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THE MAGAZINE OF ASME
No. 03
136
Technology that moves the world

ICONIC DESIGN

//// SIX DESIGNERS ON THEIR INSPIRATIONS

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BLOODHOUND USES 3-D PRINTING TO GET A NOSE

WHEN YOUR VEHICLE IS NAMED AFTER A CANINE renowned for its olfactory powers, its nose had better be something special—especially if it's to be poking through the air at 1,000 mph. That's the speed that the folks building the supersonic Bloodhound thrust car are hoping to hit. Every component of the vehicle will have to be designed with the perfect balance of strength and lightness, especially the nose, which will be made on a 3-D printer.

NUCLEAR WASTE TO ENERGY

A disaster-proof power plant with low emissions, which runs on nuclear waste, is cheap to build, and is scalable to boot: it sounds like a utopian fantasy. But the designs for just such a plant are ready to go. The inventors say only issues of funding and regulatory approval keep the world from slaking its thirst for energy with Transatomic's Waste-Annihilating Molten-Salt Reactor.

VIDEO: TESTING EMERGING SPACE TECHNOLOGIES

From testing 3-D printing in microgravity to monitoring health care in space, Dougal Maclise, technology manager at NASA Ames Research Center, discusses how NASA's Flight Opportunities Program can be used to prepare emerging technologies for future space missions and Earth applications.

THE ARTIFICIAL PANCREAS GETS REAL

Approved in September 2013, the hybrid continuous glucose monitor is a new device for diabetes care that reduces risks of automated insulin control. It's the closest thing on the market to the long-sought artificial pancreas in the FDA's "threshold-suspend" category. It's unique because it can sense when blood sugar levels drop to a doctor-programmed danger zone.

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

NEXT MONTH ON ASME.ORG

STEM AND SPORTS: THE SCIENCE OF BASEBALL

University of Arizona's new Arizona Science of Baseball Pilot Program combines baseball with science and math to get middle school kids to improve their academic performance and increase their interest in the technical fields.

PODCAST: CORNELL'S APP TO CHECK CHOLESTEROL

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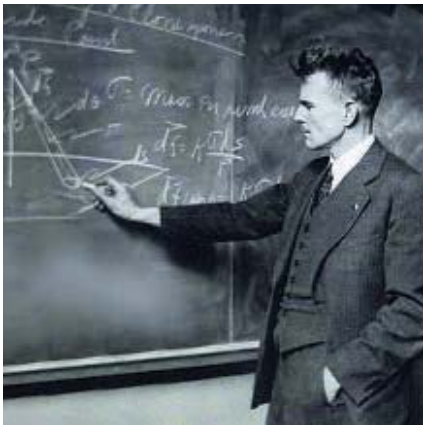

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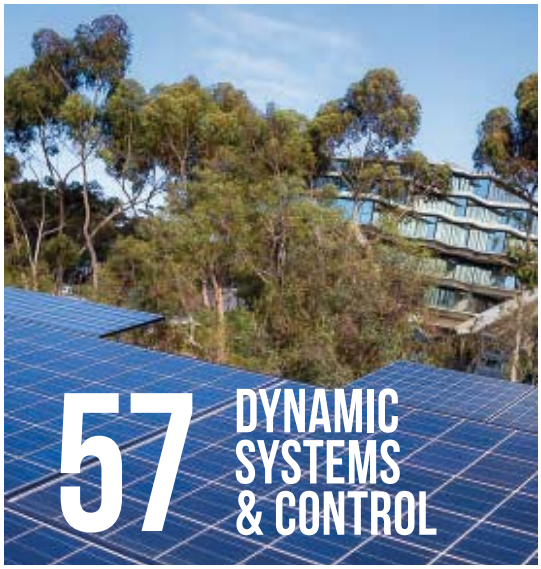

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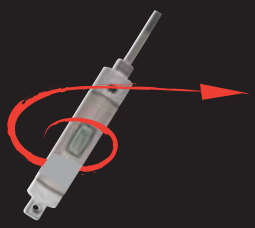

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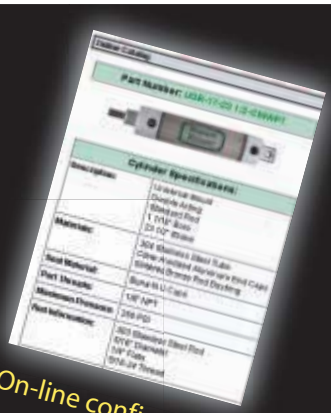


On-line configurator makes ordering simple!

John G. Falcioni
Editor-in-Chief

DESIGNS THAT GO BEYOND THE LOOK

My friends tell me that it's called a midlife crisis. I tell them they're nuts. After all, I've been hankering for a Vespa since I was in my early 30s, and that's hardly considered midlife, except maybe if you're under the age of 15. Besides if it was really a midlife crisis you'd think I'd opt for the much faster and muscular Harley than a Vespa.

Well, maybe that's not entirely so. I love the way the Vespa looks, and I like the way it makes me feel. The sleek lines, the shiny paint—of course, it has to be red. The more retro the model, the more I'm attracted to it.

The iconic design takes me back to when I was seven years old and visited my Italian relatives for the first time, in the small town of Penna San Giovanni, situated in the Adriatic-hugging region of Le Marche. My Uncle Leo (for some reason they called him Ennio) had an old, light blue Vespa. It was beat up but served as the primary transport to town, which was a few miles away from the farmhouse that he, my Aunt Gina, and my cousins lived in growing up—and boy, could Uncle Ennio slaughter a pig with his bare hands to make his insane prosciutto.

Product designs become iconic for many reasons. For me, the Vespa takes me back to my days as an innocent kid when an uncle I barely knew and who spoke a language I barely recognized would lift me on the back of his scooter and take me for a ride. I still remember hugging hard at Uncle Ennio's waist and hanging on for dear life as he would whiz through the dirt roads of Penna, seemingly oblivious to the skinny little kid sitting behind him. I see a Vespa today and it tugs at the strings of my heritage.

Our cover story this month, a series of vignettes written by top industrial designers and compiled by associate editor Alan Brown, looks at six product designs that fall into the iconic category. Some of the products are more publicly recognizable as icons than others, but all, as Brown says, perfectly match form with function. "They not only make a promise; they deliver."

Industrial design is art that, like the works of master painters and other artists, moves us and transports us to places we've been or experiences we've had. Contemporary industrial design wows us with functionality, making our lives easier and our tasks more pleasant. Sometimes we don't recognize a product as anything special, and what turns a design iconic is the passing of time.

I'm too young to have used the black Western Electric Model 302 phone, but I'm old enough to remember the equally iconic, old pink Princess telephone that was still in use in my house to make those overseas calls to Zio Ennio and Zia Gina when I was a kid. Nobody thought that the pink phone was anything really special back then, unless you were a teenage girl who yearned to have one on her nightstand. Others, like the iPhone, become icons the minute they appear.

This may just be the year when I finally get my (red) Vespa to zoom around town myself. As for butchering a pig, I might need a little more encouragement. **ME**

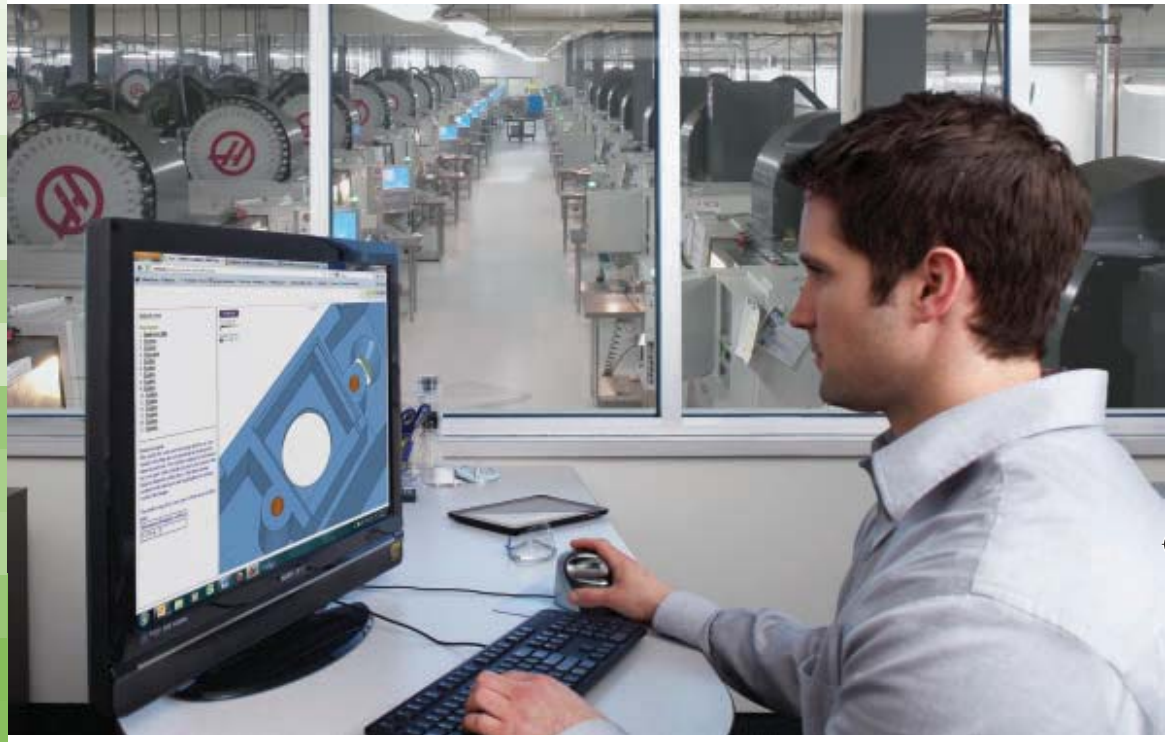
FEEDBACK

What's your favorite iconic design? Email me.

falcionij@asme.org

Others say they're FAST...

But do they have the SCALE to deliver?



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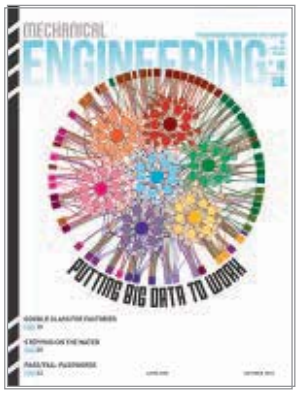


OCTOBER 2013

Reader Daley offers a new view on swimming technique.

Our article on the mechanics of swimming prompts a reader to send in a differing hypothesis. And another reader worries about the state of the profession.

ALTERNATIVE SWIM

To the Editor: I believe the central depiction in "Stepping on the Water" (October 2013) is not correct.

A more representative model would rotate the line (or plane) of the "parallel cylinders" some 80 degrees anti-clockwise—as then almost aligned with "V." The simplest example is treading water in which the hands move horizontally and generate vertical thrust. In other words, the hands are:

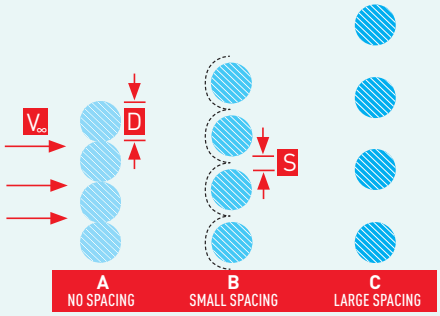
1. Acting as lifting surfaces *(hydrofoils)*. **"Swimming" is then a series of lateral sweeps.**
2. Constantly seeking "still water." *Similarly, paddle steamers were not designed with caterpillar tracks.*

Furthering the article's central thesis, finger separation is also about relaxation and energy conservation. Significant psychological and physical demand is required to keep fingers tensed together. As for "why all of us learn to swim with cupped hands," modern swimming teachers would (should) not make the same mistake, which is harder to correct later.

The previous approaches were "socially entrenched" and almost denialist. It took a long time to "see" the hand action in swimming from which analysis followed.

Neville Daley, *Brunswick, Victoria, Australia*

The diagram from the October 2013 issue that Daley refers to is reproduced above right.



$F_B > F_A > F_C$ The figure shows fingers modeled as four parallel cylinders of diameter D, moving downward into water (i.e., moving from right to left in the figure) with the speed V_∞.

Configurations A and C have the same frontal area (4D), the force F_A must be greater than F_C because the stack A has a greater drag coefficient (it is less hydrodynamic) than each of the single cylinders of configuration C.

Though B is a "stack" like A, the frontal area of B = 4D + 3S, and so is broader than the 4D frontal area of A. This happens when the spacing S is approximately the same as the thickness of the laminar boundary layer that surrounds each finger, namely $S \sim D\,Re^{-1/2}$, where $Re = V_\infty D/\nu$, when ν is the kinematic viscosity. The fluid friction on the finger surfaces (spaced S apart) sustains the pressure difference between the front and back of the S gap. The four fingers are wearing a glove of water boundary layers.

WORKING AT A DISADVANTAGE

To the Editor: Nothing in mechanical engineering has come close to the advances electrical engineers have made in microelectronics, computers, telecommunications, sensors, and the software to run them, since even before the microprocessor was introduced in 1974. Nothing in ME has produced anywhere near the technological progress, the job opportunities, the social and economic changes, and the money advances made in these fields, which are based on work done almost entirely by electrical engineers. Not even ME manufacturing engineers have benefited, since most of the hardware was built overseas.

Is mechanical engineering at a disadvantage vs. other disciplines? I'll say we are. Just the above example proves we've had our heads handed to us.

The last Apollo flight was Apollo-Soyuz in July of 1975. Microsoft was founded by Bill Gates and Paul Allen on April 4, 1975, and Steve Jobs and Steve Wozniak created Apple Computer in April of 1976. This transition from aerospace to electronics and IT as the lead cutting edge technology was no accident, no coincidence, and the EEs have held the upper hand ever since.

We're not doing well relative to accountants, teachers, pharmacists, doctors, lawyers, or masters of business administration either. We might be holding our own compared to nurses.

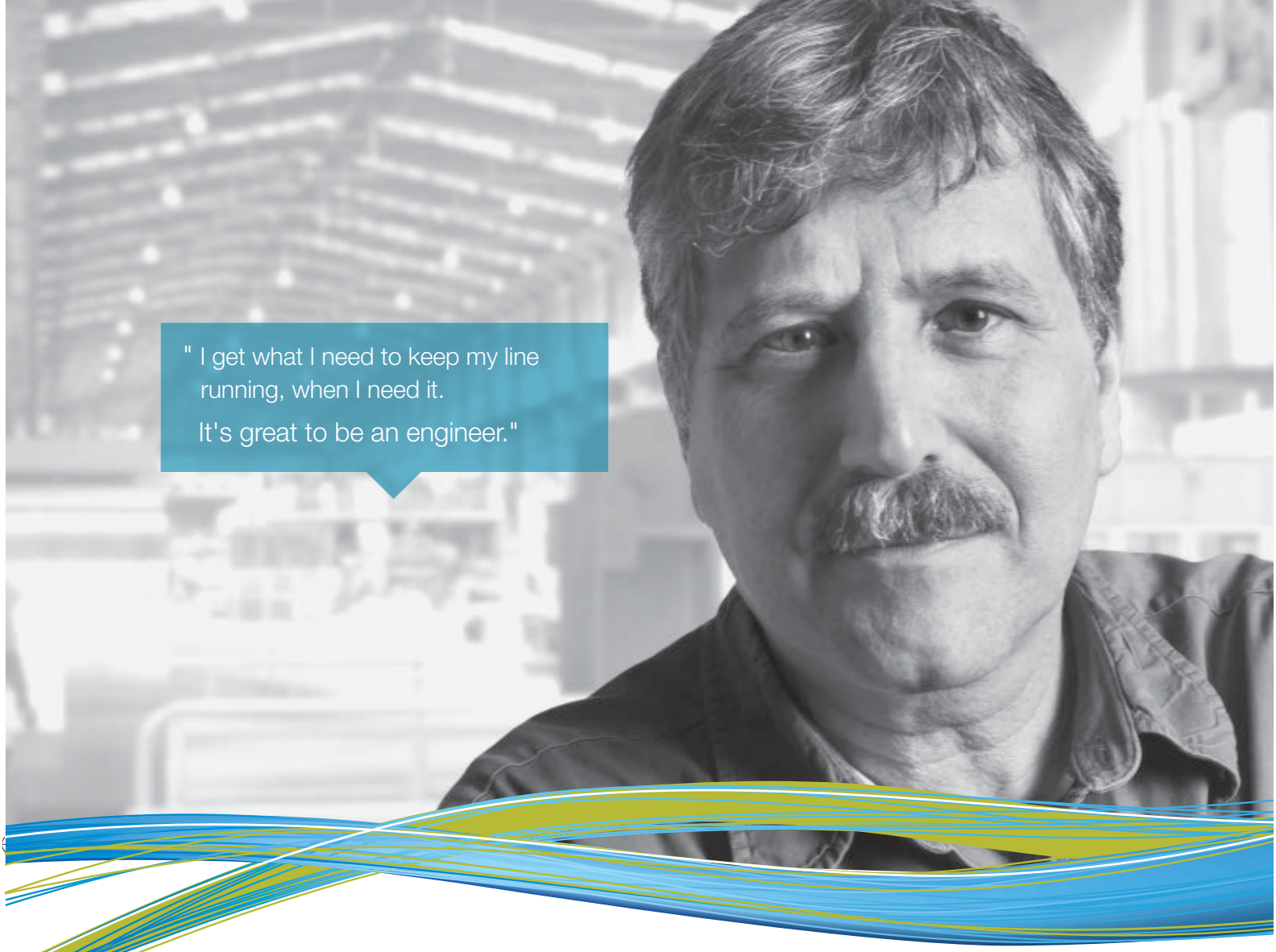
Thanks for up-to-date numbers on the percentage of engineering graduates that are women (18.9 percent), and the percentage of working engineers that are women (13 percent) in this issue (From the Editor, "The Benefits of Disadvantage," January 2014). Now let us know how many women are still working as engineers five years after graduation. I've read there is a 50 percent attrition rate after five years, for women and perhaps for men as well.

A panel discussion in this magazine a few months ago said an engineering degree has a five-year half-life. How do we maintain the profession, how do we convince smart young people to become engineers, with that sort of loss rate?

Ronald Corradin, *St. Paul, Minn.*

FEEDBACK

Send us your letters and comments via hard copy or e-mail memag@asme.org (use 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.



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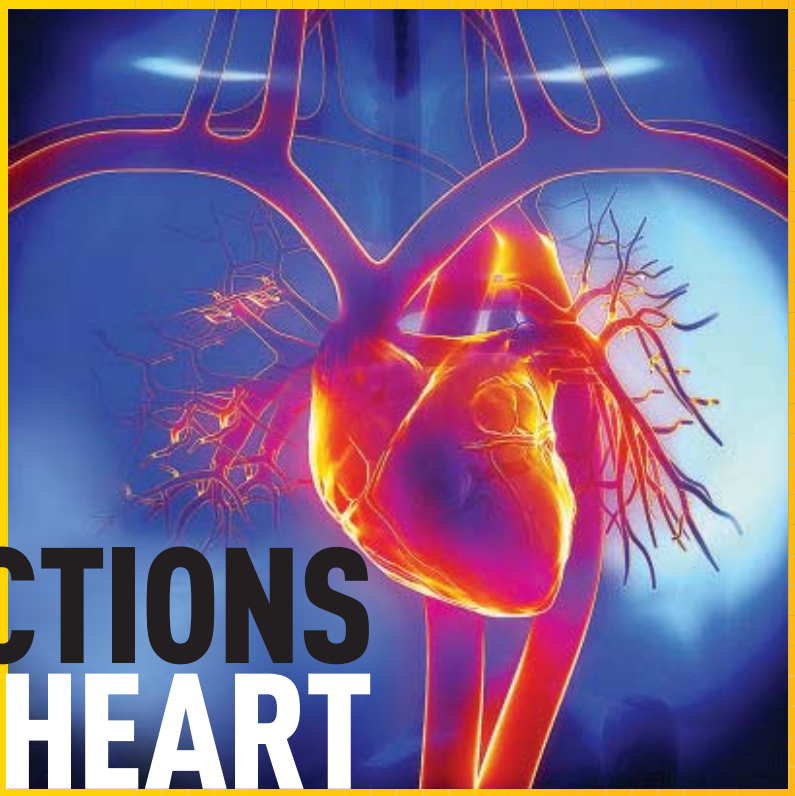
One of the most common means for treating an irregular heartbeat can be tripped up by the motion of the heart and the flow of blood. Researchers in Cleveland have developed a system that can be much more accurate, thanks to the use of magnetic attraction.



ATTRACTIONS OF THE HEART

An experimental way to treat irregular heartbeat uses magnetic fields to guide a robotic catheter.

MAGNETIC ATTRACTION: SOUNDS MORE LIKE THE recipe for the back-and-forth plot of a romance novel than a high-tech medical procedure. The technology, now being researched at Case Western Reserve University, aims to improve treatment of atrial fibrillation—an irregular beat—by using the push and pull of magnetic fields to steer a robotic catheter through the chambers of a patient's beating heart while the patient lies inside a magnetic resonance imager.

Cenk Cavusoglu, a professor of electrical engineering and computer science at the school, is principal investigator on the project.

To treat the irregular heartbeat now, doctors slip a catheter through a vein in the thigh up into the heart, where an electrode tip is used to burn, or ablate, the tissues involved in the short-circuiting that causes the fibrillation.

But sometimes a beating heart moves the target and flowing blood creates turbulence that buffets the catheter like wind currents on an airplane, Cavusoglu said.

A two-dimensional view produced through fluoroscopy that accompanies this procedure can be blurry. Surgeons sometimes burn more tissue than necessary — or not enough to eliminate the problem, he said.

"With our technologies, we believe physicians will be able to accurately navigate and target tissues; they will see exactly where they are inside the heart in real time and see the tissues they're ablating in real time," Cavusoglu said.

Doctors will still hand-feed the catheter from thigh to heart. But once there, robotics take over, Cavusoglu said.

To make a catheter robotic, the researchers have wrapped the inch behind the tip in tiny copper coils. Passing an electrical current through the coils induces a magnetic field, he said.

When this magnetic field is paired with the magnetic field created inside the MRI to produce images, the catheter moves. In order to control the movement, Cavusoglu's lab is now developing software to use the fields like a pair of deftly controlled bar magnets.

A doctor will use a joystick or touch screen to guide the catheter. In the heart, to turn the catheter to the left or right, a current will be applied to coils in either direction.

Nicole Seiberlich, an assistant professor of biomedical engineering, has developed the technology to see images inside the body 10 times faster than now commercially available. Her technology doesn't sacrifice MRI clarity, she said.

Researchers have received a $1.3 million grant from the National Institutes of Health to perfect the technology over the next four years.

Seiberlich said she and her colleagues will work on increasing the speed of the system, to give a doctor a clear view of the landscape inside the heart in three dimensions in real time. **ME**

QUICK FACTS:

WHAT IT IS:
A catheter guided by magnetic fields.

STRUCTURE:
A catheter modified with a copper coil that can carry electricity.

HEALTH IMPACT:
A more accurate and steadier method for ablating heart tissue in the treatment of atrial fibrillation.

JEAN THILMANY

CHINA TRADING UP ITS EXPORTS

THE PEOPLE'S REPUBLIC OF CHINA IS SHIFTING ITS MIX of exports away from cheap goods to higher-technology products, according to a report by Xinhua, the government-owned news service.

The shift is necessary, the report said, because of rising wages in the country and an appreciating currency.

The authors of the article, Wang Zichen and Zhang Yi, wrote: "Machinery, electrical, and high-tech products continued to expand their share of total exports with their growth rates outpacing those of other major items. In 2013, machinery, electrical, and high-tech goods accounted for about 80 percent of total exports, contrary to perceptions that textiles, shoes, and furniture make up the bulk of made-in-China goods."

They reported that China's exports last year rose 7.9 percent to the equivalent of $2.2 trillion.

The trade-up is a matter of eonomic necessity, they said. As they pointed out: "China still has to make 100 million T-shirts to trade for one airplane."

The report quoted a manager of a plastics factory in Guangdong Province, who said, "We paid junior workers 700 to 800 yuan per month in 2005. Now we have to give them more than 3,000 yuan." The authors said minimum wages have doubled since 2005 in Shenzhen, which borders Hong Kong.

The value of the national currency, the yuan renminbi, has been climbing sharply for the past three and a half years. In the middle of 2010, the U.S. dollar was worth about seven yuan. The ratio is now closer to one to six.

The report also quoted Wang Mingxin, general manager of Zhejiang Xinle Textile & Chemical Fiber Co. Ltd., who said: "It is a matter of life or death. We must upgrade, with a particular emphasis in research and development.

"About 90 percent of our staff used to work in the manufacturing department," he said. "In the future, we expect only 40 percent to work in manufacturing, and the others in development and design." ■

THE SHIFT IN EXPORTS IS NECESSARY BECAUSE OF RISING WAGES AND AN APPRECIATING CURRENCY.

POWER ELECTRONICS INSTITUTE FOR NORTH CAROLINA

IN A NOD TOWARD THE SECTOR'S INCREASING importance, President Obama announced in January the creation of a public-private center dedicated to developing next generation power electronics. North Carolina State University in Raleigh is leading a consortium of 18 companies and six universities to run the Next Generation Power Electronics Institute.

The center will focus on developing wide-bandgap semiconductor technologies in order to make them cost-competitive with current silicon-based power electronics. Wide-bandgap semiconductors can operate at higher temperatures than silicon-based technologies, and are generally more durable and efficient. The hope is that the resulting technology will enable the manufacture of energy-efficient, high-power electronic chips and devices which can improve the operations of motors and consumer electronics as well as the electric power grid.

$70M

AMOUNT TO BE AWARDED TO THE POWER ELECTRONICS INSTITUTE BY THE DEPARTMENT OF ENERGY OVER THE NEXT FIVE YEARS.

The institute will provide shared facilities, equipment, and testing and modeling capabilities to companies involved with power electronics. The goal is to help these companies, especially small and medium-size manufacturers, develop, design, and build devices using these new technologies.

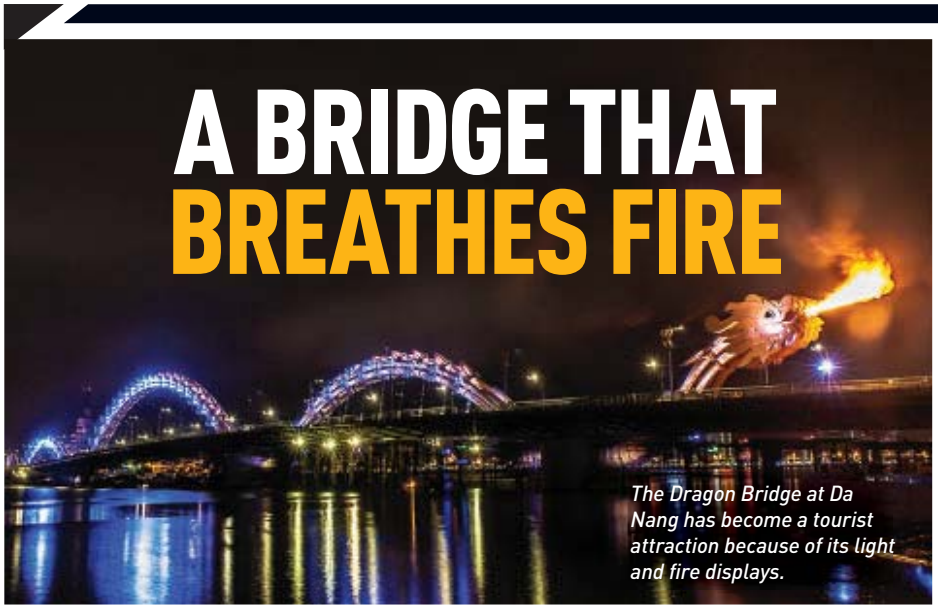
In addition to North Carolina State, the consortium behind the institute includes Arizona State University, Florida State University, University of California at Santa Barbara, and Virginia Polytechnic Institute, plus two government research labs, the National Renewable Energy Laboratory and the U.S. Naval Research Laboratory.

Private companies backing the institute include ABB, APEI, Avogy, Cree, Delphi, Delta Products, DfR Solutions, Gridbridge, Hesse Mechatronics, II-VI, IQE, John Deere, Monolith Semiconductor, RF Micro Devices, Toshiba International, Transphorm, USCi, and Vacon.

The power electronics manufacturing institute is one of three new centers that are following the lead of the National Additive Manufacturing Innovation Institute founded in Youngstown, Ohio, in 2012. Two other proposed centers, slated to develop digital manufacturing and lightweight metals, have yet to be sited.

The Department of Energy has awarded the new power electronics institute $70 million over the next five years. This amount was matched by consortium members. ■

A BRIDGE THAT BREATHES FIRE



The Dragon Bridge at Da Nang has become a tourist attraction because of its light and fire displays.

LONG-SPAN BRIDGES ARE NOTED FOR ARCHITECTURAL GRACE and engineering prowess. Vietnam has a new span that its designers call a "unique" interpretation of a single-arched bridge. It doubles as performance art.

Da Nang's 666-meter-long Dragon Bridge is a design of hybrid steel box girders supported by undulating central arches modeled after a dragon hovering over the Han River. Decorative steel plates attached to the arches represent scales, and a head on the eastern side can emit fire and water.

"It is certainly an unconventional arch structure," says Radu Dragan, senior associate for Ammann & Whitney, the New York City-based firm that won the design contract.

The design team decided on arches formed of 4-foot-diameter steel tubes unconnected to each other and held in place with horseshoe-shaped steel spider frames. Steel suspender cables connect the arch with the deck at 8-meter intervals. Below the deck, the arch structure becomes reinforced concrete and is integrated into the piers.

The deck is wide, to accommodate three lanes of traffic in each direction and pedestrian walkways. The center three spans are hybrid steel box girders supported by the arch. For the suspended portions, the deck superstructure is a box girder of a triple-cell steel box; prestressed twin-cell boxes are used for the sections over the piers. Further, 10.5-meter cantilevers extend from the box girders to bring the superstructure's width to 35 meters. It extends another meter to meter and a half to accommodate the walkways.

Steel-tube arches are sheathed in scales for structural integrity and ornamentation.

Workers connected the bridge deck to the arches with steel cables 8 meters apart.

During the design competition, the designers offered up the single-arch option in addition to a cable-stay design and the owner—the Da Nang city government—opted for the dragon.

"The arch was really different from everything else," Dragan said. "And we were able to land the bridge directly at street level. That was very important to them."

The Dragon Bridge, which *continued on page 14»*

GLOBAL

A GREEN PROPOSAL: WORLD'S TALLEST BUILDING IN 6 MONTHS

A Chinese entrepreneur claims he can build the world's tallest building in six months, although authorities have stopped construction over permitting issues, Agence France-Presse has reported.

An article based on an interview with the businessman, Zhang Yue, said his purpose is to offer a solution to the pressures of urbanization in China, because he plans to use energy-saving materials and the greater height will pack more living space into the footprint of the building.

AFP estimates his net worth at the equivalent of $180 million, and said his company has built a 30-story hotel in 360 hours in Changsha, China, the parent company's home town. The construction is recorded in a time-lapse video available on YouTube.

In a colorful note, the story pointed out that Zhang has also built replicas of an Egyptian pyramid and of Versailles, both on his corporate campus.

Zhang proposes to build a structure, which he calls Sky City, about 10 meters higher than Dubai's Burj Khalifa, a residential and commercial tower that stands 828 meters high and is billed as the tallest free-standing structure in the world.

According to the news service, Zhang made his money selling air conditioners. He now operates a company called Broad Group, which includes Broad Sustainable Building Co., a manufacturer of factory-made skyscrapers.

According to the company, its structures can withstand a magnitude-9 earthquake. The company also claims its designs are five times as energy efficient and have 20-times purer air than conventional buildings.

Ground breaking for construction took place July 20, 2013. About a week later a report in *People's Daily* said local authorities in Changsha had ordered a halt in construction and pledged that there would be no substantial construction until the project had undergone necessary legal procedures.

Procedures include examination of the construction plans for the basic structure and its firefighting facilities. Tests also were needed to establish earthquake resistance and other issues of structural soundness.

According to the *People's Daily* article, the building will be made of steel and will be able to accommodate 30,000 people with a school, hotel, hospital, apartments, offices, and an 8,000-square-meter garden. ■

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continued from page 12 »

A BRIDGE THAT BREATHES FIRE

opened in April 2013, is Da Nang's fifth crossing of the Han River and is expected to provide quicker and easier access to the seacoast, boosting local tourism. The arch design allows the bridge to transition at street level in the city's historic Cham Museum Square.

While they investigated the site, the team realized that river traffic did not require a high clearance, said Chris Gagnon, executive vice president of A&W. Most boats using the river are local sampans or other low clearance vessels. This offered the option of an arch bridge, which has a 12-meter clearance over the main shipping channel and preserves scenic views of the square.

But the main channel had to be moved to the eastern side of the crossing because the at-grade approach to the city center resulted in limited vertical clearance. The westernmost span is a variable depth cast-in-place prestressed concrete structure integral with the first pier. Competent rock on which to found the piers was found about 43 meters below the waterline so the piers are fitted within a "partially left-in-place cofferdam" to provide a permanent fixture below the river bottom and prevent scouring of drilled shafts.

