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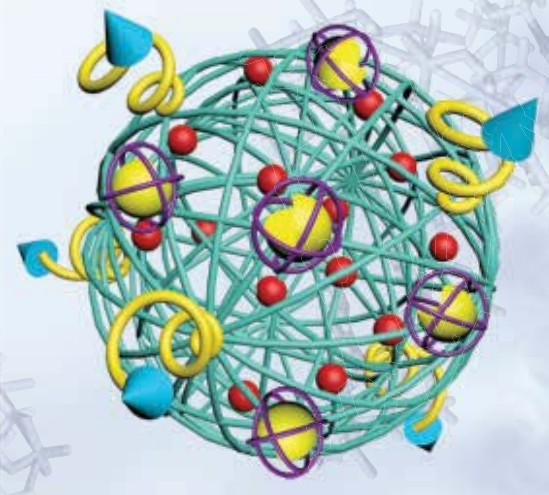
*Technology that moves the world*

THE MAGAZINE OF ASME

No. 02
138



# VERY SPECIAL DELIVERY

NANOSCALE PACKAGING GOES STRAIGHT TO THE GENES

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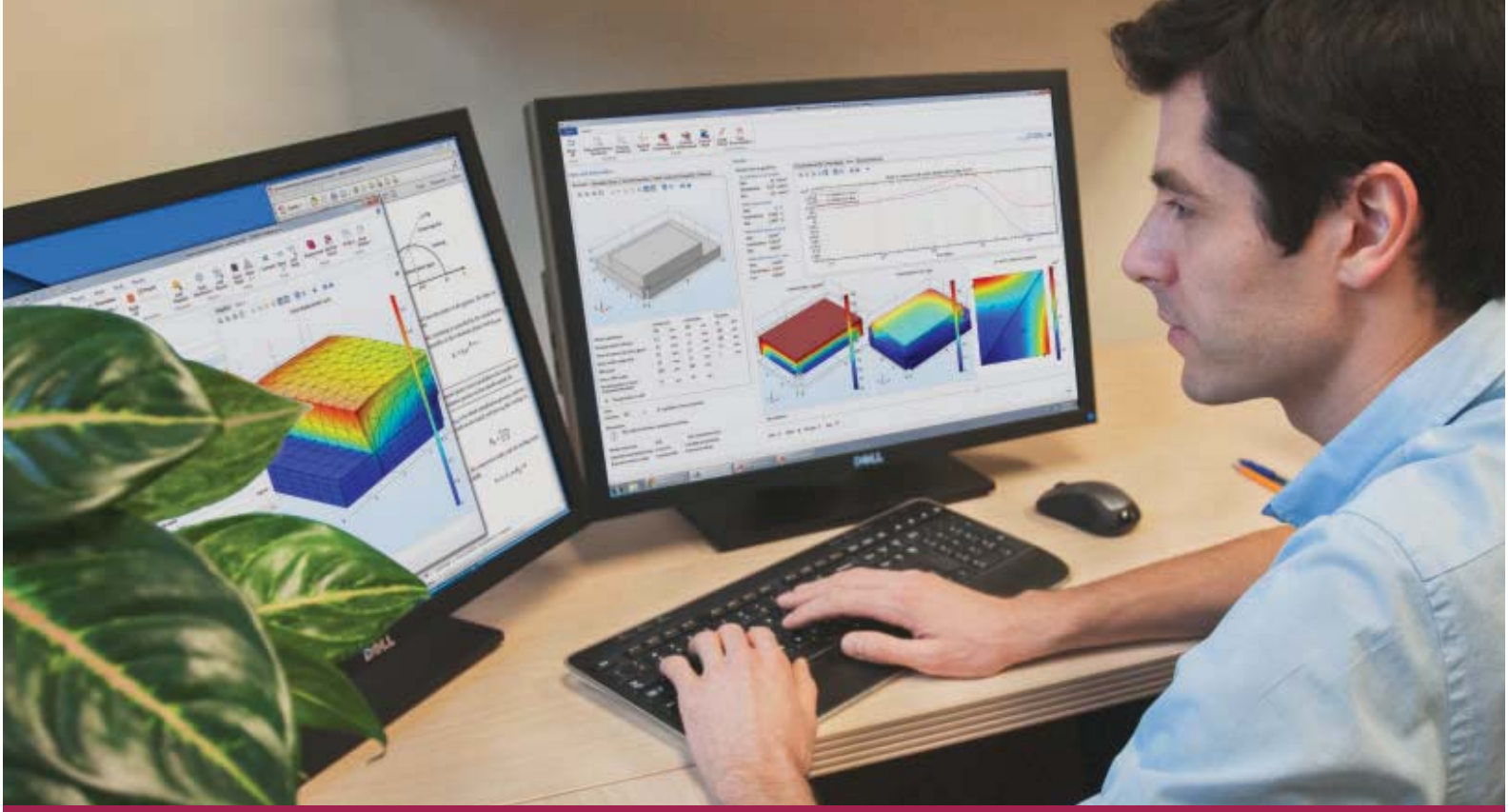

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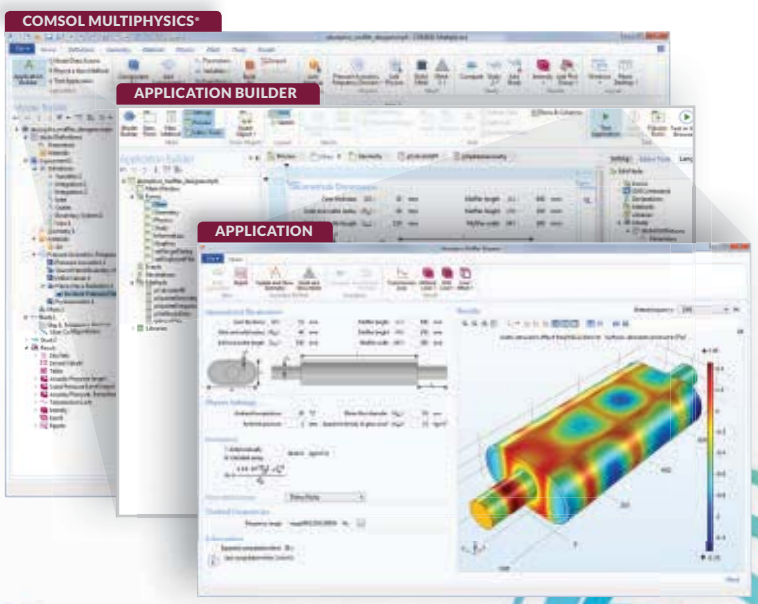


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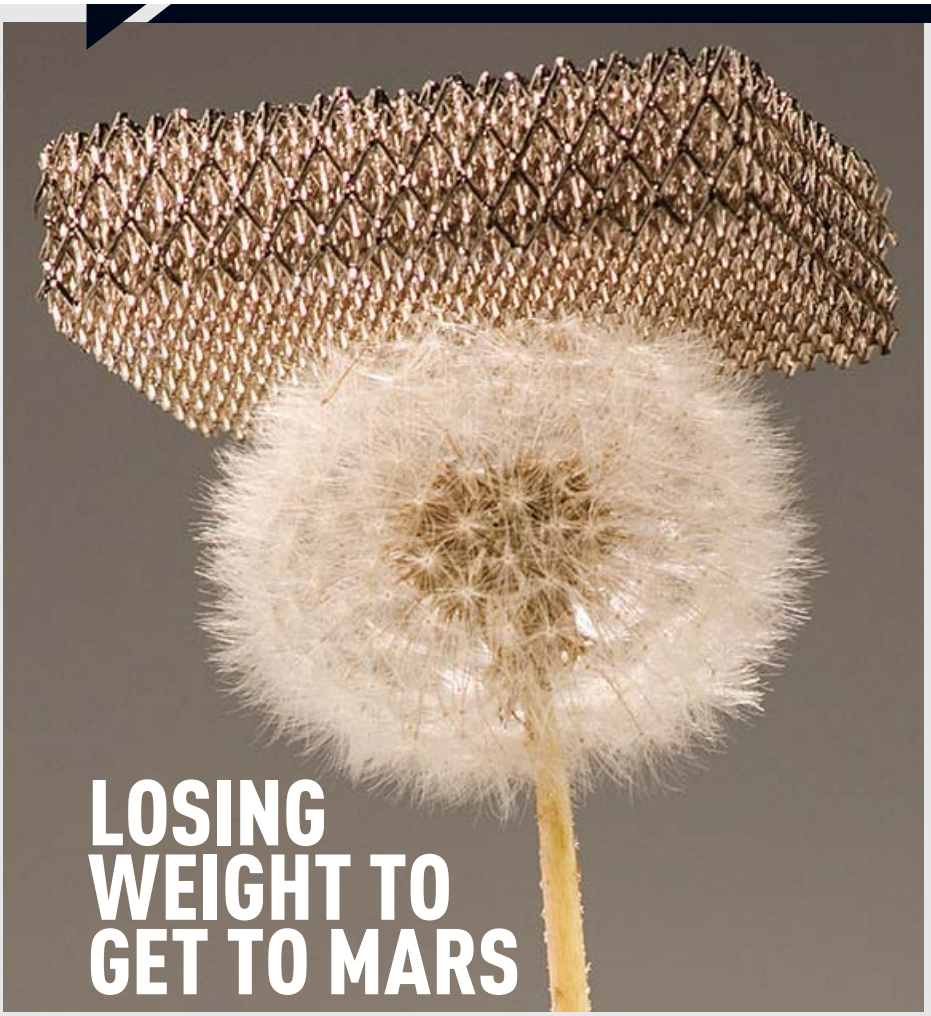

# LOSING WEIGHT TO GET TO MARS

**A NEW ULTRALIGHT METAL** has one aerospace company pondering applications in the manufacturing of jetliners that could greatly reduce the weight of aircraft. Boeing calls it "the lightest metal ever." Developed by HRL Laboratories, the material is made from a microlattice core that is 99.99 percent air and has absorption properties that enable it to spring back into shape. The metal was created as part of a NASA materials-development program aiming to reduce the mass of spacecraft destined for Mars.

## 3-D PRINTED BRIDGES

**THE MUCH-TOUTED BENEFITS OF 3-D** printing—affordability, flexibility, and rapid production—have largely been unavailable for large-scale projects. Amsterdam-based MX3D, however, is now aiming to build the world's first 3-D printed bridge.

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

## GOT MUSHROOMS? MAKE BATTERIES

**A HUSBAND-AND-WIFE ENGINEERING TEAM AT** the University of California at Riverside has developed a new kind of lithium-ion battery anode using portobello mushrooms.

## ENGINEERING AND PUBLIC POLICY

**U.S. REP. JERRY MCNERNEY IS** one of the few members of Congress with a technical background. An ASME Fellow, he talks about energy and workforce issues as public policy.

## NEXT MONTH ON ASME.ORG

**THE POWER OF DUAL-FUEL DIESEL ENGINES**
The high cost of diesel fuel, combined with an abundance of low-cost natural gas, is driving R&D investment in dual-fuel natural gas/diesel engines.

**CAN STANDARDS BENEFIT ADDITIVE MANUFACTURING?** An interview with Dave Edstrom, CTO at Memex, about the challenges the industry faces in establishing standards for additive manufacturing.

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



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Editor-in-Chief ***John G. Falcioni (r.)*** with recently retired Executive Editor ***Harry Hutchinson***

*Photo: Wilfred Haywood/ASME*

# GETTING IT RIGHT

It may not have been the seminal engineering moment that was Apollo 11's landing on the moon, but a few weeks ago—just before last year ticked away—SpaceX gently and safely landed a Falcon 9 rocket back on the ground.

Even if you're not a fan of space of travel, that was a remarkable moment and a dazzling engineering feat. Only through the prism of science fiction had a rocket ever landed safely back on Earth. Several previous attempts at a safe landing had turned into fiery explosions.

The Falcon 9 is no bottle rocket. It's a 15-story, nine-engine missile that produces 1.5 million pounds of thrust and can lug a heavy payload. In this case, it was carrying 11 small data-relay satellites for low-Earth orbit.

Just a few weeks before the successful touchdown, I met Lars Blackmore, the principal rocket landing engineer at SpaceX, which is owned by the innovator Elon Musk. Blackmore is responsible for entry, descent, and landing of the Falcon 9, yet he had no qualms talking about the spectacular failures. He stood firm on the conviction that it was only a matter of time before he and his team would get it right.

Blackmore spoke eloquently about the commitment to excellence that Musk preaches to his team and the dedication that is necessary to make sure that even the minor details of each of his algorithms are exact.

As I write this month's column, Blackmore's comments on attention to detail resonate strongly. For the past 17 years I have been privileged to work with an individual who, above all else, has always placed a priority on "getting it right." Harry Hutchinson, the magazine's executive editor, is retiring, and to say the magazine will never be the same is an understatement.

Anyone who ever contributed to the magazine with a letter or personal note, or who may have pitched a story, has most likely interacted with Harry. If you're a regular reader, you've interacted with him, too. Harry sprinkles his editorial deft in every piece of copy he touches—he's a master at his craft.

Harry's also a colorful character the likes of which you're not likely to find around much anymore. He possesses an encyclopedic knowledge of Old and Middle English and is eager to delve into the private lives of people you're not likely to have ever heard of, let alone know anything about. He's rarely seen without a tie and Fedora, even on his travels to Southeast Asia. He's also a kind and humble man who befriends the needy on the streets of New York with friendship and assistance. And when he sold his New Jersey house last year, at closing he gave the buyers a check, "just in case they need to fix the place up a bit." But if you're one of his writers, and he thinks you're not getting it right, he'll let you know it, in no uncertain terms.

On a relative scale, the impact Harry has made on the magazine when he landed here, is no less brilliant than Blackmore landing Falcon 9. Harry's kept his eye focused steadfastly on you, the reader: Always understanding what you need to know, and lobbying to publish what you want to read.

Thanks for getting it right all these years, Harry. **ME**

FEEDBACK

*Landing a rocket back on Earth was a remarkable feat. What do you think lies ahead this year? Email me.*

***falcionij@asme.org***

# LETTERS & COMMENTS


**DECEMBER 2015**

*Reader Cabak puts the value of engineering to industry in perspective.*

« One reader values engineering technologists. Another suggests licensed P.E.s may help ensure ethical behavior.

## CONGRATULATIONS, COLLEAGUE

**To the Editor:** I would like to congratulate Webb Marner for his Honorary Membership award (November, ASME 2015 Honors), and I wish him many more years of active work. I remember Webb from my work with HTRI and as a past member of ASME-HTD.

George Vago, Life Member, *West Orange, N.J.*

## KUDOS TO TECHNOLOGISTS

**To the Editor:** The September 2015 issue has been folded open and sitting on my desk with two sentences circled: "Engineering schools should be graduating engineering scientists, not engineering technologists. There is nothing to prevent the former from becoming entrepreneurs, innovators, and idea creators." (From "To MOOC, or Not to MOOC, That is the Question" by Mohamed Gad-el-Hak.)

Because I am a member of the Engineering Technology Accreditation Commission at ABET, this statement immediately caught my attention. It questions the value of a technology education and training program in today's high-tech environment.

I would like to answer that the value of mechanical engineering technology is high. I quote from the ABET *Criteria for Accrediting Engineering Technology Programs, 2015-2016*:

"An accreditable program in Mechanical Engineering Technology will prepare graduates with knowledge, problem-solving ability, and hands-on skills to enter careers in the design, installation, manufacturing, testing, evaluation, technical sales, or maintenance of mechanical systems. ... Graduates of associate degree programs typically have strengths in specifying, installing, fabricating, testing, documenting, operating, selling, or maintaining basic mechanical systems, whereas baccalaureate degree graduates typically have strengths in the analysis, applied design, development, implementation, or oversight of more advanced mechanical systems and processes."

These skills are what many businesses are scrambling to find in today's modern economy. Additionally, many with mechanical engineering degrees will eventually find themselves in more applications-based technology positions. They will fill roles with a skill set similar to what ABET lists for mechanical engineering technology degree programs.

Some of the most intelligent individuals I have ever worked with have been the technologists of the nuclear Navy and oil and gas industry. The best trainers and instructors are often technologists with a combination of formal training and hands-on experience.

Mechanical engineering technology fills the important gap between high-level design engineering and vocational technology end users by bringing the science into a usable form. The U.S. industry and economy would both grind to a screeching halt if technologists suddenly became rare.

I hope that colleges and universities across the nation continue to produce highly qualified and well educated engineering scientists and technologists. Both will be needed in ever-increasing numbers as our global society continues to advance into tomorrow.

Jared Jensen, P.E., *Houston*

## ETHICS AND RESPONSIBILITIES

**To the Editor:** Volkswagen's deception of the EPA was probably rooted in a culture that demanded results and diffused personal responsibility. The punitive consequences of this deception will be a monetary fine borne by stockholders and the termination of a few executives.

The engineering discipline has long had a process for ensuring public safety and ethical behavior, namely the connection of engineering work to a licensed Professional Engineer. P.E. certification ensures that one person carries the weight and responsibility for technical decisions. This approach avoids groupthink and reckless wanderings down ethical wormholes.

I have had to contend with many ethical dilemmas during my thirty-year career and in most cases I did not have the option to make an individual stand but rather I had to rely on gentle persuasion. Persuasion didn't always work.

The ethical challenges with which engineers contend are one of the darkest areas of our profession. We understand products and systems far better than management yet are often not the ones who control elements related to safety and standards compliance. The industry exemption for P.E. licensure needs to be reevaluated and allow engineers to do their work with a sense of individual responsibility.

Thomas Ask, *Cogan Station, Pa.*

## THE STUFF OF LIFE

**To the editor:** "Entropy and the Environment" (Energy, December 2015) made some good points but omitted some others. So-called greenhouse

gases, especially $CO_2$, are important to all life and not pollutants. The ordered wood log will be restored by Mother Nature through the actions of sunlight, water, and importantly, carbon dioxide. It is not difficult to imagine at all, as the author claims. But the presence of carbon dioxide is necessary to all life.

George E. Cort, *Montrose, Colo.*

## BAD TREATMENT

**To the Editor:** I'd like to comment on two articles in the December 2015 issue.

In regards to Llewellyn King's article (Comment, "U.S. Loves Engineers, Treats Them Badly"), there is more to the tough slogging of engineers than the cavalier life of public projects.

The mindset in society doesn't have a high regard for creativity and productivity. And few companies look beyond the next quarter when considering their business plans. When the folks in management and accounting can make millions for a firm by simply transferring a number from one column to another, it is a challenge for the engineering department to show matching value to the bottom line.

Given the complicated and convoluted matrix of state and federal tax codes, a single tax expert can make more money for a company than an army of engineers. Those of us who make a living and enjoy the work we do consider ourselves pretty lucky.

In regards to hands-free car phones (Tech Buzz, "Even Hands-Free Interactions Are Distracting"), there is a finite limit to which technology will ever be able to reduce distraction. The simple fact that a driver who is in conversation with someone removed from the car and road scene means that 100 percent of the driver's attention is not on driving. A 100 percent focus may not be needed every moment. But when it is needed, it may be a matter of life or death.

Jerry Cabak, *Santa Cruz, 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.

## TOUGH LOVE

**To the Editor:** "U.S. Loves Engineers, Treats Them Badly" (Comment, December 2015) is a great article. It's about time someone like King focused attention on this important, largely ignored issue.

Robert S. Dunham, *San Diego, Calif.*


# INTERVENTIONAL CARDIOLOGIST, PROTECT THYSELF

Minimally invasive heart procedures can quite literally save lives. But some cardiac interventions, such as angioplasties (formally known as percutaneous coronary intervention) and stent placements, can create serious health problems for the cardiologists and their staff.

Radiation from the X-rays used to guide the procedures in the catheterization lab contributes to an increased cancer risk. And the heavy, lead-lined protective aprons worn to shield the workers can lead to chronic back and hip strain.

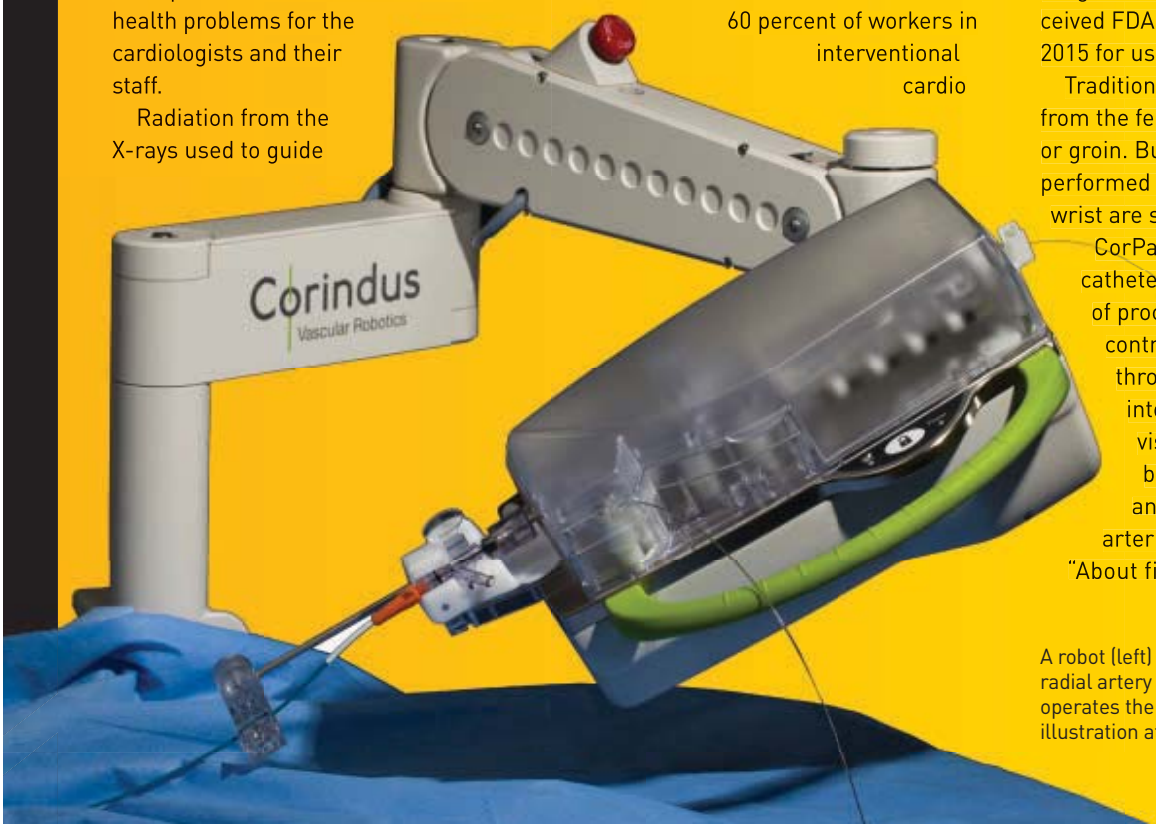
Indeed, some studies indicate that 60 percent of workers in interventional cardio labs develop spinal problems, some so painful and debilitating that they are essentially career-ending.

