Conference, ASME Fuel Cell Science, Technology & Engineering Conference, and ASME Nuclear Forum) come together to create an event of major impact for the Power and Energy sectors: ASME Power & Energy Conference & Expo.

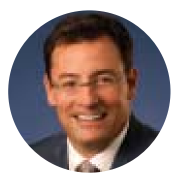
We are proud to announce our initial confirmed Keynote Speakers (stay tuned, there are more to come!)

MARK C. MCCULLOUGH
Executive Vice President of Generation, **American Electric Power**

GREG ASHLEY
President of **Bechtel Nuclear Power**



ASIM HUSSAIN
Senior Director of Marketing and Customer Experience, **Bloom Energy**



JOSEPH DESMOND
Senior Vice President of Marketing and Government Affairs, **BrightSource Energy**

CAREN ANDERS
Vice President of Transmission Affairs & Emerging Technology at **Duke Energy**

DAN BAERMAN
Director of Origination and Portfolio Design at **San Diego Gas & Electric**

LLOYD MACNEIL
Partner, **Dechert LLP**

THE HONORABLE JERRY MCNERNEY
U.S. House of Representatives

WHY ATTEND?

In Just Five Days, You'll Gain Access To

- 800 Presentations
- Up to 1,000 attendees
- Multiple Workshops
- 60–100 Advanced Energy Exhibitions
- Cocktail Receptions
- Countless Networking Opportunities

Silver Sponsor

CALNETIX TECHNOLOGIES

JOIN US AT ASME POWER & ENERGY 2015
GO.ASME.ORG/POWERENERGY

The American Society of Mechanical Engineers (ASME)


UPTIME
TIME
BIMBA®
Predictive Failure
diagnose cylinder issues before they happen
Machine Efficiency
keep your processes in control by measuring optimal stroke time
HOW TO PREDICT THE FUTURE
Remote Monitoring
collect data on cylinders from multiple locations
Production Improvement
move from emergency repair to proactive upgrades
Sensor 1
Sensor 2
Status 1
Status 2
Status 3
BIMBA
IntelliSense®
Sensor Interface Module (SIM)
I/O
PC
NETWORK
Door Actuator
500
WELCOME TO THE PNEU AGE OF CONDITION-BASED MONITORING
Introducing IntelliSense®, a one-of-a-kind technology platform that delivers real-time performance data on standard Bimba pneumatic devices for maximum uptime.
See the future at bimba.com/smarter
© Copyright 2015 Bimba Manufacturing Company. All Rights Reserved.