A&W used 3-D models and both proprietary and off-the-shelf software to review the design, which meets both local and international codes. "The deck is a hybrid, with a concrete deck and below, steel box girders," Dragan said. "It is a complex structure, but not unique or unusual."

Designers believe its uniqueness rests with the five steel tubes that form the arch. "There are no interlocking members," Dragan said. "It is certainly unusual and an innovative approach, especially having to connect the spider frame and the steel [tubes]."

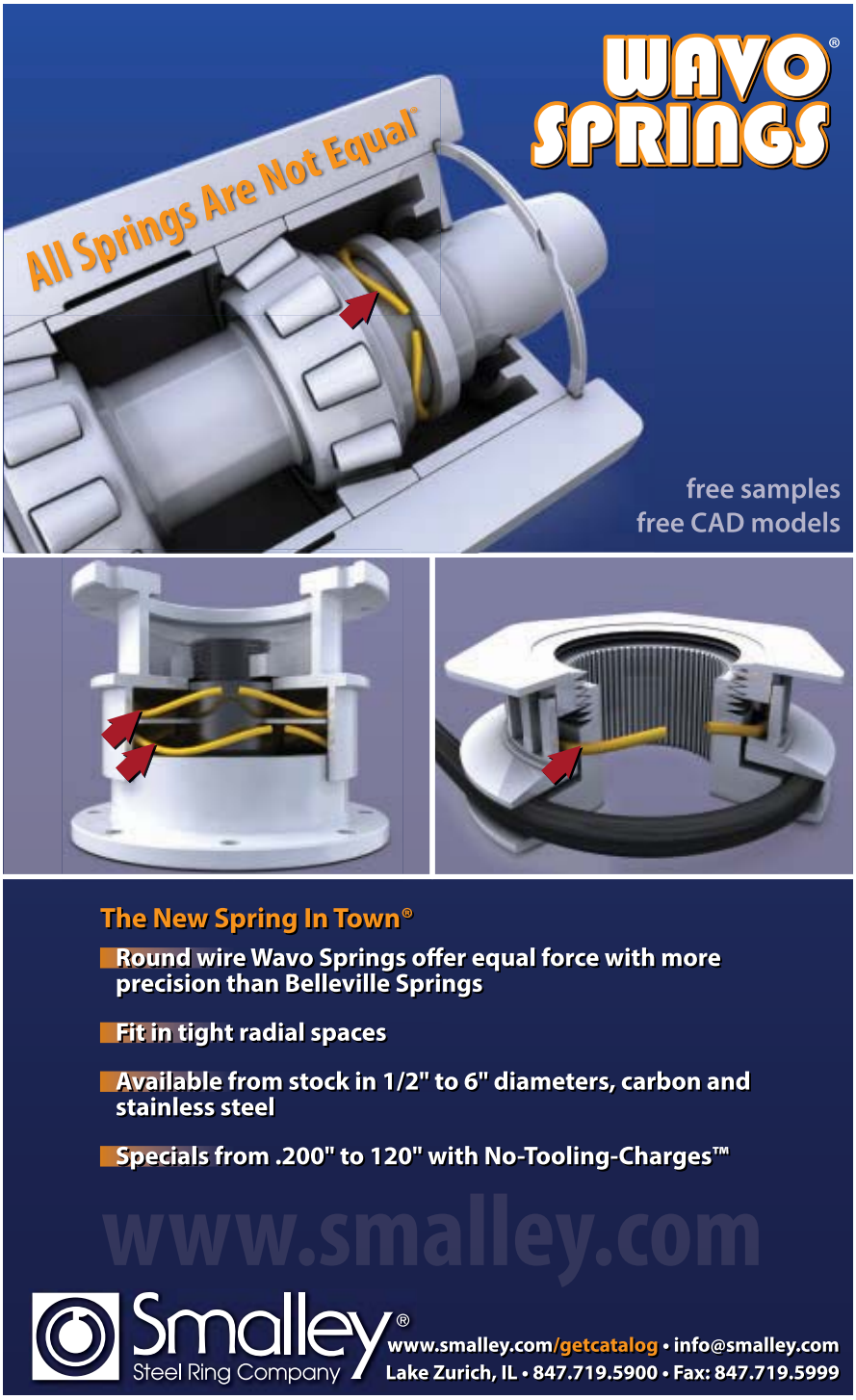
For the connection to work, the design team decided to use a layer of neoprene usually associated with material used in expansion joints and bearings. According to Dragan, it allows for movement and can be easily replaced during the course of the structure's 100-year design life.

Construction was done by two Vietnamese contractors, one for the substructure and the other the superstructure. The steel spider frames and tubes were fabricated in China and erected by crane with supporting falsework.

Since its opening, the bridge has become a tourist attraction in its own right. Its arches are illuminated with LED lighting after dark, and every weekend the dragon's heads spews fire and water. That system was developed and installed by local engineers.

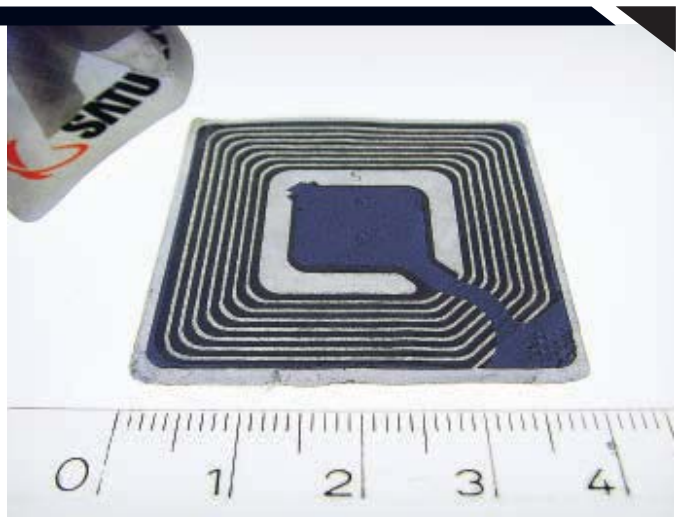
Gagnon said the original design called for a two-headed dragon but the owner opted for one head, facing east. With a final cost of $86 million, he says, "It's a low cost compared to its complexity." ME

JOHN KOSOWATZ/ASME.ORG



RFID FOR HEALTHCARE

A teetering stack of documents on a storage-room shelf can pass for a medical record filing system in some sub-Saharan African hospitals, where looking up a patient's history can mean leafing through reams of paper by hand.



A project by two early-career engineers would use electronic records and RFID tags to help manage healthcare in the developing world.

If a patient moves or is transferred to a specialist, sharing that history with another medical center can be difficult, if it happens at all. Digitizing the records would save money, space, and time, and would allow facilities to share medical data. But overhauling the system requires fundamental changes to health care in developing countries.

Now a team of volunteer international engineers has developed a detailed, low-cost plan to help. The plan, "Electronic Health Record Architecture for Rural Clinic Data Connectivity and Unique Patient Identification," recently won the IEEE Global Humanitarian Conference's Young Professionals Project Contest.

"We would say this technology is equally suited to rural or urban areas, but is particularly relevant in a rural setting given the current lack of infrastructure and particularly poor patient outcomes," Hassaan Idrees, a corrosion engineer trainee at BP *continued on page 18»*

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Q&A GEORGE WHITESIDES

GEORGE WHITESIDES HAS A JOB SOME ENGINEERS ENVY: He is creating the world's first privately owned commercial space travel company. Building on SpaceShipOne, the aircraft-launched spacecraft that won the Ansari X Prize for the first private manned spaceflight in 2004, he helped create the six-passenger SpaceShipTwo, which could undertake a manned flight as early as this year. Prior to joining Virgin, Whitesides was NASA chief of staff and executive director of the National Space Society, an advocacy group. He also held positions at Blastoff Corp., Zero Gravity Corp., and Orbital Sciences.

ME: How did you wind up at Virgin Galactic?

G.W: My wife and I were among Virgin Galactic's first customers, and we kept in touch with Virgin Galactic through that relationship. When the company began seeking a new CEO, it turned to its customers, who believed in the commercialization of space. I guess they thought that as NASA chief of staff, I knew something about the subject.

ME: Is privatization the way forward?

G.W: Government involvement is appropriate for certain activities, particularly large, complex, and costly science-related projects with long time scales. But humans innovate best in smaller teams operating under some pressure with relatively short time scales. Technology has advanced, and things that private space companies, especially smaller ones, are doing today were not in the realm of feasibility 20 years ago. The private sector is also more efficient when it comes to cost and schedule.

George Whitesides addresses a career fair. SpaceShipTwo is on the right.
Photo: Virgin Galactic

ME: A ticket on SpaceShipTwo costs $250,000. Is space only for the wealthy?

G.W: The only other way to get into space is to pay the Russians $70 million.

We're radically changing the cost of human spaceflight, and we have reason to believe that costs will come down as we amortize our development costs. I believe that in 10 years, most people in the United States will know somebody who has been to space.

ME: How fast will that happen?

G.W: Our aspiration is to bring prices down. As we build more vehicles and schedule several flights a day, I think we will be able to offer lower-cost services.

Further into the future, we want to build larger vehicles. Just as large jets drove down trans-Atlantic fares, larger spacecraft will make space more affordable. Are we going to see a 700-person spaceship any time soon? Probably not, but you get the idea. Taking more people into space at a time will have an impact on cost.

ME: What else is on the boards?

G.W: In addition to larger spaceships, we might create a point-to-point service from one side of the globe to the other. Spaceships could reduce travel times without sonic boom problems by slowing down over the ocean and landing quietly in a city.

ME: What about prolonged flights?

G.W: I'm optimistic. For example, Bigelow Aerospace, a private company, has already launched two model space habitats and plans to add one to the International Space Station in a few years. There's no reason why something like that wouldn't work. Down the road, perhaps someone will offer trips around the moon that take a few weeks. Technically, it's very doable. It just takes capital.

ME: Some people argue that robots could explore space more efficiently. Why should humans venture into space?

G.W: I believe that humanity's destiny is truly out among the stars, and that we have a responsibility to explore the solar system and eventually the cosmos. There is no question that we will collaborate with increasingly competent robots, and use technologies like telepresence and haptic feedback to share exploration with people on Earth. Ultimately, humans and robots will complement each other. ME

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continued from page 15 »

RFID FOR HEALTHCARE

Pakistan, and John Avrett, an advanced space technology engineer with the United States Air Force, who were both involved in the project, told Engineering-forChange in a statement.

The project combines electronic health records and radio frequency identification tags to maintain and track patient identification.

"Avoiding making it highly technical, this system is not training-intensive on health-care workers or doctors, and will not place strain on the local populace, whatever their literacy rate may be," Idrees and Avrett said in the statement.

The team of engineers decided on RFID cards after ruling out nearly a dozen other technologies. Some of those included satellites (poor network performance and high delays), lasers (beam dispersion is easily disrupted by weather and the environment), Bluetooth (too many technical requirements such as specific wavelength) and others, the pair said.

Similar plans piloted in rural developing communities floundered when patients resisted the concept of identification cards. To avoid that problem, the newly proposed RFID system would include public outreach and local laws, the engineers said.

The next steps will be to run a pilot program, eying medical centers in Kerala, India, for the team's test site. ■

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KOREAN BACKING FOR INDIAN POWER PLANT

A KOREAN ELECTRICITY COMPANY has bought a 40 percent stake in a 600 MW coal-fired power plant under development in Maharashtra, India, according to a report in *The Hindu Business Line*.

The company, Korea South-East Power Co. Ltd., will invest $240 million in the project, which is being led by Jinbhuvish Power Generations Pvt. Ltd.

Korea South-East Power is subsidiary of Korea Electric Power Corp., which is 51 percent owned by the South Korean government.

The newspaper reported that lenders for the project include Rural Electrification Corp., Power Finance Corp., PTC India Financial Services Ltd., and India Infrastructure Finance Co. Ltd.

Jinbhuvish said that it has received clearances and approvals for the project and expects the plant to be operational by 2016. ■

POWERING THE INTERNET OF THINGS

Microgen Systems, an Ithaca, N.Y., spinoff of Cornell University, is inching closer to commercial productions of MEMS energy-harvesting systems at X-Fab Silicon Foundries, a German sister company. The company's CEO is promoting the devices as a means of powering the wireless interconnection of everyday objects, a concept which has been called the "Internet of Things."

Harvester and electronics fit in an enclosure the size of a 9 V battery. The harvester is near the center.

Many manufacturing companies are already using wireless sensors to monitor equipment status and energy usage. In the Internet of Things concept, companies would take this one step further by making sensors inexpensive enough to use everywhere. Sensors in medicines might signal doctors when patients do not take prescriptions, or cheap drones could fly over fields and transmit where plants need more fertilizer or pesticide. In the home, connections might optimize energy use in washers, driers, refrigerators, and other appliances.

To be economical, these chip-sized sensors need small, inexpensive power sources. Batteries are small enough, but too costly, according to Microgen's president and CEO, Robert Andosca. "There's not only the cost of the batteries, but there is labor cost in continually replacing them," he said.

His solution is a MEMS piezoelectric energy-harvesting device that generates power from vibration—not only the continuous hum of appliances and industrial machinery, but also the pulses of rotating tires and striding cows. These vibrations cause a piezoelectric cantilever to oscillate rapidly and generate electricity as it flexes.

Microgen's design uses large, square cantilevers with

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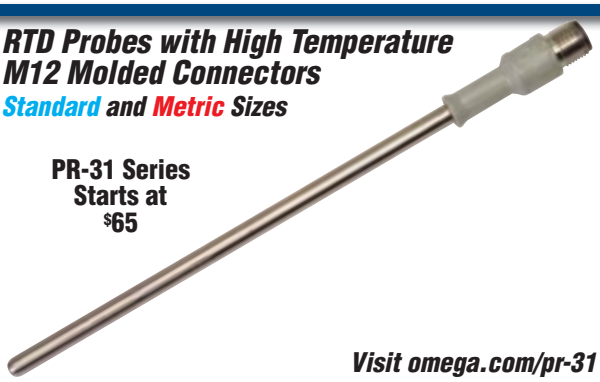

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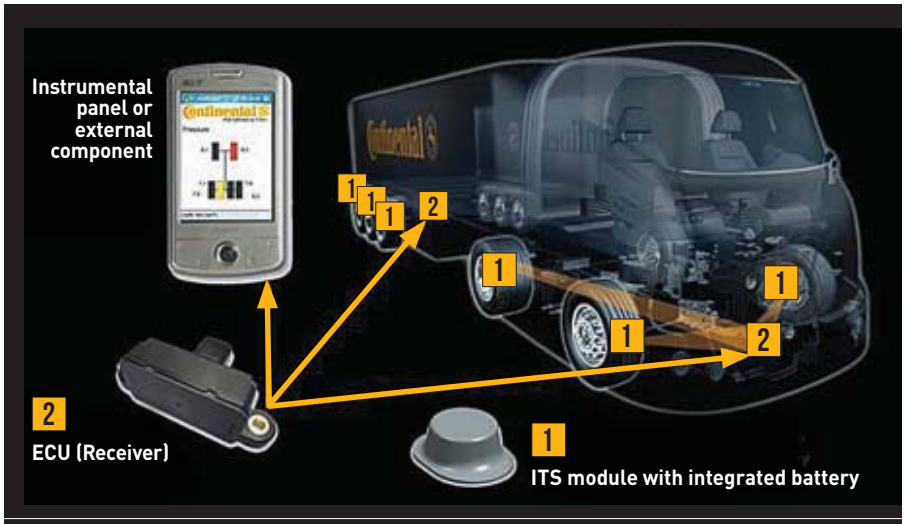
POWERING THE INTERNET OF THINGS

weighted ends, so they vibrate like a diving board with a Sumo wrestler on the edge. They can scavenge energy from vibrations between 100 and 1,500 Hz, and generate enough electricity to power small circuits.

The company encapsulates the MEMS in power cells with electronics to transform ac to dc current and regulate voltage, as well as store energy in a capacitor or rechargeable battery. Andosca is looking to launch a family of energy harvesters for wireless machinery monitoring later this year.



Pulse energy harvesters may one day power systems that will monitor pressure, temperature, and even skidding of truck tires.

Andosca sees a potential application in intelligent tire sensors. Today, many trucks already have sensors that alert truckers when tire pressure is low. Keeping tires properly inflated reduces wear significantly and improves miles per gallon. These systems measure pressure through a sensor and battery pack in the wheel rim and communicate the information wirelessly.

Many large tire makers, such as Bridgestone, Continental, and Pirelli, want to make these systems even smarter. By embedding the sensor in the tire itself, they would be able to measure not only pressure, but also tire temperature, wheel load, and skidding tires. By reacting quickly to skids, automated braking equipment could reduce the distance needed to stop a truck.

While manufacturers could bury battery-powered sensors in the inner plies of a tire, the prolonged duty cycle of commercial trucks would soon drain their power. Also, the batteries could not survive the high temperatures used to retread tires.

Microgen has teamed with Melexis, another sister company that makes tire pressure sensors, to develop a version powered by the energy harvester. The harvester would generate energy from impulses as the tire flattens to meet the road and grows rounder as it leaves the road.

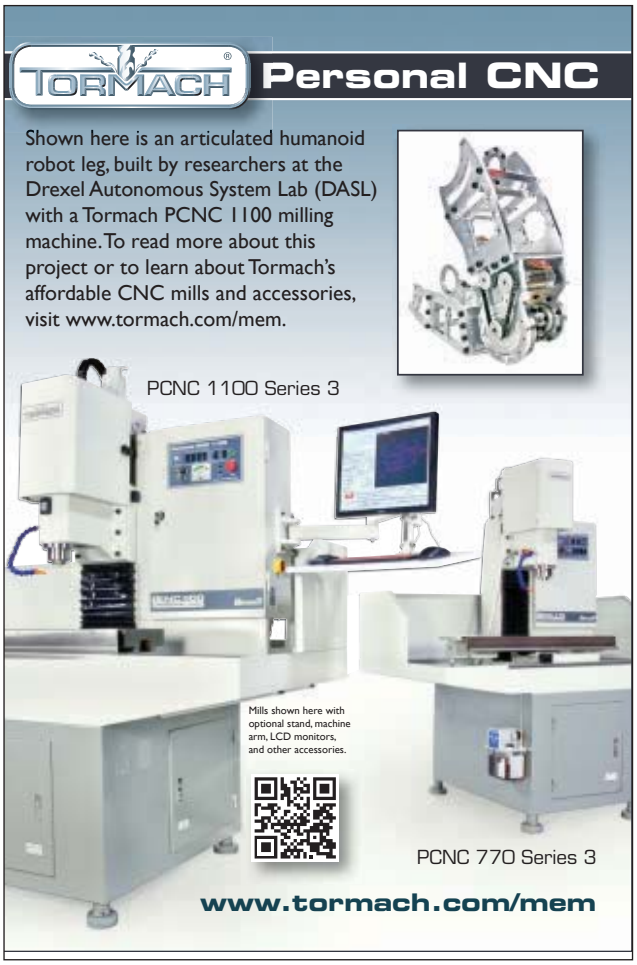
HARVESTERS CAN SCAVENGE ENERGY FROM VIBRATIONS AND GENERATE ELECTRICITY TO POWER SMALL CIRCUITS.

In addition to not needing a battery replacement and withstanding 180 °C retreading temperatures, the harvester can withstand forces generated when large trucks roll on uneven roads or hit potholes. Andosca said Microgen and Melexis are being paid to conduct trials with a major tire manufacturer, whom he declined to name.

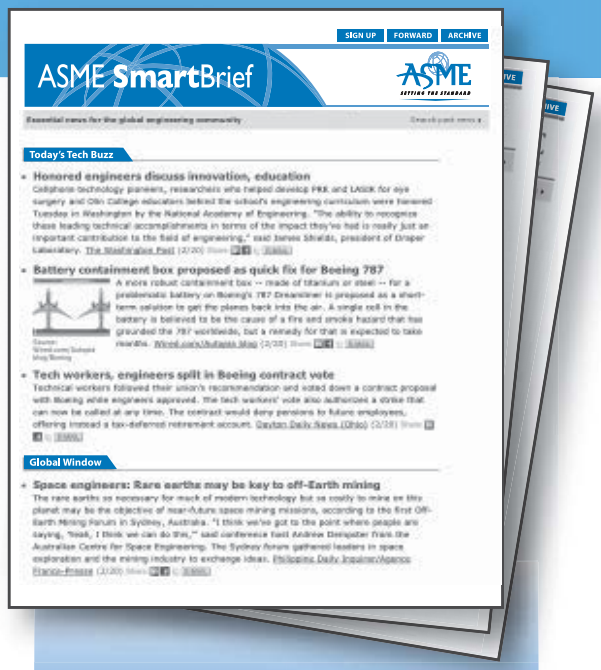
The same type of pulse energy harvester could be used to power devices that determine whether cows are in heat, Andosca said. According to DRMS Dairy Metrics, farmers miss the signs of heat about half the time, and each time they do, it results in lost milk production.

Farmers can use battery-powered sensors now to detect the fertility of cows. The harvester would eliminate the need to change batteries, Andosca said. ME

ALAN S. BROWN



Mechanical Engineering readers are raving about ASME **Smart**Brief!



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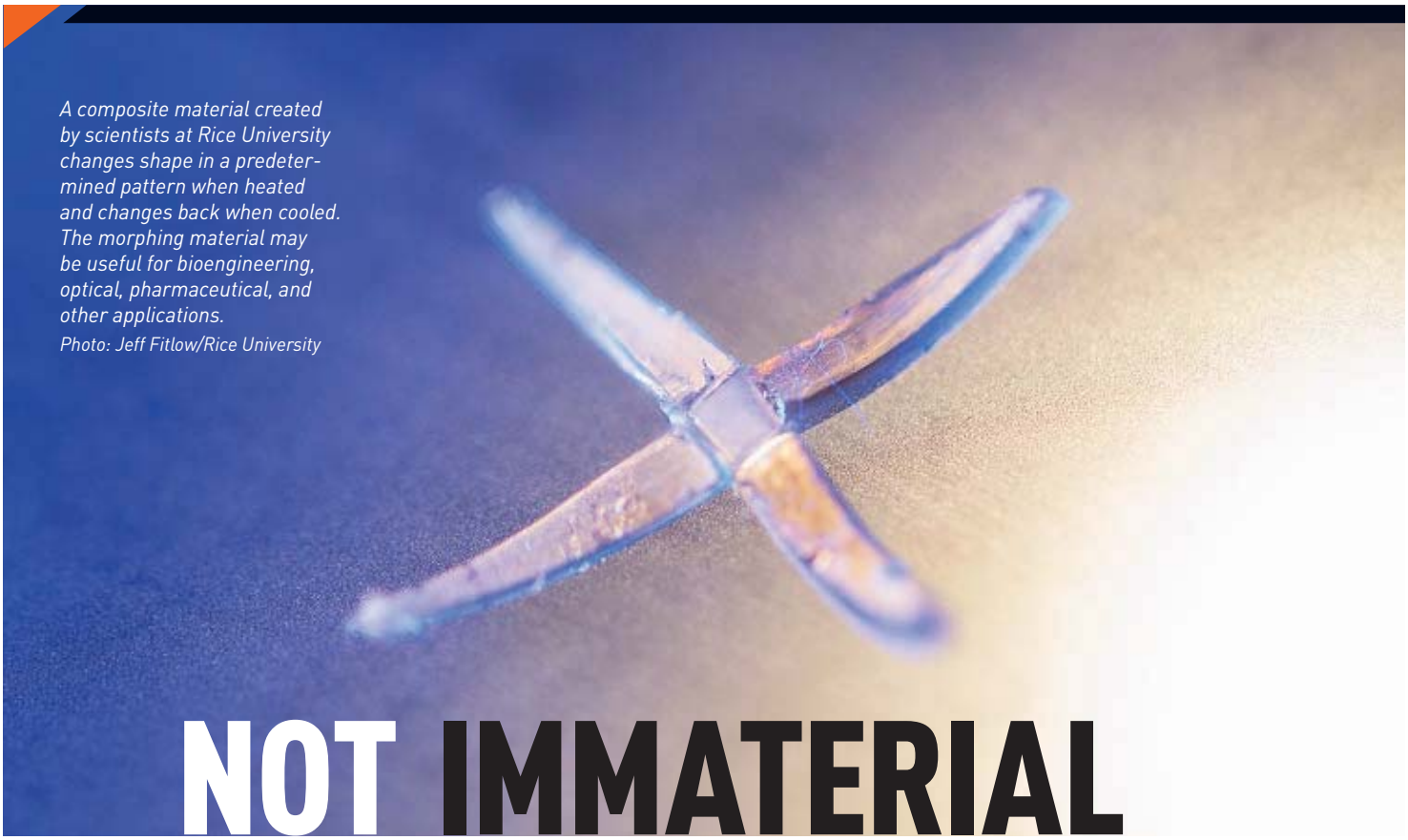
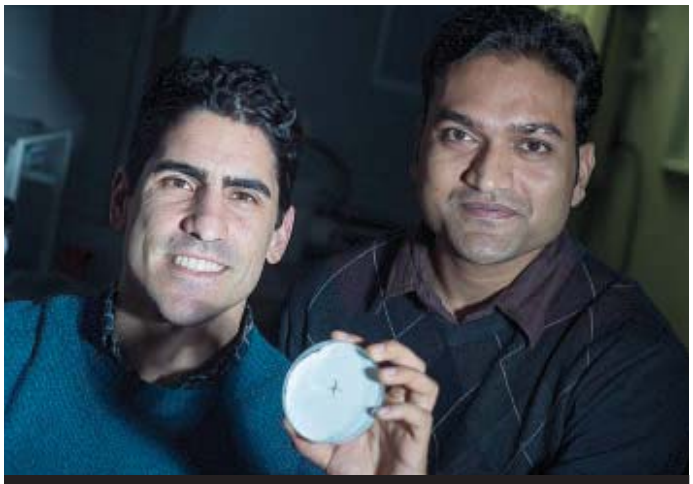


A composite material created by scientists at Rice University changes shape in a predetermined pattern when heated and changes back when cooled. The morphing material may be useful for bioengineering, optical, pharmaceutical, and other applications.
Photo: Jeff Fitlow/Rice University

NOT IMMATERIAL



SHAPE-SHIFTING ELASTOMERS

Rice University polymer scientist Rafael Verduzco, left, and graduate student Aditya Agrawal show a sample of their morphing material, which changes shape in a predetermined pattern when heated.
Photo: Jeff Fitlow/Rice University

THE LAB Verduzco Lab: Polymer Nanoscience and Engineering, Rice University, Houston; Rafael Verduzco, principal investigator.

OBJECTIVE The development of liquid crystal elastomers for use in materials that respond to stimuli.

DEVELOPMENT A shape-changing material for biomedical applications.

Whether molded in three dimensions to depict a hard-to-imagine complex mathematical model or shape shifting for use in 3-D (and non-3-D) biomedical applications—physical materials are the stuff of science and engineering. This month, we visit one lab that's making complex mathematical models tangible and another lab that's programming matter to do amazing things.

A material created at the Verduzco Lab at Rice University in Houston morphs from a flat slab into shapes that can be controlled by patterns written into their layers. Because the materials are biocompatible, stable, and inert they have significant potential for biological applications, said engineer Rafael Verduzco, principal investigator in the lab.

The material can be used for biomedical applications like three-dimensional biological scaffolds, implantable materials that contract and expand in response to stimuli, or the controlled release of drugs from capsules, Verduzco said.

For application like these, scientists seek material that can change its shape, then revert back to the original shape—or into an entirely new one, he said.

With the right patterning, Verduzco said, there's no limit

to the complexity of the shapes that could be teased from the material. The researchers demonstrated how the material could spiral or curl or shape itself into an X that could either fold its legs under or stand on four legs.

The lab's material is made of two layers, one of which is composed of liquid crystal elastomer. This rubber-like material of cross-linked polymers is reversible, unlike shape-memory polymers that change shape only once and cannot go back to their initial shape, he said.

The second layer is a thin sheet of simple polystyrene, placed either above or below the elastomer layer.

With changing temperature, the elastomer tries to contract or expand. But the stiffer polystyrene layer prevents this and instead causes wrinkling, bending, or folding of the entire material, Verduzco said.

The lab discovered that the layers would react to heat in a predictable and repeatable way, allowing for configurations to be designed into the material, he added.

Tim Evans of Imperial College London holds a 3-D-printed model of a forest fire. The monitor shows the 3-D printed table displayed at the Victoria and Albert Museum that inspired Evans's team.
Photo: Imperial College, London.

FIRE IN THE HAND

THE LAB Theoretical Physics Group, Imperial College London; Tim Evans, senior lecturer.

OBJECTIVE Research into theoretical physics, including string theory, quantum field theory, and cosmology.

DEVELOPMENT The 3-D printing of objects based on mathematical models.

Physicist Tim Evans and his fellow researchers at Imperial College in London have devised a way for students to literally hold on to the theoretical concepts they've learned in physics classes: by printing them on a three-dimensional printer.

The researchers call the method sculplexity. And they say it could transform the way ideas are presented and discussed within the scientific community.

Complex systems are made up of many parts that interact on many time and length scales and that show coherent behavior and certain patterns on the large scale, Evans said.

In many of these systems, interactions can be mapped onto a two-dimensional grid divided into identical cells. Each cell exists in a certain state, evolves over time, and is governed by a set of rules.

"A 3-D printer builds up its object in layers," Evans said. "So the height of the object can be thought of as time. The mathematical model will define at each point in time what the printer should print at one height. The next step in the model will then define what to print on top of the first layer, and so forth. The result is a 3-D object which shows how the mathematical model has evolved over time."

Evans and his team used a forest fire as an example. In that grid, each cell represented a tree that was either alive, dead, or burning. The exact state that each cell occupied over time depended on rules that took into account the cell's proximity to other burning cells, if the cell had been struck by lightning, and other such rules.

The team printed a model measuring around three inches square that described how forest fires can start and how they spread over time. It took about eight hours and cost around $20 to print the model, Evans said.

The experiment with 3-D printed mathematical models was inspired by a visit to the Victoria and Albert Museum in London where Evans came across the first 3-D printed object the museum had acquired, he said.

"The object was a table inspired by the tree-like structures found in nature, which is an example of a branching process that is commonly encountered in complex systems in theoretical physics," he said. "This led me to think, what other processes familiar to physics could be turned into a 3-D printed object?" ME

LOOKING BACK

Computers were reshaping engineering when members of an ASME task force on mechanical systems presented their findings to members in March 1984.

RESEARCH NEEDS IN MECHANICAL SYSTEMS

BY K.N. REID, R. COHEN, R.E. GARRETT, M.J. RABINS, H.H. RICHARDSON, AND W.O. WINER

A proposal to the National Science Foundation won ASME a grant to study the research needs in the field of mechanical systems. The authors of that study wrote the article from which these excerpts are taken.

While design methodology is classically a vital part of mechanical engineering, the advent of modern interactive graphics is revolutionizing the practice of design. The coming synergism among interactive graphics, computer-based analysis, expert systems, and large computer data bases has the potential to greatly expand and enhance the creative abilities of the human designer, relegate routing analytical and geometric work to computers, provide easy access to design data, and capture some aspects of the experience and insight of human designers. The discipline of Design Methodology and Interactive Graphics, which represents this synergism, is the newest and most rapidly evolving area in mechanical systems today.

Machine Dynamics has evolved from the classical fields of kinematics, dynamics, solid mechanics, and acoustics, and now is a mix of these traditional areas with new developments in finite-element and transform methods, and other computer-based methods of analysis, synthesis, and optimization. The new, emerging discipline of Machine Dynamics represents an integration of the traditional areas with the increasingly powerful computer-based methods for design and operation of machines. Application of the new discipline will lead to machines that will function with high productivity near their inherent limits of performance, reliability, efficiency, and durability. ME

MOVE OVER, DAISY WHEEL

In addition to the discussion of mechanical systems, March 1984 also saw a development that still affects how we communicate 30 years later. The first desktop laser printer, the HP LaserJet, made its debut. At $3,500, it wasn't cheap, but it was quieter than dot-matrix and daisy-wheel impact printers. It also beat the dot-matrix for legibility and provided flexibility that the daisy wheel couldn't match. Hewlett-Packard shipped its 50 millionth LaserJet in 2000.