Corindus Vascular Robotics in Waltham, Mass., believes it has a promising solution. Its CorPath System received FDA a 510(k) clearance in October 2015 for use in radial-artery access PCI.

Traditionally, angioplasties started from the femoral artery in the upper leg or groin. But data show that procedures performed via the radial artery in the wrist are safer for patients.

CorPath robotically assists in catheter manipulation for this type of procedure. A joystick-driven control steers the catheter wire tip through the patient's radial artery into the coronary arteries. With visual guidance from X-rays, blockages can be cleared and stents inserted to hold the arteries open.

"About five millimeters of the wire's




A robot (left) guides a wire through a patient's radial artery to reach the heart. A technician operates the robot from a remote cockpit (see illustration at top). *Images: Corindus*

tip is bent so it can be steered by simply rotating the back end—with robotic assistance—while watching X-rays of the procedure from the safety of a radiation-shielded cockpit," said Brett Prince, Corindus marketing vice president.

By sitting in a cockpit, Prince said, cardiologists are removed from the irradiated environment. That means they don't have to wear lead aprons that may weigh as much as 40 pounds.

"Thousands of cardiac interventions have been performed with robotic assistance," Prince said, "and more are done every day. Recently, some of these have been transmitted live at physicians' conferences to demonstrate the system's ability to work in complex cases."

CorPath systems cost about $400,000 and can be installed in a hospital's cardiac cath lab in two days.

CorPath's initial clinical trials took place in 2011, and initial FDA approval occurred within seven months. Recent clinical trials focused on Radial PCI at Spectrum Health in Grand Rapids, Mich., and St. Joseph's Hospital Health Center in Syracuse, N.Y. Those trials saw 100 percent success, according to the company.

"Everything done with CorPath in the cardiac cath labs was thoroughly documented for the FDA and all the materials and the robotic components used in the most recent trial had prior FDA clearances," Prince said. "All of the hardware driven by CorPath is standard interventional devices available commercially so physicians can use whichever device they deem appropriate for their patient."

A big plus for robotically assisted procedures, Prince said, is that they help interventional cardiologists undertake ever more complex procedures to prevent heart attacks, and save lives when attacks do occur. **ME**

---

**JACK THORNTON** is a writer based in Santa Fe, N.M.

# CHINA INVESTIGATES DUMPING CHARGES AGAINST U.S. AND JAPAN

**CHINA'S MINISTRY OF COMMERCE** is investigating imports of an iron-based alloy from the United States and Japan to see if low prices constitute dumping in the Chinese market, according to a report by Xinhua, the state-owned news agency.

Xinhua said the ministry has issued a statement of its intentions. It will try to determine whether imports of iron-based amorphous alloy ribbon, which were allegedly at "lower than normal" prices, have damaged or affected domestic producers' interest.

Iron-based amorphous alloy ribbon is used in electrical equipment, including power distribution transformers and motors.

China has taken action on dumping charges several times over the past year.

The ministry decided in August 2015 to impose anti-dumping measures on optical fiber preforms imported from Japan and the U.S. The ministry told domestic importers of fiber optics from the two countries to pay anti-dumping tariffs ranging from 8 percent to 41.7 percent to customs.

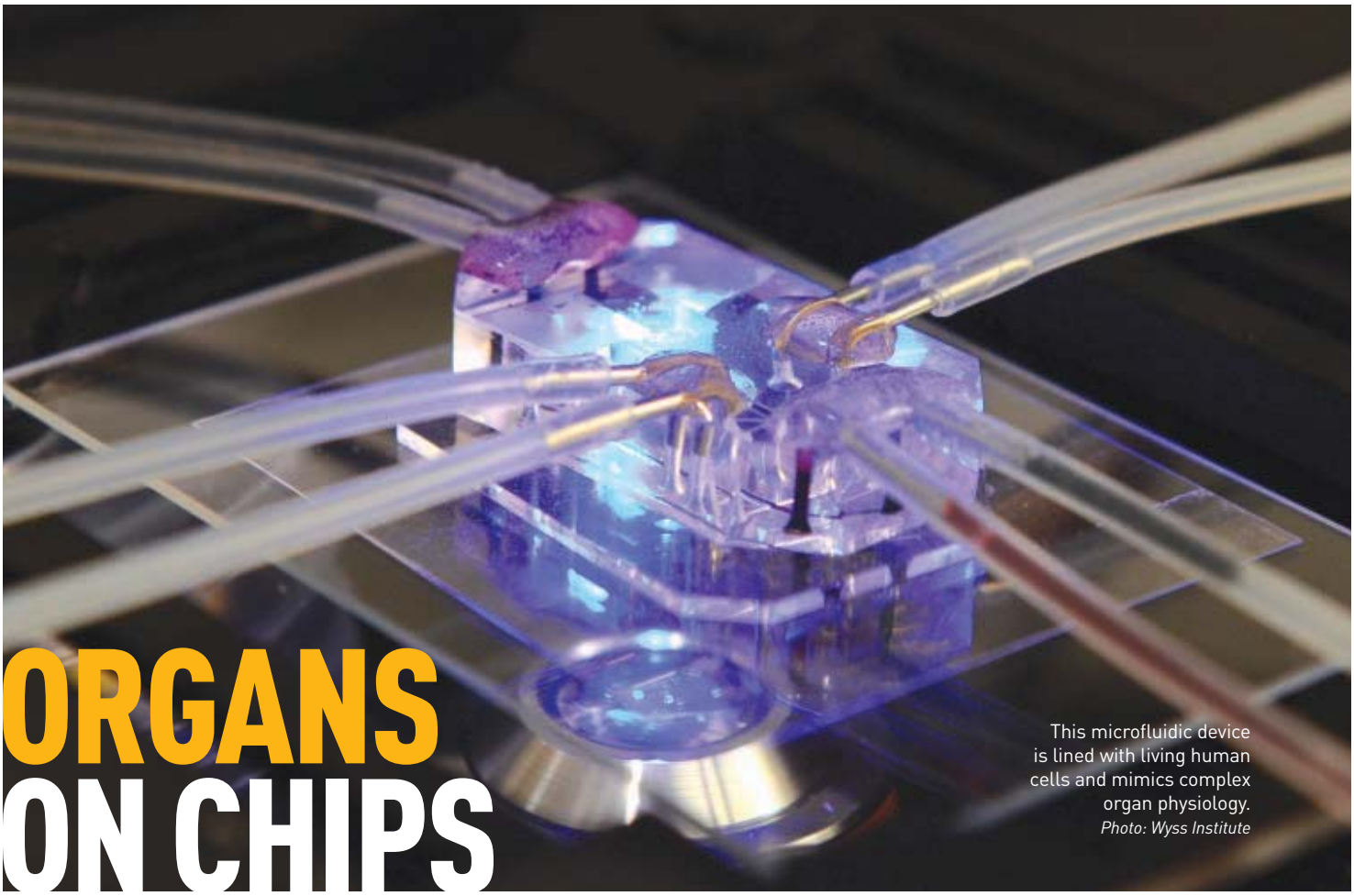
The ruling affected products with Harmonization System Code 70022010, but excluded those with a diameter smaller than 60 millimeters. Optical fiber preform is a piece of glass, which is drawn to make optical fiber.

In July 2015, the ministry announced provisional anti-dumping measures on methyl methacrylate imported from Singapore, Thailand, and Japan. Importers of the product, which is used in plastic, paint, and adhesives, were instructed to place deposits with Chinese customs ranging from 6.8 percent to 34.6 percent of the imports' value starting on August 1, 2015.

The ministry said companies from the three countries had dumped the chemical into the Chinese market and the imports caused substantial damage to the domestic industry.

When anti-dumping tariffs of 2 to 20.1 percent on purified terephthalic acid from the Republic of Korea and Thailand were due to expire in August, the ministry agreed to a request by domestic producers to re-examine the case with a possibility of extending the duties.

On the other hand, the United States has accused China of dumping products in the U.S. market. Products under tariff include solar photovoltaic panels. In June 2015, U.S. steelmakers petitioned their government for tariffs to offset dumping by companies in China and several other countries. **ME**



# ORGANS ON CHIPS

This microfluidic device is lined with living human cells and mimics complex organ physiology.
*Photo: Wyss Institute*

"I have in my bag a kidney and a brain." The plenary presentation by National Institutes of Health director Francis Collins at a recent biotechnology conference may have started on a macabre note, but no living creatures were harmed in its making. Rather, Collins carried in his bag two thumb-drive-size plastic chips that could put hordes of mice and other laboratory animals out of work.

His talk marked the coming of age of organ-on-a-chip technology. The chips can recreate complex biological functions of both healthy and diseased human cells, giving scientists a new view of their mechanical properties, biochemical microenvironment, and 3-D molecular structure. If they continue on their current trajectory, organs on chips could fundamentally alter how life scientists study human physiology, diseases, and new drugs. Industry and federal health research agencies are investing in the technology as a promising way out of today's expensive, slow, and failure-prone drug approval process.

**IT IS NOW POSSIBLE TO CREATE A CHIP THAT CAN MEASURE THE DYNAMIC BIOCHEMICAL, BIOPHYSICAL, AND BIOMECHANICAL RELATIONSHIPS BETWEEN LUNG TISSUE AND THE BLOOD VESSELS FEEDING INTO IT.**

The first organs on chips developed using microengineering technologies for cell biology applications came from researchers at Harvard's Wyss Institute for Biologically Inspired Engineering. They are microfluidic systems embedded using advanced microfabrication technologies into translucent polymer chips. Hollow microfluidic channels are lined with living human cells grown in culture to reflect the make-up of an organ or tissue.

New microchip technologies have enabled engineers to construct structures that recapitulate the complex interactions between multiple tissue types in an organ. For example, it is now possible to create a lung on a chip to measure the dynamic biochemical, biophysical, and biomechanical relationships between lung tissue and the blood vessels feeding into it. Such processes enable not only diagnosis but prediction of a disease process over time. The Wyss Institute team is currently working to build and link 10 human organs on chips to reproduce whole-body physiology—a human on a chip.

Wyss's organs on chips took first prize at the 2015 Design of the Year competition at London's Design Museum—the first medical device so honored.

Organ-on-a-chip pioneer and Wyss founding director Donald Ingber views the technology as a sorely needed fix to a drug development process that is "broken."

It currently costs millions of dollars to test any compound for

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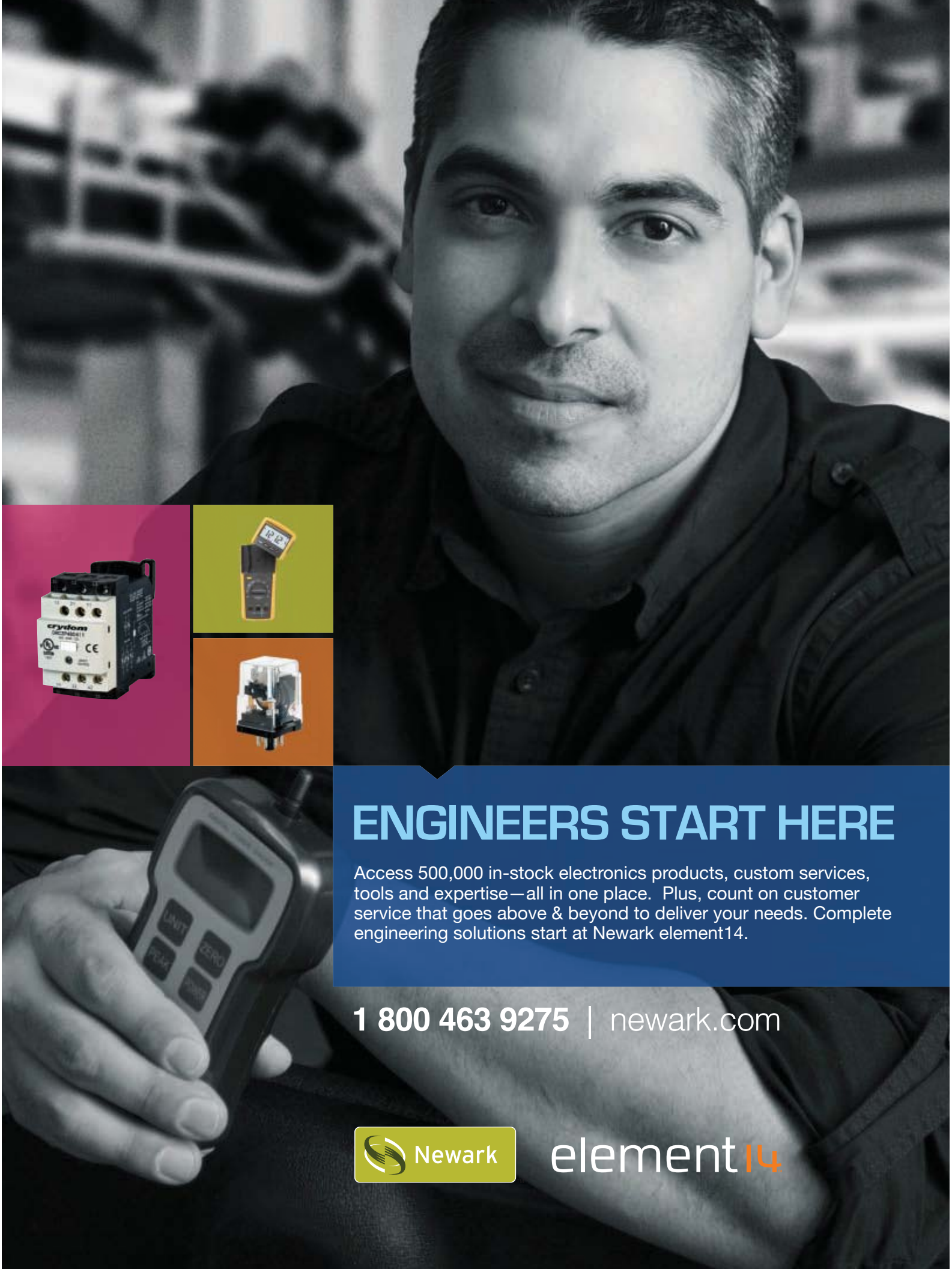
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# MICROGRIDS WHERE THE BIG GRIDS DON'T GO

**SAMUEL EGBU USED TO PAY** 50 naira (32 cents) to charge his phone battery in Umuagwu, a village in Rivers State, Nigeria. Or sometimes he would wait with his dead phone in the small crowds gathered around a neighbor's portable generator.

Electricity was scarce until solar power changed the community.

"Life used to be very difficult and uncomfortable in the village because there was no light," Egbu said. "As soon as it is dusk, everybody retires to their houses."

Now he charges his phone at his own home using a large rechargeable battery. The battery draws its charge from a solar photovoltaic array in the neighboring community of Egbeke.

Street lights, powered by the solar array, shine on the main street of Umuagwu for the first time.

"We now feel like we are living in the big cities," Egbu said.

The PV array and the battery kit are part of an electrification pilot project by Green Village Electricity to deliver power to households not connected to a central grid or traditional power plants. The Nigerian company uses technology and a business plan developed in the United States by IEEE Smart Village. Smart Village proposes to work with GVE and other partners to light up places like Umuagwu and Egbeke all over the world. The goal is to deliver electricity and educational services to 50 million people by 2025.

The project started small in Haiti after the earthquake in 2010. Ray Larsen, a Smart Village co-founder, and his colleagues helped deliver 15 solar microgrids in trailers to communities that had never been on a central power grid.

The power stations, which they called Sunblazers, shipped as kits of panels that produce 4 kilowatt-hours of electricity per day, plus 40 to 80 12-volt lead-acid battery packs. Local technicians cut and welded frames and wired the panels. Then they hauled the finished products into remote communities where they powered homes through the battery packs. The kits were composed almost entirely of off-the-shelf parts configured for efficiency and portability.

Today, 10 of the units are still running. One of the original 15 was destroyed in a riot and the others are under repair after heat and humidity rotted the wood floors of their chassis. The poor mix of wood with a wet climate is one lesson learned from that first project.

The IEEE Smart Village SunBlazer Lite is designed to provide reliable energy to off-grid communities around the world.
*Photo: IEEE Foundation*

Now Sunblazer is in its second and third generations, Sunblazer II and Sunblazer Lite. Both new models are lighter and more portable than the first, and their panels are more efficient.

Sunblazer II includes six 300-watt panels that deliver 9 kWh of electricity per day in equatorial sun. The panels store power in four station batteries that can charge a portable household battery pack in about four hours. The chassis is steel tubing with a floor of sealed plywood or steel.

Sunblazer Lite is about half the size and weight with two panels that deliver nearly 3 kWh per day. It has a stainless steel frame and an enclosure of high-density polyethylene plastic.

The new models also include mostly off-the-shelf components, and the designs are intentionally fluid, open to adaptation to suit changing conditions in communities and countries around the world. Each station can expand to deploy more panels and charge more batteries.

"You can couple them together and drive big loads. We're taking a broader look than just home lighting," Larsen said. "We're trying to be more than just a lighting company. We're looking not just at lighting, but at clean water, water purification, education, refrigeration, pumping. We build somewhat larger systems to handle those loads."

Smart Village has since branched into Kenya, Cameroon, South Sudan, and Nigeria.

In Nigeria, GVE is deploying 24 kW of solar power to three different villages to put power in 200 homes. In September, Nigeria's Bank of Industry invested more than $675,000 in the company and Smart Village added an additional $65,500 to fund the pilot program. If it is successful, the Bank of Industry plans to fund an expansion that would reach 200,000 homes in the next five years, according to Ifeanyi Orajaka, chief executive officer of GVE.

"So far from the pilot projects we have deployed, the business model has proven to be very sustainable as well as very scalable," Orajaka said.

The service appears to be working, as customers spend less and receive more.

"Before now I spend about 450 naira daily (for 3 liters of fuel) but now I spend 200 naira and yet I have a better value for my money, I have longer hours of electricity and without generator noise and fumes," one customer told Orajaka. **ME**

ROB GOODIER, ENGINEERINGFORCHANGE.ORG

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## ORGANS ON A CHIP

therapeutic potential. From synthesis to approval, the process typically drags out over 10 years. For every drug that makes it through the pipeline to FDA approval, as many as nine others fizzle out along the way because they failed in human clinical trials. Factoring in the cost of those duds, the pretax costs of developing each new approved drug shoots up to an average of $2.6 billion, according to the Tufts Center for the Study of Drug Development.

If organ-on-chip technologies prove capable of accelerating the pace of drug testing, producing more reliable data, and reducing the financial and ethical drawbacks of preclinical research, everyone could win.

For decades, scientists and drug companies have relied on animals from mice to monkeys to help them test the safety and effectiveness of new compounds. The Humane Society of the United States reports an estimated 25 million vertebrate animals are used in research, testing, and education in the U.S. each year. Many, if not most, of these animals either perish during an experiment or are euthanized afterward. Research on non-human primates—mankind's closest physiological relatives—is especially controversial.

The search for alternative methods is fueled both by animal welfare issues and by bioengineering advances. Three-dimensional bioprinting is now used to create highly detailed facsimiles of malignant tumor cells and the diverse constituents in their immediate orbits. These duplicates of the tumor microenvironment create the possibility of printing an exact copy of a living patient's tumor and measuring its response to various treatment combinations, while the patient waits.

In silico simulation applies high-end computational chemistry algorithms and 3-D computer graphics for all-virtual drug discovery and screening. None of these techniques is mature enough to supplant animal models, but rapid advances and lower equipment costs are enticing researchers to try them out.

Animal testing is still entrenched in the drug development process and will be for some time. The U.S. Food and Drug Administration still requires exhaustive preclinical animal testing of drug candidates before they enter human trials. The agency is often characterized as slow to embrace new technologies, but the FDA has shown strong support for chip-based alternatives.

MICHAEL MACRAE, ASME.ORG

# AN INTELLECT WITHOUT BORDERS

The patent record of **Nikola Tesla** is evidence of a restless mind that **respected few boundaries.**

Inventor Nikola Tesla won numerous patents during his life, most of which relate to electrical systems. His name is associated with motors, lamps, power transmission, and many other devices. Tesla's inventiveness crossed many disciplines, including mechanical engineering, as evidenced by the following Tesla patents.

In Patent No. 514,972 (1894), the electric motor of a rail vehicle is inductively powered by a wire buried between the train tracks. A conductive plate extends downward from the rail vehicle and is positioned closely adjacent to the buried wire. The benefits of such a design, compared to an overhead pantograph style power collector (invented in 1879) included lower electrical losses.

I came across Tesla Patent No. 613,809 when searching for historical unmanned aerial vehicle patents for another Patent Watch column. According to this 1898 patent, Tesla was the first to remotely control a boat or other vessel. He demonstrated a radio-controlled boat at the Electrical Exhibition in Madison Square Garden in the same year.

Tesla won two patents in 1928, Nos. 1,655,113 and 1,655,114, for an aircraft which takes off and lands in a helicopter configuration and pivots once airborne to fly like an airplane.

Tesla Patent No. 1,329,559 (1920) is for a one-way valve with no moving parts. The internal geometry of the device permits a liquid to flow through a central channel in one direction. A series of diverters called partitions and curving channels called buckets reverses the flow coming from the opposite direction.

Patent No. 568,177 (1896) discloses an apparatus for producing ozone using another of Tesla's inventions, a high-frequency electricity generator.

Tesla also liked meters. Patent No. 1,314,718 (1919) is for a speedometer for a ship. Patent No. 1,365,547 (1921) is for a flow meter, which uses a Tesla turbine immersed in the flow.