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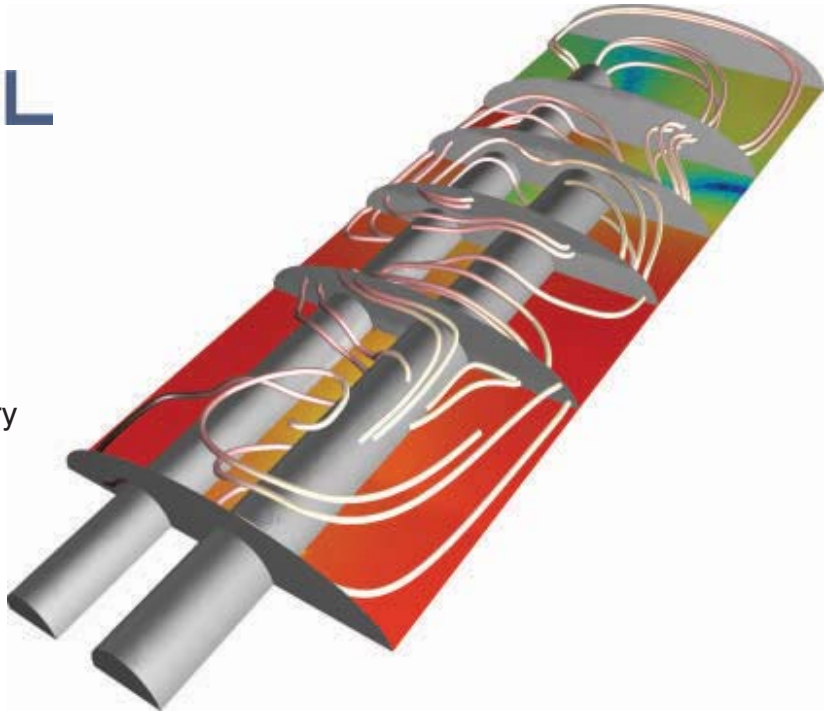

Simulation of a complex hybrid muffler in which the dissipative effects stem from acoustic losses in perforated pipes and plates.

MODERATOR:
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GRAPH 01

INCOME IN U.S. DOLLARS BY MAJOR BRANCH OF ENGINEERING

SOURCE: *2013 Engineering Income and Salary Standard Report*

GRAPH 1 Twelve representative specialties of engineering are shown with their median, 75th percentile, and 25th percentile salaries, according to a 2013 ASME/ASCE salary survey. Offshore engineering showed a surprising range, with the 75th percentile salary almost $90,000 higher than the 25th percentile salary.

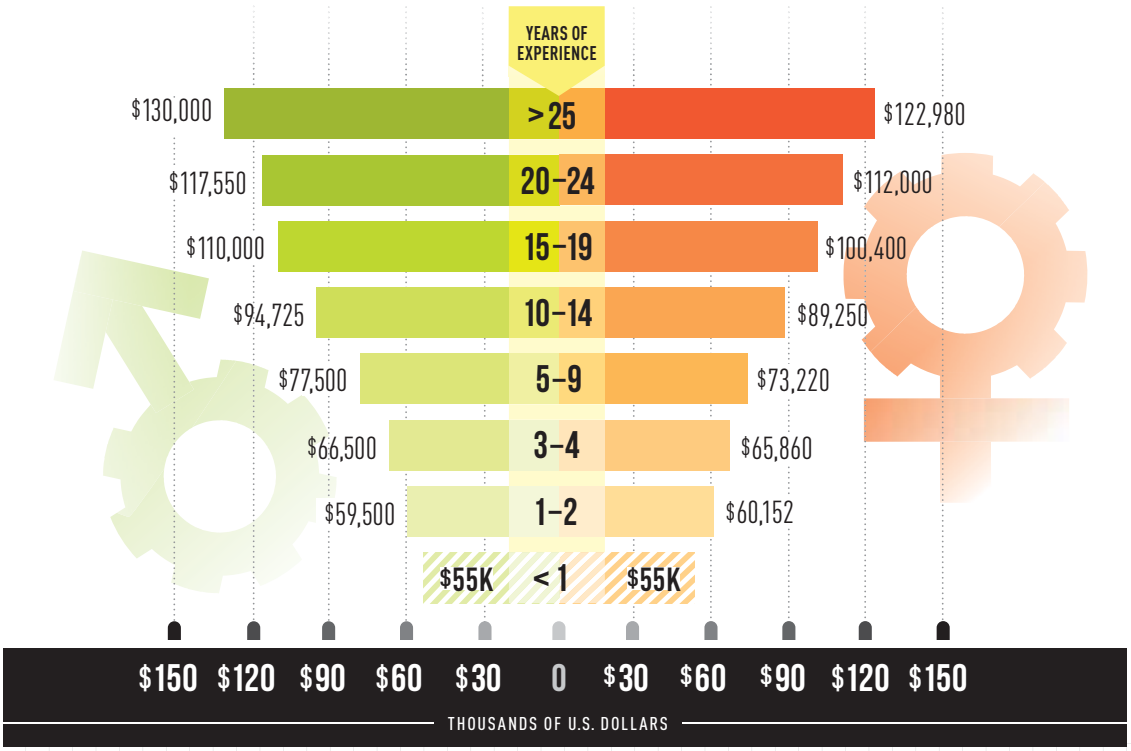
BY THE NUMBERS:

The energy sector is paying the largest engineering salaries. And the paydays are smallest in Des Moines and Nashville.

Everyone has heard why Willie Sutton robbed banks: "because that's where the money is." But if he were an engineer, he might have decided to go into offshore or petroleum engineering, or at least work in Wichita. According to *The Engineering Income and Salary Standard Report*, published by ASME and the American Society of Civil Engineers, that's where the money in engineering is.

The report, which is the result of an online survey of more than 10,000 engineers, details the income trends over the past three years and analyzes them against such factors as length of professional experience, level of education, specialty, and so on. Some of the results are not surprising, but in total they provide a revealing look at the engineering profession.

For instance, senior-level female engineers suffer from a persistent income gap



GRAPH 02

INCOME BY GENDER VS. LENGTH OF EXPERIENCE

SOURCE: *2013 Engineering Income and Salary Standard Report*

GRAPH 2 Male and female engineers begin their careers with the same starting salaries, the survey reports. Over time, however, a persistent gap opens up. The most senior male engineers average $7,000 more per year than their female counterparts.

NUCLEAR	FIRE PROTECTION	PETROLEUM	OFFSHORE	MINERALS & METALS	OCEAN
$119,000	**$123,000**	**$130,000**	**$132,258**	**$133,500**	**$134,763**
$145,906	$147,250	$180,000	$170,000	$152,500	$150,000
$89,250	$92,250	$93,400	$81,000	$107,000	$100,000

WHERE THE MONEY IS

compared to their male colleagues. For engineers with more than 15 years of experience, men averaged between 5 and 10 percent higher incomes than women. But that gap disappeared for early-career engineers; men and women with less than five years of experience had virtually identical salaries.

The salary scale for different engineering specialties also showed some surprises amid expected results. The top four disciplines—ocean, minerals and metals, offshore, and petroleum—had median salaries greater than $130,000 per year. Salaries at the 25th percentile (meaning that 75 percent of salaries were greater) ranged from $81,000 to $107,000 per year, indicating a broad-based demand for those engineers.

Among the high-paying specialties are fire protection, safety, and facilities engineering. Those engineers' salaries came in ahead of such glamorous sub-fields as mechanical, electrical, and aeronautical engineering.

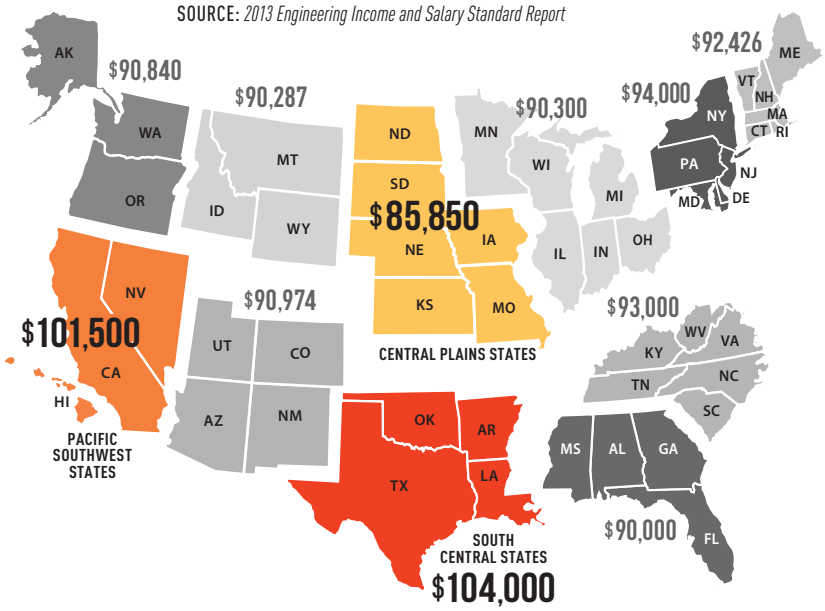
Anyone considering relocation for better money might not be surprised to learn that the Pacific southwest (dominated by California) and the Oil Patch south-central states had a median above $100,000 a year, while the median for the central Plains states was below $86,000. But within those broad regions, exceptions abounded. Engineers in the San Antonio, Texas, and San Luis Obispo, Calif., metropolitan areas reported some of the lowest median salaries, while Wichita, Kansas, had the highest median in the survey, more than $129,000 per year. ME

See the entire report at **http://tinyurl.com/kgbrcjb**

JEFFREY WINTERS

GRAPH 03 INCOME BY SUB-REGION

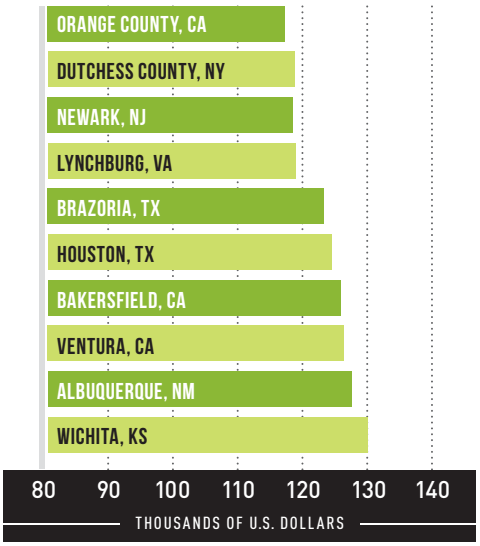
SOURCE: *2013 Engineering Income and Salary Standard Report*



GRAPH 3 Most regions reported average engineering salaries in the low to mid $90,000s. Engineers in the Plains averaged markedly less, and those in California and the Oil Patch made a bit more.

GRAPH 04 HIGHEST INCOMES BY METROPOLITAN AREA

SOURCE: *2013 Engineering Income and Salary Standard Report*



GRAPH 4 Wichita was the city with the highest average income in the survey. Texas and California cities also had high incomes.


IT BEATS
AS IT SWEEPS
AS IT CLEANS
HOOVER CLEANER

ICONIC DESIGN

We asked six leading industrial designers to tell us which products inspired them. The breadth of their choices was unexpected.

Introduction by Alan S. Brown

When we first see a product, there is something in its shape that conveys an unspoken promise. The ladder will be sturdy. The sofa will be comfortable. The scissors will be sharp.

Products become icons—the version that essentially defines the category—by perfectly matching form with function. They not only make a promise, they deliver.

Take, for example, the Harley-Davidson. It defines our image of a motorcycle because it is as powerful and as fast as it looks. Similarly, Bang & Olufsen's minimally elegant stereo system is part of the New York Museum of Modern Art's permanent collection, but the music that came out of it was heavenly because engineers built it around psychoacoustic principles. The iPhone may look like a featureless slab, but its apps offer virtually limitless functionality.

On a more mundane level, Henry Dreyfuss' circular design for Honeywell reshaped our ideas of how a thermostat should look and behave. Dreyfuss, a pioneer of industrial design and a founder of the Industrial Design Society of America, influenced generations of American designers by his ability to integrate form and function.

Another example is his 1936 Hoover 150 vacuum cleaner. Dreyfuss covered an exposed motor with a Bakelite hood, creating a streamlined style that consumer products have recreated for decades. Yet he also made the vacuum lighter and easier to maneuver by using lightweight materials and redesigning the dust bag to be less intrusive.

Dreyfuss designed scores of other products, ranging from the modernist 20th Century Limited locomotive to Western Electric's 302 and Princess telephones. Most would call them iconic designs that, in their time, exemplified their category as completely as the iPhone defines smartphones today.

Yet when we asked six top industrial designers to tell us about an iconic work that influenced them, the results were quite unexpected. While some picked classic iconic designs, others chose products that spoke to them more personally.

What their responses show, perhaps, is that industrial designers, like engineers, find sources of inspiration everywhere, from classic exemplars to frisky new products that give them insights into design problems they are grappling with today.

Images courtesy: Bang & Olufssen © Bang & Olufsen a/s | Hoover © TTI Floor Care North America | Harley Davidson © satina/123rf

ICONIC
DESIGN

HERMAN MILLER AERON CHAIR

CHARLES AUSTEN ANGELL
CEO, Modern Edge Inc.
Chair, IDSA Board of Directors

An icon is something that people see as a seminal example of that category. It might be the first, like the Xerox copier, or the best, like the iPhone. For me, it's the Herman Miller Aeron Chair. Mention it, and even people who haven't used it know what you're talking about.

Although it has a distinctive aesthetic, the Aeron Chair transcends the sculptural elements that people associate with design. The best designs have great aesthetics, plus human-centered functionality, mechanical excellence, and market impact. They bring them together in ways that define their category.

When you look at the chair, the mesh fabric gives it a feeling of lightness that is balanced by a kind of aggressive black coloring. It looks sleek, modern, and powerful. This aesthetic makes a promise of how it will perform, and its quality and mechanics live up to that promise.

The chair doesn't feel cheap when you sit on it. The mesh is cool on your backside, and doesn't warm up. It has an array of controls for height, tilt, lumbar support, posture, and arm rests that were placed so you can easily adjust its contours to meet your body the way you like it. It is an incredibly comfortable chair to sit in for long periods of time.

The Aeron Chair was truly a great industrial design project. The designers, Bill Stumpf and Don Chadwick, spent two years experimenting and building hundreds of prototypes. That is the type of refinement that rarely comes out of a time-driven corporate program.

The result is a much higher level of human-centric design that keeps whispering in the ears of anyone who will listen. It has influenced me and continues to influence many young designers. If we remember that design is a social act and that we must put people at the center of the design problem, then we are already half-way to a solution.

CINELLI ROAD BICYCLE

DON CHADWICK
Principal, Chadwick Studio
Designer of the Aeron Chair

Before Bill Stumpf and I collaborated on the Aeron Chair, we worked together on the Equa Chair, also for Herman Miller. The Walker Art Center in Minneapolis featured the chair in its *Design Quarterly* magazine and included it in an exhibition. We both attended the exhibit, and there were lots of great designs there.

The one that really stood out was a red Italian road bicycle made by Cinelli. Talk about interactive! For us, it was pure design, in terms of a minimal structure that provides a maximum benefit to the user.

Everything about it was so beautifully made and so perfectly detailed. The frame was fairly lightweight, and stiff so that it could transmit power from the pedals to the wheels efficiently. All the components—the shifts, gears, and brakes—were made by Campagnolo, which had a reputation for beautiful and very precisely machined components. The fit and finish were perfect, right down to the joints that held the frame together.

We loved how its form followed function. That bike was reduced to a minimum of parts, only what needed to define a structure and provide the user with a perfectly adjustable tool to ride on. It really influenced some of our decisions about the Aeron Chair.

For example, we tried to use the minimum amount of material to achieve the maximum level of adjustment and comfort. Many of the chair's adjustments were actuated through a cable system. I think we were one of the first to use exposed cables in office chair. It was taken right off the bike. We wanted to celebrate the chair's functions, and we did that by leaving the cables exposed.

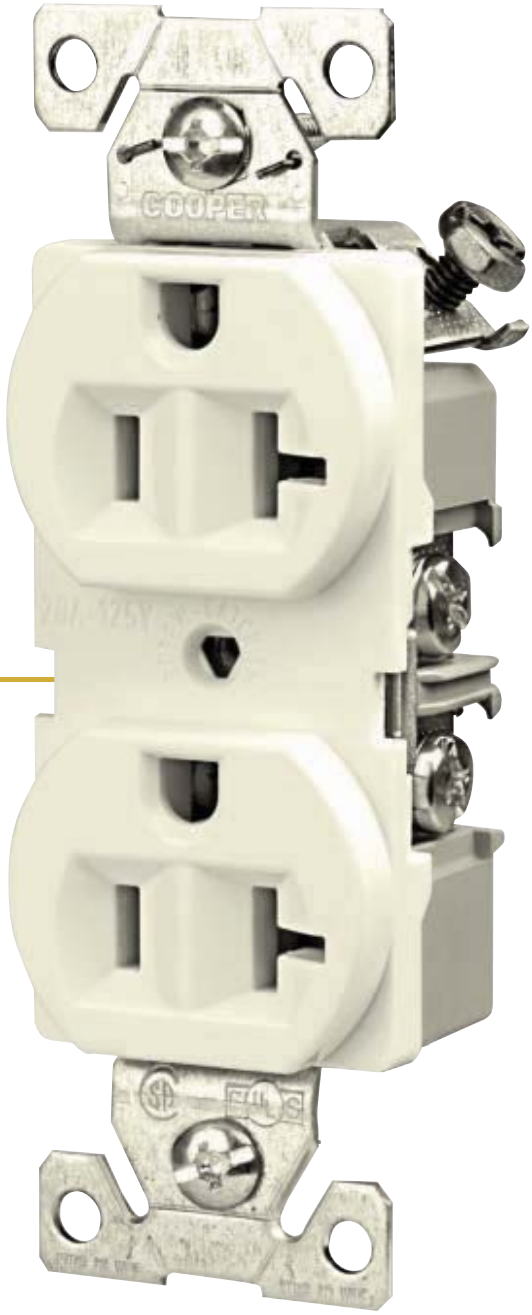
We were looking for a chair that would satisfy the requirements of people spending long hours in front of a computer, and were surprised how such a highly focused chair migrated into law offices, banks, and corporations.

Images courtesy: Herman Miller, Inc. | Supercorsa bicycle Cinelli USA

ICONIC
DESIGN

ARROW HART COMMERCIAL ELECTRICAL RECEPTACLE

MATTHEW MARZYNSKI
Fluke Corp.
Industrial Design Manager



When I was young, I learned an important lesson when I was asked to redesign a commercial electrical receptacle. I thought my job was to make it look good. What I learned is that commercial receptacles are really all about their interaction with the installer.

For example, most commercial receptacles have colored side connection screws, gold for black wires, the chrome for white. Electricians can unloosen the screws with either standard or Phillips screwdrivers. The screws do not come out all the way, so you can't drop them on the floor.

That's not the only way to attach wires. You can also stick them into holes on the back, where a one-way spring grabs them so they won't pull out. On the back of the receptacle, a plastic channel shows the exact length to strip the wire so you leave no exposed metal when you insert it into the hole. There is also a square hole to unlock the spring in case you made a mistake.

The receptacle has attachment stubs with a screw holes on both ends. Each stub has a pair of rabbit ears on either side to fit oversized electrical boxes. If the ears take up too much space, there is a gap between them and the stub so they bend off easily. These spaces are sized so the installer can use them it to strip insulation off the two most common wire gauges, 12 and 14.

Think of how much they cram into this thing. Once done, it gets shoved into an electrical box and you may never see it again. That's what makes it an unsung hero of industrial design.

The thing I learned is that every object has to function within its universe. By looking deeper than the surface, by understanding how it served contractors who want to get in and out of a job fast, it became a lesson in empathy, engineering, design, and value.

Images courtesy: Eaton | Xootr

XOOTR

MARK DZIERSK
Managing Director, LUNAR Chicago
Past President, IDSA

I've been an industrial designer for 30 years, and I have a lot of favorites. One of them is the Xootr, designed by LUNAR well before I joined the firm. The Xootr is a high-end scooter. Six months after it came out, Razr came out with a low-end scooter that was a smash, but Xootr remained the gold standard in adult scooters.

The Xootr is a beautiful machine. It has a machined aluminum or magnesium body, with a large platform that fits an adult. Its large-diameter 180 millimeter polyurethane tires and nearly frictionless ball bearings let you scoot a whole city block with just a few pushes. It also has a hand brake to slow you down, because you could reach 15 miles per hour if you push off a gentle hill.

The Xootr answers my problem of how to commute to my office in Chicago. I take a train from the suburbs, but my office is more than a mile away from the station and taxis are expensive. The Xootr is actually a transportation device that fills the white space between walking and taking a cab. It folds up so I can take it on the train, and I can unpack it and scoot to the office without working up a sweat. You could never do that on a Razr, you'd look like an idiot.

Xootr brought scooters back to life after a hiatus of 30 years. It made me realize that everything old could be new again. All you had to do is find the white space. Scooters were a kid's toy, and Razr picked up on that. But Zootr was actually a transportation device, and that was new and different.

ZÜCA BAG

MARIANNE GRISDALE
Creative Manager
TEAMS Design USA Inc.

Not so long ago, none of our luggage had wheels. Wheels were rejected because people said they were not cost effective. When someone finally introduced wheeled luggage, our first thought was, "Duh!" It was so simple, and it was amazing that it took so long.

Then designers added wheels on all four corners— spinners—so you could walk with upright bags instead of bearing all the weight in one hand. The latest innovation is the Züca, which is like a mini-locker on wheels. It has a sturdy, lightweight aluminum frame that can seat an adult. It also has two sets of two large wheels on the back. They make the bag easy to roll, and you can pull it up a staircase with no problem, though they also make it too big to fit in an airplane overhead bin.

I used to figure skate when I was younger. A majority of figure skaters are kids, and they're always tossing their skate bags in and out of trunks and lockers. Those skates cost $1,200 to $1,500. So when I started to skate again, I wanted a bag to store and protect my skates, and Züca's welded metal frame offers a lot of protection.

You can customize Züca with compartments to hold the type of things you might carry to rink. It works like a rollable mini-locker. That's why they are used by everyone, from students with lots of books to makeup artists that need to carry all their supplies with them. The first time I used it, I wondered why someone didn't design something like this for me when I was a kid.

Züca inspired a cart I have been working on. It led me to consider combining something durable that suggests quality, like welded steel, with fabric elements that reduce weight, eliminate pointy edges, and give it a softer, friendlier appearance.

NEST LEARNING THERMOSTAT

TAD TOULIS
Vice President, Creative, Sonos, Inc.
Jury Chair, 2014 IDSA International Design Excellence Awards

After Apple, designers are pushing harder to blend the geometry of an object with user interaction. The Nest thermostat is a great example of this post-Apple integration of mechanical design with digital technology. That makes sense, because it was developed by Tony Fadell, who led Apple's iPod and iPhone teams, and Frank Bould, whose designs incorporate an engineering aesthetic.

The Nest design picks up on what we think a thermostat should look like. Like Honeywell's iconic thermostats, it has a round dial that we set by rotating the ring where we want it. Nest adds more complex functionality by tethering this mechanical function with digital navigation. By pressing and turning the dial, you can navigate all sorts of menus, blending the mechanical and the digital.

The result is very elegant and practical. You dial the temperature you want, and over a week, the Nest calculates your preferences automatically to set household temperatures. It senses when you are not home and turns down the heating or cooling. It also uses wireless technology to communicate with remote temperature sensors in other rooms and with your smartphone.

Connecting an intuitive analog device to digital content is a really powerful idea. I drive a Toyota Prius hybrid, and the first time I pressed the start button was a pivotal moment for me. Some purists might prefer a key, but being able to start my car with a button, like a sophisticated piece of consumer electronics, said to me, "This is a different kind of car."

In my own work, I'm dealing with how to take mechanical precedents and digitize them in rational ways so that they are more than the sum of their parts. We only want to add digital behavior to augment what we're trying to do, so we can do things that couldn't be done otherwise. ME

Images courtesy: ZÜCA | © Nest

The Internet of very BIG

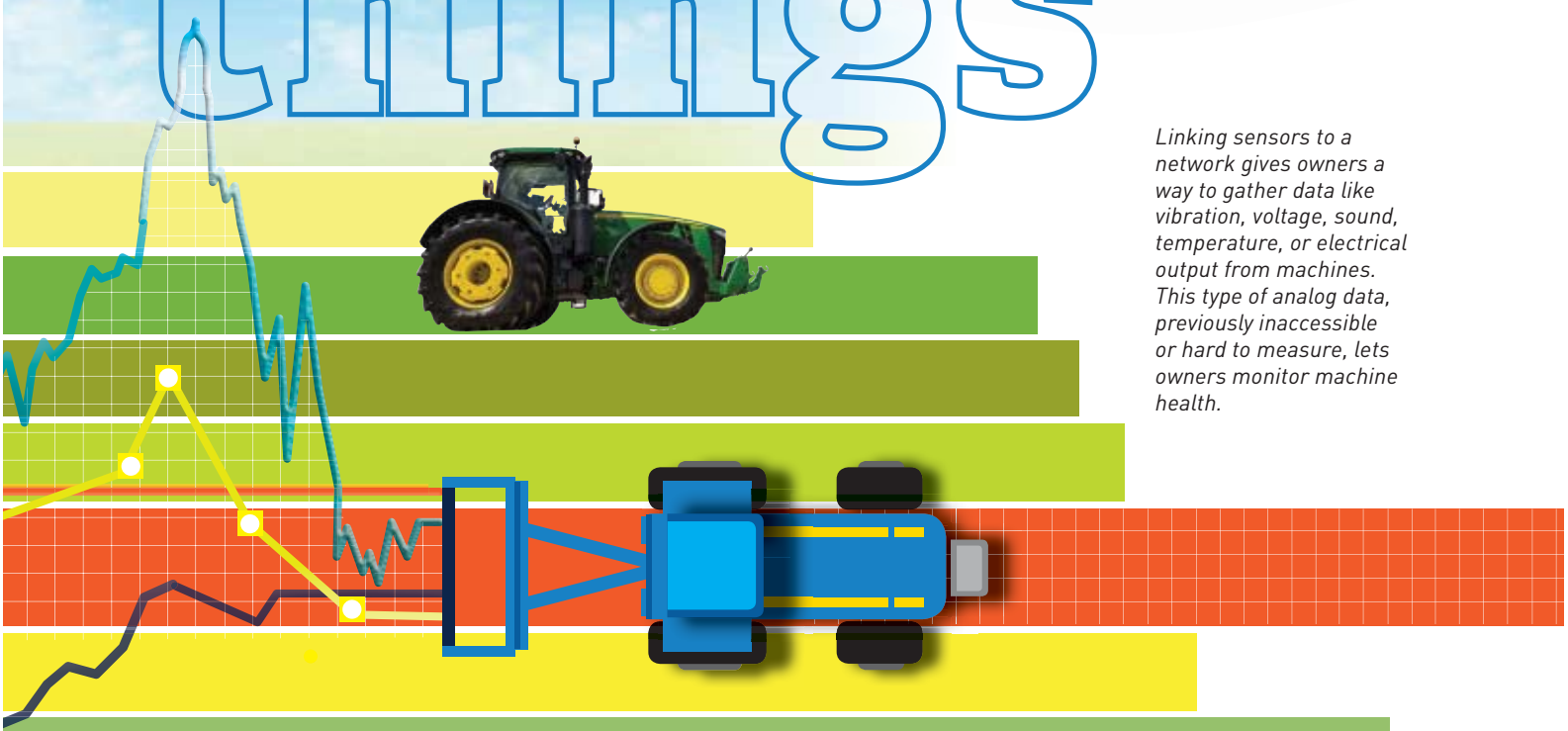
Companies that make large industrial machines are finding advantages in connecting them to computer networks. BY JEAN THILMANY

Most people have a romantic idea of farmers and their farm equipment. Farm tractors, for instance, are solidly built but a little old-fashioned, the kind a thing a farmer muscles into following straight lines and keeps running with elbow grease.

Anyone who believes that would have a hard time comprehending the kind of tractors John Deere & Co. sells today. Just as individual farms have grown to encompass entire square miles, farm equipment is now made up of large and complex pieces of industrial machinery. A single large tractor for sale by John Deere can sell for more than $400,000.

With so much money tied up in machines, farmers want them to work at peak efficiency. And so John Deere has created a system that combines embedded sensors, GPS antennas, and cellular communications technology to provide equipment operations data to anyone with an Internet connection. The system can even enable dealers to forecast impending maintenance issues and schedule repairs before there is a breakdown.

things



Linking sensors to a network gives owners a way to gather data like vibration, voltage, sound, temperature, or electrical output from machines. This type of analog data, previously inaccessible or hard to measure, lets owners monitor machine health.

Owners of John Deere farm equipment benefit from the company's JDLink monitoring system, which tracks operations in real time and includes GPS information, all instantly available in the cab.

John Deere is just one of several companies taking advantage of advances in data acquisition, transmission, and analysis to enhance their control of operations. They have created systems that link a network, sensors, and software. The result is a way to capture large amounts of analog information, organize it, and return it in bite-size chunks for business benefit.

There are different names for systems of this sort. National Instruments uses the term "Big Data Analog." General Electric calls it the industrial Internet. The goal for all is the same: to protect the investment that customers have made in their large industrial machines.

For example, a system has been measuring turbine vibration at several Duke Energy power plants for nearly two years. The system, built by National Instruments, collects vibration information, digitizes it, and analyzes it to predict when a turbine will fail or need maintenance.

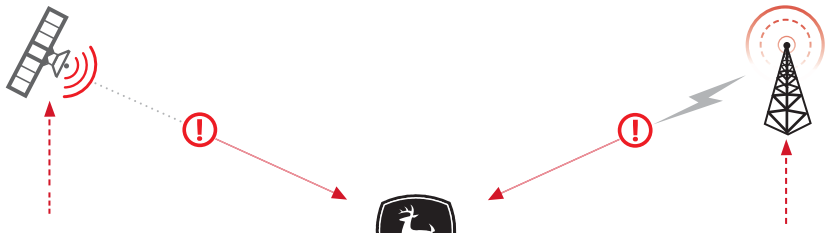
According to Tom Bradicich, research and development fellow at National Instruments, "That converts surprise outages into planned outages. If you know your equipment will fail next Wednesday, you can plan for it with backups."

When analog information is collected in the cloud, the SCADA-type scale grows exponentially and so do its uses.

Jon Bruner, an editor at large for O'Reilly Radar, an analysis and research firm in Sebastopol, Calif., has published *Industrial Internet, The Machines Are Talking*, a 52-page report that looks at characteristics of this melding of technologies.

On the report's home page, Bruner writes: "The big machines that define modern life—cars, airplanes, furnaces, and so forth—have become exquisitely efficient, safe, and responsive over the last century through constant mechanical refinement. But mechanical refinement has its limits, and there are enormous improvements to be wrung out of the way that big machines are operated: an efficient furnace is still wasteful if it heats a building that no one is using; a safe car is still dangerous in the hands of a bad driver.

"It is this challenge that the industrial Internet promises to address by layering smart software on top of machines."



ON BEYOND SCADA

According to Bradicich at NI, the systems give industries a way to gather analog data such as vibration, voltage, sound, temperature, or electrical output from machines and other physical devices. This type of analog data had been previously inaccessible or hard to measure.

Industrial Internet-type applications, Bradicich says, take a supervisory control and data acquisition system to the next level. They move SCADA beyond a single manufacturing floor or a single use in the field. When analog information can be collected in a cloud system or a private network, the SCADA-type scale grows exponentially and so do its uses, he said.

John Magee, chief marketing officer at General Electric, says savings can be found by monitoring and analyzing data from long-lived assets like generators, turbines, and aircraft in order to find ways to increase productivity and save money by cutting fuel costs or storing energy.

One of GE's industrial Internet customers is First Wind, which owns 16 wind farms in America. First Wind has recently added more sensors to its turbines to measure temperature, wind speeds, and the location and pitch of blades. Software collects and analyzes that data, enabling the operation of each turbine to be tweaked moment-by-moment, in response to that data, Magee said. In the winter, the analysis might show that the turbine blades are icing up, and corrective measures, such as speeding the turbine up or changing the pitch of the blades, could be taken.

It's clear why networking systems are catching on, O'Reilly's Bruner says.

"The cost of, say, a sensor is immaterial compared to the cost of the jet engine," he said.

"The big driver is on the data end: broadband communication, faster embedded processors, and new software tools for handling really large amounts of data have made a big difference. I also think managers in heavy industry have observed the impact of Big Data analytics on other businesses, like advertising, and have seen the value of a similar approach applied to machine data."

Bruner pointed out, for instance, that jet engines have always had sensors in them, but the information has usually just been registered on flight-deck readouts. Now, in addition to registering in the flight deck, the data from those sensors can be analyzed along with data from thousands of other jet engines to detect maintenance needs, tweak flight plans, and inform future engine design.

"Same idea with controls: microcontrollers in big machines aren't new, but now they're networked and accessible to software that can optimize entire systems of machines by adjusting their parameters in real time," Bruner said.

Bradicich attributes the interest in har-

JDLink combines sensors, a controller, modem, and GPS antennas. Information returned allows a John Deere dealer—with a farmer's permission—to remotely peer inside the machine and diagnose upcoming issues.

nessing analog information at least in part to the falling cost of sensors as well as to their increasing portability and capability to communicate wirelessly. Sensors can now be placed in large scale on airport runways or train rails to monitor them for problems, he said.

One example of this is a network of sensors deployed by the Union Pacific Railroad. The railroad has had acoustic and visual sensors in place on the underside of each rail car for decades, but according to a statement from the company, now that those sensors are networked, the railroad can call upon software to analyze sensor data to look for track and wheel problems that will likely to arise in the near future.

HARVESTING DATA

John Deere is pursuing new uses for smart machines and expanded analytical power.

The John Deere JDLink system—available on agriculture machines produced from 2011—currently enables farmers to track fuel use and machine performance. A controller collects machine information gathered by sensors and transmits it to a server.

The private information is available via the JDLink website, accessible from any Internet accessible location like a desktop computer or a smartphone, said Chris Batdorf, a mechanical engineer turned John Deere production marketing manager.

In addition to tracking and analyzing machine and fuel use, a dealer can—with a farmer's permission—remotely diagnose upcoming machine issues, he added.

And John Deere itself is making use of the JDLink-returned information, in anonymous aggregate.

"Say we recognize an anomaly of higher temperatures on our machines in the Southeast; from that our engineers can pull that data apart and say that's all related to the tolerance between the fan and the cooling package on that machine," Batdorf said. "So maybe we could be proactive and make running changes to our products and to the next generation product."

The technology can be retrofitted to machines produced as far back as 2009.

This spring, the company plans to enable

First Wind of Boston, which owns 16 wind farms in America, has added sensors to its turbines to measure temperature, wind speeds, and the location and pitch of the blades. The company is working with GE on the project.

"When you add a network connection to a machine you undoubtedly create a new security risk, but that risk can be outweighed at a higher level by the security benefits of remote monitoring and control."

customers to store crop production data like moisture and yield via wireless data transfer, Batdorf said. Farmers will be able to approve viewers who may access that information. So, based on the crop data, an agronomist could make recommendations about how much fertilizer a farmer should spread.

Because harvest data and production data are proprietary, John Deere has built a robust, specific database and repository for crop data downloaded, Batdorf said. The information is made anonymous before John Deere aggregates it to inform decisions about future equipment design.

"We could make changes to our machines based on trends that are happening," Batdorf said. "If our customers are doing 20-inch row spacing rather than 30-inch spacing we can offer more 20-inch planters for combines."

SECURITY ISSUES

Most information on the industrial Internet, including that collected by the John Deere program, sits in the so-called cloud: offsite servers on which a company rents or buys space. Given that the information exists on servers—even if a business uses its own private network—how secure is it?

According to Bruner, industrial security can be easier to address than general web security. Industrial networks tend to be highly structured systems with regular data-transmission patterns, which means security software is better at detecting intrusions and unusual activity.

"When you add a network connection to a machine you undoubtedly create a new security risk, but that risk can be outweighed at a higher level by the security benefits of remote monitoring and control," Bruner said. "A gas valve located in an isolated area is safer with a network connection than without one because operators can see when there's a problem."

Bruner acknowledged that builders must always consider data security when constructing an industrial Internet analog system.

"That said, it's usually more secure to provide the right channels for data to move through than it is to provide no channels at all," he added. "Businesses need to move large amounts of data around, and dedicated systems for collecting and analyzing it can keep track of where it's going and manage access much better than the sorts of ad-hoc systems, like e-mailing datasets as attachments, that would otherwise arise."

"A gas valve located in an isolated area is safer with a network connection than without one because operators can see when there's a problem."

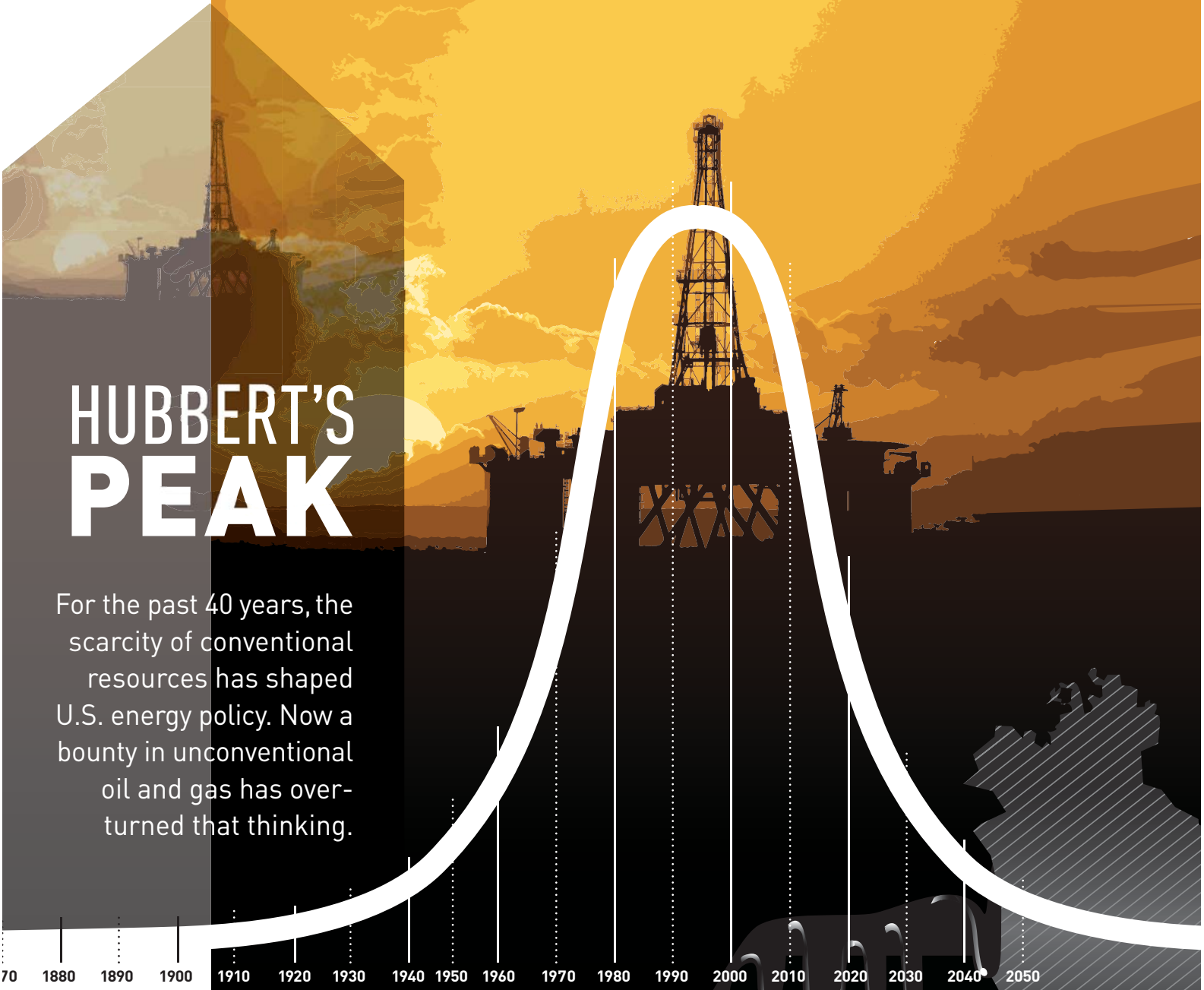
Bruner sums up the industrial Internet in his report: "The industrial Internet is this union of software and big machines—what you might think of as the enterprise Internet of Things, operating under the demanding requirements of systems that have lives and expensive equipment at stake. It promises to bring the key characteristics of the Web—modularity, abstraction, software above the level of a single device—to demanding physical settings, letting innovators break down big problems, solve them in small pieces, and then stitch together their solutions."

While it's not actually an Internet for machines, systems like the industrial Internet do give machines a voice. Heeding what they say can save a company money. ME

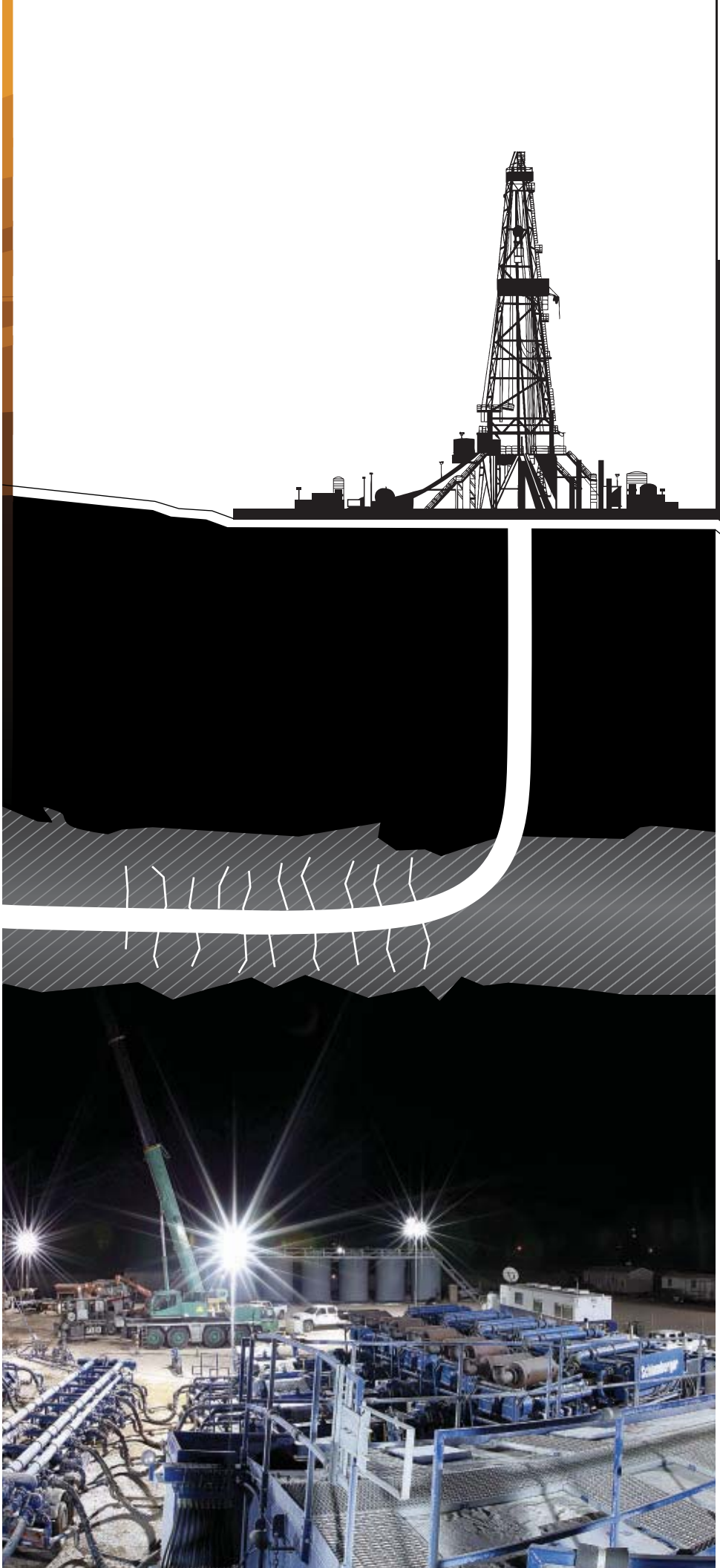
JEAN THILMANY is an associate editor of *Mechanical Engineering*.

HUBBERT'S PEAK

For the past 40 years, the scarcity of conventional resources has shaped U.S. energy policy. Now a bounty in unconventional oil and gas has overturned that thinking.



The completion of an oil or gas well using hydraulic fracturing involves deploying a small fleet of mobile pumps to force fluid deep underground. At right, BHP Billiton Petroleum runs a fracturing operation in the Eagle Ford Shale of Texas.



MITCHELL'S BOOM

BY FRANK WICKS

LAST FALL, OFFICIALS FROM AROUND the world attended a gathering in Washington, D.C., dedicated to the topic of the international shipment of energy. The House Energy and Commerce Subcommittee on Energy and Power hosted the event, and panel members listened to diplomats and energy experts from the Czech Republic, Hungary, Haiti, India, Japan, Lithuania, Singapore, South Korea, Thailand, and the Commonwealth of Puerto Rico.

The session was called,"The Geopolitical Implications and Mutual Benefits of U.S. LNG Exports." The broad consensus was that, in order to create greater stability in international energy markets, the U.S. should increase its exports of liquefied natural gas.

Not imports. Exports.

The past half century has been a whipsaw for U.S. energy policy. Fifty years ago, the country was a confident exporter of petroleum. By the early 1970s, it suddenly had become dependent on oil imports and suffered at the hands of its suppliers. Ever since, U.S. energy policy had

No mere academic, King Hubbert (left image, center) worked as a field geologist while working on his Ph.D. Later at Columbia University, Hubbert (right image, left) co-founded a group advocating decision making by scientists and engineers.

been a balancing act between reducing oil consumption, cultivating friendly oil-exporting nations, and developing substitutes for petroleum. Indeed, the last time liquefied natural gas received interest in Washington, it was as a means to import gas as a supplement for dwindling domestic supplies.

Today, the U.S. is on a track to resume its role as a top producer of gas and oil once more.

One way to understand the changing fortunes of American petroleum is to look at the activities of two men. Each man looked at the petroleum industry and saw not just what was happening, but projected what would—or could—happen. And each man was right in his way, although their respective influences represent a sharp contrast.

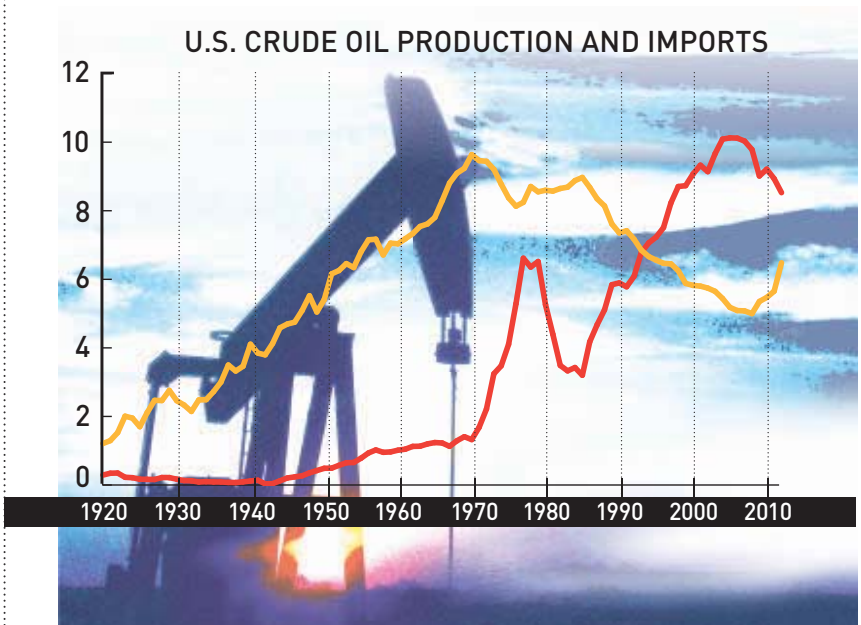
Geologist Marion King Hubbert surveyed oil field production in the mid-1950s, when gasoline sold for 30 cents a gallon and U.S. petroleum production had never been higher, and predicted that within 15 years the entire situation would reverse. Hubbert's prediction of a peak in U.S. oil production came true in 1970, and the consequences of Hubbert's Peak, as it is known, have affected almost every aspect of American life since.

Oilman George Mitchell started working to unlock the gas sealed in the Barnett Shale of Texas in the early 1980s, when declining domestic oil and gas production had begun to leave a permanent mark on the American imagination. It took took nearly two decades and a sizable Mitchell fortune to profitably commercialize these techniques, but the shale gas and shale oil "boom" of the past few years would have been impossible without his advances.

Natural gas production has never been higher, and last year U.S. oil production grew to the same level as 1956—the year Hubbert made his peak production prediction.

The story of these two men is the story of the forces that have shaped the last half century.

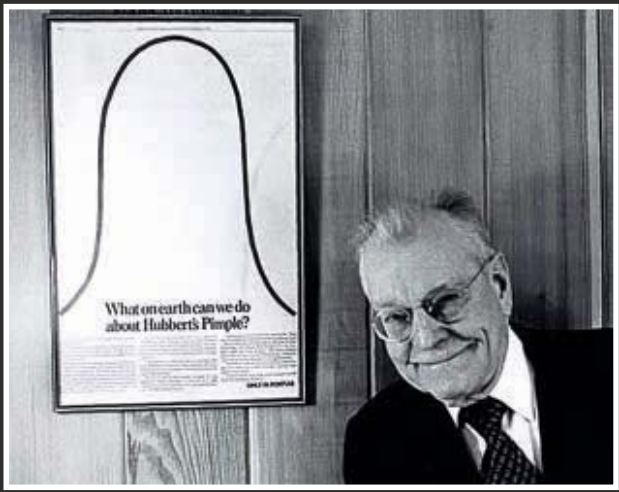
As King Hubbert predicted, oil production in the U.S. (yellow line) hit a peak in 1970. As a result, imports (red line) soared. In recent years, hydraulic fracturing has increased oil production for the first time in decades.

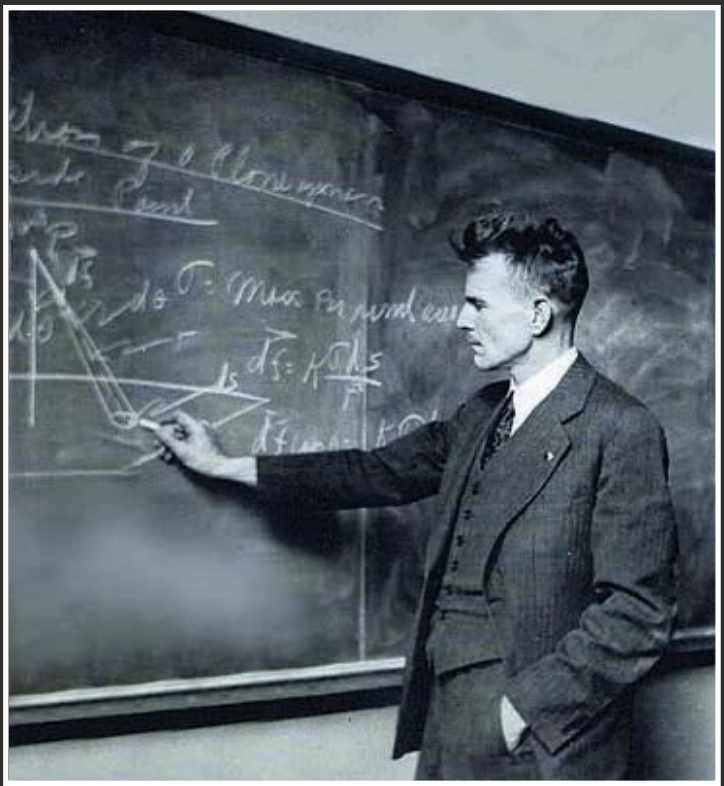


RISE AND FALL

King Hubbert, as he was known, was a polymath, having studied geology, physics, mathematics, and economics. His geology Ph.D. thesis was on "Theory of Scale Models as Applied to the Study of the Geologic Structure of the Earth." He spent the 1930s teaching at Columbia University. At the beginning of World War II Hubbert served with the Board of Economic Warfare.

In 1943, shortly before his 40th birthday, Hubbert joined Shell Oil. At the time, large companies were seeing the benefits of giving their brightest independent thinkers open-ended opportunities. Hubbert became Shell's consultant for general





Hubbert's theoretical work on the finite nature of oil resources (above) led to widespread recognition later in life (above left).

geology and helped to expand the Shell research laboratory in Houston

In time, Hubbert's research addressed the long-term prospects for oil production. Up to that point, the simplest forecasting methods in the oil business had been to graph production versus time and then extrapolate the data. These techniques had worked over the limited time frame they had been applied.

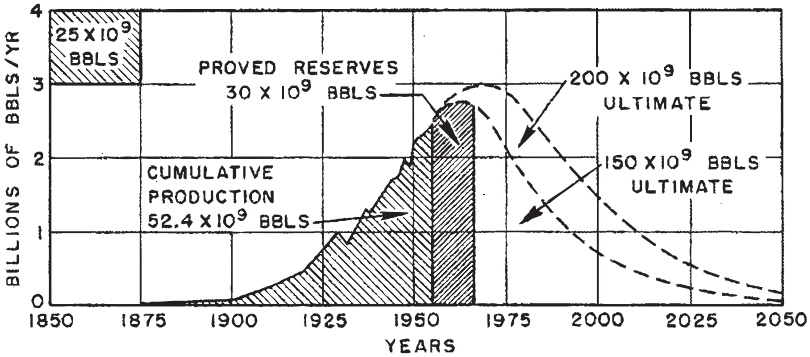
Hubbert understood the Earth as a composite of a range of interacting phenomena: chemical, mechanical, thermal, gravitational, electrical, magnetic, nuclear, and biological. He knew that there was no reason why oil production should behave differently from the mining of other minerals.

Hubbert plotted historic rates of discovery and rates of production as a function of time for a variety of minerals including gas and oil. The resulting bell-shaped curves showed a slow rise, followed by a more rapid rise, and then a slowing until a peak, and then a symmetric decline. Data for oil showed a 35-year delay between the years of peak discovery and peak production. The rate of discovery of oil in the United States had peaked in about 1935, so Hubbert concluded the country could expect production to reach its peak by 1970 at the latest.

Extending this model to the entire globe, Hubbert forecast a global peak in oil production in 2000.

Hubbert's predictions were contained in a 1956 paper presented to the American Petroleum Institute. In spite of the hue and cry over "peak oil" about a decade ago, Hubbert's paper was not alarmist. As could be guessed from its title, "Nuclear Energy and Fossil Fuels," the paper presented the case that a decline in oil production could be more than made up by a build-out in nuclear power plants.

HUBBERT'S PEAK



Hubbert included the above chart in his 1956 paper presented to the American Petroleum Institute. The chart shows a bell-shaped trajectory for the production of finite resources such as oil. Hubbert predicted U.S. conventional oil production would slow, stall, and decline as the proved reserves were used up.

Hubbert calculated there were sufficient uranium and thorium deposits that, together with breeder reactors, nuclear power could last 5,000 years.

The API article was ignored when it came out. Hubbert retired from Shell in 1964 and worked for the United States Geological Survey and taught at Stanford and Berkeley.

Then, in 1970, U.S. oil production stopped growing. U.S. oil consumption, on the other hand, did not slow down, meaning ever-larger quantities had to be imported from the international market. This left the country vulnerable

The son of Greek immigrants in Galveston, George Mitchell received a degree in petroleum engineering from Texas A&M in 1940.

In addition to his oil and gas business, Mitchell developed real estate in the Galveston and Houston areas. Photo:Curtis McGee, Houstin Chronicle Staff.

Mitchell was known for his far-sighted views on energy, housing, and sustainable development.

to price shocks, such as those that followed the Arab Oil Embargo of 1973 and the Iranian Revolution in 1979.

By then, Hubbert's forecast was renowned in geological circles. In 1981, he was awarded the Vetlesen Prize, which is described as the equivalent of a Nobel Prize for geology. By the time he died in 1989, Hubbert could look at a world that was running full steam toward his predicted peak in global oil production. His warnings seemed to go unheeded.

It should be noted, however, that Hubbert's career encompassed more than his oil production prediction. Hubbert developed an improved understanding of the underground flow of liquids, and in fact demonstrated that water pressure would fracture rocks in vertical planes.

FRACTURE AND FLOW

Oilmen have long known that fracturing the rocks within an oil or gas deposit can increase flow rates. As early as the 19th century, "shooting the well" was the method of choice for enhancing oil production. The method used a torpedo of nitroglycerine, which was lowered into a well and ignited from above. It was effective, but hazardous. Even the basic transport and handling of such a volatile explosive was highly dangerous.

By the mid-20th century, researchers upped the ante on shooting wells. As part of Project Plowshare in 1967, a nuclear device with the power equivalent of 29 kilotons of dynamite was detonated in a New Mexico gas well 4,200 feet beneath the surface. The explosion succeeded dramatically at stimulating gas flow, but the product was too radioactive for distribution. The explosion also caused a portion of the methane to be oxidized into carbon dioxide.

Attempts at hydraulic fracturing—using high-pressure water to fracture rocks—had met with moderate success in vertical wells in the 1940s. But the technique was expensive, and oil and gas was cheaply recovered using conventional methods.

By 1982, however, the incentives had shifted. Thanks to the supply disruptions predicted by Hubbert, oil and gas prices had skyrocketed. And the U.S. government was offering a tax credit for the development of unconventional natural gas.

Among those who responded to these incentives was George Mitchell. Mitchell was the son of working-class Greek immigrants in Galveston who parlayed a petroleum engineering degree from Texas A&M into a small oil and real estate empire. Mitchell had a long-term contract to supply pipeline gas to Chicago and desperately needed a better supply than what he could produce on his holdings in north Texas. Instead of buying up land elsewhere, he looked deeper to an underlying stratum called the Barnett Shale, which held its gas so tightly that conventional techniques couldn't extract it. Mitchell told his skeptical drilling team that, if they couldn't find a way to draw the gas from the shale, he would find people who could.

What they needed was a way to increase the rock's permeability, and do so cheaply enough to make the extracted gas profitable. After almost two decades of fits and starts, Mitchell's team eventually found a combination of existing techniques that would work. Drillers penetrate the relatively thin layer of source rocks with surgical precision, turning the drill head until it runs along the horizontal stratum. They then use directional explosions to puncture the pipe lining a well. High pressure fluids then fracture the rocks, and the fracturing liquid delivers proppants to keep the cracks open for the

Mitchell and his wife, Cynthia, drew praise for their philanthropic work, such as this music pavilion in The Woodlands, Tex. Houston mourned Mitchell when he died last year at age 94.

free flow of gas or oil. The fracturing fluid can be a gel, a foam, or chemically slicked water. The proppants can be hardened sand or ceramics.

The combination of techniques enabled Mitchell to do something many experts thought couldn't be done. Together, they gave industry the ability to profitably extract large amounts of gaseous and liquid fuels from tight formations.

DOOM AND BOOM

When George Mitchell died last year at the age of 94, he was widely eulogized as the "Father of Hydrofracking." His influence is seen not only in the shales of Texas, but also in the large gas-recovering operations from the vast Marcellus Shale formation that underlies a large portion of the Appalachian Basin in West Virginia, Pennsylvania, Ohio, and New York. The method has been applied to the previously forsaken Bakken oil field of North Dakota. Production there is now approaching 1,000,000 barrels a day. North Dakota may surpass Texas as the leading oil state.

Quite suddenly, the Oil Age seems to be extended well beyond Hubbert's predictions because of the success of George Mitchell. Energy Information Agency data shows shale gas has increased from 1 percent of domestic production in 2000 to over 20 percent in 2010. The EIA predicts that share will rise to 46 percent by 2035. Production has risen so quickly—and the promise of future production is so great—that some analysts predict the United States could once again become a net exporter of gas and oil.

The techniques developed by Mitchell are now being aggressively pursued on every continent, so it is too early to predict how the spread of hydrofracking will transform or rebalance the global energy market.

There also are many concerns about the environmental impact and ultimate costs of the practice. One effect may be a delay in developing renewable energy technologies and in redeveloping nuclear power. Hydraulic fracturing certainly has extended the Oil Age, but it doesn't assure a supply of gas and oil forever.

The industry is being confronted with bans and moratoria that must be resolved. New York State, which sits atop some potentially rich shale deposits, has a moratorium on drilling pending a comprehensive environmental review. The drilling boom has been linked to air and surface pollution and groundwater contamination in many areas. Even earthquakes are blamed on "fracking."

As George Mitchell has shown with the development of hydraulic fracturing, it is hard to make predictions that stick. The ability to unlock shale to release gas and oil has blown away prior assumptions about the economics, the availability, and the politics of fossil fuels.

The new abundance and the costs in achieving it have created euphoria in some quarters and deep concerns in others. As with anything new and game-changing, it will take time before we truly understand how good a thing this is.

And it must be remembered that even while these new resources are becoming recoverable, they are still part of a finite system, the kind that Hubbert based his forecast on. This may be Mitchell's day in the sun, but Hubbert cannot stay eclipsed forever. ME

FRANK WICKS is an ASME Fellow and frequent contributor to *Mechanical Engineering*. He is an engineering professor at Union College in Schenectady, N.Y., where he teaches an Oil Age seminar.

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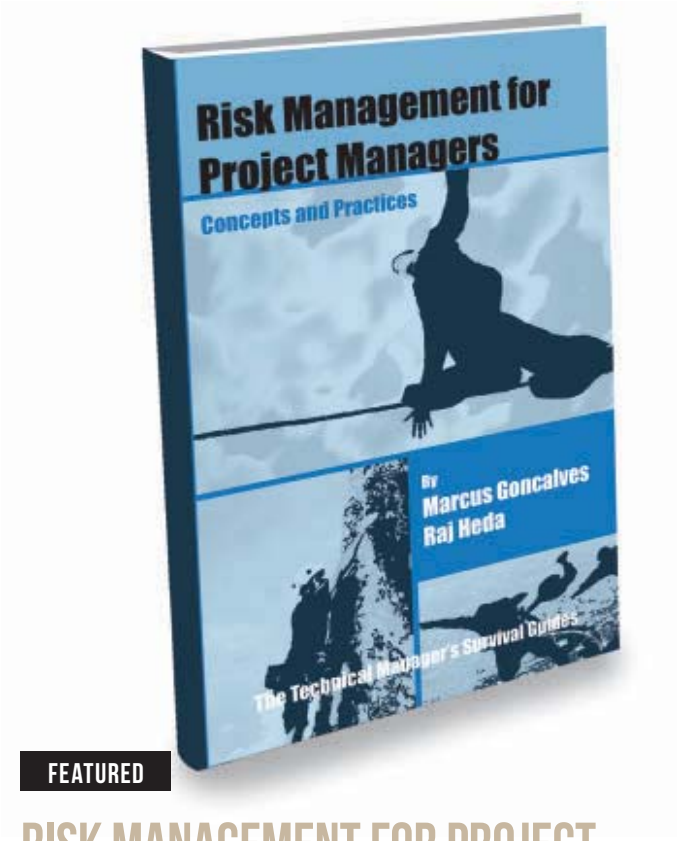

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RISK MANAGEMENT FOR PROJECT MANAGERS: CONCEPTS AND PRACTICES

MARCUS GONCALVES AND RAJ HEDA

ASME Press Books, Two Park Avenue, New York, NY 10016-5990. 2014.

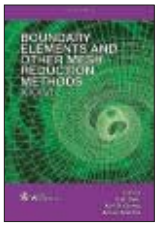
This is the newest volume in The Technical Manager's Survival Guides series. Chapter one covers how the goal of assessing risks is to understand them and to find strategies for managing them. In practical terms, risk management is the process of minimizing, or mitigating, undesirable events. It starts with the identification and evaluation of possible events and extends to the optimization of the resources used to monitor them and minimize their effects.

Chapter two discusses how risk is no longer a measure solely restricted to the financial world, where analysts monitor the risk of a financial investment.

According to the authors, anything that we endeavor in life has a risk factor associated with it. As technology has become an increasingly core aspect of world economies, risk management has come to the fore in recent years. Given the extreme importance of risk, it is inevitable that we must have a formalized theory and approach to the risk management process.

Other chapters include: "Developing a Risk Assessment and Mitigation Strategy," "The Risk Management Process," and "Risk Analysis Tools and Methodologies."

104 PAGES. $42; ASME MEMBERS, $34; ISBN: 978-0-7918-6023-6.

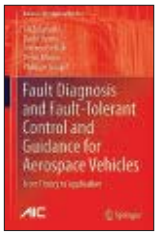


BOUNDARY ELEMENTS AND OTHER MESH REDUCTION METHODS XXXVI

X.W. Gao, A.H.-D. Cheng, and C.A. Brebbia.
WIT Press, USA, 25 Bridge Street, Billerica, MA 01821. 2014.

The Conference on Boundary Elements and Mesh Reduction Methods is an international forum for the latest advances in these techniques and their applications in science and engineering. Launched in 1978 the conference has become the forum for rapid dissemination of developments throughout the international scientific community. Practically all new boundary element ideas have first appeared in the proceedings of these meetings. The vitality of boundary element research is mainly due to its ability to evolve. This evolution has developed a range of mesh-reduction methods. Chinese researchers in particular have made major contributions to mesh reduction, which this conference hopes to highlight. The importance of research carried out in China led to the organization of the 36th Conference, which sets the basis for a closer collaboration between scientists from other countries and their Chinese colleagues.

568 PAGES. $488. ISBN: 978-1-84564-841-1.



FAULT DIAGNOSIS AND FAULT-TOLERANT CONTROL AND GUIDANCE FOR AEROSPACE VEHICLES: FROM THEORY TO APPLICATION

Ali Zolghadri, David Henry, Jerome Cieslak, Denis Efimov, and Philippe Goupil.
Springer-Verlag GmbH, Tiergartenstrasse 17, 69121. Heidelberg, Germany. 2014.

Fault Diagnosis and Fault-Tolerant Control and Guidance for Aerospace Vehicles seeks to demonstrate the attractive potential of recent developments in control for resolving such issues as improved flight performance, self-protection, and extended life of structures. The text deals with a number of considerations, including tuning, complexity of design, real-time capability, evaluation of worst-case performance, robustness in harsh environments, and extensibility when development or adaptation is required. The authors call on experience gained in research collaboration with academic and industrial partners to validate advanced fault diagnosis and fault-tolerant control techniques with realistic benchmarks or real-world aeronautical and space systems.