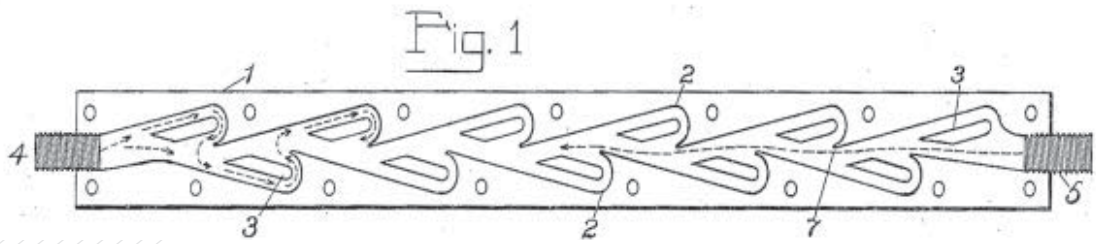
The Tesla turbine, which uses closely spaced parallel discs instead of blades, is itself the subject of patent 1,061,206, dated May 6, 1913.

Some of Tesla's inventions improved already existing technologies. For example, in Patent Nos. 514,169 and 517,900 issued in 1894, the inventor describes reciprocating engines that gain in efficiency by eliminating the conventional flywheel and replacing it with a spring.

Another involved a new kind of water fountain. In Patent No. 1,113,716 (1914), a large mass of water was moved upwards overflowing a funnel shaped conduit in the fountain.

The patent record proves that Tesla practiced in different disciplines well before "cross-disciplinary engineering" became a buzzword. Maybe he invented that too. ME

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




Tesla 1920 Patent No. 1,329,559 is for a one-way valve devoid of moving parts. As shown in Fig. 1 of the patent, fluid can freely flow from fitting 5 to fitting 4 along pathway 7 but not in reverse due to "buckets" 2 and "partitions" 3.

# ABSTRACT DEADLINE: MONDAY, MARCH 7

**20** tracks + **240** topics + **INNOVATION AT ITS FINEST** = **ONE GREAT LEARNING EXPERIENCE**

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# Q&A CHARLES CHAMPION

**AS EXECUTIVE VICE PRESIDENT** for engineering at Airbus, Charles Champion is responsible for a range of activities: research, design, product development, integration and flight-testing, and continued product airworthiness. In March 2015 he added a new role as president of Airbus Operations SAS, the aircraft manufacturing division. Champion began his career as an aerodynamics engineer. He ran the Airbus single-aisle aircraft final assembly lines from 1988 to 1992, including the development of the A321 final assembly line in Hamburg. He also headed the program for the A380—the largest commercial aircraft flying today—until that plane's certification in 2006.

**ME: What got you interested in engineering?**
**C.C**: I love the math and physics, and trying to understand how things work. I also love aircraft. I love to see planes flying. I remember going to all these air shows and seeing the planes. I built model aircraft and read aviation history. I was just an aviation fan.

**ME: What is the number-one engineering challenge at Airbus today?**
**C.C**: We've got to deliver to our customers and to our commitments. Engineering in Airbus is around 13,000 people spread across the world. It's all about flexibility and agility, and what the market wants. How can I find a technical solution that makes sense for the customer, and how can I marshal the resources and make the program happen in a time scale that makes sense for the market?

**ME: How has engineering changed during your career?**
**C.C**: We've got access to data and digitalization, and new ways of working like crowdsourcing. We are moving from a very structured approach towards empowered teams, which is a big change for an organization like Airbus. We're developing an internal approach we call "Sprint," where you go much faster with a smaller team over a limited period of time, with fast testing and rapid prototyping. Actually, this is what they did in the '40s and '50s. You see that spirit coming back.

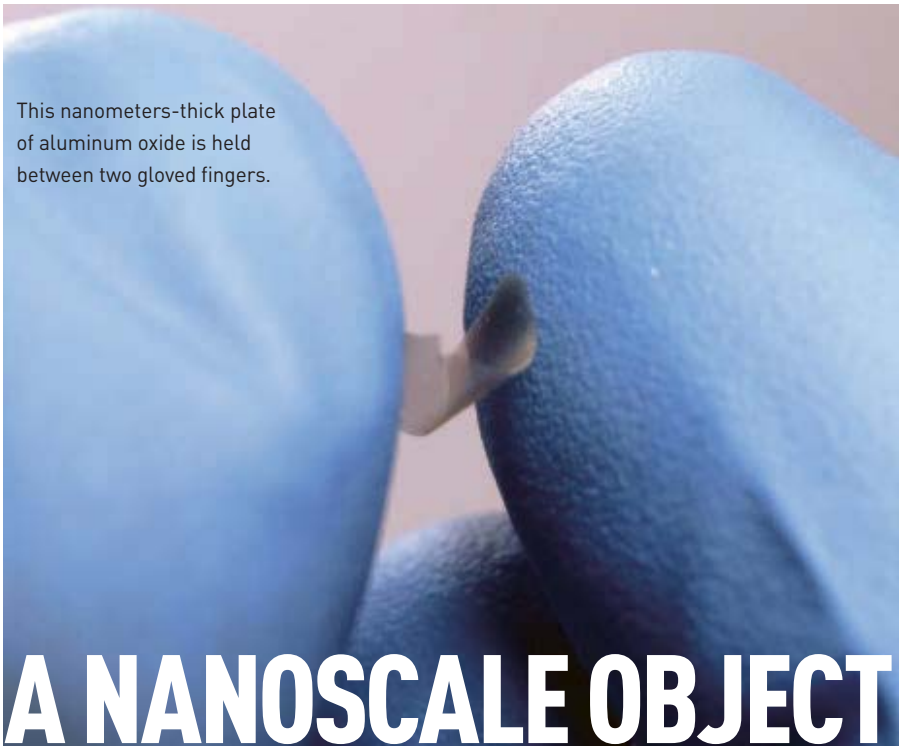
**ME: What's next in aviation?**
**C.C**: The goal is the "perfect flight." We did one from Toulouse to Stockholm. You take off with just enough thrust for the runway and conditions, climb gently, cruise, and glide quietly, in continuous descent, to landing. Integration with air traffic management will be key: how do you manage your flow of aircraft for a perfect flight with every plane that takes off in the world? The vision, the ambition, is that half of the savings in the years to come will come from better management, reducing the waste in the system today.

**ME: Any advice for engineers in today's workplace?**
**C.C**: I would say, develop engineering judgment. Some people believe you can design an aircraft on the computer, 3-D print it, and it will fly. It's nothing like that. An aircraft is a sum of compromises. You need engineering judgment to make the right choices.

**ME: I understand you enjoy opera. Engineering and opera share similar meanings in their Latin roots: *gignere*, to produce, and *opus*, work produced. Do you see parallels?**
**C.C**: Opera puts together people of various skills—singers, musicians, the chorus—for an end result that is much more than the sum of the individual talents. In engineering we also have a lot of individual talents. My challenge is to get an aircraft which is far better than the sum of the skills, so at the end we have something we can be proud of.

**ME: Would you be willing to share with readers a window into your personality?**
**C.C**: I'm very curious. I love to travel to places where everything is mind-boggling at first, but if you listen to people and don't impose your views on a subject, you learn to look at things from a different angle. I think engineering is about people, too. **ME**

**JOHN MARTIN** is a writer based in Ithaca, N.Y.



This nanometers-thick plate of aluminum oxide is held between two gloved fingers.

# A NANOSCALE OBJECT YOU CAN PICK UP

Graphene sheets are today's "it" material, prized for mechanical strength as well as interesting electrical properties. But on their own, these single atom-thick sheets will curl up or clump. And don't even think about picking one up unless it's mounted on a much thicker backing or in a frame.

Now, researchers at the University of Pennsylvania in Philadelphia have produced a plate of super-thin material that can be picked up and held between two fingers. These plates aren't quite as thin as graphene, but at 25 to 100 nm thick, they are much thinner than a wavelength of light.

The plates are made of aluminum oxide, which is deposited one atomic layer at a time to achieve precise control of thickness and a distinctive honeycomb shape.

"Aluminum oxide is actually a ceramic, so something that is ordinarily pretty brittle," said lead researcher Igor Bargatin, an assistant professor at Penn's School of Engineering and Applied Science. "You would expect it, from daily experience, to crack very easily. But the plates bend, twist, deform, and recover their shape in such a way that you would think they are made out of plastic. The first time we saw it, I could hardly believe it."

Indeed, instead of curling or clumping, the corrugated plates spring back to their original shape after being bent and twisted. Also, when held firm on one end, the plates remain rigid rather than sagging like a thin sheet of plastic.

The plates are also less prone to sticking to the side of a surface due to Van der Waals forces. The honeycomb structure doesn't provide for as many surface-to-surface contact points as a simple plane.

The material has intriguing potential for aerospace and micro-mechanical applications, where strength and light weight are critical properties.

"The wings of insects are a few microns thick, and can't be thinner because they're made of cells," Bargatin said. "The thinnest man-made wing material I know of is made by depositing a Mylar film on a frame, and it's about half a micron thick. Our plates can be ten or more times thinner than that, and don't need a frame at all. As a result, they weigh as little as a tenth of a gram per square meter."

The team published its findings in the journal *Nature Communications*. ME

# HOUSE BACKING FOR NUCLEAR R&D

More than 20 sponsors, including key members of the House Science, Space, and Technology Committee, are backing a bill that calls on the Department of Energy to establish programs to support public-private research into advanced nuclear reactors.

The goal is to keep the U.S. competitive in the nuclear energy field.

Randy Weber, a Texas Republican who chairs the Energy Subcommittee, introduced the Nuclear Energy Innovation Capabilities Act, designated H.R. 4084. Co-sponsors include Lamar Smith, chairman of the House Science Committee, and the committee's ranking member, Eddie Bernice Johnson.

The bill would have the Department of Energy use its supercomputing power to simulate advanced reactors. It also calls for the DOE to complete a test reactor to validate supercomputing models and a means for the private sector to team with the national laboratories to develop prototypes of advanced reactors at DOE sites.

According to Weber, the test reactor will involve the use of fast neutrons for researching materials and fuels, and the only place where that is currently available for civilian use is in Russia.

John F. Kotek, Acting Assistant Secretary for Nuclear Energy, told a hearing that the DOE has already begun some activities mentioned in the bill. An Energy Innovation Hub centered at Oak Ridge National Laboratory has been established to provide modeling and simulation of reactors.

"With respect to a new versatile neutron source," Kotek said, "DOE is evaluating the potential need for a new research reactor capability."

Dale E. Klein, associate vice chancellor for research in the University of Texas System and a former chairman of the Nuclear Regulatory Commission, told the hearing, "Nations such as China, Russia, South Korea, and India are moving aggressively to develop export oriented nuclear product offerings. If the U.S. is not in a position to compete, we will lose our international influence on key safety and security issues and forgo significant economic and job creation opportunities."

Ray A. Rothrock, partner emeritus in Venrock, a venture capital firm, said the bill "would be irrelevant today if it were not for the fact that we found over 40 nuclear energy startups in North America. These companies are backed by at least $1.6 billion private capital dollars."

The text of opening statements and recording of the hearing are available online at http://tinyurl.com/HouseNuclearR-D. ME

# WAVE POWER INSTALLED OFF AUSTRALIA

An Australian energy company, backed by state and federal funding, has placed the hardware to test its system for harnessing waves to generate electricity.

The company, BioPower Systems, has placed a 250 kW pilot unit in Australia's Southern Ocean, near Port Fairy, Victoria. The unit, called bioWAVE, oscillates under the ocean swells. A proprietary O-Drive power take-off module converts the irregular mechanical power of the waves into regular alternating current for the grid.

According to a statement, the project has been in development for three years at a cost of $21 million. The Australian Renewable Energy Agency, or ARENA, has contributed $11 million and the Victoria government has added $5 million.

According to BPS, the bioWAVE system was lifted into place by a crane mounted on a ship. The entire installation process took about five hours. The system will be connected to the electrical grid for the demonstration.

The structure was angled slightly, piercing the surface like a diver to avoid any impacts from the waves, before being leveled out and landed on the seabed, BPS reported. Divers monitored the process from below to ensure accurate placement.

The bioWAVE device is a 26 meters high. Its oscillating structure is designed to sway back and forth beneath the ocean swell in order to capture energy from the waves and convert it into electricity that is fed into the grid via an undersea cable. The design was inspired by undersea plants and the entire device can lie flat on the seabed out of harm's way during bad weather.

The bioWAVE unit, on the docks. *Photo: BioPower Systems*

According to the company's CEO, Timothy Finnigan, "Installation of the bioWAVE in the Southern Ocean marks the culmination of an intensive development phase, and the beginning of a testing and demonstration phase for bioWAVE. We will now turn our attention to commissioning the plant for operation, and we aim to be delivering electricity into the grid very soon." ME

# RUSSIAN NUCLEAR PLANTS ABROAD

**RUSSIA WILL CONTINUE TO PARTICIPATE** in the construction of the first nuclear power plant in Vietnam, even though the launch of the project has been delayed, according to a report by Tass.

Meanwhile, a deal for Russia to build a 4.8 gigawatt nuclear plant in Egypt has taken another step forward.

The plant in Vietnam is one of two planned for Ninh Thuan province. Rosatom, the Russian nuclear power company, is currently working with the Vietnamese government to build the first two units at the plant known as Ninh Thuan 1. The long-range plan is to build a total of four units, which will have a capacity of 1,000 MW each, at the site.

The second plant, Ninh Thuan 2, will have the same capacity and will be built by a Japanese consortium.

According to Tass, Russia's First Deputy Prime Minister Igor Shuvalov said, "The Vietnamese government confirms that it's still interested in cooperation with the Russian Federation regarding the issue and the Ninh Thuan 1 nuclear power project will happen."

According to Shuvalov, "For Vietnam this is a very challenging project as everyone remembers the Fukushima tragedy."

He said Russian experts will appear at Vietnamese parliamentary hearings to assure officials of the safety of the technology.

According to a statement by Rosatom, the latest development in the Egyptian project is the signing of additional agreements for the partnership between the two countries. The plant, to be built at Dabaa, is scheduled for completion in 2022 and will have four units generating 1,200 MW each. It is the largest joint project of Russia and Egypt since construction of the Aswan Dam, which was completed in 1970.

Egypt's Minister of Electricity and Energy and the director general of Rosatom signed an agreement for collaboration in the construction and operation of the nuclear power plant. The Russian and Egyptian regulatory bodies for nuclear and radiological safety also have signed a memorandum of understanding covering further development of the nuclear infrastructure.

Documents specified questions of nuclear fuel supply, and obligations in operation, maintenance and repair of nuclear power units.

Russian and Egyptian officials signed an earlier agreement, covering specifications of the nuclear power plant and key areas of cooperation, in February 2015. ME

The biomechanics lab's research includes improvements in manual wheelchair propulsion techniques.
*Photo: USC Biomechanics Research Lab*

# SAFETY FACTOR

**HUMAN-FACTORS ENGINEERING GOES** beyond physical, chemical, and mechanical properties of matter to take into account the physical and psychological impacts of a product on the person who uses it. How can a product be improved to become safer, more comfortable, or more efficient to use? This softer side of design can't be taken for granted and is the subject of a great deal of study. This month we touch base with two university labs studying human factors to make the world a safer place.

If you want to perform like the best, you have to learn from the best. That's the philosophy at the University of Southern California Biomechanics Research Laboratory, where researchers study individuals with a high level of skill acquired through years of practice, including elite athletes, performing artists, and people in technically demanding work environments, such as dental hygienists.

The goal is to combine results from these studies with modeling simulation approaches to identify ways people can improve how they perform various tasks, both routine and exceptional.

"We have used these methods to improve the take-off mechanics of national team divers and horizontal jumpers, the landing mechanics of gymnasts and volleyball players, and the turning mechanics of dancers, golfers, and older adults," said lab director Jill L. McNitt-Gray. "We have also improved manual wheelchair propulsion techniques for individuals with spinal-cord injuries."

McNitt-Gray and her team capture key features of human movement using sensors and high-speed motion capture tools. Wearable inertial measurement units quantify motion (acceleration, angular velocity, orientation). Piezoelectric force plates embedded in the flooring measure reaction forces during contact

**ROLE MODELING**

**THE LAB** University of Southern California Biomechanics Research Laboratory, Los Angeles; Jill L. McNitt-Gray, director.

**OBJECTIVE** To improve physical performance and reduce the risk of injury during strenuous physical activity by optimizing the interaction of the nervous system, musculoskeletal system, and the physical environment.

**DEVELOPMENT** Real-time feedback and analytical tools (sensors, electrodes, high-speed motion cameras, piezoelectric force plates) for evaluating the stresses involved during physical movement.

with the ground. Electrodes allow researchers to monitor the on-and-off patterns of muscles activated during the performance of the task. These same tools can be used to provide real-time and immediate feedback to the clinician, performer, and researcher.

"For example, when working with our Paralympic sprinters, we can provide information about how they accelerated their bodies during the first few steps of the sprint start by integrating the high-speed video and reaction forces measured during contact with the ground," McNitt-Gray said. "This information can be used between attempts to clarify and track improvements in how horizontal impulse generated during foot contact contributes to increases in horizontal velocity of the body. We can also make personalized changes to a training program and/or the fit of an assistive device to improve performance and reduce the risk of injury."

The lab is also using biomechanics to engage and stimulate the next generation of STEM (science, technology, engineering, and mathematics) students. Graduate students work with local K-12 teachers to engage students in the study of how the body works. These efforts have ranged from after-school workshops and volunteering in the classroom to summer camps for female students who want to improve athletic skills. ME

Adaptive cruise control, which is a system designed to maintain a safe distance between vehicles, is touted as a major safety advance. But too often drivers don't use ACC as intended.

"There are many limitations associated with ACC systems," said Linda Ng Boyle, director of the Human Factors and Statistical Modeling Laboratory at the University of Washington in Seattle. "Our studies show that over 50 percent of drivers who own vehicles with this system are not aware of the limitations."

Boyle's lab is conducting a research project funded by the National Science Foundation to study how drivers interact with ACC. Boyle and her team used data from on-road studies of new ACC users in natural driving environments, driving simulator studies that replicated at-risk driving scenarios, and drivers' assessments of their driving habits and perceptions. Instrumentation in the car and simulator recorded speed, acceleration, and how quickly the drivers braked while the ACC was in use.

A statistical technique called cluster analysis was used to group drivers according to various driving performance measures. This revealed which drivers were more likely to set their cruise speeds at higher-than-posted limits and initiate closer gap settings.

"There are different types of ACC users," Boyle said, "those who are more likely to take risks and those who use ACC more conservatively. Those who are more risky may over-trust ACC and use it in situations they should not—for example, assuming the ACC system will take control in situations when it may not."

Current research projects include evaluating naturalistic driving behaviors and performance of commercial vehicle drivers and how much text drivers can read and input while driving without decreasing their safety.

Researchers studied how subjects operating a driving simulator behaved when adaptive cruise control was in use.
*Photo: University of Washington*

In addition to driver behavior, Boyle said the lab also looks at operator behavior in health care and manufacturing.

"Our focus has moved toward the design of increasingly autonomous systems, given that the human is still in the loop and will most likely be involved for many years to come," Boyle said. "We look at designing and understanding the interaction of systems that are adapting to the human, as the human is adapting to the system." ME

**MALADAPTIVE DRIVERS**

**THE LAB** Human Factors and Statistical Modeling Laboratory, University of Washington, Seattle; Linda Ng Boyle, director.

**OBJECTIVE** To enhance driver/operator safety by using appropriate analytical tools to reduce the risk of injuries and fatalities.

**DEVELOPMENT** Primary research for developing guidelines for driver distraction, and to identify intervention methods that can help drivers get to their destinations safely.

**MARK CRAWFORD** is a geologist and writer based in Madison, Wis.

Institution of MECHANICAL ENGINEERS

# PRESTIGE AWARDS 2016

The Institution of Mechanical Engineers is committed to recognising excellence and encouraging the highest standards in mechanical engineering. That's why it awards more than 400 prizes for outstanding merit and achievement in a variety of fields and areas of expertise. These accolades include the Prestige Awards – an eminent collection of prizes that celebrate excellent engineering, in academia and professional practices.

The Prestige Awards act to champion engineers who can truly be said to have improved the world, or advanced the discipline of mechanical engineering. There is real breadth to the Prestige Awards. They cover individuals and organisations and all grades of membership and non-members from across the world. They provide a unique opportunity for individuals or groups to share the results of their work with a wider audience and truly celebrate their achievements.

## JAMES WATT INTERNATIONAL GOLD MEDAL

The James Watt International Gold Medal is a prestigious award that recognises the lifetime achievements of engineers from across the globe. Having such a wide remit and scope, it's no surprise to find that previous winners have been hugely impressive individuals with truly distinguished careers.

That was certainly the case when Professor Richard Parry-Jones, CBE BSc FREng FIMechE FRSS, was awarded the James Watt International Gold Medal for his contributions to vehicle development in the areas of driving dynamics and refinement, and for his technical vision and guidance to steer the UK automotive industry towards a prosperous and successful world-class future.

Parry-Jones has enjoyed a stellar career, having graduated with a First in mechanical engineering at Salford University in 1969, and going on to join the research and development centre at Ford's Dunton plant in Essex, UK. He is credited with transforming the appeal of Ford cars, making them wonderfully connected, responsive and smooth, through meticulous attention to detail in the development of vehicle attributes. His team developed a set of industry-leading metrics, and of particular importance was the way the dynamic performance was measured using objective data. He devised the '50m test' to help evaluators focus on how to sensitise themselves to understanding the subtle nuances of many dimensions of human/vehicle interaction.

Following his retirement from Ford in 2008, Parry-Jones leveraged his experience into a wider variety of roles which include technology consulting, industrial non-executive directorships and public service, and he has been actively involved in the development of industrial policy through the Automotive Council UK, which he chaired jointly with the then BIS (UK Department of Business Innovation and Skills)

## JAMES CLAYTON PRIZE

First awarded seventy years ago, the James Clayton Prize is regarded as the most prestigious annual award made by the Institution to a member(s) of the Institution in any grade (Affiliate to Fellow), recognising exceptional contribution to mechanical engineering and related science, technology and invention. Achievement is best demonstrated by way of a recent product or research project, or experimental work, from either an industrial or academic source in any geographic location over a typical period circa the past 5 years.

Andy Cowell CEng FIMechE, the managing director of Mercedes AMG High Performance Powertrains Ltd, clinched the award for his outstanding contributions to engine design and development in the Formula One world, especially V10, V8 and the new V6 with Hybrid Energy Recovery System. He was also been recognised for his inspirational leadership at Mercedes-Benz.

After graduating from Lancaster University, Cowell joined Cosworth Racing on its graduate scheme before specialising in the design and development of Formula One engines. By 1999, Cowell was leading the engine project group responsible for the top end of the innovative CK engine as raced by Stewart Ford.

After a year spent with BMW Motorsport, where he managed the engineering group responsible for the concept and detail of the 2001 engine used by Williams BMW, he returned to Cosworth as principal engineer for F1 design and development, managing the new engine projects in 2001 and 2003.

Cowell then joined Mercedes-Ilmor in 2004 as principal engineer for the FQ V10 engine project. He was then Chief Engineer on the V8


ANDY COWELL


PROFESSOR RICHARD PARRY-JONES

Secretary of State, the Rt Hon. Vince Cable.

Such an extensive and varied career means that Parry-Jones is regarded as one of the world's most highly-respected engineers. But despite his achievements, Parry-Jones remains a modest individual, and he says that he was astonished to have received the accolade. "I found out I had won by letter from the President of the Institution. I am not usually speechless, but this time I was!" he says.

He was pleased and flattered, if slightly wary of sharing the honour of this prize with other such eminent engineers. "When I compared what I have done with some of the previous winners, I didn't really feel that I was in the same league, but my peers had nominated and voted for me, and out of respect for them I humbly accepted."

**APPLICATION DETAILS:**

*The Institution awards every two years a Gold Medal to an eminent engineer who has attained worldwide recognition in mechanical engineering in any direction - science and research, invention, and production. The award is open to Institution members as well as non-members.*

*Closing date for all application is **31 March 2016**. Find out more at imeche.org/prestigeawards.*

project before taking on responsibility for the technical and programme leadership of all engine projects, including the KERS hybrid. He was engineering and programme director for Mercedes-Benz High Performance Engines from 2008 until 2013, when he became Managing Director of Mercedes AMG High Performance Powertrains.

Cowell has always been an active member of the Institution, and has supported the Formula Student automotive competition for many years. So he was delighted when the Institution recognised his achievements, awarding him the James Clayton Prize for his contribution to modern engineering science. "It was a complete surprise to learn that I had won, and not something I ever imagined I would be awarded with. Looking at the list of previous recipients, it's humbling to think the Institution regards me as worthy of being added to such a prestigious list.

"I've had the good fortune to work with some exceptionally talented engineers, both past and at present. It's exciting to be achieving things in the future that today people believe are impossible. Engineers have the opportunity to amaze the world."

**APPLICATION DETAILS:**

*Awarded to a member(s) of the Institution in any grade (Affiliate to Fellow) for an exceptional contribution to mechanical engineering and related science, technology and invention. Candidates are permitted to self-nominate. All nominations must be supported by a Proposer and Seconder. The prize comes with a £10,000 award.*

*Closing date for applications is 31 March 2016. Find out more at imeche.org/prestigeawards*


**THE INSTITUTION IS KEEN TO RECOGNISE INNOVATION AND EXCELLENCE IN ACADEMIA, AND DOES SO THROUGH ITS WIDE RANGE OF PRESTIGE AWARDS.**

If you have an engineer or an organisation who you think are worthy of nomination or indeed would like to nominate yourself (James Clayton Prize), then now is the time to act. Applications for the 2016 awards are now open, with a closing date of **31 March 2016**. The winners and their respective nominators will be invited to celebrate their achievements at a ceremony and annual dinner held in London.

**OTHER PRESTIGE AWARDS INCLUDE:**

- **Alastair Graham-Bryce Award** – Awarded to an individual or group making a significant contribution to the encouragement of young people towards a career in engineering. *Eligibility: Members and non-members. Prize: £5,000*
- **IMechE Award for Risk Reduction in Mechanical Engineering** – Awarded to any eminent engineer who has contributed the most in the understanding and/or reduction of risk in any area of mechanical engineering. *Eligibility: Members and non-members. Prize: £1,000*
- **Thomas Hawksley Gold Medal and George Stephenson Gold Meda**l - Awarded for the best original papers published by the Institution in the past 12 months. *Eligibility: Members and non-members. Prize: Gold medals*
- **The Verena Winifred Holmes Award** – To recognise individuals who have achieved by undertaking a unique challenge or experience to benefit people from groups with different needs, or those with a past record of disadvantage or low participation. *Eligibility: Members of the Institution. Prize: £1,500*

For details on all of the awards on offer and eligibility criteria, please visit imeche.org/prestigeawards or E: prizes@imeche.org T: +44 (0)1284 717887

LOOKING BACK

Accused of catering to the nuclear industry, the editors of the magazine said they wanted "to give both sides of the story," when they published an article by Ralph Nader in February 1976.

# NUCLEAR POWER: MORE THAN A TECHNOLOGICAL ISSUE

BY RALPH NADER, PUBLIC CITIZEN INC.

*A leading environmental and consumer-protection advocate presented objections raised by opponents of nuclear power.*

**Although the national debate on nuclear power is intensifying**, some engineers and scientists view the nuclear issue as merely a technical one. Technologists such as Ralph Lapp and Norman Rasmussen condescendingly dismiss all doubts. If ordinary people will just leave nuclear power to the "experts," they feel, all the problems will be solved or disappear.

Of course, this technical elitism has been severely undercut by more than 2,000 scientists and engineers who recently stated that the risks of nuclear power were "altogether too great" and urged a national energy policy based on energy conservation and nonnuclear power.

But although this scientific controversy exists, the debate on nuclear power cannot be based on technical issues alone. Nuclear power is fraught with, if not dominated by, issues that are institutional and political rather than technical. There are technical issues, to be sure, but even these are ridden with controversy and unresolved problems.

Reactor safety is one example of an unsettled technical question. In August 1974, the Atomic Energy Commission released a draft report which concluded that the chances of a major nuclear reactor accident were equivalent to the chances of a meteor striking a large city. From the fanfare with which the report was released, it is evident that the AEC and the nuclear industry hoped the report would lay to rest all concerns about reactor safety. But these hopes were not realized. The severe weaknesses of the report have contributed to greater skepticism over nuclear power.

At the outset, it should be emphasized that the report, *Reactor Safety Study*, only presumed to cover nuclear reactors themselves. The report did not cover the transportation of radioactive materials by truck, rail, and barge; the disposal of radioactive wastes; the risks of sabotage, theft, or terrorism; fuel reprocessing plants; or uranium mining processes and wastes. ME

## TESTING IN DEPTH

Ralph Nader's article appeared in *Mechanical Engineering* during the age of underground testing of nuclear weapons. On January 3, 1976, the Nevada Test Site saw its deepest underground test. The United States exploded a nuclear device with an 800 kiloton yield at a depth of 1,452 meters. There were a few tests elsewhere at greater depth. The deepest was conducted in September 1969 in Colorado at 2,570 meters, with a yield of 40 kt. A 5 kt device was detonated at 1,790 meters under Alaska in November 1971.

Baneberry, with a yield of ten kilotons, was buried about 278 meters beneath the surface. When detonated on Dec, 18, 1970 at the Nevada Test Site, it released radioactive material into the atmosphere. *Photo: National Nuclear Security Administration / Nevada Site Office*

## TECHNOLOGY SNAPSHOT

### INDUSTRY OVERVIEW

Smart drug delivery or targeted drug delivery is a collection of technologies that will improve the concentration of a drug and absorption by the tissue or organ it is intended for. This manner of drug delivery will result in fewer side effects and improve therapeutic potential. Some of the major areas of focus are oncology, autoimmune disorders, neurological disorders, cardiovascular diseases, pulmonary disease, and ocular disorders. These diseases currently have a high need for advanced drug delivery technologies that will improve the safety, effectiveness, and efficiency of the drugs that are being administered.

### DEVELOPMENTS

- This market is growing rapidly due to the steady growth of nanotechnology, biomarker discovery, and genetic engineering.
- Researches in nanocarriers, cell surface receptors, and biodegradable materials will improve the efficacy and efficiency of the drug that is being delivered.
- Novel developments are also emerging in targeted drug delivery in terms of improving the type of physical administration of the drug (oral, injectable, or non-injectable). These will also have a direct impact in improving the safety and efficacy of the drugs that are currently available in the market.

—Frost & Sullivan, *Top Health and Wellness Technologies in 2015*

**16,072**

**TOTAL PATENTS/ PUBLICATIONS 2013-2015**

# BY THE NUMBERS: BIOTECH ON TARGET

## NEW TECHNOLOGIES THAT CAN DELIVER THERAPEUTIC CHEMICALS TO THE CELLS THEY NEED TO TREAT ARE REACHING THE MARKETPLACE.

Everyone knows you need to be pretty sharp to be a doctor, but these days the drugs themselves are getting smart. By increasing the concentration and absorption of therapeutic drugs by the tissue or organ they are intended for, pharmaceutical companies are improving the effectiveness of medication while reducing the potential side effects.

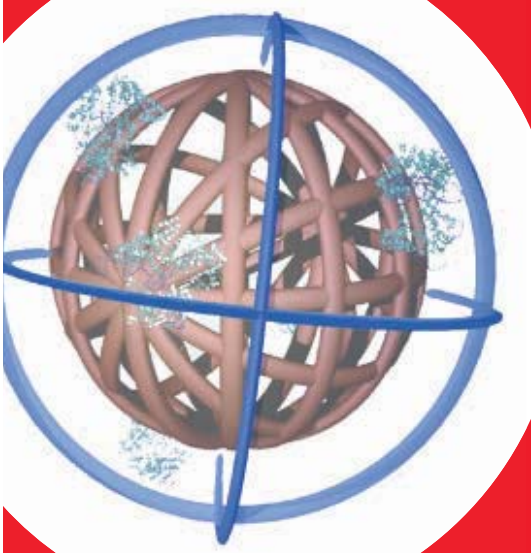
Last year Frost & Sullivan, the market research and consulting firm based in San Antonio, Texas, looked at a suite of what it called the health care technologies of the future, and targeted drug delivery was in the top ten. According to Frost & Sullivan, advances in nanotechnology, biomarker discovery, and genetic engineering have contributed to the technology's growth.

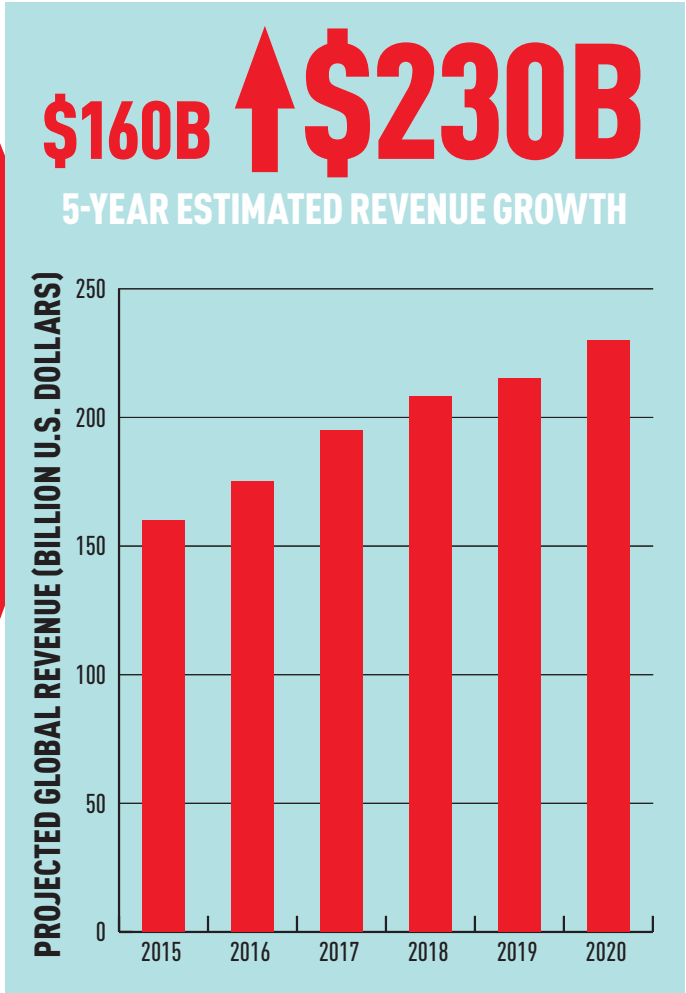
"Novel developments are also emerging in targeted drug delivery in terms of improving the type of physical administration of the drug (oral, injectable, or non-injectable)," the report states. "These will also have a direct impact in improving the safety and efficacy of the drugs that are currently available in the market."

The report shows that targeted drug delivery patents are on the rise, with both the U.S. and China each issuing more than 3,900 from 2012 to 2014. Frost & Sullivan predicts revenues for pharmaceutical companies from targeted drug delivery systems will increase from $160 billion in 2015 to $230 billion in 2020.

The report states that nanoscale systems will be the predominant means for delivering these drugs to the target tissues. Abraxane is one example of a nanoparticle-based drug delivery product developed for carrying cancer therapeutics.

"Certain blockbuster drugs that performed well in clinical trials did not meet expectations when utilized in






Source: Frost & Sullivan

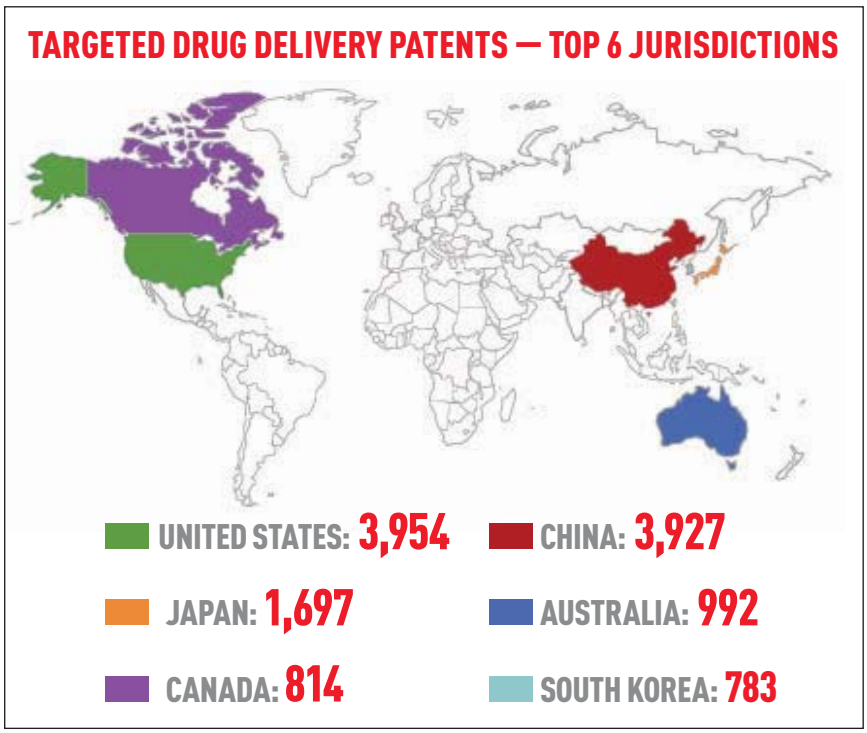
real patients, largely due to poor drug delivery techniques and lack of biocompatibility," the report says. "Pharmaceutical companies are heavily investing in this space; they want customized drug delivery platforms developed from well-validated technologies so that they can move into the personalized medicine era with ease."

But while Frost & Sullivan is bullish on this sector, it did have a note of caution.

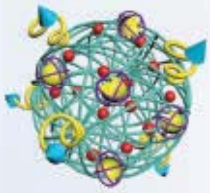
"There are currently no long-term study results on the potential hazards of nanotechnology-based therapeutics," the report says. "This lack of knowledge has left many skeptical in the industry, which negatively impacts its growth."

For more information on this field, turn to this month's cover feature, "Neat Little Packages," on page 30. ME

JEFFREY WINTERS



# NEAT LITTLE PACKAGES



# Engineering creates delivery systems that harness genetic medicine—even as researchers still struggle to understand it.

By Alan S. Brown

When Layla Richards was only 14 weeks old, she was diagnosed with acute lymphoblastic leukemia, a type of cancer that kills three quarters of the infants who contract it. Her doctors at Great Ormond Street Hospital in London immediately started the standard treatment—chemotherapy to kill the cancer and a bone marrow transplant so her body could replace her damaged blood cells—and hoped for the best.

Seven weeks later, the cancer returned.

The doctors then tried an experimental treatment. That also failed.

The doctors told her parents that Layla faced certain death and gently suggested palliative care.

In another part of Great Ormond Street Hospital, Waseem Qasim, a professor of cell and gene therapy at University College London, was treating mice by genetically modifying their immune cells. Immune cells are nature's first line of defense against disease. They are designed to attack any foreign body. Unless they are a very, very close match, immune cells transplanted from one animal into another will also attack their new host.

Working with mice, Qasim had shown he could genetically modify immune cells from donors so they would ignore their new host. He did that through use of an artificial enzyme called TALEN (for "transcription activator-like effector nuclease"). Like a pair of robotic scissors, TALEN hunts down and cuts DNA at a pre-programmed location. Once the DNA is cut, Qasim can add or subtract genetic material or even an entire gene. That enables him to alter the DNA's code, and therefore the cell's behavior.

Instead of going after the host, Qasim's altered immune cells targeted only leukemia cells. Qasim also found a way to boost the immune cell's resistance to a powerful drug used in the treatment.

When Layla's parents were told about Qasim's work, they were adamant about going ahead with what was a treatment that had never been tested on humans.

"We didn't want to accept palliative care, and so we asked the doctors to try anything for our daughter, even if it hadn't been tried before," her mother, Lisa Foley, said.

At that point, however, Qasim had just begun the laborious process of treating enough immune cells to test for safety on humans. He had only enough to fill one vial. Layla was injected with 1 ml of the experimental cells.

Within a few weeks, Layla's health improved. After two months she was without cancer and had received a bone marrow transplant so that she could begin making her own immune cells. One month later, in the fall of 2015, Layla returned home.

Stories of genetics-based cures like this make it seem as if we live in an age of medical wonders. And to a certain degree, we do. But for all the advanced proposals for treating intractable disease, says Matthew Porteus, associate professor of pediatrics at Stanford Medical Center, there is still one pressing problem. He and his colleagues need better delivery systems.

"You can have the fanciest ideas and molecules," said Porteus, who himself was the first researcher to modify genes in human cells at rates high enough to cure diseases. "But if you can't get them into the cell, they are no use," he said.

Better delivery systems will take engineers.

## The Package

Although the cancer treatment that Layla Richards received was a first, the concept of genetically modifying cells in a Petri dish and injecting them into a patient, as Qasim did, is fairly standard. Ideally, though, physicians would like to deliver genetic medicine to cells inside the body. It is the only way to attack cancer and disease where they live. It would also make it easier to treat genetic diseases by changing the DNA in cells that continue to divide and multiply.

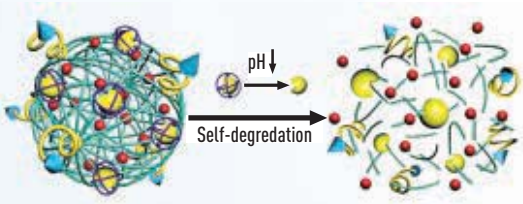



*Image: Zhen Gu*

Zhen Gu's DNA "nanoclew" has ligands on its surface that bind to receptors on the surface of cancer cells. It is then absorbed inside the cancer cell, whose acidic environment destroys the polymer sheath containing enzymes that slice through the DNA cocoon, spilling anticancer drugs into the cancer cell and killing it.

Doing that, however, increases the difficulty for delivery systems. In addition to convincing the targeted cells to open up and accept a gene-altering payload—no mean feat—in-body systems must first find the right cells and also protect their package from the body's immune system.

Fortunately, researchers have been learning how to do that for more than 20 years while developing nanoscale drug delivery systems. Those solutions have now moved into the mainstream, said Mark Saltzman, a Yale University professor of biomedical and chemical engineering and physiology. Saltzman has published more than 300 papers in the field.

"The pharmaceutical industry was built on the notion that if you find the right chemical or compound, everything is going to be okay. If it has dangerous side effects or lacks effectiveness, you just tune the drug's chemistry," Saltzman said. "What's different now is that we can achieve greater safety and effectiveness by changing the packaging instead."

Pharmaceutical companies do that with doxorubicin, a cancer drug that also causes heart disease. Entangling the drug in liposomes, sac-like structures made from fatty acids, keeps it from interacting with heart cells or other tissues. And because the liposomes are smaller than 100 nanometers in diameter, the body's immune system ignores them. They are small enough to pass through the leaky blood vessels that surround tumors, and cancer cells have no mechanism to remove them.

The fact that fatty acids are common molecules helped allay Food and Drug Administration concerns about the packaging, Saltzman said. Doxorubicin became the first FDA-approved nanomedicine in 1995.

Since then, packaging has grown a great deal more sophisticated. Saltzman's work is a case in point. He prefers to work with synthetic polymers, for example, because they offer a great deal of flexibility. The polymers enable him to package two or more medicines at a time and control precisely how fast the packages will release their payloads. Also, since artificial materials do not trigger immune responses, he can deliver very high doses of medication without a reaction.

Saltzman draws on decades of research to target specific types of tissues or cells.

"People have been studying cancer for a long time," Saltzman said, "and some characteristics of cancer cells are well known. For example, they reproduce rapidly, and need to accumulate folate molecules to make DNA. We put folate on the surface of our molecules, and cancer cells think

they are folate and ingest them. We also put cell-penetrating peptides on the surface to speed uptake once the cell recognizes the package."

Saltzman developed a range of approaches to deliver cancer drugs. Yet many of these techniques would adapt easily for genetic medicine. In fact, many researchers are already putting them to work.

> "You can have the fanciest ideas and molecules, but if you can't get them into the cell, they are no use."
>
> — Matthew Porteus, associate professor of pediatrics at Stanford Medical Center

## The Ball of Yarn

Arcturus Therapeutics in San Diego bills itself as an RNA medicines company. Cells use RNA to carry instructions encoded in the DNA to ribosomes, structures inside the cells that build proteins to spec; by interfering with that process, RNA medicines can disrupt the formation of proteins that cause disease and tumor growth.