240 PAGES. $129. ISBN: 978-1-44715-313-9.

Noise Control & Acoustics Division Newsletter

March 2014

A small group of engineers met on March 16, 1980, during the ASME Winter Annual Meeting, and agreed to form an organization that could promote developments in acoustics and noise control. At that point, they laid the foundation for the Noise Control and Acoustics Division (NCAD).

The vision of this small group was fulfilled less than two years later at Washington, D.C., when NCAD attained full division status in the ASME technical family on Nov. 19, 1981. Since its inception, NCAD has grown from a few visionaries to over 500 primary members. NCAD is the 32nd technical division of ASME and is part of the Council of Engineering's Environment and Transportation Technical Group. Other divisions in the group include Aerospace, Rail Transportation, Environmental Engineering, and Materials and Energy Recovery.

The goal of NCAD is to establish a program within ASME that will encourage, focus, and further the development and application of noise control and acoustics principles to engineering. The division serves its members who represent various disciplines within ASME, acts as an outreach to other organizations, and encourages participation from those who have an interest in the field. NCAD accomplishes this by ensuring a balance between the theoretical studies of acoustics and its applications in terms of noise control engineering.

The primary vehicle used by NCAD to distribute information and encourage interaction among members, specialists, and interested parties is through participation in conferences. NCAD routinely participates in ASME's International Mechanical Engineering Congress and Exposition. In an effort to reach out to others interested in acoustics and noise control, NCAD periodically joins with other professional societies to sponsor a joint conference, generally every three or four years. Past participation has been primarily with the Institute of Noise Control Engineers, but NCAD is eager to team with additional organizations, particularly those within ASME.

The division sponsors several awards to recognize excellence in acoustics and noise control. Some of these awards are presented at the annual conference. Each year, a highly distinguished person is chosen to present the Rayleigh Lecture; this award is given to an individual who has made pioneering contributions to the field of noise control and acoustics. Additionally, in an effort to encourage and recognize students who are performing research and development in noise control and acoustics, a monetary award is given to the best student-authored technical paper presented at the conference.

The division also awards the Per Bruel Gold Medal for Noise Control and Acoustics in recognition of eminent achievement and extraordinary merit in the field of noise control and acoustics. The achievement includes useful applications of the principles of noise control and acoustics to the art and science of mechanical engineering. This medal, established in 1987, honors Dr. Per Bruel who pioneered the development of sophisticated noise and vibration measuring and processing equipment. The recipient is also recognized with a monetary award.

NCAD is managed by an executive committee and technical committees. The executive committee is filled by five members who commit to a five-year term. Technical committees are composed of people with diverse backgrounds, covering industry and academia, and with various focuses of research, development, and applications. The technical committees represent the key interests of engineers in the field of noise control and acoustics, and are crucial to the long-range success of the division. The three technical committees are *Active and Passive Control*, *Structural Acoustics*, and *Aero/Hydro Acoustics*.

The success of the NCAD is due to the participation of our members. We would like to specifically thank all of our volunteers for all their hard work and invite anyone interested in noise control and acoustics to participate. Any level of participation is welcome and encouraged. Members of the executive committee and of the technical committees are anxious to hear from those who have an interest in these fields. Participation in the annual committee meetings, which are held during the annual conference, can open up opportunities for engineers to interact, learn from one another, and develop new relationships with others who share an interest in noise control and acoustics.

Here is a brief look at each of the division's committees and at some of its activities.

The goal of NCAD is to establish a program within ASME that will encourage, focus, and further the development and application of noise control and acoustics principles to engineering.

Structural Acoustics Committee

Chair: Shung H. (Sue) Sung, shsung@asme.org

The Technical Committee on Structural Acoustics represents the technical areas related to numerical methods relating to structural-borne noise and the complex interaction between acoustics and structures. For decades, the committee has successfully led the technical sessions with many pioneering papers in numerical methods in vibrations and acoustics, general structural acoustics and vibration, and more recently phononic crystals and acoustic metamaterials. The papers on these topics have steadily increased, with even more advanced technically challenging applications.

In view of recent development of new lightweight materials, structural-acoustic interaction has become more important as the mechanical properties, stresses, topological surface shapes, and thermal and optical performance of the structure can be influenced by acoustics, and vice versa. For solid media in general, the sound propagation in porous materials such as in absorptive material and soil, as well as fluids, also involves the interaction of acoustics and structures.

The recent applications that use acoustics in non-contact monitoring applications also have prompted more understanding of sound propagation in air and solid media.

New sessions that have been launched since 2010 include: Noise, Vibration, Fatigue and Atmospheric Propagation, and Smart/Functionally Graded Materials for Vibration and Noise Control Applications (IMECE 2010, Vancouver, British Columbia); Noise, Vibration, and Reliability in Vehicle Systems, Modeling and Analysis of Acoustic Wave Propagation, and Attenuation in Porous Materials (IMECE 2011, Denver); Acoustic Wave Propagation in Porous Media, Innovative Lightweight Materials for Noise Control and Abatement (2012 Inter-Noise INCE/NCAD/SAE, New York); and Acoustic and Elastic Wave Propagation, Nonlinear Vibration, Vibroacoustics-Based Energy Harvesting, Vibroacoustic Characterization, Monitoring and Damage Detection (IMECE 2012, Houston).

The committee invites ASME members and colleagues to contribute papers to these symposia. Besides the traditional topics sponsored by the committee in the past years, the newly added topics listed above will also attract multi-disciplinary technical papers to the symposia. We are looking forward to your attendance at the ASME IMECE 2014 and to your participation in the recent developments in structural acoustics.

Per Bruel Award

The ***Per Bruel Gold Medal for Noise Control and Acoustics*** was established in honor of Dr. Per Bruel, who pioneered the development of sophisticated noise and vibration measuring and processing equipment. The medal recognizes eminent achievement and extraordinary merit in the field of noise control and acoustics, including useful applications of the principles of noise control and acoustics to the art and science of mechanical engineering.

The winner in 2013 was Richard H. Lyon of the R.H. Lyon Corp.

Anyone wishing to nominate deserving engineers for the Per Bruel award is welcome to do so by submitting the form at: https://www.asme.org/about-asme/get-involved/honors-awards/achievement-awards/per-bruel-gold-medal-for-noise-control-and.

Inter-Noise 2015

Every three to four years NCAD supports a non-ASME conference to explore the synergy with sister organizations. As it has been done in 2008 (NoiseCon) and 2012 (Inter-Noise), NCAD will join forces with the Institute of Noise Control and Engineering for Inter-Noise 2015. For more information please check http://www.internoise2015.com/.

Aero/Hydro Acoustics Committee

Chair: Robert Tomko, tomkorp@yahoo.com

The goal of the Technical Committee on Aero/Hydro Acoustics is to increase the understanding of mechanisms related to both sound and vibrations that are generated and propagated in air, water, or both (e.g. multi-phase flows). This covers a wide range of sources and applications that are of interest to the academic community, industry, and government agencies. Specific interests include source mechanisms, flow over internal and external features, turbomachinery noise, flow tones and fluid instabilities, measurement and analysis techniques, fluid-structure interaction, and mitigation methods. Computational, analytical, and experimental methods are all well covered in multiple sessions annually at IMECE and at other conferences.

Our members consist of representatives from academia, government, and industry. We are active in organizing paper sessions, lectures, and tutorials. Topics addressed at conferences in the last couple of years include flow-induced vibration, vibration and acoustic measurement techniques and facilities, rotating machinery noise, and sound propagation in the atmosphere. At IMECE 2013, a longtime member of our committee, Dr. Michael Jonson of Penn State Applied Research Lab, led a tutorial on unsteady dynamometry.

Leadership has turned over this year from Dr. Zhongquan (Charlie) Zheng, professor in aerospace engineering, University of Kansas, to Robert (Bob) Tomko of Bechtel Bettis. Our committee encourages you to attend our conference in Montreal, Canada, November 14 – 20, 2014. Please see http://www.asmeconferences.org/congress2014 for general information about IMECE. In addition, Track 16 "Vibration, Acoustics & Wave Propagation" is the track sponsored by the division. We look forward to having you participate and join as a division member.

Active and Passive Noise Control Committee

Chair: Hugo E. Camargo, HCamargo@cdc.gov

The primary goal of the committee is to increase and disseminate theoretical and practical methodologies aimed at reducing noise. All aspects of the noise control process are of interest, from noise source identification to final installation and placement procedures of treatments. The topics of focus for the committee are active, passive, and hybrid approaches to controlling and abating unwanted sound.

In 2013, the division maintained a significant presence at the IMECE 2013 conference in San Diego, Calif., November 15-21. The Active and Passive Noise Control Technical Committee sponsored two sessions: Noise and Vibration Control I, and Noise and Vibration Control II.

The Noise and Vibration Control I session covered various topics from the development of noise controls for a shearer drum used in the mining industry, a multinational research effort to develop a gradient thickness plate to focus bending waves, an active Helmholtz resonator for acoustic noise attenuation, and the use of photodeformable materials to control paraboloidal thin shells, just to name a few. The Noise and Vibration Control II session focused on research currently being conducted in the automotive industry. Some examples of topics presented in this session include energy harvesting from car vibrations for wireless sensor nodes, vibration reduction systems for vehicle seats, time-frequency analysis of disc brake squeal, and tools for fault detection and vibration behavior monitoring of bearings.

As the conference has done in previous years, IMECE 2014 will gather experts, academics, and researchers from around the world working on various aspects of active and passive noise control. Therefore, this is an opportunity not only to make contacts in the field and meet people with similar interests, but to learn about current research efforts in noise control. The Active and Passive Noise Control Technical Committee has proposed several sessions for IMECE 2014, including:

- Passive noise and vibration control.
- Active vibration control for complex structural systems.
- Applications of active noise and vibration control.
- Aircraft interior noise: modeling and methodologies.
- Application of noise controls in the mining industry.

New ASME Fellow, 2012

DR. STEPHEN HAMBRIC
Penn State/ARL
Senior Scientist, Noise Control and Hydroacoustics Division

Dynamometry Lecture

It was our pleasure to have Dr. Michael L. Jonson from the Pennsylvania State University Applied Research Lab give the NCAD Tutorial on Dynamometry this year. Dr. Jonson discussed applications of dynamometry and presented measurement methods for both steady and unsteady forces and moments. He also described methods for calibration, data reduction and processing. Both quasi-steady and unsteady measurements were considered. Dr.Jonson's presentation is available on the ASME community website for the Noise Control and Acoustics Division. Past tutorials sponsored by NCAD, are also available at: https://community.asme.org/noise_control_acoustics_division/m/default.aspx.

Rayleigh Lecture: Walking-Induced Vibrations

The Rayleigh Lecture is an ASME division-level award given by the Noise Control and Acoustics Division in recognition of the lecturer's pioneering contributions to the fields of noise control and acoustics. Last year we were privileged to have Dr. Eric E. Ungar give the Rayleigh Lecture on "Walking-Induced Vibrations in Buildings: Evaluation and Prediction." His lecture reviewed vibration criteria for both sensitive equipment and human perception. He also described the characteristics of footfall-generated vibrations and discussed the current state of the art with regard to predictions. Dr. Ungar is currently the chief engineering scientist at Acentech Inc. in Cambridge, Mass.

Dr. Ungar's Rayleigh Lecture is available on the ASME community website for the Noise Control and Acoustics Division. Past Rayleigh Lectures are also available at: https://community.asme.org/noise_control_acoustics_division/m/default.aspx.

2012-2013 NCAD Executive Committee

2012-2013 NCAD EXECUTIVE COMMITTEE
From left to right: Bob Tomko, Kristin Cody, Brent Paul, Liang-Wu Cai, Noah Schiller.

The activities of the division are directed by an Executive Committee, which establishes the Division's policy and goals. The Executive Committee is supported by other committees as needed. The NCAD Executive Committee can be reached at ncad@asme.org.

LIANG-WU CAI
Kansas State University, Vice-Chair

Dr. Liang-Wu Cai is currently an associate professor in the Department of Mechanical and Nuclear Engineering at Kansas State University. His research interests include applied mechanics, mechanics of composite materials, mechanical vibration, acoustics, ultrasonic nondestructive evaluation, sonic crystals, and acoustic metamaterials.

BRENT PAUL
Alion Science and Technology, Chair
(bpaul@alionscience.com)

Brent Paul is a principal engineer in the Hydrodynamics and Hydroacoustic Signatures Group at Alion Science and Technology. His areas of expertise include the prediction of flow induced noise, acoustic analysis of advanced turbomachinery, vortex shedding, and computational fluid dynamics.

NOAH SCHILLER
NASA Langley Research Center, Secretary/Treasurer

Dr. Noah H. Schiller is a research engineer in the Structural Acoustics Branch at NASA Langley Research Center where he is involved in aircraft noise research. His research interests include active noise and vibration control, vibroacoustic modeling, and more recently phononic crystals and acoustic metamaterials.

KRISTIN CODY
Bechtel Bettis, Inc., Program Chair

Dr. Kristin Cody is a principal engineer for the Bechtel Marine Propulsion Corp., which operates the Bettis and Knolls Atomic Power Laboratories for the Department of Energy. Her research interests include flow-induced noise and vibration and structural-acoustic interactions.

CHARLIE ZHENG
Member

Dr. Zhongquan (Charlie) Zheng is currently professor in the Aerospace Engineering Department at University of Kansas, Fellow of ASME, and Associate Fellow of AIAA. He received his B.S. and M.S. degrees from Department of Engineering Mechanics at Shanghai Jiao Tong University in 1984 and 1987 respectively, and his Ph.D. degree in 1993 from Department of Mechanical Engineering and Mechanics, Old Dominion University. He has been a member of numerous TCs in ASME and AIAA, Chair of Computational Fluid Dynamics TC in ASME, and is associate editor of *The Journal of Fluids Engineering*.

Journal of Vibration and Acoustics

The *Journal of Vibration and Acoustics* is the ASME journal best suited to match the needs, information, and careers of the members of NCAD. The division supports the journal by providing three associate editors for reviewing and editing paper submissions. Currently they are Liang-Wu Cai, Theodore Farabee, and Lonny Thompson.

The purpose of the *Journal of Vibration and Acoustics* is to serve as a vehicle for the communication of original research results of permanent interest in all areas of vibration and acoustics. Papers published by the journal are full-length research papers of considerable depth. The journal also presents Technical Briefs, which are intended to serve as a means for the rapid communication of recent developments in an abridged form.

Examples of specific topic areas covered include: vibration of continuous and lumped parameter systems; linear and non-linear vibrations; random vibration; modal analysis; mechanical signatures; structural dynamics and control; vibration suppression; vibration isolation; passive and active damping; machinery dynamics; rotor dynamics and vibration; acoustic emission; noise control; machinery noise; structural acoustics; fluid-structure interaction; aeroelasticity; and flow-induced noise and vibration.

Find Us

- Check out our **Facebook** site for the latest acoustics and vibrations news: https://www.facebook.com/pages/NCAD-Noise-Control-and-Acoustics-Division/211722612197712

- Also follow the NCAD on the **ASME Community** at: https://community.asme.org/noise_control_acoustics_division/default.aspx. There you can find information on volunteering with NCAD, previous Rayleigh Lectures and Workshop Tutorials, as well as our yearly newsletter.

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- Composite Repair Solutions for Pipeline Anomalies
- Defect Assessment
- In-line Inspections for Pipelines
- Integrity Management
- Onshore Design and Construction
- Practical Welding Technology
- Pipeline Pressure Testing

ASME Pipeline Training Week At-a-Glance

Technical Track	Monday April 14	Tuesday April 15	Wednesday April 16	Thursday April 17	Friday April 18
Bolting	Bolted Joint Assembly Principles Per PCC-1-2013 (PD577) David Lay (2 Days)				
Piping and Pipelines	Pipeline Pressure Testing (IPTI203) Larry C. Decker (1 Day)	Composite Repair Solutions for Pipeline Anomalies (IPTI202) Chris Alexander (1 Day)	B31.8 Gas Transmission and Distribution Piping Systems (PD370) Mike Rosenfeld (2.5 Days)		
	Integrity Management (IPTI210) Tom Bubenik (1 Day)	Defect Assessment (IPTI280) Tom Bubenik (2 Days)		In-line Inspections for Pipelines (PD706) Martin Phillips (2 Days)	
	Onshore Design and Construction (IPTI265) Shashi Menon (3 Days)			ASME B31.4 Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids (PD391) Carolyn Kolovich (2 Days)	
Welding			Practical Welding Technology (PD359) Al Moore (3 days)		

For information and to register visit: go.asme.org/pipelinetraining

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CONFORMITY ASSESSMENT: For a listing and description of ASME Conformity Assessment (accreditation, registration, and certification) programs, visit the Standards and Certification website at http://www.asme.org/kb/standards/certification---accreditation.

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SCHEDULE OF MEETINGS: Meetings of Codes and Standards Development Committees are held periodically to consider the development of new standards and the maintenance of existing standards. To search for scheduled meetings of Codes and Standards Development Committees, by date or by keyword, visit the Standards and Certification website at http://calendar.asme.org/home. cfm?CategoryID=1.

PUBLIC REVIEW DRAFTS

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

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

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

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

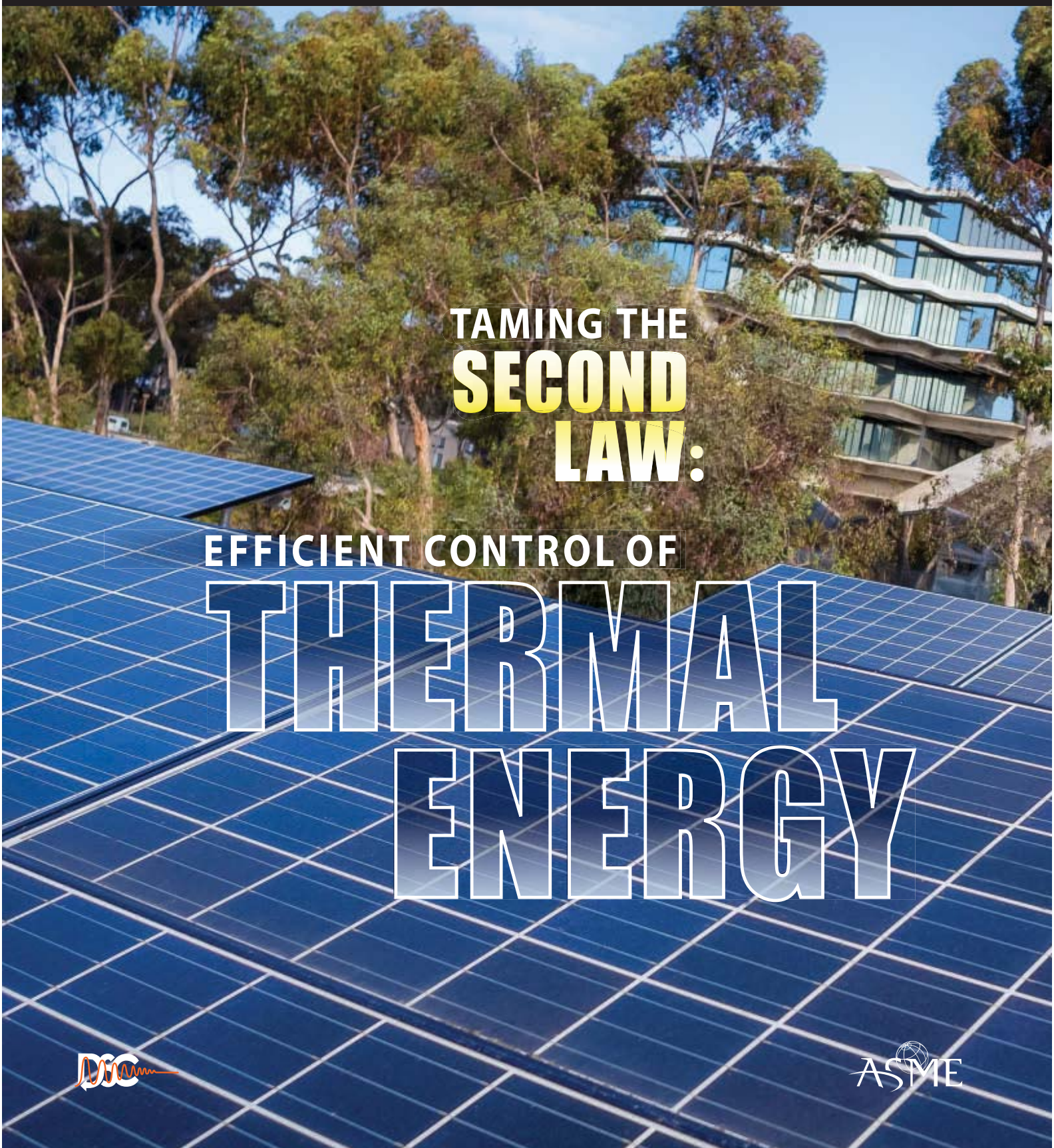
Authorized Inspections
Automotive
Bioprocessing Equipment
Boilers
Certification and Accreditation
Chains
Controls
Conveyors
Cranes and Hoists
Cutting, Hand, and Machine Tools
Dimensions
Drawings, Terminology, and Graphic Symbols
Elevators and Escalators
Energy Assessment
Fasteners
Fitness-For-Service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

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

A forum for emerging systems and control technologies.

DYNAMIC SYSTEMS & CONTROL

MARCH 2014 VOL. 2 NO. 1



TAMING THE SECOND LAW:

EFFICIENT CONTROL OF THERMAL ENERGY

DSC

ASME

EDITOR

A. Galip Ulsoy, University of Michigan, *ulsoy@umich.edu*

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Future issues of *Dynamic Systems & Control Magazine* will include the following themes:

June 2014
Modeling and Control of Batteries

September 2014
Rehabilitation Robotics

Efficient Control of Thermal Energy

This fifth issue of ASME *Dynamic Systems and Control (DSC) Magazine*, which focuses on dynamics and control of energy systems, marks our second year of publication. The first year issues highlighted advances in control of automotive systems, fluid power systems and wind power, as well as monitoring and diagnostics. It is gratifying to report that, in a recent survey of the ASME Dynamic Systems and Control Division (DSCD) membership, more than 97% of respondents indicated that they would like to see continued publication of ASME *DSC Magazine* in some form (i.e., hardcopy and/or online). We will continue publication in 2014 as part of ASME's *Mechanical Engineering* magazine with the March, June, September and December issues. During the next few months, the DSCD Executive Committee will undertake a cost/benefit analysis and make a decision about publication beyond 2014.

In this issue, authors Andrew Alleyne and Neera Jain, in their article "Transient Thermal Systems: Dynamics and Control,"discuss the understanding, modeling, analysis and efficient control of thermal energy and its conversion to other forms of energy. Their example is the refrigerated transport of goods.

In the article "Extremum Seeking for Wind and Solar Energy Applications," authors Azad Ghaffari, Miroslav Krstic and Sridhar Seshagiri discuss the extremum seeking method, its suitability for energy systems, and its application to wind and solar energy conversion systems.

Also in this issue, we are highlighting DSCD news and upcoming events, and and other items. We also include a thought provoking message from the incoming and current chairs of the DSCD Executive Committee, Andrew Alleyne and George Chiu, respectively. Entitled "Decisions that Matter," the essay follows this editorial on the next page.

The next issue of *DSC Magazine,* scheduled for June 2014, will showcase articles that focus on and explore the ways in which control technology is impacting the performance of batteries.

As always, I look forward to receiving your comments and suggestions at **ulsoy@umich.edu.**

A. Galip Ulsoy
Editor, *DSC Magazine*

ANDREW ALLEYNE, UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN
DSCD EXECUTIVE COMMITTEE CHAIR 2014–2015
GEORGE CHIU, PURDUE UNIVERSITY DSCD EXECUTIVE COMMITTEE CHAIR 2013–2014

DECISIONS THAT MATTER

WHAT IS A GOOD DECISION WORTH? This fundamental question gets at the heart of how members of ASME's Dynamic Systems and Controls Division (DSCD) contribute to society. For example, during the mid-2000's, the U.S. and coalition forces were embroiled in a difficult ground war in Iraq.

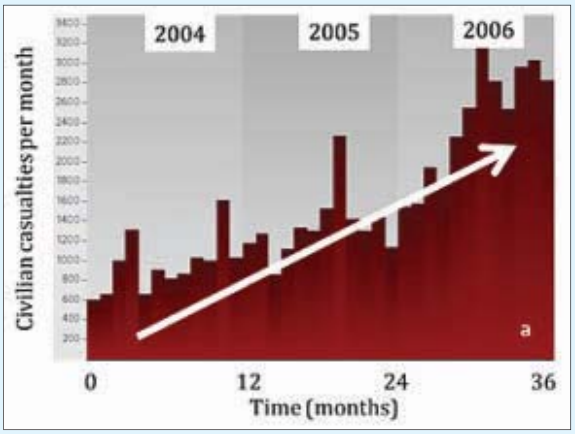


FIGURE 1A Civilian casualties per month in Iraq prior to coalition-led surge.

Figure 1a illustrates the civilian deaths per month from the start of 2004 until the end of 2006[1]. The steady increase in casualties would be well modeled by an integrator, $\dot{x} = c$, where x is civilian casualties and c is a forcing function that was an incredibly complex mix of political and religious forces at the time.

In 2007, coalition forces made a key decision to commit a surge of troops and implement a 'capture-and-hold' strategy for key geographical areas. This decision was based on an in-depth knowledge of geopolitical situations on the ground as well as coalition capabilities: in other words, detailed knowledge of the physical plant upon which the decision was to be enforced.

Figure 1b illustrates the stabilization effect of that key decision that resulted in an approximately first order response, , with a time constant, a, of about 18 months. This key decision saved tens of thousands of lives and countless other resources. The surge strategy was clearly a decision that made a difference.

There are many other types of important societal decisions that truly make a difference. Food, health, energy, transportation, security, manufacturing; these all matter to our daily lives. **Figure 2** illustrates a matrix structure with columns showing the breadth of societally relevant topics upon which decisions are made.

For example, the decision to administer a flu vaccine is based on careful analysis and prediction of anticipated viruses[2]. In terms of dynamical systems and control, this feedforward or anticipatory decision (i.e., *control*) is based on past data and a prediction governed by the most accurate knowledge of the present global epidemiological situation (*plant*).

Millions of impactful decisions are necessarily made each day. ASME's Dynamic Systems and Control Division is equipped to make significant contributions to such decisions and play a key role in society. We are able to make decisions restricted by time scales of any imaginable length—from microseconds to months.

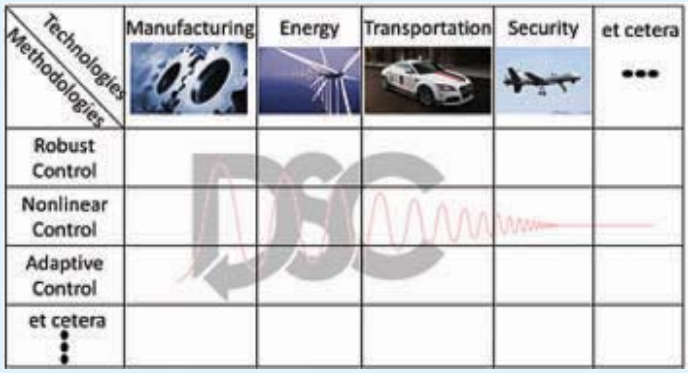


FIGURE 2 Matrix representation of ASME DSCD contribution space.

Moreover, we are uniquely positioned by our in-depth knowledge of the physical systems upon which any decision will ultimately be implemented. An understanding of mechanical engineering underscores our broad knowledge of the behavior of these systems. We determine what is essential about these systems in order to make informed decisions, or how to change the plant by redesign when it is evident that decisions alone will not achieve the desired goal.

Numerous domain experts can understand the columns of **Figure 2** and other fields that focus on the rows containing specific decision making tools, possibly devoid of end use application. The DSCD community understands the matrix shown in Figure 2. For a given column, we can identify which particular row is most appropriate as a solution path and explain why it is most appropriate.

The DSCD community has the invaluable ability to visualize the overall problem and solution space presented in Figure 2. While the development of algorithms to expand the rows outlined here is of great technical value, true impact comes from seeing the whole picture. Because it commands this skill, ASME's DSCD community is uniquely positioned to make decisions that matter. ■

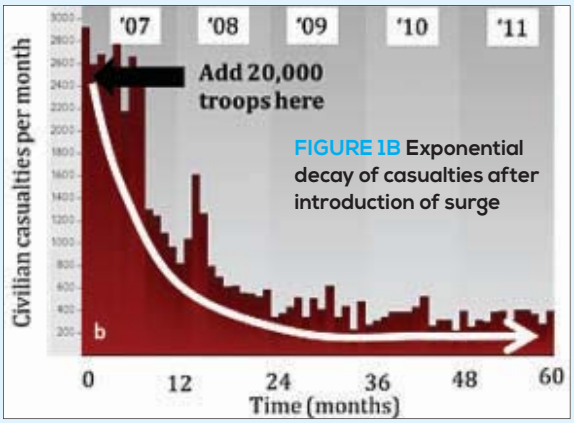


FIGURE 1B Exponential decay of casualties after introduction of surge

References: **1** www.iraqbodycount.org **2** http://www.cdc.gov/flu/

2013 ASME Dynamic Systems and

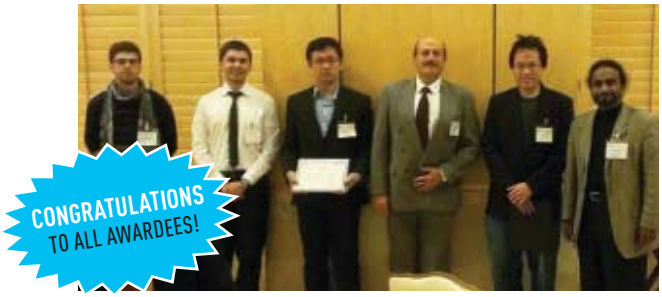
The Sixth Annual Dynamic Systems and Control (DSC) Conference, sponsored by the Dynamic Systems and Control Division (DSCD) of ASME International, and led by General Chair Nejat Olgac and Program Chair Miroslav Krstic, was held during October 21-23, 2013, at Stanford University, Munger Center, Palo Alto, CA.

This year's ASME DSC Conference hosted 440 registrants from 24 countries, and covered the presentation of 290 scientific papers in 49 sessions across seven parallel tracks of 29 contributed and 20 invited sessions. The conference also featured special sessions, exhibits by industry sponsors, and a first-time single-track experimental session where a group of researchers displayed their research findings in-situ. The conference technical program included dynamical systems modeling, simulation, analysis, design, control theory, industrial applications, control education, and information sessions on new opportunities and challenges in the dynamical systems and control field.

A. Galip Ulsoy (*University of Michigan*) delivered the 2013 Nyquist Lecture, while **Graham C. Goodwin** presented the Oldenburger Lecture. Both **Joseph J. Beaman Jr.** (*University of Texas at Austin*) and **Oussama Khatib** (Stanford University) gave plenary talks, all lectures ranging from reconfigurable systems, opportunities in control science, to advanced manufacturing, and human-robot systems. ■

George Chiu (*left; Purdue University & NSF*) and Program Chair **Miroslav Krstic** (*right; University of California, San Diego*) with ***Nyquist Lecturer*** awardee **A. Galip Ulsoy** (*center*).

George Chiu (*left*) and Program Chair **Miroslav Krstic** (*right*) with ***Outstanding Young Investigator*** awardee **Maurizio Porfiri** (*center*).



Finalists, ***Best Paper: Theory*** (*l. to r.*): **Michele Giorelli** (*Scuola Superiore Sant'Anna*) representing co-authors **Federico Renda, Gabriele Ferri**, and **Cecilia Laschi**; **Umut Zalluhoglu**, **Qingbin Gao**, and **Nejat Olgac** (*University of Connecticut*); **Arom Boekfah** and **Santosh Devasia** (*University of Washington*).

2013 AWARD RECIPIENTS...

RUFUS T. OLDENBURGER MEDAL **Graham C. Goodwin** *University of NewCastle* ◆ NYQUIST LECTURER **A. Galip Ulsoy** *University of Michigan* ◆ OUTSTANDING YOUNG INVESTIGATOR AWARD **Maurizio Porfiri** *Polytechnic Institute of New York University* ◆ RUDOLPH KALMAN BEST PAPER AWARD **Nikhil Ravi, Chen-Fang Chang, Han Ho Song, J. Christian Gerdes, Hsien-Hsin Liao, and Adam F. Jungkunz** for their article "Modeling and Control of an Exhaust Recompression HCCI Engine Using Split Injection," *ASME Journal of Dynamic Systems, Measurement and Control*, 134(1), 011016, 2012. ◆ DSCC BEST STUDENT PAPER (FINALISTS) **Qingbin Gao** *University of Connecticut*, **Xin Zhou** *University of Michigan*, **Mehdi Maasoumy** *UC Berkeley*, **Hari Vasudevan** *Yale University* ◆ DSCC BEST STUDENT PAPER **Scott Wilcox** *University of Washington* ◆ BEST STUDENT MECHATRONICS PAPER **William Gallagher** *Georgia Institute of Technology* ◆ BEST STUDENT ROBOTICS PAPER **Javad Sovizi** *University of Buffalo* ◆ BEST ROBOTICS CONFERENCE PAPER **Vinay Chawda** *Rice University*; **Ozkan Celik** *San Francisco State University*; **Marcia K. O'Malley** *Rice University* for their paper "A Method for Selecting Velocity Filter Cutoff Frequency for Maximizing Impedance Width Performance in Haptic Interfaces." ◆ NEW AWARD BEST CONFERENCE PAPER: THEORY **Qingbin Gao, Umut Zalluhoglu, Nejat Olgac** *University of Connecticut*, for their paper "Equivalency of Stability Transitions Between the SDS 'Spectral Delay Space' and DS 'Delay Space.'" BEST CONFERENCE PAPER: APPLICATION **Jun Zhang, Emmanuelle Merced, Nelson Sepulveda, and Xiaobo Tan** *Michigan State University, for their paper* "Optimal Compression of a Generalized Prandtl-Ishlinskii Operator in Hysteresis Modeling."

UPCOMING CONFERENCES

12th IFAC Workshop on Time Delay Systems

June 28–30, 2015 University of Michigan, Ann Arbor

Led by General Chair **A. Galip Ulsoy** and program editor **Gabor Orosz** (*University of Michigan*), the 12th workshop will explore traditional and contemporary topics on time delay systems ranging across theory to applications. Discussion topics will include manufacturing, automotive systems, networked dynamics, economics, biological systems, mechatronics and robotics. For more information, visit: **http://me.engin.umich.edu/dirifac/**

Correction: Photo credits in the December 2013 issue of *DSC Magazine* for Professor John J. Moskwa and Professor Bryan Rasmussen, are given respectively to SAE international and ASHRAE.

PUBLISHED BOOKS

Robust Control of Uncertain Dynamic Systems

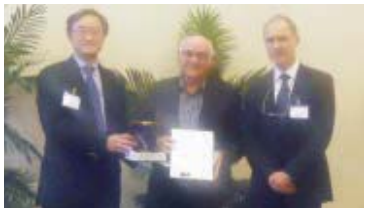
RAMA K. YEDAVALLI *Springer, 2014*

This textbook aims to provide a clear understanding of the various tools of analysis and design for robust stability and performance of uncertain dynamic systems. In model-based control design and analysis, mathematical models can never completely represent the "real world" system that is being modeled, and thus it is imperative to incorporate and accommodate a level of uncertainty into the models. This book directly addresses these issues from a deterministic uncertainty viewpoint and focuses on the interval parameter characterization of uncertain systems. Various tools of analysis and design are presented in a consolidated manner. This volume fills a current gap in published works by explicitly addressing the subject of control of dynamic systems from linear state space framework, namely using a time-domain, matrix-theory based approach.

Control Conference

Finalists, ***Best Paper: Application*** *(l. to r.)*: **Hosam K. Fathy** and **Saeid Bashash** (*Pennsylvania State University*), **Dr. William D. Robinson** *(John Deere),* **Atul Kelkar** (*Iowa State University*), author **Jun Zhang** (representing co-authors **Emmanuelle Merced, Nelson Sepulveda,** and **Xiaobo Tan**).

George Chiu *(far left)* and Program Chair **Miroslav Krstic** (*far right*) present the ***Rudolph Kalman Best Paper*** award to the authors (*l. to r.*): **J. Christian Gerdes, Chen-Fang Chang, Adam F. Jungkunz, Hsien-Hsin Liao** and **Nikhil Ravi**. *Author* **Han Ho Song** *could not attend the ceremony.*



George Chiu *(left)* and Program Chair **Miroslav Krstic** *(right) award* **Graham C. Goodwin** (*center*) with the ***Rufus T. Oldenburger Medal.***

George Chiu *(far left)* stands with the finalists for ***Best Student Paper*** *(l. to r.)*: **Hari Vasudevan**, **Scott Wilcox** (winner), **Mehdi Maasoumy, Xin Zhou, Qingbin Gao,** and Students and Young Members Chair **Atul Kelkar.**

Recognition of ASME Dynamic Systems and Control (DSC) Division Members

Start-Up Company to Commercialize Tissue Tension Sensor

A handheld device to measure tension in soft tissues such as ligaments, muscles and tendons developed by **Rajesh Rajamani** and **Kalpesh Singal** at the University of Minnesota has been licensed to a start-up company FocusStart for commercialization. The pen-sized handheld device *(above photo)* is used by simply pushing it against a tense segment of soft tissue, to measure the site specific axial tension in the tissue. The device will be useful during a variety of orthopedic surgical procedures, including total knee replacement, ACL repair, shoulder stabilization, patella dislocation, tendon repair and total hip replacement. The start-up company plans to make the device ready for FDA submissionin 3 years. The inventors Rajamani and Singal are ASME DSCD members.

Graduate students Ke Li and Chen Zhang working with Professor of mechanical engineering **Zongxuan Sun** at the University of Minnesota, received two awards for their research on a free piston engine. The students won first place in the Dow Sustainability Innovation Student Challenge Award (SISCA). They also won first place in the poster competition at the 2013 annual meeting of the NSF Center for Compact and Efficient Fluid Power (CCEFP). The authors Sun and Li are ASME DSCD members. ■

Process Control for Sheet-Metal Stamping

YONGSEOB LIM, RAVINDER VENUGOPAL, A. GALIP ULSOY
Springer, 2014

This book presents a structured and comprehensive approach in designing and implementing controllers for sheet metal stamping. Employing process control significantly reduces defects in deep-drawn parts and can yield material savings from reduced scrap. Sheet-metal forming is a complex process, most often characterized by partial differential equations that are numerically solved using finite-element techniques. This book reviews twenty years of academic research, and the resulting technology is transitioned to the industrial environment. The sheet-metal stamping process is modeled according to multiple input–output control system design, with commercially available sensors and actuators. The models are used to design adaptive controllers, and real-time controller implementation is then discussed. Results from experiments in shopfloor deployment are presented along with ideas for optimizing the technology.

Delay Systems: From Theory to Numerics and Applications

TOMÁŠ VYHLÍDAL; JEAN-FRANÇOIS LAFAY; RIFAT SIPAHI (EDS.) *Springer, 2014*

This volume is the first of the new series *Advances in Dynamics and Delays*. It offers the latest advances in controlling dynamical systems with delays, which can arise in a variety of real-world problems. The contributions in this series have been collected across various disciplines,

such as engineering, physics, biology, and economics. Some are extensions of those which have been presented at IFAC (International Federation of Automatic Control) conferences since 2011. The series is categorized in five parts covering the main themes of the contributions, namely, stability analysis and control design, networks and graphs, time delay and sample data systems, computational and software tools, and applications. This volume is a solid reference source for researchers and PhD students studying delay systems. It is also a resource for control engineers, as it offers innovative control methodologies for relevant applications, from both the perspectives of theory and numerical analysis.

TRANSIENT THERMAL SYSTEMS:

BY ANDREW ALLEYNE AND NEERA JAIN MECHANICAL SCIENCE AND ENGINEERING, UNIVERSITY OF ILLINOIS, URBANA-CHAMPAIGN

Energy exists in multiple domains, such as mechanical energy, electrical energy, and chemical energy. Thermal energy, the subject of this article, is similarly ubiquitous. The transfer of energy from one domain to another usually involves a thermal component in some portion of the process. The understanding of thermal energy transfer and conversion is critical to maintaining and increasing efficiency measures of all aspects of the energy supply chain, consisting of energy conversion, transmission, conservation, and scavenging, because it allows for better control of available energy resources.

The research communities in the fields of thermodynamics or heat and mass transport number in the thousands, and a great deal of excellent work is being performed across the world. However, it should be noted that the majority of the attention has focused on the spatial dependence of thermal system behavior as opposed to the temporal behavior[1,2]. Most thermodynamics that is taught and researched assumes a static equilibrium approach, illustrated in the pressure-enthalpy (*P-h*) diagram depicted in **Figure 1**[2]. Similarly, heat transfer is most often analyzed from a steady state perspective[1]. It is certainly possible to analyze temporally varying thermal systems, but the analytical solutions are usually available for only the simplest physical geometries or systems—an example of which involves heat conduction in a cylinder. For more complex geometries, the most common approach uses correlations for good spatial properties and numerical methods for determining time variations[3]. These numerical models may be good for system design, but they are less suited for analysis and potential control design since they do not present the types of functionality control engineers typically need, such as inputs, dynamic states and outputs.

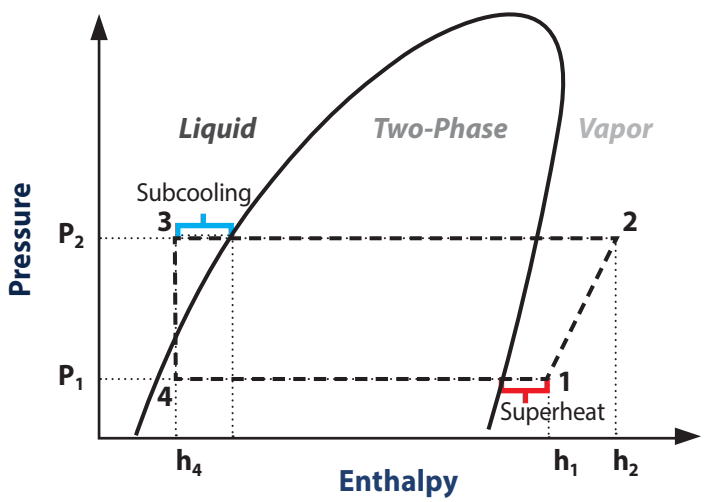


FIGURE 1 Pressure-enthalpy (*P–h*) diagram of a standard vapor-compression thermodynamic cycle.

To maximize both the performance and efficiency of transient thermal systems, it is imperative that their dynamics be well

DYNAMICS AND CONTROL

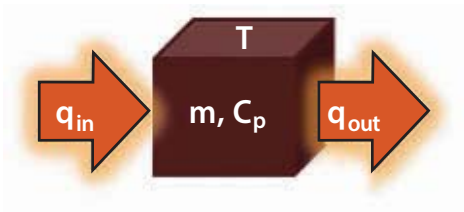


FIGURE 2 Lumped parameter representation of thermal energy change.

understood and their control systems well designed. Many of these systems operate within constraints; pushing them closer to their constraints increases their performance/efficiency but may also increase their susceptibility to harm. One example is the tradeoff of evaporator efficiency versus compressor protection in a Vapor Cycle System (VCS) that manifests itself as a safe minimization of evaporator superheat. This is shown as location "1" in Figure 1 depicting the increase in enthalpy beyond the vapor dome occurring at the compressor inlet. Too little superheat risks crossing under the saturation dome and exposing the compressor to undesirable liquid ingestion that increases compressor failure rates. Too large a superheat, while safe, greatly reduces the efficiency of the evaporator by not maximizing heat transfer through the heat exchanger.

Being able to control these systems close to the edges of acceptable safety thus enables us to extract greater system efficiencies, but guaranteed safety, often through control, is imperative for any practical acceptance.

In this article we outline several approaches to control-oriented dynamic modeling of transient thermal systems. We also illustrate the advantage of model-based control design to improve system performance.

MODELING AND SYSTEM DYNAMICS

In order to understand transient thermal systems, it is imperative that we are able to construct relatively accurate models for them. Here we review three standard approaches, in varying levels of complexity.

Lumped Parameter Models

Lumped parameter models perform basic balances of mass and energy regarding some control volume of interest. The dynamics within the control volume are 'lumped' together into a small number of variables of interest, hence the name. An example of such a lumped parameter system would be the control volume shown in **Figure 2**.

The balance of energy into and out of the volume would be

$$mC_p\dot{T} = \sum \text{(heat in flow)} = \underbrace{h_{in}}_{\substack{\text{heat}\\\text{transfer}\\\text{coefficient}}} \cdot \underbrace{A_{in}}_{\substack{\text{cross}\\\text{sectional}\\\text{area}}} \cdot \left(T_{in} - T\right) - h_{out} A_{out} \left(T - T_{out}\right). \quad 1$$

This simplified model leads to 1st order system behavior. This approach is often sufficient to coarsely represent a large number of transient thermal problems, particularly where there is no phase change. The heat transfer coefficient is governed by the specific problem: convection or conduction. If there is mass accumulation in a system, then a conservation

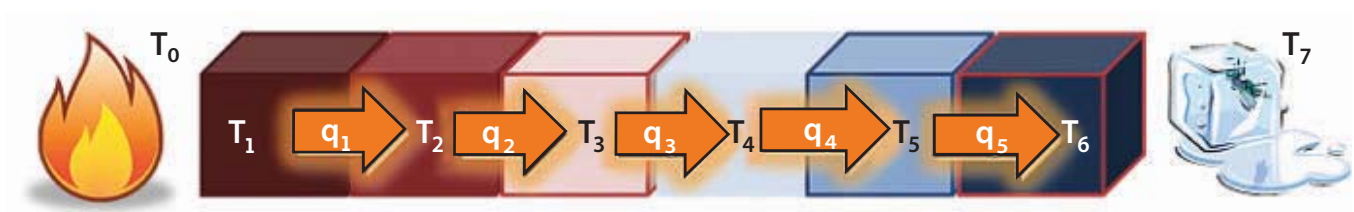


FIGURE 3 Finite volume representation of heat conduction problem.

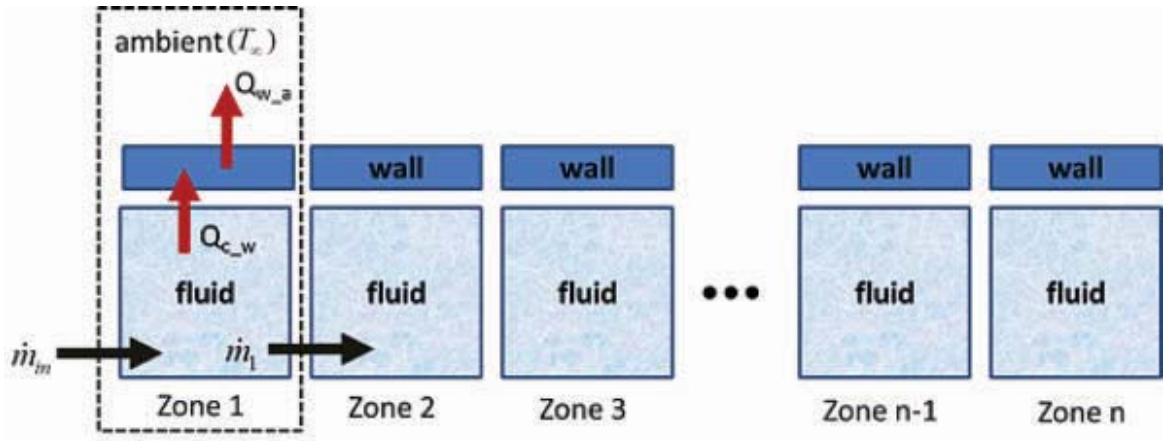


FIGURE 4 One dimensional finite volume representation of a liquid-to-air heat exchanger system.

of mass calculation can be used to determine system characteristics such as pressure in a given volume.

Finite Volume Models

An alternative to the lumped parameter approaches are finite volume modeling approaches. Conceptually, one can think of these as lumped parameter models but with a large degree of spatial discretization. A given system would be reduced to a collection of N individual subsystems, each with a fixed volume. Within each volume, the appropriate equations of state can be numerically integrated with the adjacent volumes providing the boundary conditions. **Figure 3** demonstrates a 1-dimensional heat conduction example discretized into N=6 distinct volumes with heat flowing from hot to cold reservoirs.

Within each zone, the individual heat conduction equations can be determined across each interface with *U* representing the conductance.

$$C_{p\_i}\dot{T}_i = \dot{Q}_{in\_i} - \dot{Q}_{out\_i} \quad i \in \{1,\ldots,6\} \qquad 2$$

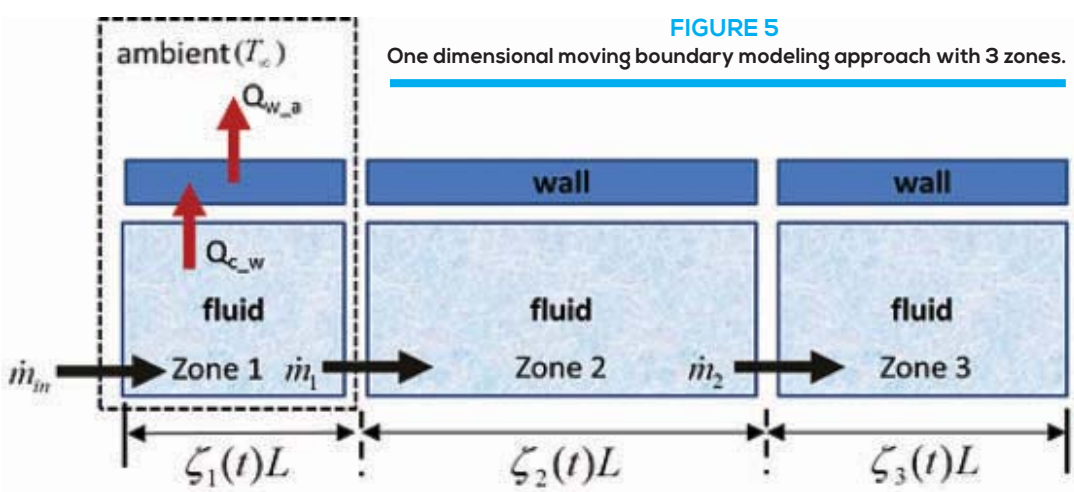
$$\dot{Q}_{in\_i} = U \cdot A \cdot \left(T_{i-1} - T_i\right);\ \dot{Q}_{out\_i} = U \cdot A \cdot \left(T_i - T_{i+1}\right) \quad i \in \{1,\ldots,6\} \qquad 3$$

This results in a series of coupled equations with the number of dynamic variables equal to the number of volume elements. **Figure 4** shows a 1 dimensional combined heat and mass transport problem where an energy carrying fluid interfaces with a heat exchanger which then rejects the heat to ambient. The number of states equals 2N where N is the number of individual volume elements. Each volume utilizes energy and mass conservation to track the thermal energy flowing from the fluid to the heat exchanger wall (Q_{c_w}) and then from the wall to the ambient air ($Q_{wvggb\,gbb\_a}$).

It is also possible to utilize conservation of momentum in each volume to determine changes in pressure as the fluid flows from one zone to the next. However, this may introduce numerical challenges due to incompressibility if the fluid is liquid. The resulting system will have fast pressure dynamics relative to the thermal dynamics making for a stiff set of differential equations to solve.

The advantage of the finite volume approach is a spatial resolution that the lumped parameter approach does not have.

FIGURE 5
One dimensional moving boundary modeling approach with 3 zones.



This resolution usually results in increased accuracy since the variations in parameters such as specific heat and/or heat transfer coefficients can be tailored to individual subsections of a given component. For example, a bend in a heat exchanger could be given a different pressure drop coefficient than the straight sections of the heat exchanger thereby resulting in a more precise system simulation. The primary drawback of the finite volume approach is the increased state dimensionality resulting from an increased number of volumes. This reduces its simulation speed and limits its use in real-time applications. For most modern computing platforms, this is not a serious concern. However, the high dimensionality of the approach creates many more dynamic states than can be measured or even estimated. Therefore, the finite volume approach is better suited for 'desktop' system simulation than it is for controller or estimator design[4].

Moving Boundary Models

Moving boundary models attempt to bridge the behavior of both the lumped parameter and finite volume approaches[5,6]. Moving boundary methods have a lumped parameter formulation for a particular volume. However, the boundaries of that volume are allowed to move and vary as a function of the dynamics of the overall system. As shown in **Figure 5**, the N zone cooling system of Figure 4 is replaced by a 3 zone model, but the length of each zone, denoted by $\zeta_j(t)L$, $j \in \{1,2,3\}$, can vary as a function of time. Here, $\zeta_j(t)$, $j \in \{1,2,3\}$ is the fraction of the total volume, L, encompassed by the j-th zone. The dynamics of each zone are governed by their j individual conservation laws (mass, momentum, energy) which results in differential equations for each zone. For many classes of systems, particularly those involving fluid phase changes, the moving boundary approach allows for improved accuracy over low order lumped parameter models. However, it also avoids the high dimensionality of the finite volume approaches thereby proving amenable to controller or estimator design[5,6].

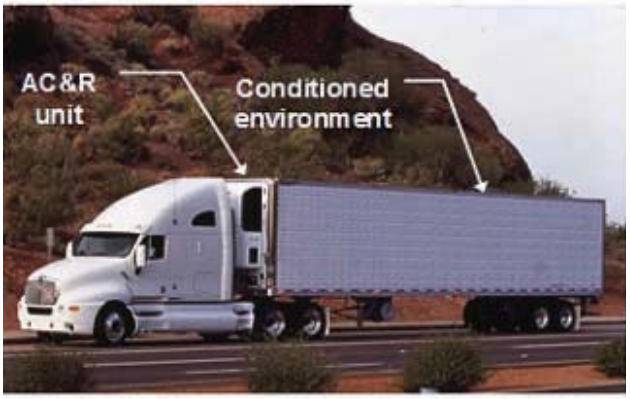


FIGURE 7A VCS unit on a trailer.
Photo: Thermo King Corp

FIGURE 7B Standalone VCS unit.
Photo: Thermo King Corp

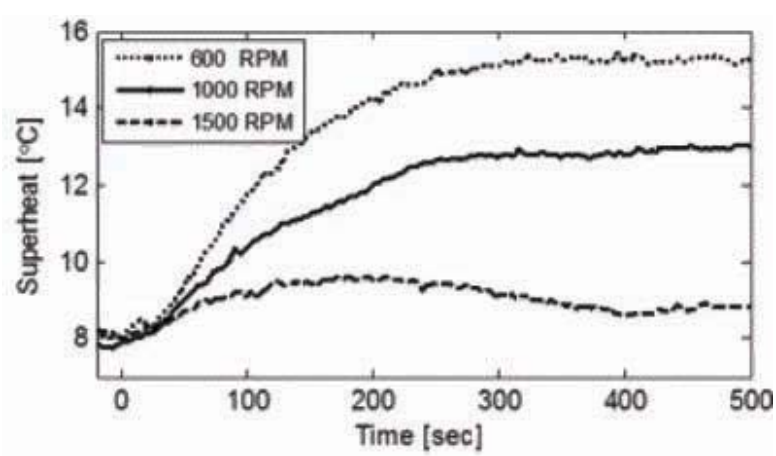


FIGURE 6 Time domain illustration of nonlinear gain in system step responses.

System Nonlinearity

The modeling relationships presented above are often valid only around an operating point. One of the key aspects of thermal systems is their large change in behavior as a function of operating conditions: i.e. nonlinearity. The mass flow elements, such as fans, compressors, or pumps, usually have an efficiency that varies with operating condition. For example, the nonlinear relationship between air flow rate and power consumption of a typical fan follows a 3rd order polynomial[7]. Similar nonlinear variations in efficiency occur in pumps/compressors and valves[7].

Similar to the mass flow elements, the thermal energy transfer elements in these systems also vary in their behavior as a

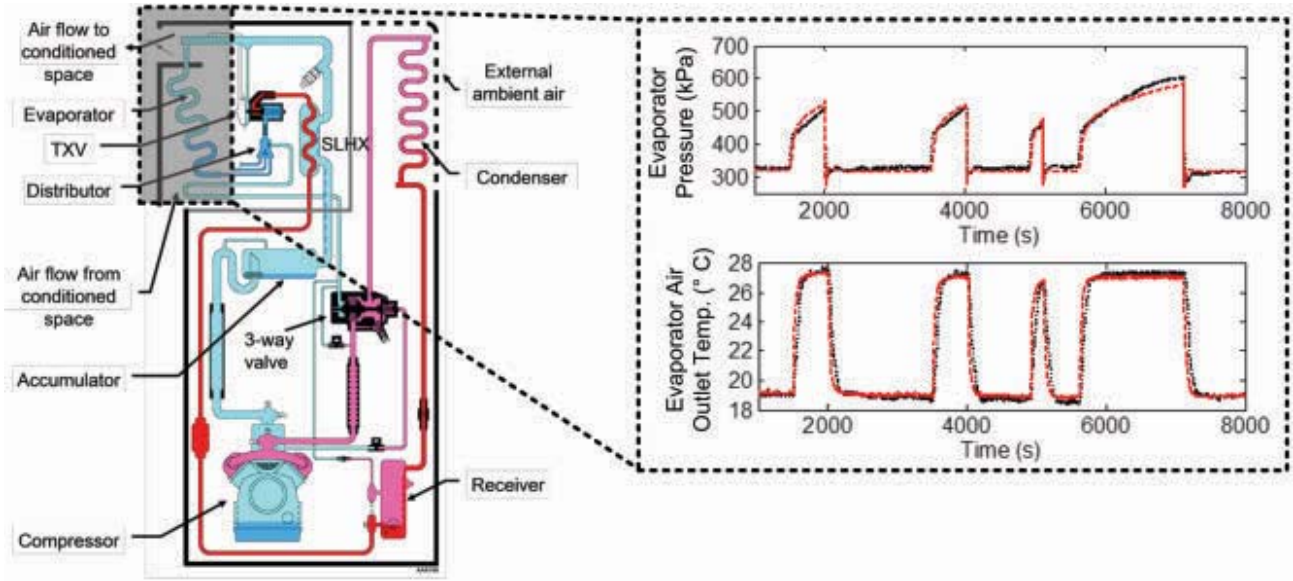


FIGURE 8 Validation of evaporator refrigerant pressure and evaporator air outlet temperature.

function of operating condition. Convective heat transfer coefficients (i.e. gains) change drastically as a function of Reynolds number. Should the working fluid also perform a change in phase, the resultant changes in heat flow gains are amplified.

The variations in critical component gains can make the transient performance of thermal management systems inherently nonlinear. **Figure 6** illustrates a VCS operating at different compressor speeds where the valve and compressor are changed about their nominal operating point. Nonlinearity is evidenced by the large variation in evaporator superheat owing to 100 rpm step variations in compressor speed at different operating speeds[8]. There is a factor of 7 change in the steady state response as the operating condition changes by a factor of 2.5. This affects the ability to perform tight control of the system with a single controller. The current state of the art is to linearize the system behavior about critical operating points and switch system representations and controllers as a function of these points [9, 10].

SYSTEM MODELING AND CONTROL EXAMPLE: REFRIGERATED TRANSPORT

As a case study, the modeling techniques described previously will be applied to a truck transport refrigeration system (TTRS). This example is chosen here because it is susceptible to widely varying external transient loads, more so than a home or building. Additionally, it is composed of multiple sub-systems some of which, such as the refrigeration unit, have a sufficiently low thermal capacitance that transient analysis is necessary. A typical TTRS in operation is shown in **Figure 7a**. Here a VCS unit is attached to the cargo compartment of a trailer as it transports perishable food. **Figure 7b** gives a detailed view of the VCS unit that conditions the environment within the trailer.

The schematic of the VCS in **Figure 8** shows several components interconnected to form a complete system. The ambient side of the system rejects hot air to the external environment, and the refrigerated side pulls heat from the conditioned environment. There are several components in the physical system of Figure 7b that have been abstracted away in the schematic shown in Figure 8 including the prime mover operating the compressor. The modeling approach described in the section on Moving Boundary Models has been used to model and validate a number of different VCSs[6], including this example TTRS. Figure 8 shows evaporator refrigerant pressure and evaporator air outlet temper-ature varying as the compressor starts and stops and as the thermostatic expansion valve (TXV) opens and closes[13]. Note the transients caused by the starting and stopping of the entire system; to properly capture these, a dynamic system representation is a necessity.

These systems often utilize a hysteretic on-off control logic, which turns the cooling system on or off when the temperature exceeds some maximum (T_{high}) or minimum (T_{low}) value respectively. The value of the nonlinear model is that it can perform an embedded online controller optimization, based on environmental conditions, and

NSF SPONSORED WORKSHOP ON BUILDING SYSTEMS

BUILDINGS CURRENTLY ACCOUNT FOR A LARGE FRACTION OF GLOBAL energy usage and contribute 40% of global greenhouse emissions. In the U.S. buildings consume approximately 40% of total energy usage, including 70% of electricity and 50% of natural gas. This is on par with all transportation systems and the carbon footprint is actually higher. As the world population becomes more urbanized, this cost will rapidly increase with the current pace of global urbanization.

The National Science Foundation (NSF) sponsored a Workshop on Building Systems at the University of Illinois Urbana-Champaign on 24-25 May 2010. The goals of this workshop were (1) to identify priority areas for research to improve energy efficiency of buildings and provide comfort, safety, and productivity of their occupants, and (2) to raise awareness in the controls community of the research issues in this area. Three dozen leading researchers from industry, academia and government convened to determine future directions for building 'science' from a systems and controls perspective. The participants were from industry, government, and academia. Four major issues were deemed fundamental to making progress:

Modeling Current modeling tools are not sufficient for predicting the actual behavior of buildings across the relevant range of dynamics, lack validation data, and are challenging to use and integrate into decision-making algorithms.

Estimation/Diagnostics The sensor networks in large buildings are extremely complex and while it is easy to get data, it is harder to obtain useful knowledge for modeling, diagnostics and control.

Information and communication Building network configuration and maintenance is a labor-intensive endeavor where the design, specification and deployment of networked sensors are challenging, particularly for retrofits. Integration and interoperability of building information sources could be greatly improved.

Controls and Optimization Controls systems must be developed that optimize the number of required sensors, provide building services at minimal cost, and are robust to variability and faults in equipment. This is required because buildings have a long lifetime and are not as carefully maintained as high precision equipment. Also, there is tremendous opportunity in integration with the power grid for demand response.

Since much of the energy use within buildings falls into the domain of the mechanical engineer, it is important that the ASME community, along with partner communities such as ASHRAE, IBPSA, and IEEE, turn significant attention to these systems. ■

choose optimal (T_{high}/T_{low}) switching points for the controller logic. **Figure 9a** illustrates a locally convex cost function that for a specific condition, can be computed online. As conditions vary, the cost function minimum guides continuously varying switching conditions illustrated in **9b**[14]. In reference 14, the online optimization approach demonstrated a 5-10% fuel savings over a well-tuned industrial baseline controller. The finite volume approach was too computationally intensive and the lumped parameter too inaccurate to achieve effective online optimization. The switched system moving boundary approach, documented in reference 15, achieved the right balance of complexity versus accuracy.

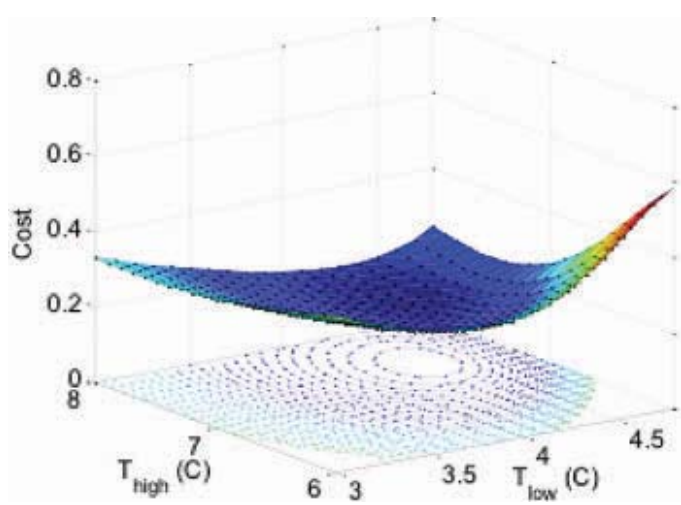


FIGURE 9A Locally convex cost function for online optimization.

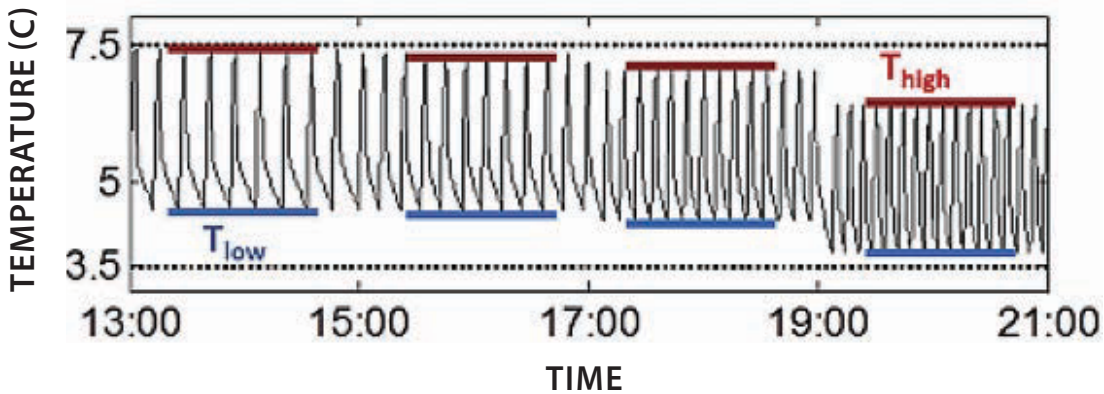


FIGURE 9B Controller parameter (T_{high}/T_{low}) variation as a function of time.