In June, Arcturus signed an agreement to commercialize RNA medicines with Janssen Pharmaceuticals, a Johnson & Johnson company.

Arcturus wants to package these RNA medicines using a fatty acid-based nanoparticle system, a delivery technology that it calls "lipid-enabled and unlocked nucleic acid modified RNA" (so that its acronym can be LUNAR).

The company says this is an advance over previous lipid-based delivery systems. In those systems, lipids were made from permanently charged molecules called quaternary amines; their positive charge held negatively charged medicines and RNA molecules in place. Unfortunately, the charged particles accumulated in body tissues the way balloons with a static charge stick to a wall.

"That's not a problem if you deliver one or two doses," said Arcturus CEO Joe Payne. "But if you are dosing every day, every week, or even every month, it is a problem."

Arcturus's solution is a biodegradable lipid with a temporary charge, just enough to wrap medicines and RNA in a loose, yarn-like bundle. When the bundle reaches the targeted cell, the cell engulfs it, trapping it in a small sac that travels into the cell. By the time that sac breaks down, the lipid has fallen apart, releasing its medicines or RNA to go to work in the cell.

To target specific cells, Arcturus follows Saltzman's playbook. It decorates the LUNAR surface with different molecules, and also changes its size, shape, and charge.

This yields some surprisingly sophisticated systems. For example, Arcturus attaches small umbrella–like structures to LUNAR. They hook onto liver tissue, allowing the package to break free and enter the cells.

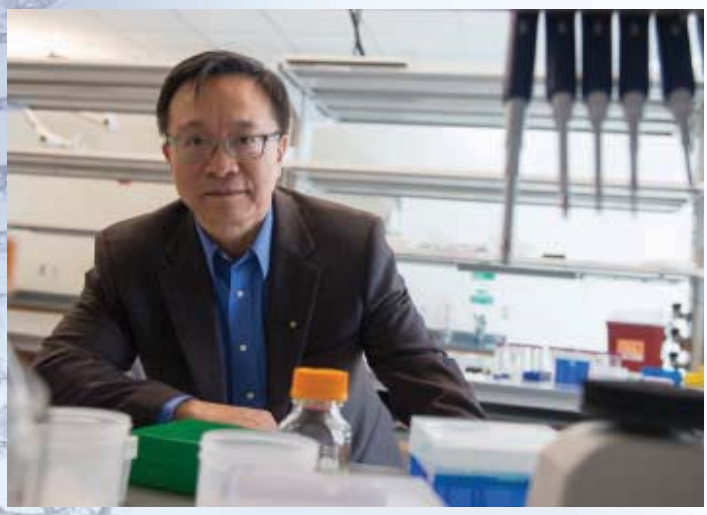
"A lot of this sounds like science fiction, but it's real," Payne said.

It must seem that way to Andre Watson, chief technology officer of Ligandal, a fledgling Silicon Valley startup building delivery systems for genetic medicines.

Three years ago, Watson was an undergraduate at Rensselaer Polytechnic Institute looking for a project he could work on in graduate school. A professor pointed him towards delivery systems.

Watson quickly hit upon the strategy of building a multilayer package. The outside layer would target specific types of cells. Once inside, it would disintegrate, leaving behind a second package containing scissor enzymes and genetic material.

Watson makes both shells from peptides. "Peptides are the way biology presents information. They dictate where things go inside the cell," he said.



"This is the most important question for genome editing, how to raise the percentage of template-based repairs."

Gang Bao, ASME Fellow, Nanomedicine Center for Nucleoprotein Machines, Rice University.

Watson leverages this by programming the peptide shell to carry its genetic payload into the cell nucleus, where DNA creates RNA. By targeting the nucleus and tuning his peptide package to disintegrate slowly, Watson can flood the DNA with active genetic material for weeks at a time. As a result, he claims he can achieve gene replacement rates that are much higher than standard processes.

Watson came to Silicon Valley with $1,500, but Ligandal has lined up $500,000 in angel investments. The company is working with several leading researchers and pharmaceutical firms, and plans to begin publishing results soon, he said.

If Watson is still trying to build his reputation, Zhen Gu has begun to establish one. He was named one of MIT Technology Review's 2015 list "35 Innovators Under 35," in part for an injectable nanoparticle package that breaks down and releases insulin when it encounters high levels of sugar in the bloodstream.

Gu, an assistant professor in University of North Carolina-North Carolina State University's Joint Department of Biomedical Engineering, is now seeking to do something similar by packaging genetic materials in DNA.

He calls his system a nanoclew, after a clew of yarn, because it looks like a tightly wound ball of DNA. The DNA is shaped to hold gene-cutting material as well as polyester groups that give it an electrical charge that promotes uptake in cells.

At the cellular level, Gu's DNA creations look good enough to eat, and cells do ingest them. The DNA, although biocompatible, is artificial and does not trigger an immune response.

To test the system, Gu's team gave mice tumors that had been modified to produce green fluorescent proteins. The researchers then programmed their nanoclews to cut out the DNA that made those proteins. According to Gu, about one third of the cancer cells stopped fluorescing after treatment.

## The Template

The human body is made up of a couple of hundred different types of cells—blood, brain, muscle, skin, and so on, not even counting the microbial hitchhikers—and it is improbable that any one type of packaging will reach them all. As engineers test the design of delivery systems, they will find themselves working with scientists to understand how all the pieces fit together.

The gaps in science's understanding come across clearly when talking with Gang Bao, an ASME Fellow who heads the Nanomedicine Center for Nucleoprotein Machines at Rice University in Houston.

Bao has been working on genetic cures for sickle cell anemia. It is a promising application for genetic therapy, since a single mutation in a single gene in just one type of stem cell causes the disease. This gives Bao a very specific target to attack.

His game plan sounds simple: remove the stem cells that make blood cells from the bone marrow; splice in a gene segment to fix the mutation; and then inject the modified cells back into the bone marrow so they can produce healthy red blood cells. Executing the plan has proven difficult, which is one reason why Bao has been working on the problem since 2008.

For instance, Bao uses CRISPR—a powerful, low-cost genome-editing technology—to break DNA strands. Cells repair 95 percent of those breaks by rejoining the broken ends the way we might tie a broken shoelace. Often, this introduces small mutations into the gene, destroying its ability to produce RNA. This technique helps eliminate unwanted or dangerous proteins.

The other 5 percent of the time, however, cells use a molecular template to build and then insert a new gene into the missing gap. Bao hopes to take advantage of this mechanism to alter genes and reprogram anemic stem cells to make healthy red blood cells.

"This is the most important question for genome editing, how to raise the percentage of template-based repairs," Bao said. "We must learn to control which type of repair the cell selects, or how to separate the properly corrected cells from those with end-to-end repairs so they do not compete with each other when we replace them in the patient."

Bao is also tackling another template repair problem, when scissor enzymes sometimes make the wrong cut. CRISPR targets DNA by looking for a specific sequence of 20 pairs of molecular building blocks that form DNA. Human DNA contains 3 billion pairs, so that sequence is likely to appear in several different places. Scissor enzymes also may sometimes settle for getting 19 out of 20 pairs right.

Bao calls this off-target cleaving, and it could lead to unwanted mutations and unexpected side effects. He is developing a web-based tool that will rank DNA segments by their vulnerability to off-target cleaving.

"We can show researchers the problem, but we do not have a way to fix it yet," he said.

## The Future

Bao's realism is bracing when set against the rise of venture capital-backed genetic medicine companies. The technology is risky. This is why Ligandal's Andre Watson describes the ideal test subject as someone in the late stages of a rare, lethal disease. Most other researchers would agree.

Yet the future is coming fast. Watson, for example, imagines that clinics 30 years from now will sequence patients' genomes and biopsy their conditions, and prescribe treatments that target the precise cause of disease.

That may seem like more fiction than science. But this time last year, so were the genetically modified immune cells that cured Layla Richards's cancer.

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

# MAKING


**A privately funded high-speed rail line promises to whisk passengers from Houston to Dallas at 200 mph. But building the project may divide rural areas even as it unites cities.**

## PRAIRIE HOME

The countryside in Ellis County, Texas, shown here, could soon be split by the grade-separated tracks of the Texas Central Railway. The high speed line will use Japanese bullet-train technology (opposite).

*Photo (opposite): Texas Central Railway*

# TRACKS

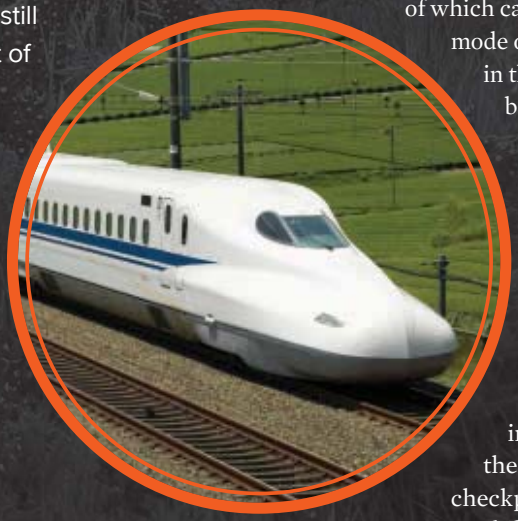
By Bridget Mintz Testa

At first, Marty Hiles was delighted to hear that a high-speed railway–the Texas Central–was going to travel through rural Ellis County, Texas, where Hiles lives. Ellis County is just south of Dallas, part of the 7 million-person Dallas-Fort Worth Metroplex, and its economy is dominated by the city. The county had been the site of the ill-fated and long-since canceled Superconducting Super Collider, a gigantic particle accelerator that had begun to be carved out of the underlying chalk. The place still needed development "to get it out of the shadows of Dallas," said Hiles, who is a veteran lobbyist and local booster.

"TCR seemed to offer a great opportunity to bring business there," he said. "We worked on an economic development summit for Ellis County involving universities, government, business, and the cities." Hiles formed a group, Texas Concerned Citizens, to hold the economic development summit. He thought the Texas Central would play a big role in his plans.

But after Hiles and his group attended the first TCR meeting in Dallas, Hiles said, "I came home dumbfounded. There would be no underpasses—just berms. It would be like the Berlin Wall."

There would be no stops, either. Hiles said the train would simply "fly over" his county, with no economic benefit except possibly a little residual business from the Dallas station. That was the plan for all the counties between Houston and Dallas.



It's easy to believe in high-speed rail when you are sitting in jammed traffic on Houston's Katy Freeway—all 26 lanes of it—or wasting four hours at DFW for a 90-minute flight. High-speed rail, such as that in Europe, Japan, and now China, is promoted as beautiful, comfortable, quiet, pleasant, convenient, and, of course, fast, none of which can be said about any mode of transportation in the U.S. In Europe, bankers take the Eurostar from London to Paris for lunch (it's just two hours away) and then head back.

Shouldn't we be as civilized when we travel, rather than holding our shoes at the airport security checkpoint?

But while high-speed rail backers have spent decades trying to get Americans on board, it has been a losing battle up to now. Amtrak's Acela, which is as fast as it gets in the U.S., barely qualifies as "high speed" and elected officials pick up more votes for slashing subsidies and canceling projects than for greenlighting them. Indeed, the Republican majority in Congress has imposed a ban on federal subsidies for high-speed rail projects.

Even in the face of that opposition, projects are going forward. In California, a long-gestating HSR project is being funded with state money. And in Texas and elsewhere in the U.S., entrepreneurs are seeking investment to build privately owned passenger railways.

In 2015, for instance, the TCR obtained $75 million in its first round of fundraising, a step toward the $10 billion it will need to build the route.

What those private companies are finding, though, is that it is easier to draw up a business plan than to build a railroad.

Texas is big. Houston is about as far from El Paso as Paris is from Vienna—and no one is suggesting that Texans or Americans generally are going to ditch their cars in favor of mass transit. But two points suggest that high-speed rail could find a niche here. First, a survey of 1,005 Americans from September 2015 showed that, once informed of high-speed rail's benefits, 63 percent of them (including 65 percent of Republicans) would use such a service if it were available today. Previous HSR surveys have shown that even "car people" aren't opposed to giving up their cars for long trips.

The second point is that Amtrak hit new—positive—financial records in 2014. The U.S. passenger rail company generated record revenue of $3.2 billion and the lowest operating loss since 1973—$227 million. Moody's Investors Service, a company that rates the creditworthiness of businesses and government agencies, renewed the rail service's rating of A1, the best possible.

Also, the business case for a high-speed rail system is stronger than ever. Michael Ahn, assistant professor of public policy, and Malcolm Einhorn-Russell, senior fellow at the Center for Peace, Democracy, and Development, both at the University of Massachusetts, Boston, believe that high-speed rail is the key to building a nationwide knowledge economy—one that isn't limited to hotspots like Silicon Valley or Cambridge, Mass.

Ahn recently visited South Korea and saw how easy the Korea Train eXpress (top speed: 190 mph) makes business trips and meetings, even impromptu ones.

"You can meet face-to-face in one day," Ahn said. "Face-to-face builds trust. It's different from a video conference. If you can get to New York City in 45 minutes from Boston, everything becomes one city. HSR opens up a lot of opportunities. It lowers barriers to social interactions that include sharing ideas, which are the engines of the information economy."

Einhorn-Russell added, "HSR could be the fuel for economic development in the next decade. Lowering the barriers increases competitive advantages."

The two say that there should be a national strategy where local or regional HSR strategies—like those in Texas, California, Florida, and elsewhere—are linked into a national one. "HSR offers such an explosive model," Ahn said.

It's a model, however, that would have to be built. Amtrak created its Acela corridor out of the remains of an East Coast rail network it inherited when Penn Central went bankrupt in the 1970s. Upgrades to that network have had to fit within the existing landscape of rail infrastructure, some of which is more than a century old, as well as the cities it runs through. Those limitations have made it well-nigh impossible to raise the Acela's average Boston-to-Washington speed above 65 miles per hour (though individual stretches are faster).

Newly constructed track running from one population center to another could increase that average speed considerably. In France, where TGV vehicles are designed to run at 200 mph, dedicated track was

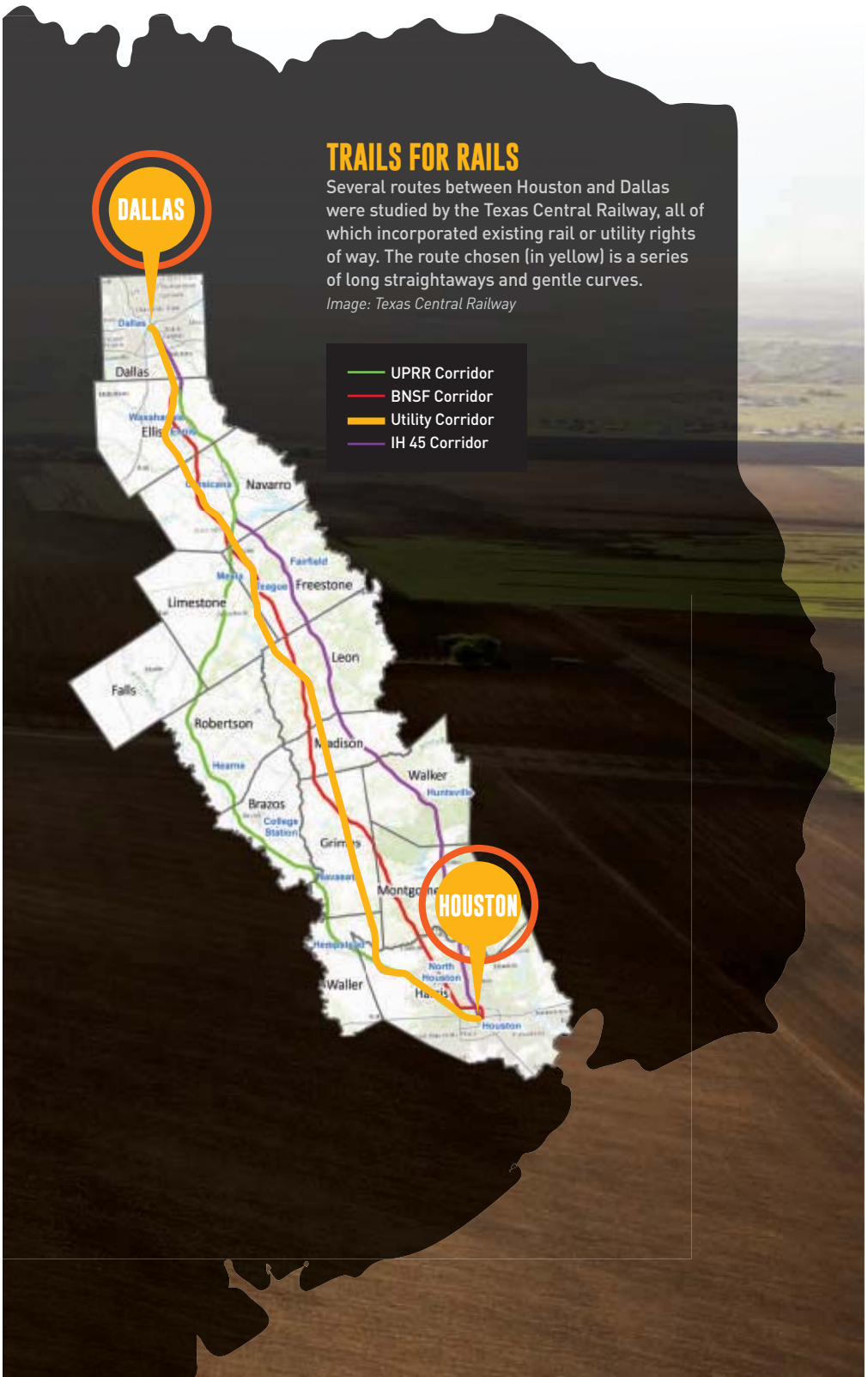
## RAIL CARRIAGES AND PICKUP TRUCKS

The Texas Central promises a comfortable 90-minute ride from Houston to Dallas in modern coaches (inset top), but the route will bypass rural spaces between the major cities.

*Photo (above): Texas Central Railway*

built between metropolitan suburbs; those lines then connect to existing railroads to bring trains (at slower speeds) to stations in the center of the city. A high-speed trip from Paris to Marseilles, for instance, travels more than 400 miles before making its first stop, bypassing every other city along the way. A train that serves every city—decelerating to a stop, then slowly accelerating back to running speed—would take forever.

Unfortunately for businessmen in places like Ellis County, that means watching the train whiz past.




## TRAILS FOR RAILS

Several routes between Houston and Dallas were studied by the Texas Central Railway, all of which incorporated existing rail or utility rights of way. The route chosen (in yellow) is a series of long straightaways and gentle curves.

*Image: Texas Central Railway*

Even more problematic are the tracks. Standard-issue freight track, with its joints and connections and curves, can't handle a train going 200 mph. The track needs tighter tolerances and welded joints to keep the trains from shaking themselves apart.

Indeed, engineering the tracks is one of the biggest challenges in building the TC.

"Texas soils have high clay content," said Shaun McCabe, Texas Central vice president of engineering and environmental. "[This produces] high shrinkage and swelling. Because the track has strict tolerances, there will be geotechnical challenges related to civil structures and corresponding performance criteria relative to the track. The track must be relatively flat. We can't have shrinkage and swelling that has an impact on the track geometry. We'll investigate innovative technologies to ensure stability both for situations where the track is elevated via a viaduct or on an embankment."

Those technologies include various methods to stabilize the soil, such as geo-membranes, which are fabrics that cover the ground to minimize changes in moisture content. Other techniques include driving pilings or using retained engineered fill, where each type of fill is designed to address specific soil issues.

Other challenges are related to the physics of high-speed travel. For instance, to keep down radial acceleration—the force that would push passengers against the wall of the car or throw trains clean off the tracks—high-speed rail alignments have curves so gentle that they look like straight lines. According to a 2015 study commissioned by the Texas Central, "In order to support the desired operating speed of 205 mph, the HSR curves would need to have a minimum radius of 17,060 feet." (Because radial acceleration goes up by the square of the velocity, a track for a hypothetical 300 mph train would need a radius of curvature of more than 7 miles.)

The route that the Texas Central is developing runs along utility corridors in the counties between Houston and Dallas. According to Ellis County Commissioner

Lane Grayson, the utility corridor route is going to cut the county into multiple, virtually isolated segments. "We'll be greatly impacted," Grayson said, "with emergency and school bus routes and farmers who may have to travel 10 to 20 miles to get to their property. Even if we do have elevated sections [of the rail], we don't know if we can get the big farm equipment under it."

The prospect of taking more time for farmers to reach their fields than for London bankers to get to their Paris lunch dates has led to opposition to the project in every county along the TC route—except for Harris and Dallas counties, initially the only places where stations were planned. But in October, the company announced a station for northern Grimes County, between the college towns of Huntsville and College Station.

So, a small victory for "flyover counties," but at a cost measured in time.

"A stop is about seven minutes," McCabe said, "including stop and start."

Texas Central Railway chose the Japanese Shinkansen (almost perfectly rhymes with Wisconsin) bullet train technology for its trainsets and rail. The Japanese bullet train was the first operating high-speed railroad in the world when it was inaugurated in 1964, and it has "demonstrated best-in-class performance and safety with 50 years of no passenger fatalities as a result of derailments or train-on-train collisions," McCabe said. "Nobody else in the world has a perfect safety record."

The Shinkansen established the basic technological template for high-speed rail. Electric power is supplied by overhead lines via a pantograph, the trainsets are lightweight and streamlined, and the trains run over newly built dedicated track. A version of tilting technology, which enables trains to lean into curves and thus take them at higher speeds, was introduced in Japan in the 1970s, but was refined elsewhere and is now fairly universal. Distribution of the motors has differed from system to system, with some using a power car (an electric version of the old steam locomotive) at the front and back, while others distribute the propulsion units along each of the passenger cars.

Since TC is a private venture, it can disregard standard government requirements for minimum U.S. content or States-side manufacture of the equipment. That means the Texas Central can be pragmatic about where its initial buy of 15 eight-car trainsets will be manufactured. The current plan is for all the power and passenger cars to be made in Japan. However, for the Texas Central, McCabe said, "The cars are a very small part of the project costs. We are focused on bringing $10 billion to Texas in jobs for civil works alone."