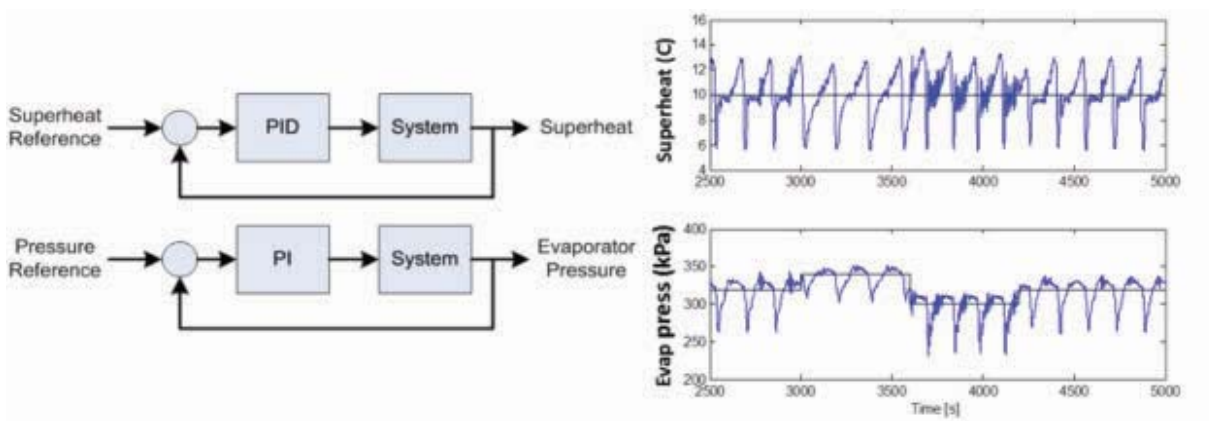


FIGURE 10 Demonstration of controller fighting between individual feedback loops in a VCS system.
Note: Evaporator pressure is a surrogate for cooling capacity.

ADVANCED TRANSIENT THERMAL CONTROL SYSTEMS

The simple thermostatic approach given above is suitable for many systems where only one control degree of freedom is utilized. With increased electrification of modern systems, additional control degrees of freedom are available. These include electronically variable mass flow devices such as variable speed pumps, fans, and compressors as well as electronically variable valves. This electrification provides significant flexibility in system operation. A typical approach is to incorporate proportional-integral-derivative (PID) loops around individual pairs of inputs and outputs. For example, within a VCS such as the one shown in Section 3, it is important to control the compressor speed providing cooling capacity. At the same time, evaporator superheat should be controlled for system efficiency plus safety. Two separate PID controllers can be incorporated on each of these feedback loops whereby the compressor controls the cooling capacity and an electronic expansion valve controls evaporator superheat. **Figure 10** illustrates an example of the type of 'fighting' that commonly arises between the two control loops as they both try to command the use of a common resource: refrigerant mass flow rate. One approach to this problem is to significantly detune the response of each individual controller and, for systems that operate at steady state, this is usually an acceptable option. The potential downside is the decrease in efficiency that may need to be absorbed in order to accommodate a lower performing controller.

For systems that have multiple inputs and outputs, a direct approach is multi-input multi-output (MIMO) control. Since the majority of thermal systems have temperature time constants on the order of minutes to hours, they are relatively slow from the perspective of embedded processors. Additionally, the desired system performance often incorporates constraints into the formulation. Model-based optimization approaches lend themselves naturally to the solution of these types of problems. These include mixed integer linear/non-linear programming (MILP/MINLP)[16] as well as more compact Model Predictive Control (MPC)

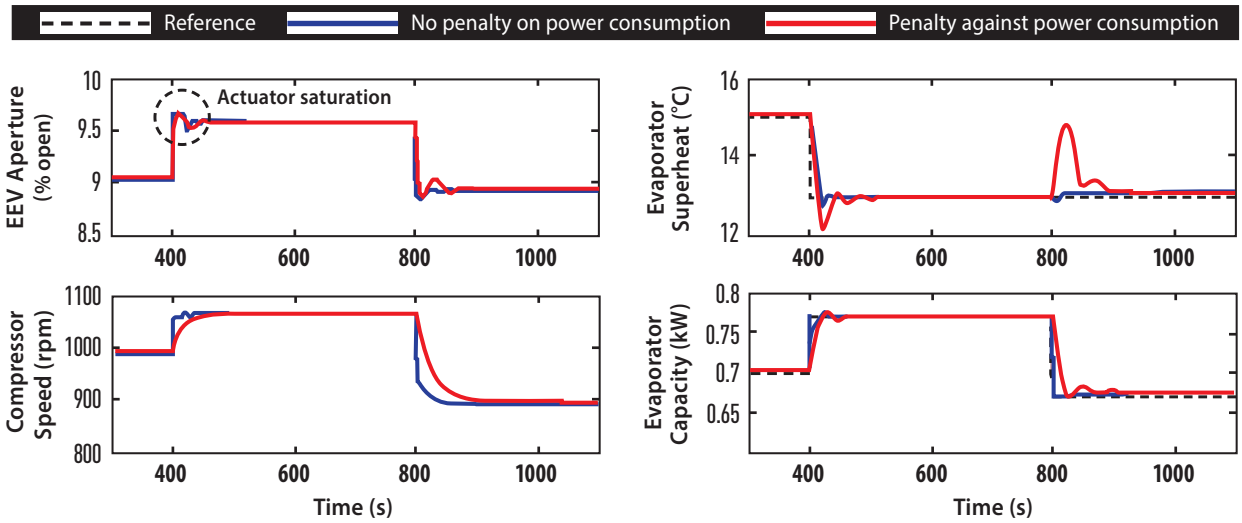


FIGURE 11 **(A)** **Control input signals generated by MPC and** **(B)** **feedback variable tracking performance for different penalties on compressor power consumption.**

approaches[17, 18]. The use of more sophisticated constrained optimization approaches tends to scale with the associated thermal system. For district-level systems supplied by power plants, a static solution may be sufficient since the relevant time dynamics are slow relative to exogenous signals such as disturbances and setpoint changes. This means that MILP approaches via CPLEX, or other numerical methods, can be readily applied[16]. For smaller systems, such as buildings, supermarkets, or manufacturing facilities, an MPC approach can be highly effective once an overall system model capable of prediction has been created[18]. The compact system representations afforded by the switched systems moving boundary models[15] provide an excellent balance of complexity versus accuracy for model based controls.

Figure 11 illustrates the performance of an MPC and its improvement over Figure 10 in tracking evaporator cooling capacity without 'fighting.' In addition to capacity tracking, this MPC also handles actuator constraints and minimizes transient compressor power consumption by incorporating a simple penalty on the actuation term. An MPC gives the designer of the controls the flexibility of easily considering multiple objectives, particularly in the presence of actuator constraints.

CONCLUSIONS

Thermal systems are critically important to nearly all domains of energy conversion, and controls are vital to extracting maximal efficiency from the overall system. Clearly, understanding the dynamics of transient thermal systems is the first step towards effective control design. While a great deal of understanding of steady-state performance of an overall system already exists, the combined performance of coupled and interconnected systems during transients is still not well described or understood. This becomes more important with increased system complexity (number of components, operational modes, etc.) or increased transient relevance (e.g., power electronics). Continued improvement in control-oriented modeling will be very valuable in terms of accuracy, speed, etc. As we develop better transient understanding, it will

REFERENCES

1 F. Incropera and D. DeWitt, *Fundamentals of Heat Transfer*, Wiley, 1981.

2 J. Howell and R. Buckius, *Fundamentals of Engineering Thermodynamics*, McGraw-Hill, 1992.

3 W. Minkowycz, E. Sparrow and Murthy, J.Y., Eds., *Handbook of Numerical Heat Transfer*, 2nd ed., Wiley, 2006.

4 B. S., J. Braun and E. Groll, "A comparison of moving-boundary and finite-volume formulations for transients in centrifugal chillers," *International Journal of Refrigeration*, vol. 31, no. 8, pp. 1437-1452, December 2008.

5 B. Rasmussen, "Dynamic modeling for vapor compression systems—Part I: Literature review," *HVAC&R Research*, vol. 18, no. 5, pp. 934-955, September 2012.

6 B. Rasmussen and B. Shenoy, "Dynamic modeling for vapor compression systems—Part II: Simulation tutorial," *HVAC&R Research*, vol. 18, no. 5, pp. 956-973, September 2012.

7 *ASHRAE Handbook: HVAC Systems and Equipment, American Society of Heating Refrigerating and Air-Conditioning Engineers*, 2012.

8 A. Alleyne, V. Chandan, N. Jain, Otten and R. Otten, "Modeling and Control of Air Conditioning and Refrigeration Systems," *The Control Handbook*, Salem, MA, CRC Press, 2010.

9 B. P. Rasmussen and A. G. Alleyne, "Gain sheduled control of an air conditioning system using the Youla parameterization," *IEEE Transactions on Control*

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be important to simultaneous introduce new control approaches to monitor, diagnose and optimize these systems. For larger scale systems (e.g. buildings, districts), a nonlinear, hybrid complex systems representation becomes appropriate. Common SISO control tools will be insufficient for extracting the performance and efficiency gains necessary. Model based optimization tools are an excellent option provided the appropriate models exist. Since many thermal systems have predictable loads (e.g. diurnal cycle), it is often possible to introduce a predictive model element to the optimization. These models should all be compact, low-dimensional, and consistent with the information gathering used to validate them. Since viable instrumentation will comprise sensors located at particular points in space, it is important for the associated system models to be able to predict thermal phenomena at individual points rather than over an entire spatial domain.

With energy as a crucial theme for a sustainable future, it is clear that the Mechanical Engineering community must play a key leadership role in achieving this potential since the thermal energy domain is one with which we are most familiar. Utilizing our understanding of the physical phenomena as well as control theoretic tools is the best way to ensure we maximize the use of key resources in the future. ■

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The authors in the lab: *Andrew Alleyne (foreground), in discussion with Neera Jain (background).*

Andrew Alleyne received his B.S.E. from Princeton University in 1989 in Mechanical and Aerospace Engineering and the M.S. and Ph.D. degrees in Mechanical Engineering in 1992 and 1994, respectively, from The University of California at Berkeley. He joined the University of Illinois, Urbana-Champaign in 1994 where he currently holds the Ralph M. and Catherine V. Fisher Professorship in the College of Engineering. He is the recipient of the 2008 ASME Gustus L. Larson Memorial Award and is also a Fellow of ASME. His research interests are a mix of theory and implementation with a broad application focus.

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REFERENCES ...continued from the previous page

Systems Technology, vol. 18, no. 5, pp. 1216-1225, 2010.

10 B. Hencey and A. G. Alleyne, "A robust controller interpolation design technique," IEEE Transactions on Control Systems Technology, vol. 18, no. 1, pp. 1-10, 2010.

11 S. Bendapudi, J. E. Braun and E. A. Groll, "A comparison of moving-boundary and finite-volume formulations for transients in centrifugal chillers," International Journal of Refrigeration, vol. 31, no. 8, pp. 1437-1452, 2008.

12 B. Li, N. Jain, W. Mohs, S. Munns, V. Patnaik, J. Berge and A. Alleyne, "Dynamic Modeling of Refrigerated Transport Systems with Cooling/Heating Mode Switch Operations," HVAC&R Research, vol. 18, no. 5, pp. 974-996, 2012.

13 B. Li, Dynamic Modeling, Simulation, and Control of Transportation HVAC Systems, Urbana, IL: University of Illinois at Urbana-Champaign, Ph.D. Thesis, 2013.

14 B. Li, R. Otten, V. Chandan, W. Mohs, J. Berge and A. Alleyne, "Optimal On-Off Control of Refrigerated Transport Systems," IFAC Control Engineering Practice, vol. 18, no. 12, pp. 1406-1417, 2010.

15 B. Li and A. Alleyne, "A Dynamic Model of a Vapor Compression Cycle with Shut-down and Start-up Operations," International Journal of Refrigeration, vol. 33, pp. 538-552, 2010.

16 M. Carrion and J. Arroyo, "A Computationally Efficient Mixed-Integer Linear Formulation for the Thermal Unit Committment Problem," IEEE Transactions on Power Systems, vol. 21, pp. 1371-1378, 2006.

17 F. Oldewurtel, A. Parisio, C. Jones, D. Gyalistras, M. Gwerder, V. Stauch, B. Lehmann and M. Morari, "Use of model predictive control and weather forecasts for energy efficient building climate control," Energy and Buildings, vol. 45, pp. 15-27, 2012.

18 Y. Ma, A. Kelman, A. Daly and F. Borrelli, "Predictive Control for Energy Efficient Buildings with Thermal Storage: Modeling, Simulation, and Experiments," IEEE Control Systems, vol. 32, no. 1, pp. 44-64, 2012.

EXTREMUM SEEKING FOR WIND AND SOLAR ENERGY APPLICATIONS

BY AZAD GHAFFARI, MIROSLAV KRSTIC AND SRIDHAR SESHAGIRI

Extremum seeking (ES) was invented in 1922 and is one of the oldest feedback methods. Rather than regulation, its purpose is optimization. For this reason, applications of ES have often come from energy systems. The first noted publication on ES in the West is Draper and Li's application to spark timing optimization in internal combustion engines[1]. In the ensuing decades, ES has been applied to gas turbines and even nuclear fusion reactors. Renewable energy applications have brought a new focus on the capabilities of ES algorithms. In this article we present applications of ES in two types of energy conversion systems for renewable energy sources: wind and solar energy. The goal for both is maximum power point tracking (MPPT), or, the extraction of the maximum feasible energy from the system under uncertainty and in the absence of a priori modeling knowledge about the systems. For the wind energy conversion system (WECS), MPPT is performed by tuning the set point for the turbine speed using scalar ES. Performing MPPT for the photovoltaic (PV) array system entails tuning the duty cycles of the DC/DC converters employed in the system using multivariable ES. Experimental results are provided for the photovoltaic system.

Increasing availability of energy storage devices intensifies the effort to harvest maximum power from renewable sources, particularly wind turbines (WT) and PV systems. Renewable sources operate under a wide range of uncertain environmental parameters and disturbances. For example, uncertain quantities such as wind speed in WT and solar irradiance in PV modules affect the respective power maps and the maximum power points (MPP). The power map is also a function of a control input—the turbine speed in WT and the terminal voltage in the PV modules. The power map of a WT has a unique MPP with respect to turbine speed at each level of wind speed. Likewise, the power map of a PV module has a unique MPP with respect to terminal voltage at each level of solar irradiance.

The process of governing a WT or PV module to its MPP is know as maximum power point tracking (MPPT). The conventional perturb and observe (P&O) techniques do so by a combination of adding a step perturbation to the control signal and monitoring the direction of changes in power[2]. Most techniques derived from P&O are based on discrete analysis and require a delicate balance between the amplitude of the control input step perturbation and the possible changes in environmental parameters. Moreover, the sampling frequency needs to be carefully selected with respect to the response time of the system to the step perturbation. Since the system is not linear, the sampling frequency is also a function of the step size and of the magnitude of changes in environmental parameters.

Extremum seeking is an attractive alternative to P&O techniques for solving MPPT problems in wind and solar systems. As a model-free, real-time optimization approach, ES is well suited for systems with unknown dynamics or those that are affected by high levels of uncertainty or external dynamics, like WT and PV systems. Similar to P&O techniques, ES employs perturbations. However, instead of employing a discrete step perturbation, ES uses a

continuous oscillatory perturbation, also known as a "probing function." More importantly, ES does not merely monitor the direction of the output response but exploits the measured response to estimate the gradient of the power map and update the control input in proportion to the gradient of the power map[3–6].

ES has the dual benefit of rigorously provable convergence and the simplicity of hardware implementation. In addition to a probing signal, the ES algorithm employs only an integrator, as well as optional high-pass and a low-pass filters. The amplitude and frequency of the probing function in ES influence the precision of the MPPT algorithm. However, the frequency selection is not as complicated as the selection of the sampling frequency in P&O technique. For dynamic systems, it is enough to select the ES probing frequency reasonably smaller than the highest frequency that can pass the system without significant attenuation.

ES guides the system to its MPP regardless of changes in environmental parameters, as long as the changes are slow. While the power map shape defines the convergence rate of the conventional gradient-based ES, we also present in this article more sophisticated schemes like the Newton-based ES to alleviate the issue of unsymmetrical transients[7].

In some cases we need an inner-loop control to achieve desired closed-loop performance, for example, for speeding up the convergence rate and alleviating magnetic saturation in WT systems. Combining a discrete MPPT method such as P&O with a continuous inner-loop control creates a hybrid system that needs careful parameter selection, particularly the sampling period and perturbation amplitude. In contrast, ES can be applied without modifications to any system with a stabilizing inner-loop control.

A distributed MPPT architecture is not the most efficient option for handling a multivariable power map, such as a cascade PV configuration with one converter per module. For multivariable MPPT, the complexity of P&O algorithms increases dramatically with the size of the input vector. In contrast, ES trivially extends to multivariable MPPT, with only a few restrictions in selecting the probing frequencies. Furthermore, with ES we have the option of employing the algorithm's Newton-based version to achieve transients that are symmetric relative to the peak of the MPP and uniform in speed for multiple modules.

This paper is organized as follows. The next section introduces both gradient and Newton-based ES schemes. Subsequently, a Scalar gradient-based ES is combined with a nonlinear inner-loop control developed from field-oriented control (FOC) to achieve power control and optimization in WT. Simulation results demonstrate the effectiveness of the proposed algorithm. Finally, multivariable MPPT based on ES for PV systems are presented, and the validity of the proposed algorithms with experimental results are verified.

THE BASICS OF EXTREMUM SEEKING

A gradient-based ES for multi-input static maps is shown in **Figure 1**. The algorithm measures the scalar signal $y(t) = Q(\theta(t))$, where $Q(\cdot)$ is an unknown map whose input is the vector $\theta = [\theta_1, \theta_2, \cdots, \theta_n]^T$. The map has a unique maximum point at $\theta^* = [\theta_1^*, \theta^*, \cdots, \theta_n^*]^T$ where

$$\frac{\partial Q}{\partial \theta}(\theta^*) = 0, \quad \frac{\partial^2 Q}{\partial \theta^2}(\theta^*) = H < 0, \quad H = H^T \qquad 1$$

where H is the Hessian matrix and defines the shape of the unknown map around its maximum point.

Gradient estimation is helped by the signals

$$S(t) = [a_1 \sin(\omega_1 t) \ \cdots \ a_n \sin(\omega_n t)]^T \qquad 2$$

$$M(t) = \left[\frac{2}{a_1} \sin(\omega_1 t) \ \cdots \ \frac{2}{a_n} \sin(\omega_n t)\right]^T \qquad 3$$

with nonzero perturbation amplitudes a_i and with a gain matrix K that is diagonal. Some restrictions are imposed on the probing frequencies, ω_i. For the unknown map, $Q(\cdot)$, the averaged system is

$$\dot{\tilde{\theta}} = KH\tilde{\theta} \qquad 4$$

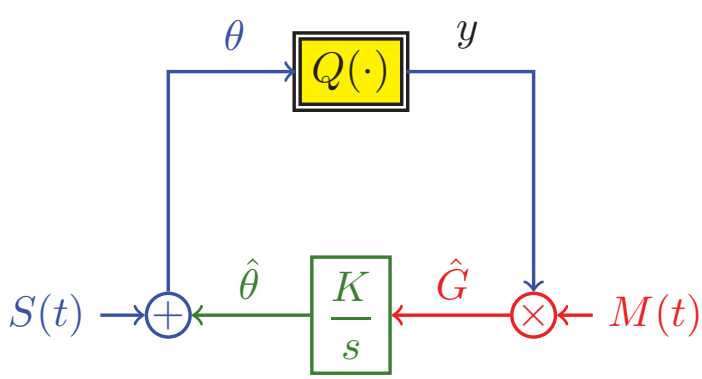


FIGURE 1 The gradient-based ES for a static map.

where , and is an estimate of the optimal input vector, . If the user chooses the elements of the diagonal gain matrix as positive, the ES algorithm is guaranteed to be locally convergent. However, the convergence rate depends on the unknown Hessian H. This weakness of the gradient-based ES algorithm is removed with the Newton-based ES algorithm.

A Newton version of the ES algorithm, shown in **Figure 2**, ensures that the convergence rate be user-assignable, rather

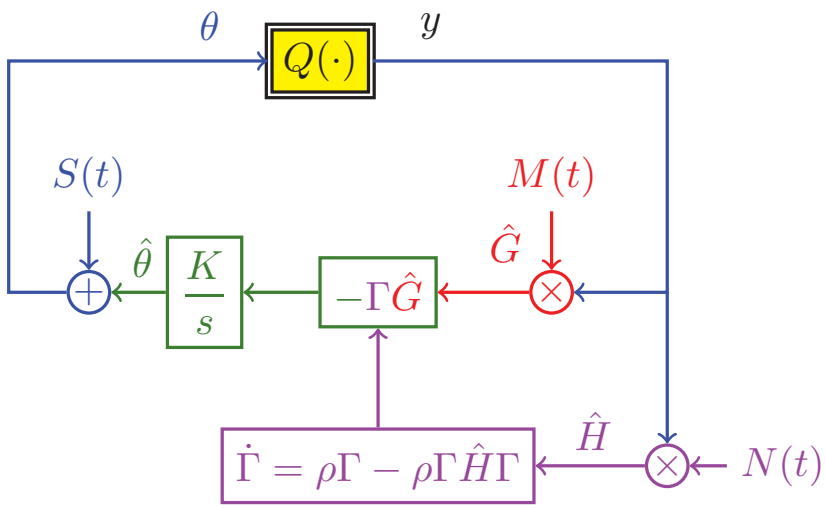


FIGURE 2 A Newton-based ES for a static map.

than being dependent on the unknown Hessian of the map[7]. The elements of the demodulating matrix $N(t)$ for generating the estimate of the Hessian are given by

$$N_{ii}(t) = \frac{16}{a_i^2}\left(\sin^2(\omega_i t) - \frac{1}{2}\right), N_{ij}(t) = \frac{4}{a_i a_j}\sin(\omega_i t)\sin(\omega_j t). \quad 5$$

The multiplicative excitation helps to generate the estimate of the Hessian as $\hat{H}(t) = N(t)y(t)$. The Riccati martrix differential equation $\Gamma(t)$ generates an estimate of the Hessian's inverse matrix, avoiding matrix inversions of Hessian estimates that may be singular during the transient.

A quadratic map's averaged system in error variables $\tilde{\theta} = \hat{\theta} - \theta^*$, $\tilde{\Gamma} = \Gamma - H^{-1}$ is

$$\frac{d\tilde{\theta}}{dt} = -K\tilde{\theta}, \quad \frac{d\tilde{\Gamma}}{dt} = -\rho\tilde{\Gamma}. \quad 6$$

Because they are determined by K and ρ, the eigenvalues are independent of the unknown H. As a result, the (local) convergence rate is user-assignable.

ES extends in a relatively straightforward manner from static maps to dynamic systems, provided the dynamics are stable and the parameters of the algorithm are chosen so that the dynamics are slower than those of the plant.

In the following section, the scalar gradient-based ES is applied to MPPT of a wind energy conversion system (WECS), with an inner-loop control.

WIND ENERGY CONVERSION SYSTEMS

Wind turbines work in four different regions (see **Figure 3**). Available wind power on the blade impact area is defined as

$$P_w = 2\rho_a A V_w^3, \quad A = \pi R^2, \quad 7$$

where R is the blade length, ρ_a is air density, and V_w is wind speed.

For Region II MPPT the turbine power is related to the wind power as

$$P_t = \omega_t T_t = C_p(V_w, \omega_t)P_w, \quad 8$$

where T_t is the rotor torque, ω_t is the turbine speed, and C_p is the non-dimensional power coefficient, which is a measure of the ratio of the turbine power to the wind power.

The turbine speed can be used to change the power coefficient, C_p, which results in power control and optimization. The MPPT algorithm in sub-rated power region should be able to guide the WT to its MPP regardless of the variations of the wind speed. The power captured by the WT is defined by the wind speed, V_w, and the turbine speed, ω_t. The wind speed is a disturbance input and the turbine speed can be manipulated to govern the turbine power to its MPP in sub-rated region. The variation of turbine power versus turbine speed is shown in **Figure 4** for different wind speeds. As shown in Fig. 4, under a constant wind speed the relevant power curve has a unique MPP, which is defined by a specific turbine speed.

Inner-Loop Control Design for WECS

One can manipulate the stator voltage amplitude, V_{om}, and its frequency, ω_o, to obtain the desired closed-loop performance for WECS. We introduce an integrator

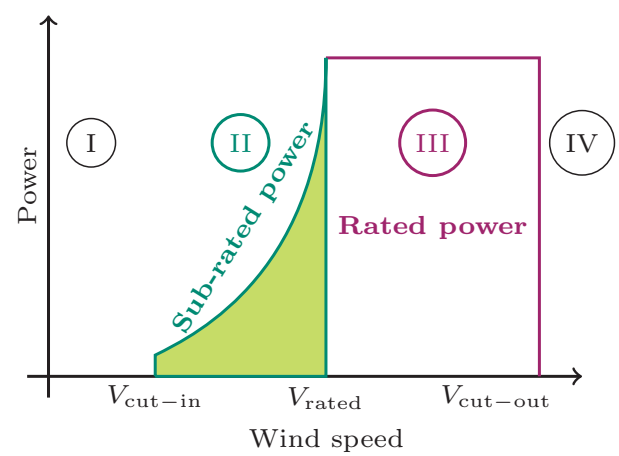


FIGURE 3 Typical power curve of WT including four operating regions.

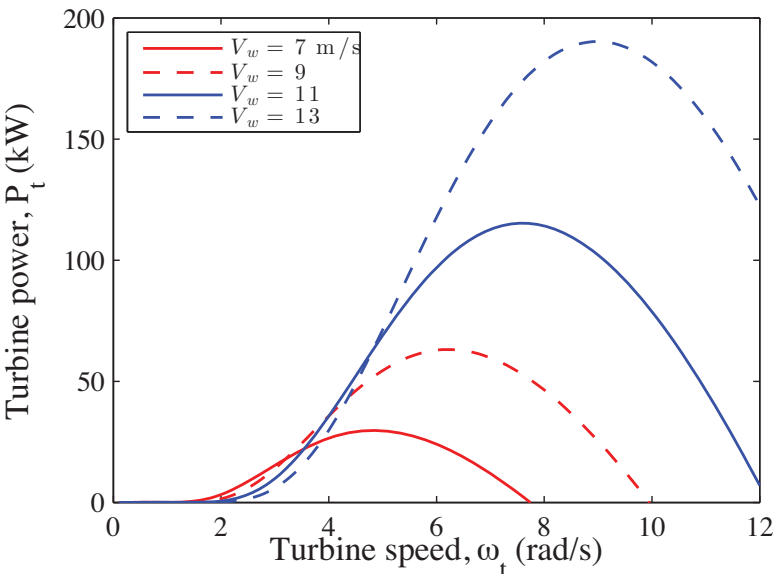


FIGURE 4 Variation of the turbine power versus turbine speed for different wind speeds.

and an auxiliary input, u_2, to achieve input-output decoupling in WECS dynamics. Using one step of integration in front of V_{om} the extended equations of WECS are introduced as follows:

$$\dot{x} = f(x) + g_1 u_1 + g_2 u_2, \quad x \in \mathbb{R}^9, u \in \mathbb{R}^2 \qquad 9$$

where $x = [\, i_\alpha, i_\beta, \lambda_\alpha, \theta_o, V_{om}, \omega_r, \tilde{\theta}, \omega_t \,]^T$ where i_α and i_β are stator currents, λ_α and λ_β are rotor fluxes, $\tilde{\theta} = \theta_t - \frac{\theta_r}{pn}$, $\theta_r = \int_0^t \omega_r dt$, ω_r is the rotor electrical frequency, $u_1 = \omega_o$ is the electrical frequency of the stator, u_2 is an auxiliary input (voltage amplitude rate) which generates the voltage amplitude of the stator.

As seen in Fig. 4, turbine speed controls power generation. Decoupling the rotor flux and electromagnetic torque produces the benefit of field-oriented control (FOC). Turbine speed, x_9, and flux amplitude, $x_3^2 + x_4^2$, are introduced as measurable outputs for this reason. Feedback linearization is applied based on the selected outputs. This results in the regulation of turbine speed, ω_t, to its reference value ω_t^{ref}, while the amplitude of rotor flux, $|\lambda| = \sqrt{x_3^2 + x_4^2}$, converges to its desired value, $|\lambda|^{\text{ref}}$.

Wind Turbine Power Optimization

To overcome challenges associated with the conventional power control and optimization algorithms and to remove the dependence of the MPPT algorithm on system modeling and identification, an ES algorithm for MPPT of WECS is employed.

Access to turbine power measurements and speed manipulation are assumed in this article. Although there is no model of the power coefficient or turbine power, its power map has one MPP under any wind speed.

The proposed nonlinear control not only achieves the desired closed-loop performance, but faster response time (high power efficiency) as it also prevents magnetic saturation. The ES scheme with inner-loop control is shown in **Figure 5**. Shown here, the reference inputs of the inner-loop control are ω_t^{ref} and $|\lambda|^{\text{ref}}$. The MPP is parameterized by the optimal turbine speed at each wind speed, as estimated by the ES loop. The other control input, $|\lambda|^{\text{ref}}$, defines the level of the flux linkage of the rotor which prevents induction generator from magnetic saturation.

Combination of the Controller and WECS results in fast dynamics, while the dynamics contained in the ES algorithm are of slow and medium speeds. The algorithm estimates the optimal turbine speed, $\omega_t^{\text{ref}} = \omega_t^*$. With respect to the controller-system's fast dynamics, this can be considered a constant value.

Simulation Results on a WECS Model

A time frame of 30 seconds demonstrates the differences between the proposed algorithm and that of the conventional MPPT which is based on P&O with an FOC in the inner loop. The MPPT process is shown in **Figure 6**. The extracted energy by our proposed algorithm is 2.36% higher than the extracted energy by the conventional MPPT and FOC. Our algorithm provides perfect input-output decoupling and guarantees a larger domain of attraction, which increases performance robustness with respect to the system parameters. The improved efficiency also increases the competitiveness of wind energy.

PHOTOVOLTAIC SYSTEMS

Extremum seeking has been applied to MPPT design for photovoltaic (PV) micro-converter systems, where each PV module is coupled with its own DC/DC converter. Most existing MPPT designs are distributed (decentralized), i.e., they employ one MPPT loop around each converter, and all designs, whether distributed or multivariable, are gradient-based[2]. The convergence rate of gradient-based designs depends on the Hessian, which in turn is dependent on environmental conditions such as irradiance and temperature. Consequently, when applied to large PV arrays, the variability in conditions, and/or PV module degradation, results in non-uniform transients in the convergence to the MPP. Using a multivariable gradient-based ES algorithm for the entire system instead of a scalar one for each PV module, decreases sensitivity to the Hessian, but does

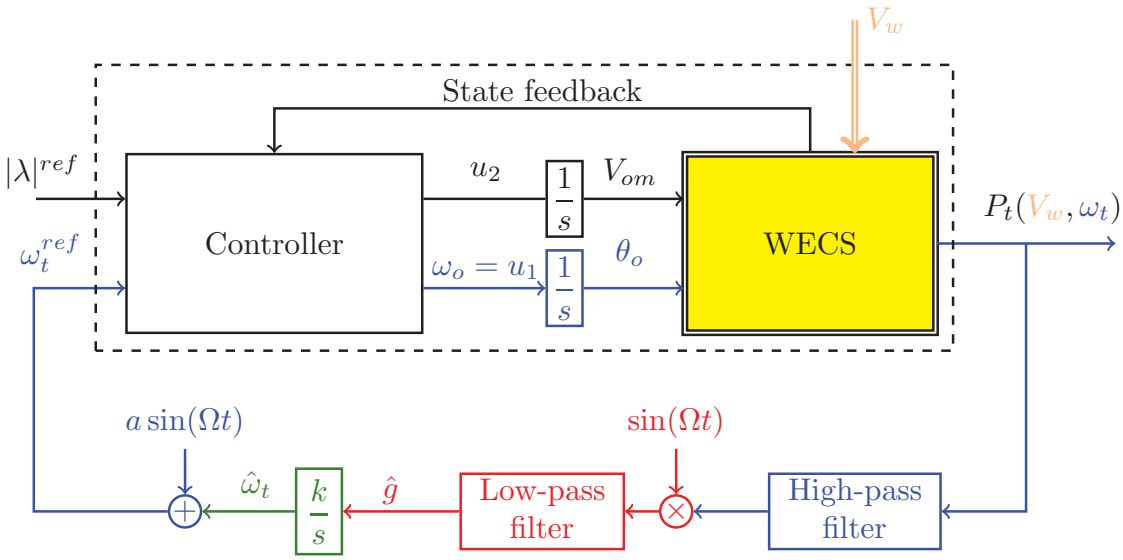


FIGURE 5 The ES algorithm for MPPT of the WECS with the inner-loop control.

not eliminate this dependence. The Newton-based ES algorithm is used, as it simultaneously employs estimates of the gradient and Hessian in the peak power tracking. The convergence rate of such a design to the MPP is independent of the Hessian, with tunable transient performance that is independent of environmental conditions. Experimental results demonstrate the effectiveness of the proposed algorithm in comparison to existing scalar designs, as well as multivariable, gradient-based ES.