However, should TC accept any federal funds—which, as of now, is not yet determined—McCabe said, "We're aware of the government's requirements related to different loan programs and will continue to investigate potential sources of capital investment."

In spite of the political objections and technological challenges, maybe the best argument in favor of high-speed rail in the U.S. is the cost of the alternatives.

"Our population forecast is 50 million by 2050," said Orville Thomas, a spokesperson for the California High-Speed Rail Authority, which is building a Los Angeles-to-San Francisco line scheduled to begin limited service in 2022. California's current population is about 38 million, Thomas said, and already travel on the state's congested Interstate Highway System is rising five times faster than the rate at which capacity is being added. Flights between Los Angeles and the Bay Area are the most-delayed in the country.

If the state built enough new highways and airports to handle the worsening

## SLOW TRAFFIC OR FAST TRAIN

California is building a high-speed rail system; one station is illustrated in the photo at the top of the opposite page. While track for bullet trains requires a grade separation, congested freeways (see inset) create much the same sort of barrier.

*Photo (bottom): Texas Central Railway. Photo (top of opposite page): California High-Speed Rail Authority*

traffic from population growth—which some state politicians want instead of building the HSR system—the California High-Speed Rail Authority says it would cost more than twice as much as constructing the rail system. It would also, according to the Authority, mean building 4,300 new highway lane miles, 115 additional airport gates, and four new airport runways, which would total an estimated $158 billion. Operations and maintenance on new highway lanes would cost $132.8 billion for more than 50 years.

And highway building can create the kind of displacement that rail opponents in Texas and elsewhere object to. "Cars provide almost universal freedom of movement, but what car-based development does is almost the same as those big railroad berms," said Raphael Clemente, executive director of the downtown development authority for West Palm Beach, where in 2017 a privately owned, faster-than-Amtrak rail project called All Aboard Florida will connect the city with Miami and Orlando.

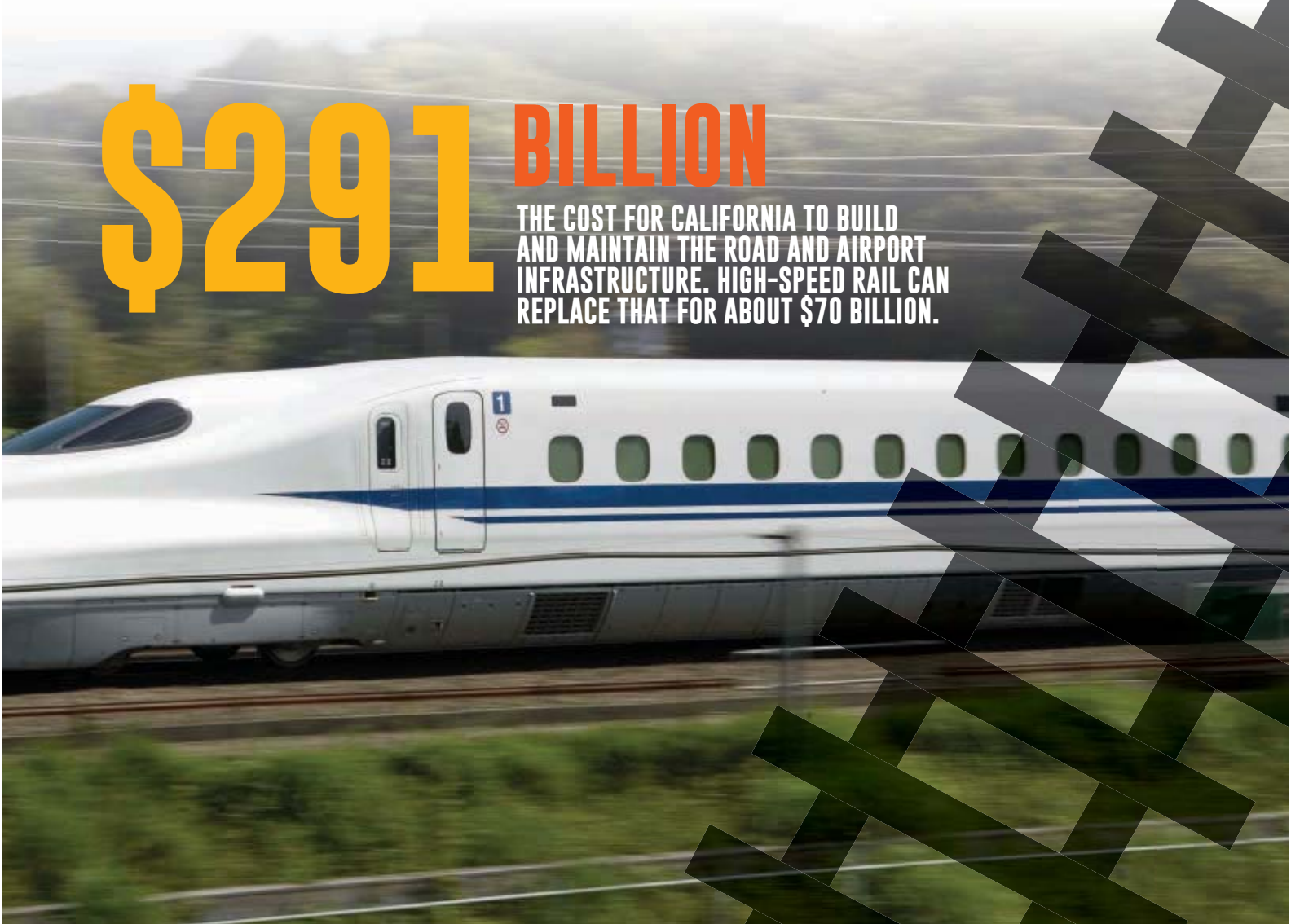
"To get from my neighborhood to downtown, you must cross an eight-lane road," Clemente said. "It splits my city in half."

Inter-regional passenger car travel and three- to five-hour air flights—the kinds of trips high-speed rail aims to supplant—are increasingly plagued by delays, hassles, and bureaucratic security theater. Ahn and Einhorn-Russell at UMass-Boston believe high-speed rail can compete in that market, potentially transforming the way we conduct business and conceive of the national geography.

That is, of course, if the companies building high-speed rail lines can find the right alignments between cities without alienating residents, businesses, and farmers along the way.

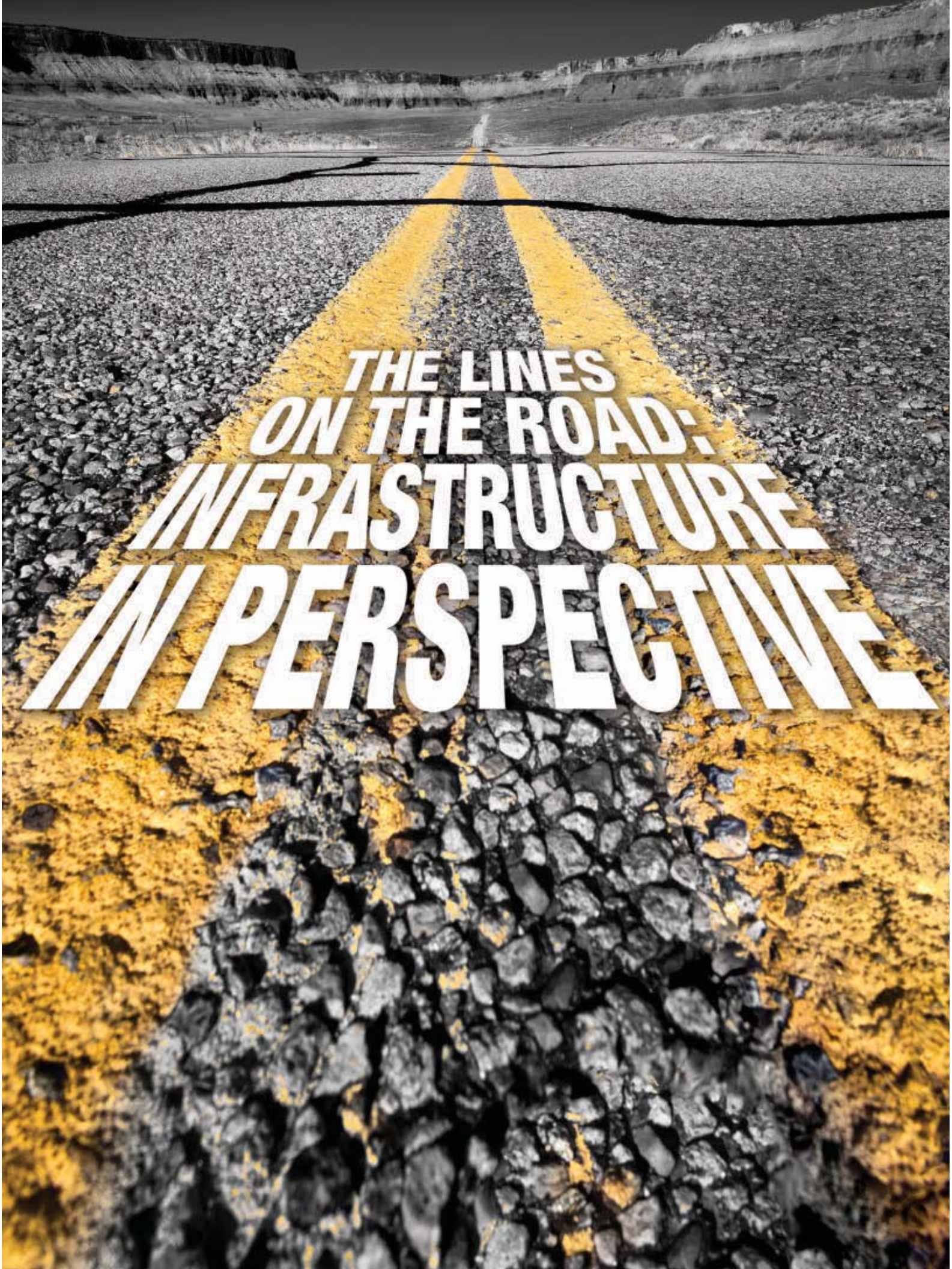
Right now, the HSR reality is gnarly and controversial. But if it can meet the technological, logistical, and even political challenges, it could change the nation. **ME**

**BRIDGET MINTZ TESTA** is a freelance writer based in Houston and a frequent contributor to *Mechanical Engineering* magazine.



**$291 BILLION**

**THE COST FOR CALIFORNIA TO BUILD AND MAINTAIN THE ROAD AND AIRPORT INFRASTRUCTURE. HIGH-SPEED RAIL CAN REPLACE THAT FOR ABOUT $70 BILLION.**



# THE LINES ON THE ROAD: INFRASTRUCTURE IN PERSPECTIVE

BY HENRY PETROSKI

***Infrastructure is a vast, often invisible web, shaped by inspired ideas and politics-driven choices. Understanding the story behind those choices, such as how our roads got their white and yellow stripes, will help us build a better infrastructure in the future.***

Trying to follow barely visible highway lines is a frustration drivers have experienced on many a road, in good weather and bad, in day and nighttime conditions, especially where the lines have become all but totally erased by the rubber tires of traffic relentlessly driving across them.

This is not a new problem, and as long ago as the 1930s the California Department of Transportation—familiarly known as Caltrans—began looking for improved ways to mark highway pavement. However, it was not until the greatly increased traffic and traffic accidents brought about by the postwar boom that serious research began under the direction of the Caltrans engineer Elbert Dysart Botts. The result was slightly raised round pavement markers that came to be known as Botts' dots. When these white ceramic objects were used in place of or in addition to painted lane markings, they not only projected out of standing water on the road but could also be felt and heard when a driver's tires ran over the line they formed. The problem with Botts' dots was that they could be used reliably only in regions of temperate climate, for snowplow blades tended to slice the markers right off the pavement. A variety of raised and depressed reflective lane markings has since been developed, but problems with keeping them undamaged, uncovered, and in place remain.

The visibility of pavement markings has thus continued to be problematic, especially where winter and snow are virtually synonymous. Where salt is used to keep roads clear of snow and ice, its whitish residue masks painted lane markings. During the winter of 2014, the Wisconsin Department of Transportation tested an orange-colored reflective epoxy paint at several locations around the Milwaukee Zoo interstate highway interchange to determine if that color was more readily visible than the federally man-

Botts' dots (above and left) and reflective orange stimsonite markers augment or replace painted lines. They are damaged by snowplows and cannot be used where it snows.


**PEDESTRIAN ZONE:** Crosswalks are believed to have been painted on the streets of New York City for more than 100 years.

dated white and yellow pavement markings even under light snow accumulation and in dark and rainy conditions. Drivers did find the bright orange an improvement, but the results of the test remained to be reviewed by the Federal Highway Administration, which as history shows tends to move slowly.

As late as 1917, pavements on rural highways were unadorned with lines or stripes of any kind. It was supposed to be understood that an automobile was to hug the right side of the road when encountering a vehicle coming the other way. However, when approaching a tight curve to the left, some drivers were accustomed to cutting the corner and so driving on the left side as they rounded it. This was of little consequence when traffic was slow and sparse, of course, but if a fast-moving vehicle coming the other way was hugging the inside of the same curve, the vehicles would encounter each other in a sudden game of chicken that would leave little time to react and escape a collision.

Before there were standardized road signs, especially dangerous curves were marked by local residents in an ad hoc way. A "horror sign" might have featured the image of the grim reaper and the words "Just Around Curve" or a skull and crossbones and the warning "Danger—Go Slo." Such notices were expected to serve as adequate reminders and warnings to the driver to proceed with caution. Marking the road to keep moving vehicles from encroaching upon one another's space is actually an old idea. About five hundred years ago, a road near Mexico City had its centerline defined by stones of a lighter color than the rest of the pavement. This practice persists in some European cities to this day. In the late nineteenth century, bridges on which a collision would likely do damage not only to the vehicles involved but also to the bridge structure itself had lines painted on their road surfaces to lower the risk.

It was also important to control automobiles at crossroads and cross streets and to separate motor vehicles and pedestrians. As early

**The American reinvention of the highway centerline, attributed to Edward N. Hines, has been described as "the most important single traffic safety device in the history of auto transportation."**

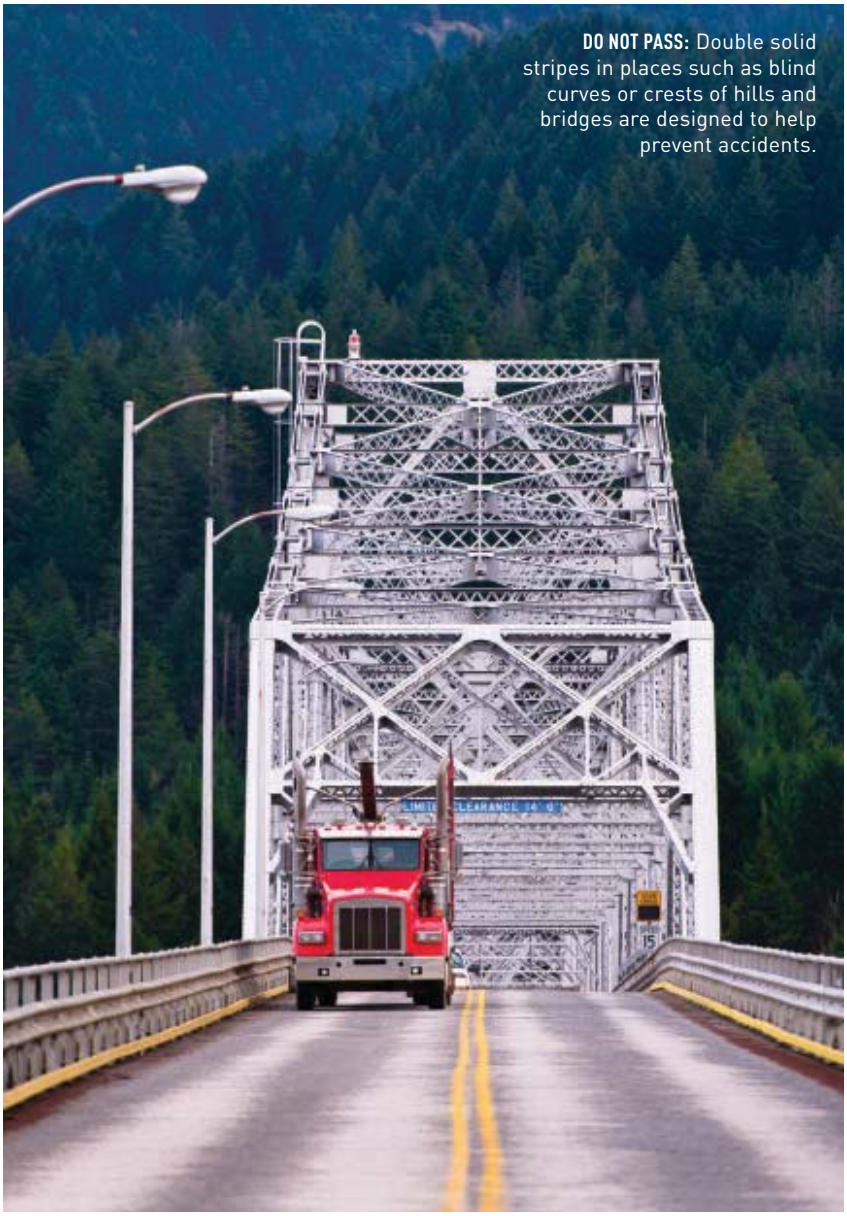
as 1907, stop lines were painted on roads in Portsmouth, Virginia; the first crosswalks are believed to have been painted in 1911 on the streets of New York City. The American reinvention of the highway centerline dates from the early twentieth century and is commonly attributed to Edward N. Hines, a charter member of the Wayne County, Michigan, Road Commission, on which he served from 1906 until his death in 1938. It is Hines's idea that has been described in the trade magazine *Michigan Roads & Construction* as "the most important single traffic safety device in the history of auto transportation." Among Hines's other notable achievements was instituting the construction of the first full mile of concrete roadway, which was placed in Detroit in 1909. Two years later, Hines is said to have observed a milk wagon leaking some of its contents and leaving a white stripe behind it as it progressed down the road. This gave Hines the idea for the modern centerline, the first of which was painted on River Road in Trenton, Michigan, just south of Detroit.

The first centerline on a rural highway is believed to have been painted in 1917 in milk white on the portion of the Marquette–Negaunee Road known as Dead Man's Curve, which is located on Michigan's Upper Peninsula. The line was the work of Kenneth Ingalls Sawyer, who was veteran superintendent of the county board of road commissioners and had drafted the state's first gas and weight tax laws, along with a good deal of its other basic highway legislation. As he wrote in the September 1920 issue of *Municipal and County Engineering*, "the handling of motor traffic upon our main trunk highways through the country is rapidly becoming as serious a problem as traffic control has ever been in our cities." It was, therefore, necessary to adopt methods of urban traffic control in rural areas. Sawyer related how traffic between the towns of Marquette and Ishpeming, farther down the road past Negaunee, had "become heavy enough to make travel dangerous unless some means of control is adopted." His means was "white 8 in. center lines upon the black surface of the road upon the more dangerous curves, with an arrow pointing down the right hand side of the road at either end." He believed that drivers responded to the white line because they had become accustomed to obeying similar devices controlling traffic in cities. The result was an "immediate reduction in the number of accidents."

**HIGH VISIBILITY:** The Wisconsin Department of Transportation has studied whether stripes in orange reflective epoxy paint (left) mark lane boundaries better than standard yellow or white stripes.

Sawyer acknowledged, however, that the centerline was not a panacea; it worked on that road because of its "smooth black surface," which allowed the white line to "stand out in sharp relief." To maintain that condition of visibility, the highway patrolman touched up the line every Saturday morning, something not practical on today's interstates.

Clearly the goal of road safety would be better served if the design of road markings and signs did not vary from urban to rural roads, from state highway to state highway. Following studies, conferences, and reports, the American Association of State Highway Officials and the National Conference on Street and Highway Safety issued in the late 1920s manuals for signs and control devices on rural and urban roads and streets. But two separate manuals did not help standardization, and so in 1932 a Joint Committee on Uniform Traffic Control Devices was formed, and in 1935 it published in mimeographed form the first *Manual on Uniform Traffic Control Devices*, known as *MUTCD*, which soon became an American standard.



**DO NOT PASS:** Double solid stripes in places such as blind curves or crests of hills and bridges are designed to help prevent accidents.

***As important as keeping vehicles from crossing over the centerline is, preventing them from veering off the side of the road is equally imperative.***

The great demand for the manual caused a printed version to be issued in 1937; the 166-page document covered signs, markings, signals, and islands. (The latest edition, published in 2009, is 864 pages long.) The first manual did not require centerlines everywhere. They needed to be painted only on hill-crest approaches with limited sight lines; tight or restricted-view curves; and pavements wider than forty feet. The acceptable colors for the lines were white, yellow, or black, the choice being dependent on which provided the greatest contrast against the pavement, whose color could vary from coal black for asphalt to almost white for concrete. (Such considerations remain important and dictate that lane markings on concrete-surfaced bridges consist of white lines painted over wider and longer black ones. Concrete taxiways and runways at airports are typically marked with yellow or white lines outlined in black.)

By 1954, forty-seven of the then forty-eight states had adopted white as the standard color for the highway centerline. The holdout was Oregon, whose highway department believed yellow to be the more visible color. Indeed, it is easier to see under a dusting of newly fallen snow, but the State Highway Commission capitulated. In an editorial on the matter, the *Oregonian* newspaper incidentally noted that the claim that the highway centerline originated in Oregon was unsubstantiated, attributing the concept to "several states" that had "hit on the idea independently at about the same time." However, in a letter to the editor, Peter V. Rexford, a retired captain of the Multnomah County Sheriff's Office, claimed that "the first yellow centerline ever painted on pavement" was done under his direction in April 1917. He may have been correct that it was the first *yellow* centerline.

Oregon citizens were not happy that at midcentury their traditional yellow road markings had been changed, and public pressure caused the highway commission to reverse itself. However, after two years of trying out white, yellow was reinstated. And then just two years later, in 1958, the Bureau of Public Roads decided on white as the standard for lines marking the new interstate highway system. If Oregon did not conform, it stood to lose at least $300 million in federal funds. Citing a series of tests that found yellow to be the safest color deer hunters could wear, the *Oregonian* editors argued for keeping yellow lines on roads under the sole jurisdiction of the State Highway Department. As for the interstates and U.S. highways,

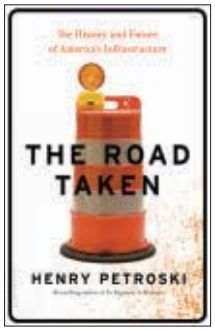
the yellow lines would have to be changed to white.

Soon the federal government reversed itself. The 1971 edition of the *MUTCD* declared a new standard for marking two-way roads, whether containing a median or not. To emphasize that they separated traffic moving in opposite directions, all centerlines were to be painted yellow. Where there was a median, the line marking the left edge of the leftmost of two or more lanes was to be yellow. White was to be reserved for regulating traffic moving in the same direction. Thus, broken white lines would continue to separate adjacent lanes carrying traffic in the same direction. Oregon had to change its roadway colors again, but this time it did so gladly.

As important as keeping vehicles from crossing over the centerline is, preventing them from veering off the side of the road is equally imperative. The solid white line that marks the right-hand edge is thus considered another significant innovation. Although the idea may have been on the minds of many in the early 1950s, it was the chemist and metallurgist John Van Nostrand Dorr who was prompted by his wife to do more than talk about it. The Dorrs, like a lot of drivers using dark rural roads at night, tended to hug the centerline, which aggravated the glare of approaching headlights and caused a driver to veer to the right toward the shoulder and often go off the road. Dorr convinced the Connecticut highway department to paint an experimental right-edge line on a four-mile stretch of the Merritt Parkway. When the line proved to help drivers stay centered in their lane, the entire parkway was so painted, along with many additional miles of the state's busiest roads. Other states soon followed.

Yellow stripes divide traffic even on highways where the median is impassable.

Whereas wheeled contraptions attributable to numerous Rube Goldbergs were used to paint highway centerlines as early as the 1920s, the invention of an edge-line machine is attributed to one John Edward White, who worked for the Ohio Department of Transportation. One day, while driving down a highway in dense fog, White was having difficulty seeing the road. To drive on, he had to hang his head out the window to keep the median line in view. Apparently independent of Dorr, he conceived of painting a white line on the right side of the road to mark its edge. In dense fog a navigator might have to stick his head out the passenger window, but that would be safer than the driver exposing his head to oncoming traffic. In 1956, to implement his idea more efficiently, White developed a prototype edge-line machine employing a subcompact Crosley automobile chassis. He was encouraged to do this because, whereas the 1948 manual had recommended against the use of edge markings generally, a 1954 revision modified the prohibition. The white line delineating the pavement's right-hand edge was explicitly advocated in the 1961 manual, and the 1978 edition made it required for all multilane rural highways. Such standardization, while it may take time to be codified, certainly does make our highways safer and less stressful to navigate. ME




**NOTE:** *This essay is adapted from the book,* The Road Taken: The History and Future of America's Infrastructure, *which will be published this month by Bloomsbury.* 

**HENRY PETROSKI**, an ASME Fellow, is the Aleksandar S. Vesic professor of civil engineering and a professor of history at Duke University. *The Road Taken* is his 19th book.

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- Practical Welding Technology
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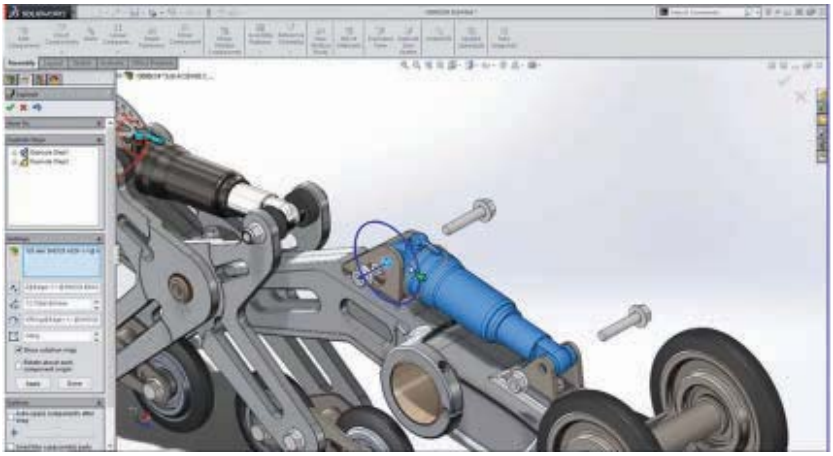
# 3-D DESIGN

DASSAULT SYSTÈMES, PARIS.



SolidWorks 2016 is the recently released update to Dassault's portfolio of 3-D design and engineering applications. The company says it has added several frequently requested features, including the ability to flatten any surface, validate design performance, and create images suitable for marketing use. The new version also enables users to create super-smooth blends or "curvature continuous" fillets faster than before for all fillet types, including asymmetric and variable sizes. The user interface has also been updated.

## CUSTOMIZABLE DRAFTING TOOL

COREL, OTTAWA.

CorelCAD 2016, the latest version of Corel's CAD application, offers new customizable 2-D drafting tools, native .DWG file support, and improved 3-D design capabilities. Among the new features are quick input, which establishes a command interface in projects using the cursor in the drawing area, annotative scaling, which enables important text to be readable regardless of the scale of the drawing, and the ability to align dimension lines with consistent distances from surrounding shapes to achieve perfectly aligned technical drawings. In addition to the new features included in the desktop versions of CorelCAD 2016, the application includes free access to a one-year license of the all-new CorelCAD Mobile for Android tablets.

## MANAGING MATERIALS

HAWK RIDGE SYSTEMS, MOUNTAIN VIEW, CALIF.

Anew release of xBOM, an application designed and optimized to process bills of materials within the SolidWorks PDM environment, is intended to enable users to manage their BOMs within their current infrastructure without the need for costly product lifecycle management systems. SolidWorks Enterprise PDM users can merge BOM data from PDM, Excel, and CSV files and track the source history. This capability is designed to give multiple departments a single place to manage BOMs and 3-D CAD data. For a limited time, Hawk Ridge Systems is offering a free trial of xBOM for qualified PDM users.

## DWG FOR IPHONES

GRAEBERT GMBH, BERLIN.

Graebert, a developer of CAD software, solutions, and services, has released ARES Touch for iOS, an application to enable the creation and modification of DWG drawings on Apple iPhones and iPads. The company is offering one year of ARES Touch to customers who purchase its ARES Commander desktop CAD software. The mobile application offers a full-featured set of CAD tools to create or modify DWG drawings, the company says, and shares the same API as the desktop version. This could allow developers the ability to use code written in C++, Lisp, or DCL to build mobile applications.

## STEEL FABRICATION

AVEVA, CAMBRIDGE, U.K.

The maker of applications for power and process plants has released new enhancements to its Aveva Bocad product range for structural steel detailing software. Aveva Bocad features a plate and bar nesting capability for more efficient planning and use of materials. The new nesting engine increases efficiency in materials usage by enabling more parts to be cut from the same amount of steel. It also enables more efficient procurement and scheduling. In addition elements of Aveva Bocad can now be brought into Aveva Marine production tools to fabricate detailed ship and offshore designs.

## CFD FOR WINDOWS

ESI-OPENCFD, PARIS.

OpenCFD recently offered OpenFOAM binaries for Windows versions 7 and 8. OpenFOAM is a free, open-source computational fluid dynamics software pack-

age for use in many areas of engineering and science. The software is designed to solve complex fluid flows involving chemical reactions, turbulence and heat transfer, electromagnetics, and many other scenarios. It includes tools for meshing, notably snappyHexMesh, a parallelized mesher for complex CAD geometries, and for pre- and post-processing. The company says the Windows version will produce the same results as the original Linux-based product.

## PLANS AND IMAGES

AUTODESK, SAN RAFAEL, CALIF.

An application previously known as iDraw, Graphic is a full-featured vector design and illustration application for the iPad, iPhone, and Macintosh computer that has recently been released by Autodesk. Designs can be created in Graphic and shared across all devices, the company says, and users can now quickly view and edit their designs from anywhere using the new iPhone version. The software supports pressure-sensitive input from Wacom tablets and Force Touch trackpads. Graphic can be used to create everything from dimensioned-to-scale floor plans, product mockups, user-interface designs, and artwork for media. It can import and export vector designs to other Autodesk products, such as Fusion 360. Users may also export bitmap and vector files to other applications that accept PNG, JPEG, GIF, TIFF, SVG, PSD, AI, and PDF formats.

## CAM WITH A PRE-FINISH PLUNGE

VERO SOFTWARE, GLOUCESTERSHIRE, U.K.

The Edgecam 2016 R1 computer-aided manufacturing software contains more than 30 enhancements to its CAD and CAM functionality for milling, turning, and machining. Turners now have a pre-finish plunge option found in the finishing grooving cycle, and five more milling CAM cycles have been upgraded to use images and help tooltips. Roughing, profiling, turning, and 4- and 5-axis commands have been enhanced, as well as the addition of a new chamfering operation. A number of significant upgrades have been made to the operations function, which the company says is a quick and easy way to develop complex toolpaths.

## SLICE OPTIMIZATION

TDM SOLUTIONS, BARCELONA.

Manufacturers working with cutting tools need to get the maximum amount of parts out of each slab of material. RhinoNest, recently upgraded to version 4.0, is a software tool designed devolve a finished product into the sum of its cuttable parts, and uses an algorithm to optimize the placement of those parts onto a panel for cutting. These slices can even be derived from a complex solid, useful for making laminated objects. The software is capable of both importing and exporting HPGL files, which are commonly used in cutting and milling machines.

## 3-D RENDERING

NEXT LIMIT TECHNOLOGIES, MADRID.

Version 3.2 of the Maxwell Rendering Suite has added the ability to use a fisheye lens when outputting images for virtual reality headsets such as Oculus Rift. The company says that due to a new nested priority method for nested dielectrics, it is now possible to render a complex surface features of water, glass, and ice without numerical issues by adding a small overlap between geometries. Maxwell V3.2 can now save the render in PSD format in 8, 16, and 32 bits, and supports multi-layered PSDs so channels and light buffers can be embedded as separated passes.

## 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.

## DEFORMATION MONITORING

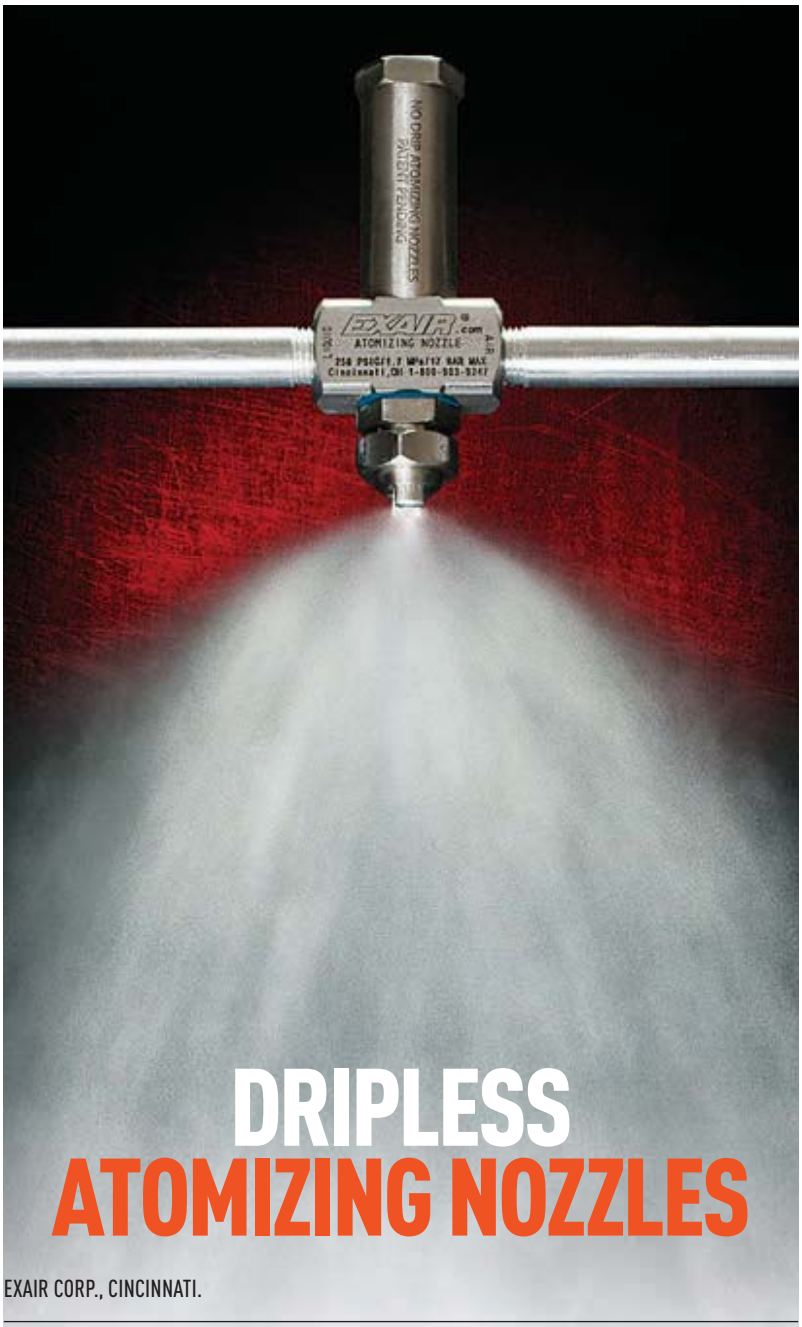
TRIMBLE, CAPE TOWN.

The latest version of Trimble's deformation monitoring software—Trimble 4D Control version 4.5—features new add-on capabilities, such as support for non-Trimble total stations and frequency domain analysis based on fast Fourier transform calculations. These improvements are intended to enable better analysis of complex data communicated from a broad range of sensors. Version 4.5 also provides users with improved functionality for data processing and visualization. Custom views, webcams, 3-D scenes, and high-frequency charts allow the complex data on the condition and behavior of land and structures such as buildings, dams, mines, and bridges to be presented in more meaningful ways.

## GRAPHICS RENDERING

REDWAY3D, PARIS.

REDsdk is a C++ programming toolkit dedicated to image visualization. It covers all the graphics features for real-time 2-D, 3-D, and photo-realistic rendering using a single integrated API. Its hybrid rendering technology can use graphics hardware or run in full software mode. The publisher, Redway3D, has released version 4.1, introducing next generation on-line documentation and the addition of realistic material with light conservation. The new release runs on any Windows version, from Windows 2000 to Windows 10 with native 32-bit and 64-bit support, as well as Linux 32 and 64-bit and MacOS X 64-bit.




# DRIPLESS ATOMIZING NOZZLES

EXAIR CORP., CINCINNATI.

No-drip external mix atomizing spray nozzles work like standard atomizing nozzles do, but stop liquid flow when compressed air is shut off. They are recommended for use on applications where drips can damage sealing or mating surfaces, or ruin the appearance of a product. They can also prevent waste of expensive coatings and chemicals. The nozzles are available in three different liquid patterns: round, narrow angle flat fan, and wide angle flat fan. External nozzles can be used on liquids up to 800 centipoise. The products are CE compliant and free of conflict minerals. Prices start at $346.

## BRUSH TERMINALS

AMPHENOL INDUSTRIAL PRODUCTS GROUP, SIDNEY, N.Y.

The manufacturer says it has taken a brush terminal designed for harsh military and aerospace applications and adapted it for heavy equipment, mining, medical, rail transit and other industrial markets. The Amphenol high vibration brush is designed to withstand vibrations of at least 53.8 grms at 8 hours per axis and 2,000 Hz. Intermeshing two small wire bundles together assures 14 to 70 points of contact per mated pair. The size 22 signal terminals can accommodate up to size 16 gauge cable or a PCB tail and are rated up to 5 A continuous. The AHVB terminal series exhibits zero fretting and can handle up to 100,000 mating cycles.

## SUBMERSIBLE LEVEL TRANSMITTERS

BLUE RIBBON CORP., GRAND ISLAND, N.Y.

The Model BC001 Birdcage Series of submersible level transmitters are made of 316 stainless steel for harsh environments. An integral 3-inch sensing diaphragm eliminates process media clogging. The design also allows the Birdcage to read true level depth within foam. A protective stand-off baffle plate protects against effluent sensor damage, particularly from particulate matter. The dual sealed cable entry is designed to prevent leakage. The Hytrel cable with integral vent is impervious to many chemicals found in effluent waste. Units are offered with standard surge protection against lightning or voltage spikes. The Model BC001 also features an intrinsically safe option for continued reliability within hazardous locations.

## SMART DEFROST CONTROL

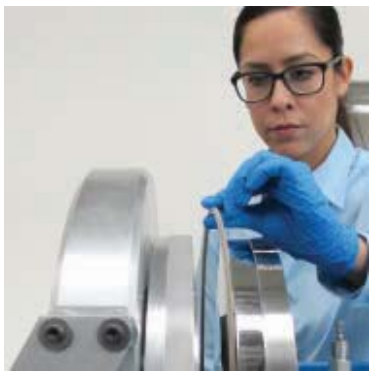
CENTURY REFRIGERATION, PRYOR, OKLA.

The Centinel intelligent defrost control system consists of a microprocessor-driven controller, four temperature sensors, and a suction transducer. It is designed to improve energy efficiency, eliminate icing and fogging, and reduce operating costs. According to Century, the microprocessor, paired with the advanced temperature sensors, controls the system better than mechanical controls. The system uses a self-learning algorithm that allows it to automatically adjust to changing system conditions and so customizing it to each individual evaporator. The controller is not refrigerant-specific and can be configured for use with mechanical or electronic expansion valves in a wide range of refrigeration applications.


## SEAL TESTING SERVICE

BAL SEAL ENGINEERING INC., FOOTHILL RANCH, CALIF.

A new test service offers to verify performance of Bal Seal low-friction spring-energized seals used in rotary/face applications. The service is intended to help OEMs and suppliers eliminate costs, delays, and complications associated with in-house or outsourced seal testing. Rotary/face seals are frequently used in dynamic housings and mounts to protect electronics and other internal components from environmental contaminants. To minimize stick-slip and meet motor torque requirements, the seals must exhibit very low friction, but also minimize leakage over long periods of exposure. Test equipment measures friction and leak rate using customer-defined hardware tolerances and operating conditions, including pressure and speed. Fixtures can accommodate seals up to 22 in. OD.




## STAINLESS BALL BEARINGS

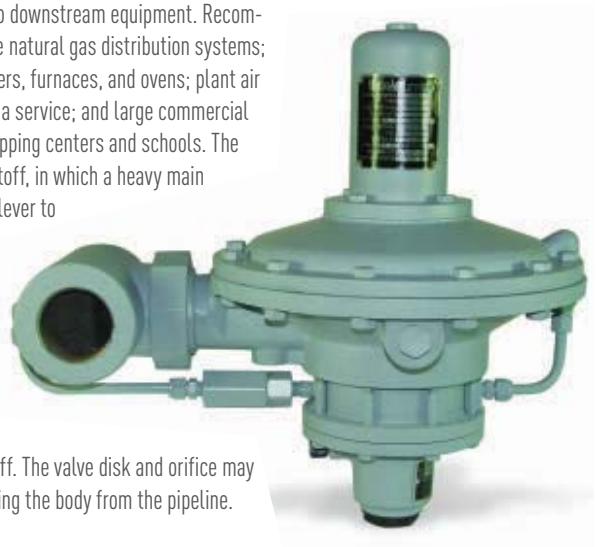
EDT CORP., VANCOUVER, WASH.

The manufacturer has expanded its offerings of stainless ball bearings and classified them in three price levels: Value Bearings, Choice Bearings, and Classic Bearings. It is a new addition to the high performance plane bearings for which the company is most noted. The bearings are made of 440 stainless and are available greased or with food-grade lubricant. Value Bearings are designed for general use in severe service environments at an economical price. The Choice series are eccentric lock bearings with a 304 stainless steel locking collar. The Classic series are set-screw locking, wide inner ring inserts that EDT has offered customers for years. They now include EDT's custom anti-rotation pin that allows drop-in fit to most manufacturers' housings.

## GAS PRESSURE REGULATION

MARSH BELLOFRAM CORP., NEWELL, W.VA.

The Type T99 industrial gas pressure reducing regulators are designed to help maintain consistent inlet pressures to downstream equipment. Recommended applications include natural gas distribution systems; gas supply to industrial boilers, furnaces, and ovens; plant air service; oxygen and ammonia service; and large commercial establishments such as shopping centers and schools. The regulators feature tight shutoff, in which a heavy main spring is working through a lever to provide a high seat loading force. Regulator loading pressure bleeds downstream through the pilot via the downstream control line. No atmospheric bleed occurs when the regulator is shut off. The valve disk and orifice may be inspected without removing the body from the pipeline.



## INTERLOCKING SAFETY SWITCHES

AUTOMATIONDIRECT, CUMMING, GA.

INCH and MK1 miniature tongue interlock safety switches are designed to fit leading edge, hinged, or lift-off machine guards. Mounting profile ranges from 16.5 mm to 22 mm. The switches have rotating heads with dual actuator entry and force guided normally closed contacts. They are available with plastic or stainless steel housings and with M16, M12 quick disconnect or half-inch NPT threaded connections. Another series, designated HC, consists of shaft hinge interlock switches with solid or hollow shafts. Some have two normally closed slow-action contacts and others have one normally open contact and one normally closed slow-action, make-before-break contact. Switches start at $29.50; actuator keys are sold separately starting at $6.50. Backed with a one-year warranty, interlocking safety switches are cULus approved and are CE, RoHS and Reach compliant.

## 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.


## FLIGHT-QUALIFIED PRESSURE SENSOR

GP:50 NY LTD., GRAND ISLAND, N.Y.

The Model 7202 flight-qualified pressure transducer measures static pressures from 0 to 15,000 psia (0 to 1,034 bar) with 0.30% FSO accuracy. Accuracy to 0.05% FSO is optional. A 0.1 to 5.1 V dc output is standard. Other formats are available upon request. Units incorporate stainless steel housings and 15-5 wetted parts. Inconel or Hastelloy material is an option for wider media compatibility. The Model 7202 is also offered with an improved optional compensated temperature range from -65 °F to +250 °F, as well as an optional integral RTD temperature output. The transducer is 1.5 inches (38.09 mm) long and weighs less than 5 ounces (141.7 grams). Its overall design meets both MIL-STD-810F and MIL-STD-461, as well as J-001/NASA 8739.3 soldering workmanship standards.

## METALWORKING FLUIDS

MILACRON HOLDINGS CORP., CINCINNATI.

Cimpulse 51MP, Cimpulse 45MP, and Cimpulse 33MP, new fluids in the Cimcool family, are designed to allow metalworking shops to utilize one fluid in their operations. The fluids have been formulated for use in both high-pressure systems and standard flood applications. According to Milacron, a Cimpulse fluid can in most cases be used to replace all the different fluids being used in a plant. Cimpulse metalworking fluids utilize a hybrid blend of lubricants to enhance mix stability and reduce tool wear as well as provide long sump life.

## EPOXY FOR CORROSIVE CONDITIONS

KALENBORN ABRESIST CORP., URBANA, IND.

Kalpoxy 255 is a 100% solids epoxy coating for tough corrosive and erosive conditions. It is formulated with aliphatic (straight chain) curing agents to obtain flexible and light colored films and avoid the handling problems of aromatic polyamines. It is solvent-free for odor-free application and curing and elimination of osmotic blistering. The epoxy tolerates substandard surfaces and can be applied and cured under water. It can be used in marine and offshore applications, power generation, and heavy-duty lining in heat exchange equipment and steel exposed to chemical or physical abuse. The coating can also be used in heavy-duty linings for steel and concrete that require extreme resistance to aggressive chemicals such as 50% caustic soda or 98% sulfuric acid.

# 2016 CONFERENCES

## ENERGY SOURCES AND PROCESSING (ESP)

Energy sources engineering, processing, transport, manufacturing, testing and safety in industries involved with petroleum, natural gas, petrochemicals, coal, shale, LNG, pipelines, pressure vessels & piping.

## ENERGY CONVERSION AND STORAGE (ECS)

Power generation, power distribution, solar, wind and sustainable energy, fossil fuel and nuclear power plants, steam and gas turbines, fuel cells, transportation including hybrid technologies, internal combustion engines, batteries and energy storage.

**HFC**
Hydraulic Fracturing Conference
Mar 7–10, 2016, Houston, TX
go.asme.org/fracturing

**OTC Asia**
Offshore Technology Conference Asia
Mar 22–25, 2016, Kuala Lumpur, Asia
2016.otcasia.org

**OTC**
Offshore Technology Conference
May 2–5, 2016, Houston, TX
2016.otcnet.org

**OMAE**
Intl Conf. on Ocean, Offshore & Arctic Eng.
June 19–24, 2016, Busan, Korea
go.asme.org/omae

**PVP**
Pressure Vessels & Piping Conference
July 17–21, 2016, Vancouver, BC, CA
go.asme.org/pvp

**IPC**
International Pipeline Conference
September 26–30,2016, Calgary, AB, CA
ipcyyc.com

**ATC**
Arctic Technology Conference
October 24–26, 2016, St Johns, NL, CA
arctictechnologyconference.org

**TURBO EXPO**
Turbomachinery Technical Conference and Expo
June 13–17, 2016, Seoul, South Korea
go.asme.org/turboexpo

**P&E**
Power & Energy Conference
June 26–30, 2016, Charlotte, NC
go.asme.org/powerenergy

**ICONE**
International Conference on Nuclear Engineering
June 26-30, 2016, Charlotte, NC
go.asme.org/icone

**ICEF**
Internal Combustion Engine Fall Conference
October 9–12, 2016, Greenville, SC
go.asme.org/icef

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Design engineering, computer aided engineering, advanced manufacturing, 3D printing, smart materials, adaptive structures, dynamic systems & control, automation, mechatronics, electronics packaging; often involving multi-disciplinary research and engineering in automotive, medical devices, aerospace, computer & electronics, information processing systems, transportation, robotics and manufacturing.

**JRC**

Joint Rail Conference
April 12–15, 2016, Columbia SC
go.asme.org/jrc

**ISPS**
**IOT**
**InterPACK**

Information Systems Processing Conference

IOT Connect Intelligent Hardware Packaging & Integration of Electronic & Photonic Microsystems Conference
June 20–22, 2016, San Jose, CA
go.asme.org/iot

**MSEC**

Manufacturing Engineering Science Conference
June 27–July 1, 2016, Blacksburg, VA
go.asme.org/msec

**AM3D**

Additive Manufacturing +3D Printing Conference
August 21–24, 2016, Charlotte, NC
go.asme.org/3dprinting

**IDETC**
**CIE**

International Design Engineering Technical Conference Computer Information in Engineering Conference
August 21–24, 2016, Charlotte, NC
go.asme.org/idetccie

**SMASIS**

Smart Materials, Adaptive Structures & Information Systems Conference
September 28–30, 2016, Stowe, VT
go.asme.org/smasis

**DSCC**

Dynamic Systems & Control Conference
October 12–14, 2016, Minneapolis, MN
go.asme.org/dscc

## ENGINEERING SCIENCES (ESS)

Fundamental and applied research in heat transfer, fluids engineering, applied mechanics, advanced materials, micro & nano technology, environmental engineering and bioengineering, often including multi-disciplinary engineering research in fields such as aerospace, automotive, bioengineering, energy and manufacturing.

**MNHMT**

Micro Nano Heat & Mass Transfer Conference
January 4–6, 2016, Singapore
go.asme.org/mnhmt

**NEMB**

Nanotechnology in Engineering, Medicine & Biology Conference
February 21–24, 2016, Houston, TX
go.asme.org/nemb

**V&V**

Verification & Validation Symposium
May 18–20, 2016, Las Vegas, NV
go.asme.org/vandv

**HT**
**FE**
**ICNMM**

Heat Transfer Summer Conference

Fluids Engineering Conference

Intl. Conf. on Nanochannels, Microchannels and Minichannels
July 10–14, 2016, Washington, DC
go.asme.org/htfeicnmm

**COMS**

Commercialization of Micro, Nano, and Emerging Technologies
August 28–31, 2016, Houston TX
go.asme.org/coms

**IMECE**

International Mechanical Engineering Conference & Exhibition
November 11–17, 2016
Phoenix, AZ
go.asme.org/imece

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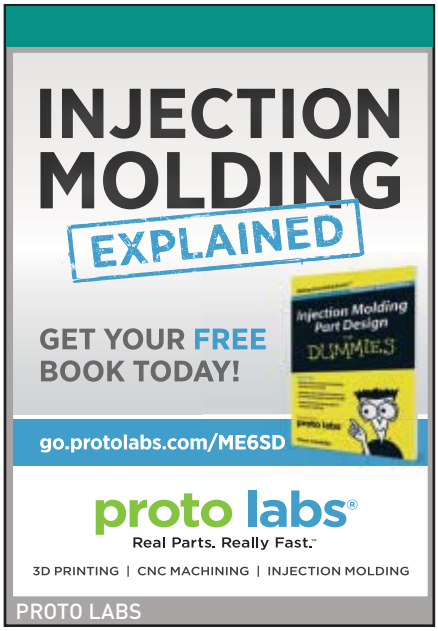


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**OCEAN ENGINEERING**
**TEXAS A&M UNIVERSITY**

The Department of Ocean Engineering at Texas A&M University, a department in the Dwight Look College of Engineering, invites applications for a non-tenure track faculty position in the Offshore and Coastal Systems Engineering program (OSCSE) at the Instructional Assistant Professor level. This position is located at our Galveston campus. The successful applicant will be expected to teach approximately three classes in each of the fall and spring semesters relevant to his/her specific expertise and may develop and teach elective courses in his/her specialty; teaching during the summer semester is negotiable on an as-needed basis. In addition to teaching, the position is expected to participate in departmental and university service efforts, to be active in the profession, to supervise and mentor students and to interact in a collegial way with current faculty. For more information on the department, please visit https://engineering.tamu.edu/ocean

Applicants must have at a minimum, an earned bachelors and a graduate degree (masters) in engineering from an institution recognized in the field. Applicants should submit a cover letter, curriculum vitae, teaching statement and a list of four (can be between 3-5) references (including postal addresses, phone numbers and email addresses) by applying for this specific position at www.tamuengineeringjobs.com.

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## POSITIONSOPEN

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**DEPARTMENT OF BIOENGINEERING**
**PROFESSOR & DEPARTMENT CHAIR**

**Applications are invited for the position of chair and professor. Candidates must have an earned doctorate in bioengineering or a related field and be eligible for a tenured appointment at the rank of full professor. The successful applicant should have appropriate administrative experience, including disciplinary research/education and mentoring students, faculty and staff. Please see http://bioengineering.gmu.edu for information about the department.**

**Applicants should apply for position number F9261z at http://jobs.gmu.edu and upload a cover letter, CV, vision statement (attached as 'Other Doc'), and the names of three professional references with contact information. The review of applications will begin February 15, 2016 and will continue until the position is filled.**

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# POSITIONSOPEN

**THE DEPARTMENT OF MECHANICAL ENGINEERING AT LAMAR UNIVERSITY** invites applications for **MULTIPLE FULL-TIME POSITIONS** at the rank of **ASSISTANT PROFESSOR** in all areas of Mechanical Engineering starting Fall, 2016. Responsibilities include teaching at the undergraduate and graduate levels, recruitment and supervision of graduate students, and the development of an actively funded research program of high quality. Qualifications include a Doctoral degree in Mechanical Engineering or a related field by the starting date of the appointment, a demonstrated record in research, and proven ability as an excellent teacher. Review of applications will start in January, 2016 and will continue until the positions are filled. Interested candidates must complete online application at: https://jobs.lamar.edu/. For more information, please contact Dr. Kendrick Aung at (409)880-8764 or e-mail aungkt@lamar.edu.

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GEORGE MASON UNIVERSITY

**MECHANICAL ENGINEERING DEPARTMENT**
**MULTIPLE POSITIONS**

**Applications are invited for several new faculty positions at all ranks, as well as an Associate Chair position, to start Fall 2016.**

**Qualifications**

**Candidates must have an earned doctorate in mechanical engineering or a closely-related discipline for all ranks, except the instructor rank which requires at least a master's degree. A commitment to teaching excellence is fundamental to these positions and to the mission of George Mason University. For a more complete and specific list of qualifications please visit http://jobs.gmu.edu and apply to one of the following position numbers: F000Az, F001Az or F002Az. The review of applications will begin on February 15, 2016, and will continue until all positions are filled.**

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## SUBMISSIONS FOR SPECIAL ISSUE ON SIMULATION

The editorial board for ASME's *Journal of Mechanical Design* is accepting papers for a special issue covering simulation-based design.

The special issue, scheduled to be published later this year, will concentrate on uncertainty quantification, propagation, and design using probabilistic and non-probabilistic methods—a field that has experienced significant growth in the past decade. Design under uncertainty has implications in decision making as well as reliability, quality, safety, and risk tolerance of many products.

Other topics of interest include computational techniques for uncertainty quantification and propagation; design for resilience; fusion of simulation and experimental data for design under uncertainty; lifecycle analysis and design under uncertainty; methodologies for design under uncertainty using probabilistic and non-probabilistic methods; model verification, validation, and calibration; and multidisciplinary analysis and optimization under uncertainty; risk- and safety-based design and optimization; and uncertainty propagation and quantification through multiple scales and disciplines.

Submissions for the "Special Issue on Simulation-Based Design Under Uncertainty" are due Feb. 29.

For more information on the *Journal of Mechanical Design*, visit http://journaltool.asme.org and select "Mechanical Design" from the menu on the left side of the page. **ME**

# GUERRERO SAYS YOUNG ENGINEERS NEED INSPIRATION

During his President's Luncheon address at the ASME International Mechanical Engineering Congress and Exposition in Houston in November, ASME President Julio C. Guerrero passionately argued that today's engineers have the responsibility to inspire young people to become engineers and members of the Society.

"We need to inspire students and young engineers to share our love and passion for engineering and life," Guerrero said. "We are right now shaping the future of our society and our planet."

Guerrero asked the audience to imagine a scenario where an engineering student sees an ASME booth at a conference and begins to contemplate whether to join ASME. "He or she will face this fundamental question that all of us have faced at least once in our lives, which is: 'Why? Why should I join ASME?' ... How we help them answer the question is very important," he said.

ASME President Julio C. Guerrero (left) with 2015 Outstanding Student Section Advisor Award recipient Selin Arslan.

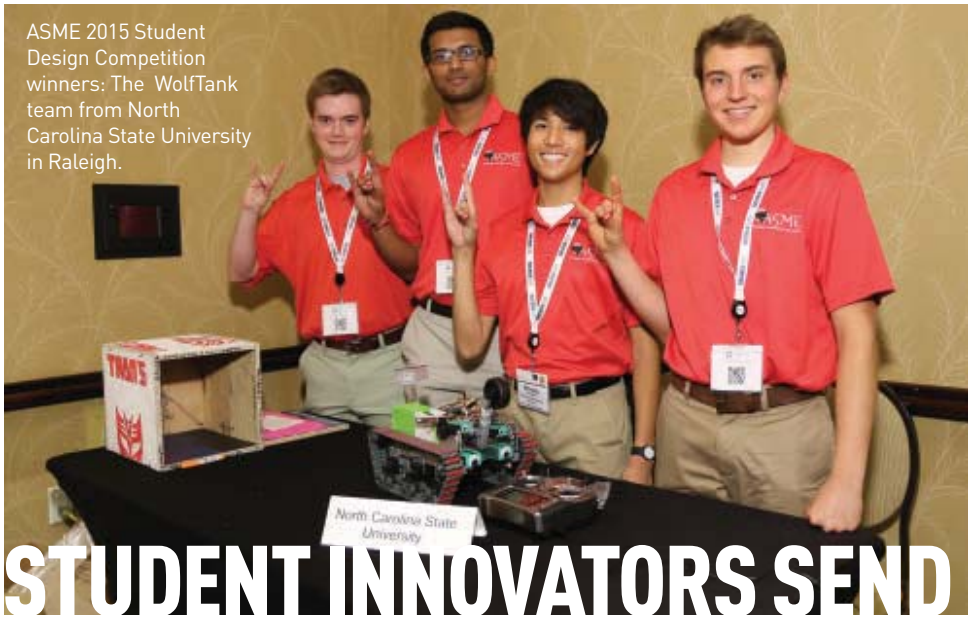
"The engineers that will come after us will face a profession that will be very multi-disciplinary," he continued. "Mechanical engineers are not anymore just pressure vessels, engines, and nuts and bolts. As you know, ASME has 32 technical divisions and two institutes. And the technologies that we deal with run through robotics, nanotechnology, fluid mechanics ... all of that. We at ASME have tools that can help us to help the students and the young engineers to handle the challenges they will face in their careers."

Guerrero focused on what ASME was doing to inspire students and early career engineers, including the Society's codes and standards and professional development programs, engaging conferences such as the recent Additive Manufacturing + 3D Printing Conferences in India and Boston, and the Engineering for Change program and ASME's Engineering for Global Development initiatives, which aim to help inhabitants in the world's underdeveloped regions.

"We need to inspire students and young engineers to share our love for engineering and life," he concluded. "We need to take our role as members, volunteers, leaders of our organization very thoroughly. And we need to work together."

Prior to Guerrero's speech, Judy Vance, chair of the ASME Committee on Honors, presented Society awards to 14 engineering leaders during the luncheon, including David T. Blackstock, recipient of the Per Bruel Gold Medal for Noise Control and Acoustics; Andy Walker, winner of the Thomas A. Edison Patent Award; George W. Sutton, recipient of the Nancy Deloye Fitzroy and Roland V. Fitzroy Medal; Thomas D. Gillespie, recipient of the Soichiro Honda Medal; and Parnia Mohammadi, Liping Liu, and Pradeep Sharma, the winners of the Melville Medal.

Others receiving awards at the luncheon were Thomas C. Heil, winner of the Performance Test Codes Medal; Ahmed F. Ghoniem, recipient of the James Harry Potter Gold Medal; Kaufui V. Wong, winner of the Dixy Lee Ray Award; Dewey H. Hodges, recipient of the Spirit of St. Louis Medal; Peter A. Molvie, recipient of the J. Hall Taylor Medal; John H. Lau, winner of the Worcester Reed Warner Medal; and Jinkook Lee, winner of the Henry R. Worthington Medal. **ME**




ASME 2015 Student Design Competition winners: The WolfTank team from North Carolina State University in Raleigh.

# STUDENT INNOVATORS SEND ROBOTS TO THE RESCUE

Seventeen teams of young engineer-innovators from around the world competed in the finals of the ASME 2015 Student Design Competition in November in Houston. Top honors were won by the WolfTank team from North Carolina State University in Raleigh.

The competition challenged the student teams with the task to design and build a scaled-down transport robot vehicle. Each had to race over difficult terrain simulating a landscape after a natural disaster. Each robot was to deliver a payload of emergency supplies and return in good condition.

"We definitely didn't think we were going to win, considering last night," said Michael Suguitan, the team leader and pilot for the WolfTank team, after the event. "One of our servos had burned out unexpectedly, so we had to modify it into a continuous rotation servo. We ripped out all its guts, replaced the board with an electronic speed controller, and ran it just like a continuous rotation motor. And it worked!"

Another North Carolina State team finished third with its Rescue Rover. Second place went to a team from McNeese University of Lake Charles, La. ME

## ASME CELEBRATES NSF ENGINEERING RESEARCH CENTERS

ASME, together with IEEE-USA and the Optical Society of America, hosted an event recognizing the 30th anniversary of the establishment of the National Science Foundation's Engineering Research Centers.

The 57 centers around the nation integrate engineering research and education with technological innovation with the intent to improve economic performance and national security. Nearly 200 spin-off companies and more than 730 patents have resulted from activity at the centers.

During the event at the Cannon House Office Building Caucus Room on Capitol Hill on October 16 currently NSF-supported centers showcased demonstrations and research findings related to engineering discovery, technologies, and tools that have resulted in high-impact achievements and addressed national priorities. Three finalists from the program's Perfect Pitch Contest explained their research in the context of societal needs and the broader impact of their success.

# ASME PRESS TO START NEW IMPRINT WITH WILEY

ASME and global technical publisher John Wiley & Sons Inc. have begun to develop and publish a collection of mechanical engineering books under the co-branded Wiley-ASME Press Series imprint. New titles under the imprint, which will carry both the Wiley and the ASME Press logos, will be released early this year.

Books published under the new Wiley-ASME Press Series will target a diverse audience, from industry analysts, researchers, and professional engineers in industry to educators and upper-level undergraduate and post-graduate-level students.

ASME and Wiley plan to publish 10 new titles per year, with the potential to increase this number in future years.

The first title in the series, *Introduction to Dynamics and Control in Mechanical Engineering Systems* by Cho Wing Solomon To of the University of Nebraska-Lincoln, is scheduled to be published in April. The book is an introductory textbook covering dynamics and controls of engineering systems, with a specific focus on mechanical engineering systems. Copies of the book can be pre-ordered on the Wiley website.

ASME and Wiley also plan on releasing two additional titles—*Nonlinear Regression Modeling* by Russ Rhinehart from Oklahoma State University and *Fundamentals of Mechanical Vibrations* by Liang-Wu Cai of Kansas State University—under the new imprint in the first half of 2016.

In addition to the creation of the new co-branded imprint, the agreement will enable ASME members to receive a 20 percent discount on all Wiley books. ME

# THREE-FACED

**THE SIMPLEST PLATONIC SOLID, THE TETRAHEDRON, HAS FOUR FACES, EACH AN EQUILATERAL TRIANGLE. HOW, THEN, CAN YOU BUILD A SOLID OBJECT THAT WILL ROLL AND RANDOMLY TURN UP ONE OF ONLY THREE FACES?**


The puzzle intrigued Joseph Toumanios, a mechanical engineering student at the New Jersey Institute of Technology in Newark. He said it started in his freshman year, while he and a friend were playing a game that involved rolling dice of various shapes. They started speculating: Was it possible to make a three-sided die?

The friend said no. Toumanios, on the other hand, found the challenge of a three-faced die irresistible. He learned 3-D modeling software so he could try to create one.

What began as a light-hearted diversion ended with two workable solutions, which Toumanios calls Trice. He has printed a few prototypes of each design and has even applied for a patent.

Both designs are essentially cubes adapted to show only three faces. The first orients each face on a plane diagonally joining two sides of the cube.

The second uses a wire-frame cube. The surfaces that present the numbers are on a prism connected diagonally across the void inside the wire-frame.

Both versions of Trice will roll and bounce like conventional six-sided dice. Trice are unbiased and always display a single number, randomly rolled and face up.

Toumanios said that the solution was always in his head, but it took him six or seven months to fully develop the two designs. It took another six months of working through theoretical and experimental data to build a statistical case for Trice—that they are a better design than a triangular prism, any object with curved edges, or even a six-sided die with two sets of numbers.

Toumanios, now a junior, said that the three-sided dice could be a good addition to Dungeons & Dragons and other role-playing games. Publishers of the games could add Trice to their dice collections, and sell them in various colors and styles.

He also believes that the form can be used in a satellite. With a solar panel on each face, one side can always be exposed to the sun. It could supply more power than a cube arrangement, and be simpler than a sphere.

Rolling two Trice could change the game of craps. There is a one-in-six chance of rolling the most common number, seven, with a pair of six-sided dice. There is a one-in-three chance of rolling a four with a pair of Trice.

Toumanios currently has six working prototypes (three of each design), generated by 3-D printing. The first two were created to realize the physical design and the other four were created with slight adjustments in size so that they may be more clearly seen and used.

Toumanios said he would like to sell the design to a company one day, but he said his main target right now is "to get the design out there, to the degree that it's a common household object, familiar to the average person. Kind of like a deck of cards, or a sponge."

He said one avenue may be to find a casino willing to hear the statistics behind a new dice-based game that could draw in a new crowd of players.

"It could be made for beginners or those willing to take more of a risk depending on dice quantity," he said. "Plus they would be able to sell the dice exclusively from their casino."

But marketing his idea is almost an afterthought. He said his true purpose in taking on the design challenge was not to create something to sell, but to create something new. ME

JAMES PERO

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