Using a multivariable gradient-based ES MPPT design for the micro-converter architecture, where each PV module is coupled with its own DC/DC converter, reduces the number of required sensors (hardware reduction). Transients under sudden changes in solar irradiance are more uniform as is the environmental temperature in comparison to a scalar gradient-based ES for each PV module. True of gradient-based designs, the convergence to MPP is dependent on the unknown Hessian: it varies with irradiance, temperature, and module degradation and mismatch.

In comparison with the standard gradient-based multivariable extremum seeking, the Newton-based ES removes the dependence of the convergence rate on the unknown Hessian and makes the convergence rate of the parameter estimates user-assignable. In particular, all the parameters can be designed to converge with the same speed, yielding straight trajectories to the extremum even with maps that have highly elongated level sets. When applied to the MPPT problem in PV systems, the method offers the benefit of uniform convergence behavior under a wide range of working conditions that includes temperature and irradiance variations and the non-symmetric power generation of the neighboring PV modules as a result of module degradation or mismatch.

Multivariable MPPT of PV Systems

Conventionally, each DC/DC converter has a MPPT loop to extract maximum power from the PV system (known as power optimizer in industry). The output sides of the converters are connected in series. The PV system is connected to the power grid through a DC/AC inverter, which has its separate controller. Two problems arise here. First, two sensors, current and voltage, are required per module which increase the levelized energy cost. Second, the coupling effect between PV modules is not addressed by this distributed control.

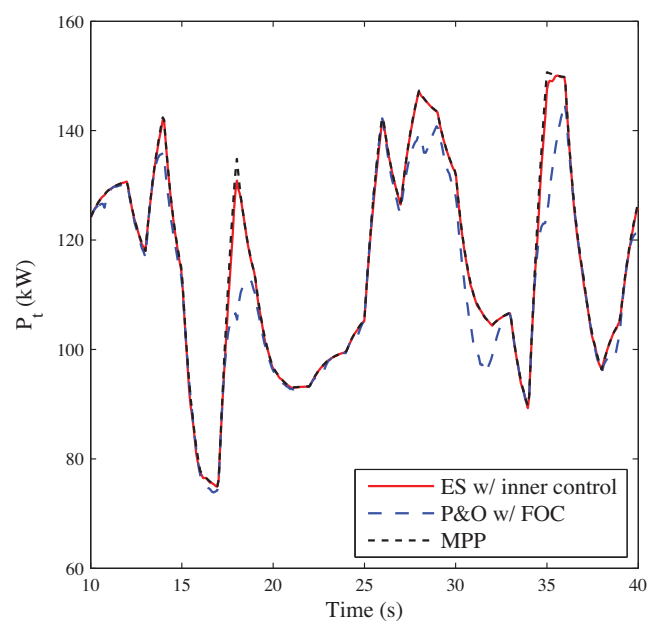


FIGURE 6 Proposed algorithm, MPPT (solid red); conventional P&O with FOC (dashed blue); maximum power available to the WECS (dashed black).

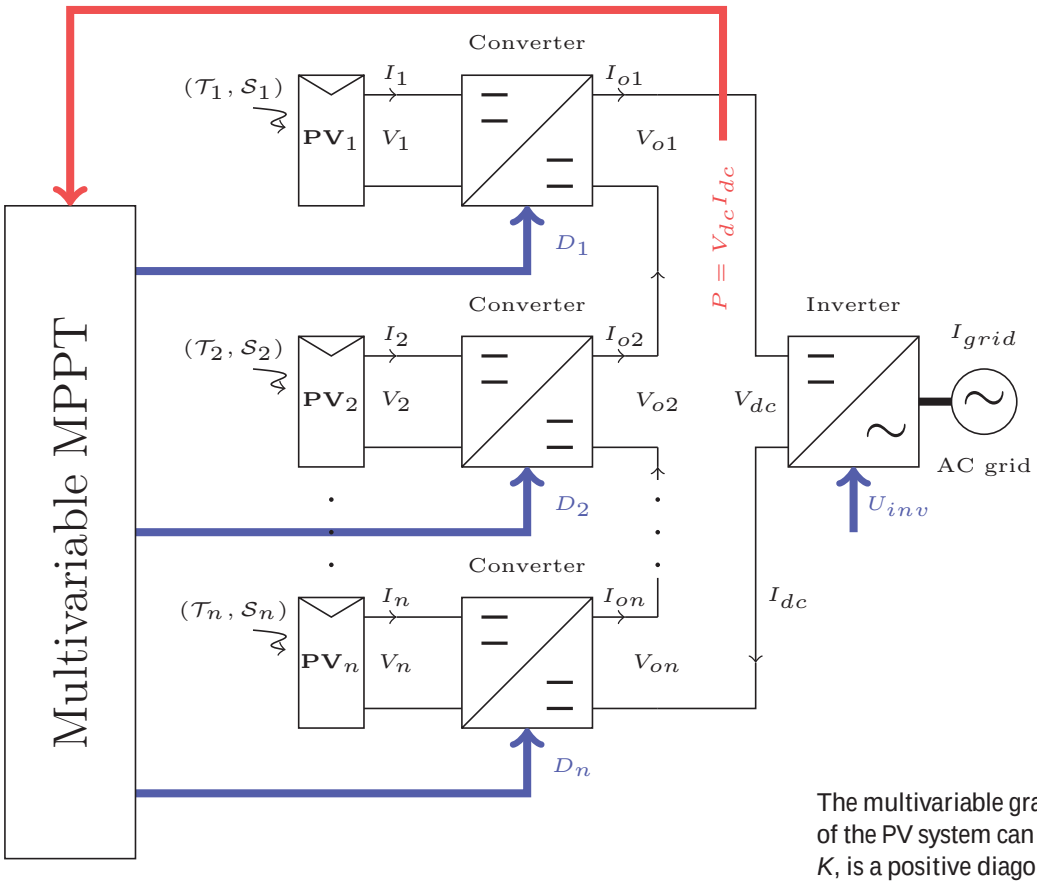


FIGURE 7
Multivariable MPPT for a PV system. One MPPT is used for the entire system. Temperature, and irradiance, vary all over the modules.

Figure 7 presents a multivariable MPPT based on an ES scheme with the following features:

- As it is applied to micro-converter systems, characterized by non-unimodal power, the design specializes in the issue of module mismatch—for example, different irradiance levels as a result of partially shaded conditions.
- The use of the non-model-based ES technique enables the design to respond robustly even with partial knowledge of system parameters and operating conditions.
- More efficient and cost-effective than a scalar design, the multivariable model requires just 2 sensors—one for the overall PV system current, and another for DC bus voltage—a significant hardware cost reduction.
- Interactions between PV modules are inherent to the multivariable design, so the transient performance is less sensitive to variations in environmental conditions than a corresponding scalar model.

Gradient-Based ES

Maximizing the power generated by all PV modules is equal to

$$P = \sum_{i=1}^{n} P_i = V_{dc} I_{dc} . \qquad 10$$

For a micro-converter structure including n PV modules in cascade connection, there exists $D^* \in \mathbb{R}^n$ such that

$$\frac{\partial P}{\partial D}(D^*) = 0, \quad \frac{\partial^2 P}{\partial D^2}(D^*) = H < 0, \quad H = H^T. \qquad 11$$

The multivariable gradient-based ES design to MPPT of the PV system can be used in Fig. 7. The ES gain, K, is a positive diagonal matrix, and the perturbation signals are defined as equations **2** and **3**.

In particular, the design derives an estimate $\hat{G}$ of the gradient vector by adding the "probing signal" $S(t)$ to the estimate $\hat{D} = [\hat{D}_1, \hat{D}_2, \cdots, \hat{D}_n]^T$ of the pulse duration vector (of all the DC/DC converters). With no additional information on the Hessian (and also for simplicity), we choose the amplitudes of the probing signals to all be the same value a. It can be shown that for a proper set of ES parameters and with $K > 0$, the estimate $\hat{D}$ of the pulse duration vector and the output P settle in a small ball around the optimal pulse duration $D^* = [D_1^*, D_2^*, \cdots, D_n^*]^T$ and the MPP $P(D^*)$, respectively. The lowest probing frequency and its corresponding amplitude define the radius of the ball.

Since the cost function P varies with irradiance, temperature, and degradation of the PV modules, so does H, and therefore a fixed adaptation gain K results in different (condition dependent) convergence rates for each converter. In order to alleviate the issue of unknown Hessian dependent convergence, we present in the next section a modified version of the multivariable Newton-based ES. The Newton-based algorithm makes the convergence rate of the parameter estimates user-assignable. In particular, all the parameters can be designed to converge with the same speed, yielding straight trajectories to the extremum even with maps that have highly elongated level sets. When applied to

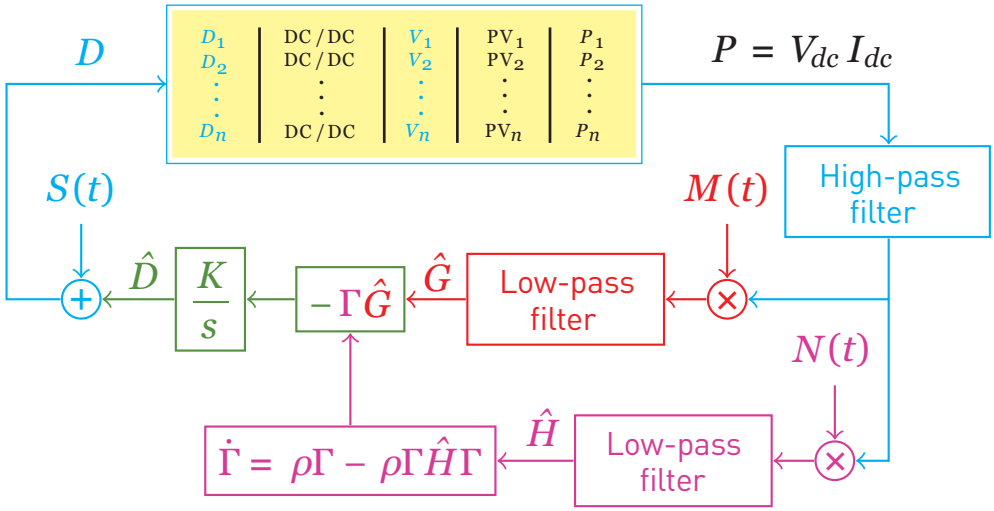


FIGURE 8 Multivariable Newton-based ES for MPPT of a PV system. The purple part is added to the gradient-based ES to estimate the Hessian.

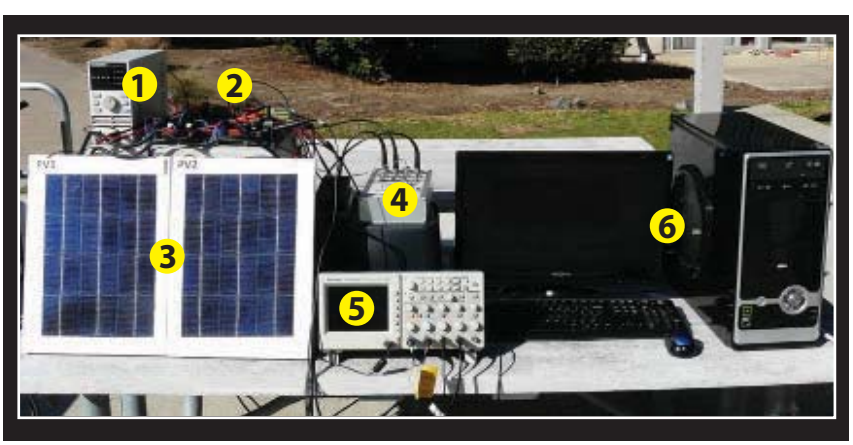
the MPPT problem in PV systems, the method offers the benefit of uniform convergence behavior, under a wide range of working conditions that include temperature and irradiance variations, and under the non-symmetric power generation of the neighboring PV modules as a result of module degradation or mismatch.

Newton-Based ES

The multivariable Newton-based ES that we propose is shown schematically in **Figure 8**. As is clear from the figure, the proposed scheme extends the gradient-based ES with the estimate of the Hessian. The perturbation matrix is defined as equation **5**.

FIGURE 9 Experimental setup.

1 DC Bus
2 DC/DC Converters, 1 and 2
3 PV Panels, 1 and 2
4 CP 1104
5 Oscope
6 DS 1104, Simulink and Control Desk



The goal of the Newton-based design is to replace the estimation-error dynamics $\dot{\tilde{D}} = KH\tilde{D}$ with one of the form $\dot{\tilde{D}} = -K\Gamma H\tilde{D}$, where $\Gamma = H^{-1}$, that removes the dependence on the Hessian H. Calculating Γ (estimate of H^{-1}) in an algebraic fashion creates difficulties when $\hat{H}$ is close to singularity or is indefinite. To deal with this problem, a dynamic estimator is employed to calculate the inverse of $\hat{H}$ using a Riccati equation.

Consider the following filter

$$\dot{\mathcal{H}} = -\rho\mathcal{H} + \rho\hat{H} \qquad 12$$

Note that the state of this filter converges to $\hat{H}$, an estimate of H. Denote $\Gamma = H^{-1}$. Since $\dot{\Gamma} = -\Gamma\dot{\mathcal{H}}\Gamma$, then equation **12** is transformed into the differential Riccati equation

$$\dot{\Gamma} = \rho\Gamma - \rho\Gamma\hat{H}\Gamma. \qquad 13$$

After a transient, the Riccati equation converges to the actual value of the inverse of Hessian matrix if $\hat{H}$ is a good estimate of H.

The convergence rate of the parameter is independent of the shape of the cost function, and consequently, after transient, when the Hessian is close enough to its actual value, the output power converges to the MPP with the same performance regardless of environmental or mismatch conditions.

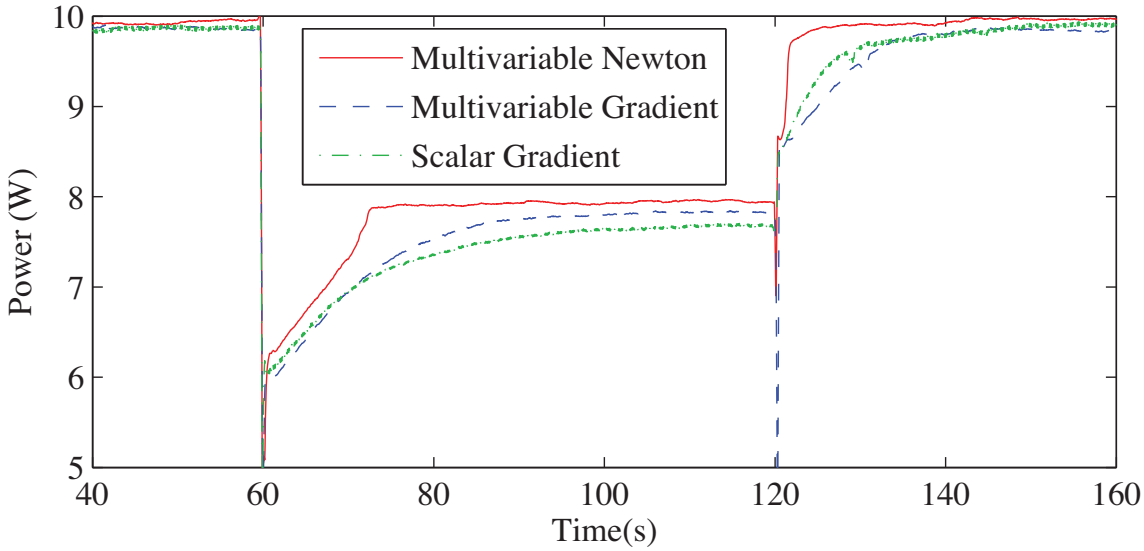


FIGURE 10 Variation of power versus time. The Newton algorithm shows uniform and fast transient with low steady-state error.

Experimental Results

To show the effectiveness of the proposed Newton-based design in Fig. 8, and compare its performance with that of the gradient-based design, we present experimental results for a PV system with $n = 2$ cascade modules. The physical hardware setup is shown in **Figure 9**. The temperature of PV modules is 25 °C and the modules are fully exposed to the sun between 0-60 s and 120-180 s. To simulate the effect of partial shading, PV1 is covered with a plastic mat from time 60-120 s. When one module is partially shaded the overall power level decreases. We not only compare the multivariable gradient-based and Newton-based designs, but also the traditional scalar gradient-based design, that has one MPPT loop for each converter.

Figure 10 shows the performance of the 3 designs, and it is clear that the Newton algorithm recovers from this power level change faster than the other 2 algorithms. While the Newton method has the least steady-state error and uniform response under step down and step up power scenarios, the scalar design has the highest steady-state error and large response time in face of power decrease. The multivariable gradient-based ES performs better than the scalar MPPT under partial shading conditions.

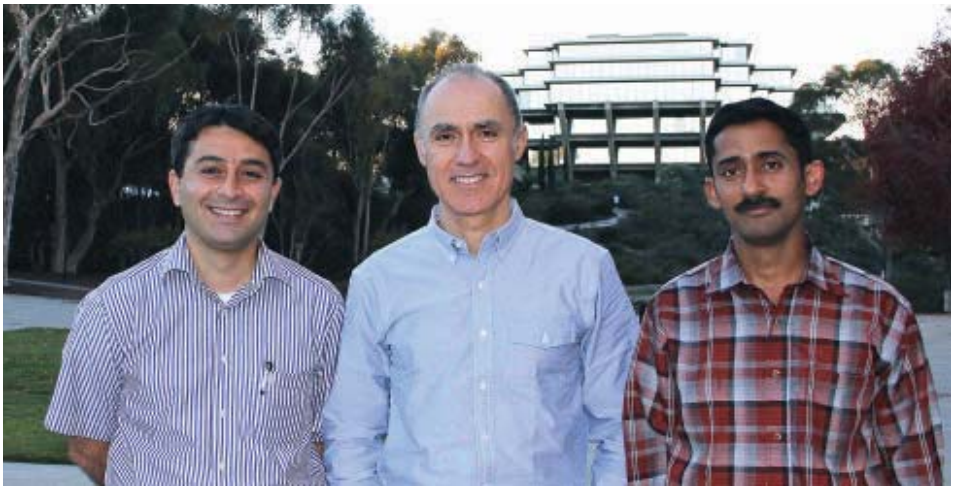
The irradiance level of the partially shaded module is returned to normal level at $t = 120$ s. At this point the Newton scheme shows faster transient in comparison to the similar transient of the multivariable gradient-based ES and the distributed ES. The results demonstrate that the convergence rate of the Newton scheme does not vary largely from step up to step down in power generation, which is not true for the gradient-based and distributed MPPT schemes. Not surprisingly, the experimental results are in keeping with the analytical results.

CONCLUDING REMARKS

Since environmental parameters like solar irradiance and wind speed affect the power map and maximum power point (MPP) of photovoltaic (PV) and wind energy conversion systems (WECS), we propose extremum-seeking (ES), which is a model-free real-time optimization algorithm, for maximum energy harvest or maximum-power-point-tracking (MPPT) in such systems.

Extremum seeking is effective at guiding the WECS to its MPP in the sub-rated power region. However, the open-loop dynamics of the WECS have slow left half-plane poles that make the response time of the ES even slower. In order to achieve fast closed-loop response and extra features like constant voltage-to-frequency or vector control in the system, we design an inner-loop control based on the field-oriented control (FOC) concept. The combination of the inner-loop controller and the ES algorithm improves the performance of the WECS, as shown by the simulations.

For PVs, we consider the microconverter architecture, where each module is connected to its own DC-DC converter. Conventional designs are scalar. First, they ignore the interaction between modules, and secondly, they require two (sensor) measurements per module. A multivariable design that improves on each of these aspects is



Left to right: ***Azad Ghaffari, Miroslav Krstic, and Sridhar Seshagiri.***

ABOUT THE AUTHORS

Azad Ghaffari received his B.S. degree in Electrical Engineering and M.S. degree in Control Engineering from K.N. Toosi University of Technology in Tehran, Iran. He received his PhD degree in Mechanical and Aerospace Engineering from the Joint Doctoral Program between San Diego State University and University of California, San Diego. His research interests include demand response in power systems, extremum seeking and its application to maximum power point tracking in photovoltaic and wind energy conversion systems, induction machines, power electronics, and sliding mode control.

Miroslav Krstic is the Alspach endowed chair professor at UCSD, founding director of the Cymer Center for Control Systems and Dynamics and Associate Vice Chancellor for Research. Krstic is a recipient of PECASE, NSF Career, ONR Young Investigator, Axelby, Schuck, and UCSD Research award, and is a Fellow of IEEE and IFAC. He has held Springer-Berkeley and Royal Academy of Engineering distinguished visiting professorships. He has served as Senior Editor of *IEEE TAC* and *Automatica*, VP of CSS, and chair of its IEEE Fellow Committee. Krstic is coauthor of ten books on nonlinear, adaptive, PDE control, and delay systems.

Sridhar Seshagiri received his B.S. Tech degree from the Indian Institute of Technology, Madras, and his M.S. and Ph.D degrees from Michigan State University, in 1995, 1998, and 2003 respectively, all in electrical engineering. He joined the Electrical & Computer Engineering Department at San Diego State University in 2003, where he is currently an Associate Professor. His research interests are nonlinear control with applications to energy systems.

REFERENCES

1 Draper, C. S., and Li, Y. T., "Principles of Optimalizing Control Systems and an Application to the Internal Combustion Engine," *Optimal and Self-Optimizing Control*, M.I.T. Press, 1951

2 Esram, T., and Chapman, "Comparison of photovoltaic array maximum power point tracking techniques," *IEEE Transactions on Energy Conversion*, vol. 22, pp. 439–449, 2007.

3 Krstic, M., and Wang, H.-H., "Stability of extremum seeking feedback for general nonlinear dynamic systems," *Automatica*, vol. 36, pp. 595–601, 2000.

4 Ariyur, K. B., and Krstic M., *Real-Time Optimization by Extremum Seeking Feedback*, Wiley-Interscience, 2003.

5 Tan, Y., Nesic, D., and Mareels, I.,"On non-local stability properties of extremum seeking control," *Automatica*, vol. 42, pp. 889–903, 2006.

6 Liu, S.J., and Krstic, M., *Stochastic Averaging and Stochastic Extremum Seeking*, Springer, 2012.

7 Ghaffari, A., Krstic, M., and Nesic, D., "Multivariable Newton–based extremum seeking," *Automatica*, vol. 48, pp. 1759–1767, 2012.

proposed. A multivariable gradient-based ES algorithm was considered first, where the Hessian of the power map has a dominant role in the closed-loop performance. Next, a Newton-based ES algorithm was employed, which removed the performance dependence of the gradient-based design on the Hessian. The Newton-based design has two distinguishing components that are key: a perturbation matrix that generates the estimate of the Hessian, and a dynamic filter that estimates the inverse of the Hessian. Experimental results verify the effectiveness of the Newton-based MPPT, versus its scalar and multivariable gradient-based counterparts. ■

2014

SAN ANTONIO, TEXAS
OCTOBER 22–24, 2014

ASME DYNAMIC SYSTEMS AND CONTROL CONFERENCE

Led by General Chair **Suhada Jayasuriya** (Drexel University) and Program Chair **Jordan M. Berg** (Texas Tech University), the seventh ASME Dynamic Systems and Control Conference (DSCC) will be held in San Antonio, Texas during October 22-24, 2014.

The DSC Conference, organized and led by the members of the ASME DSC Division, provides a focused and intimate setting for dissemination and discussion of the state of the art in the broad area of dynamic systems and control, from theory to industrial applications, and innovations in dynamical systems and control education. Technical themes in the 2014 ASME DSCC will be featured in special tracks and include advanced manufacturing, renewable and traditional energy, bioengineering and biomedical engineering, and cybersecurity for critical infrastructure.

The program will also include contributed sessions, invited sessions, tutorial sessions, special sessions, workshops, and exhibits. Full manuscripts are due on March 14, 2014. Details about the conference can be found at **http://www.asmeconferences.org/DSCC2014/index.cfm.**

ACC 2014 PORTLAND

Led by General Chair **Dawn Tilbury** (University of Michigan) and Program Chair **Gary Balas** (University of Minnesota), the 2014 American Control Conference (ACC) will be held in Portland, Oregon, June 4–6, 2014. In America's most bike friendly city, the 2014 ACC will gather control systems engineering experts from around the world. More than 950 peer-reviewed papers will be presented in regular and invited sessions. Tutorial sessions cover industrial and application topics, exhibits highlight new advances and recent books, and special sessions include job-hunting and renewable energy, among others. Pre-conference workshops cover topics in adaptive and robust control, linear parameter-varying systems, uncertainty analysis, and model-based design. The conference will also feature plenary lectures by **Keith Glover** (University of Cambridge), **Anna Stefanopoulou** (University of Michigan), **Bassam Bamieh** (University of California, Santa Barbara), **Juan de Bedout** (GE Energy Management), and **Vijay Gupta** (University of Notre Dame).Collectively, these lectures will encompass theory and practice in the control systems field, control in powering vehicle mobility, both networked and distributed parameter systems, as well as the effects of control in shaping the business of future energy management and control of cyber-physical systems.

2014

AMERICAN CONTROL CONFERENCE

Portland, Oregon
June 4-6, 2014

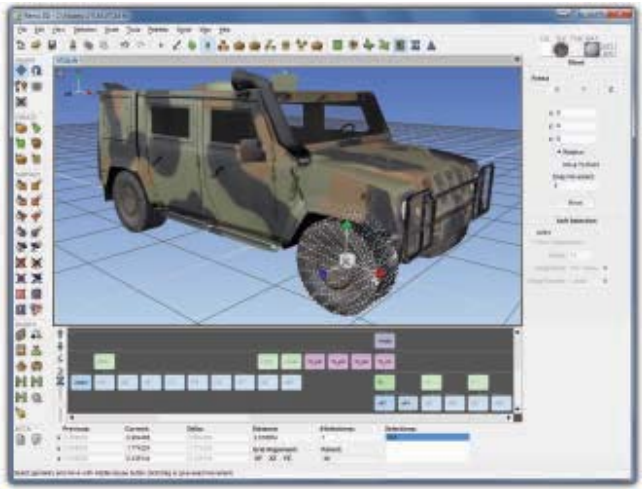
Portland Oregon OLD TOWN

For more information, please visit **http://a2c2.org/conferences/acc2014**

TEXTURE TRANSFORMED

REMOGRAPH, LINKÖPING, SWEDEN.

REMO 3D VERSION 2.4 HELPS CREATE AND MODIFY 3-D VISUALIZATION models. This upgraded version includes new texture transformation tools, support for eliminating transformation matrices, and various fixes for the past version. It uses the OpenFlight file formation. The application is available for systems running Windows 7, 8, Vista, XP, 2000, or Linux.



Remo 3D offers the user full control of the model scene graph and allows for modification of features like degree-of-freedom nodes, level-of-detail nodes, and switch nodes.

MODEL TRANSLATION

ELYSIUM, HAMAMATSU, JAPAN.

The multiple-computer-aided design data translation software MultiCAD Gateway is for use with the Aras Innovator product lifecycle management software from Aras Corp. of Andover, Mass. The translation software is for companies that use different 3-D CAD systems to collaborate on the same part or assembly design. The software automates the conversion of CAD data to other CAD formats, including NX, Creo, SolidWorks, and other popular formats. The user must be running Aras with embedded functionality for CAD model interchange, translation, validation, and geometry comparison.

ELECTRONICS ANALYSIS

ANSYS, CANONSBURG, PA.

ANSYS 15.0 for electronics allows engineers to analyze electrical performance of smartphone circuit boards, stealth aircraft, and other electronic devices. The release delivers solver and meshing technology and automated workflows for electronics design. It includes new multiphysics analysis for noise, vibration, and harshness for electric machines and other electromechanical devices. It also includes new preprocessing capabilities to boost automation and ease of setup and enhancements for the analysis of larger models and faster processing times than were available in past versions.

SPECIALTY PUNCHING TOOLS

MERRY MECHANIZATION INC., ENGLEWOOD, FLA.

The developer recently added a Shape Creator to its SMP/IS CAD/CAM sheet metal fabrication and nesting software to reduce the time needed to create special tools for punching. The shape creator gives engineers and fabricators a way to create commonly used specialty tools in a few simple steps. Using the shape creator within SMP/IS, the programmer can design special tools in a matter of seconds, add the shape to a tool library, and print an image with a description for a tool catalog, according to the developer.

STRUCTURAL ANALYSIS IN EXCEL

AUTODESK, SAN RAFAEL, CALIF.

The beta version of Project Octopus is a free technology preview available through June 1 from Autodesk Labs. It allows users to access data and results from an Autodesk Robot Structural Analysis model using simple Excel formulas. It's integrated with Excel. The application eliminates copy and paste or import and export. Users need no programming skills or knowledge of the application programming interface to extract data for spreadsheets. They can select a formula from a predefined list. Data is available for post processing via Excel formulas, graphs, pivot tables, and other methods. The software runs on Windows 7 or 8 and Office Excel 2010 or 2013. ME

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

DIGITAL PRESSURE GAUGE

ASHCROFT INC., STRATFORD, CONN.

The DG25 digital gauge provides measures pressure to 25,000 psi. Readout is an LCD display of five characters 0.48-inch high. Standard accuracy is rated at 0.5 percent. An optional enhanced accuracy of 0.25 percent is also available. Standard features include an IP67 enclosure, selectable units of measure, a 20 segment bar graph indicator, min-max, tare, and a list of agency certifications. A backlight and rubber protective boot are also available.

LED PANEL SWITCHES

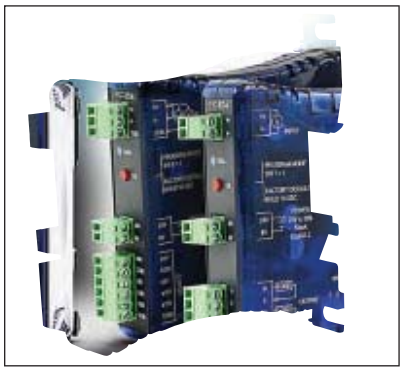
CIT RELAY & SWITCH, ROGERS, MINN.

The AD Series panel switches are offered in a range of colors, and custom designs are available. Model AD 01 has a total travel of 4.5 mm. AD 02 has a travel distance of 3.5 mm. Actuation force is 250 +/- 50 gF. Contacts are gold-plated. Typical electrical life of the switches is 1 million cycles. Insulation resistance is rated at a minimum of 100 mΩ at 250 V dc.

PRESSURE TRANSDUCERS

OMEGA ENGINEERING, STAMFORD, CONN.

The PX409 high speed USB pressure transducer connects directly to a computer. Free software provides for data logging and charting. Also included are .NET and Labview drivers and a command set for command line access. The micro-machined silicon design are useful for pressure or level applications in laboratory, test platforms, or bio/pharmaceutical applications, and for industrial applications that require a rugged transducer. Accuracy is rated at ±0.08%.



SIGNAL CONDITIONER

AUTOMATIONDIRECT, CUMMING, GA.

The FC-P3 signal conditioner converts a resistive input to an isolated analog output. The input resistive range can be set through the use of a pushbutton programming routine. The device is field configurable for three-wire potentiometer/slide-wire inputs with end-to-end resistance ranges from 0-100 ohms to 0-100 kilohms. Switch-selectable, analog output options include 0-20 mA, 4-20 mA, 0-5 V, and 0-10 V.

SAFETY CONTROLLER

SICK USA, MINNEAPOLIS.

The Flexi Loop, which is part of SICK's safety controller family, uses a single cable with an M12 plug to connect e-stops, sensors, switches, lamps, pushbuttons, and interlocks. Flexi Soft safety controllers can support up to eight Flexi Loops, enabling a total of 256 switches in a small footprint. The modular safety concept integrates all common fieldbuses, including EtherNet/IP, CANopen, DeviceNet and PROFINET IO.

COMPRESSION LATCH

SOUTHCO INC., CONCORDVILLE, PA.

The company has added a lightweight, aluminum version of its E3 Vise Action compression latch, which delivers robust, vibration-resistant fastening. The aluminum E3 is suitable for use in a variety of transportation applications and across numerous other industries. The compression latch features lightweight, aluminum construction and provides higher strength and superior cycle life for heavy duty installations.

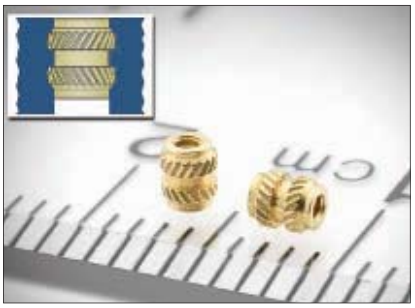
SUBMISSIONS

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.

THREADED BRASS INSERTS

PENN ENGINEERING, DANBORO, PA.

New microPEM through-threaded brass inserts promote secure and reliable attachment for devices ranging from hand-held consumer electronics to medical equipment. The fasteners have threads as small as M1 and install easily in a wide range of plastic materials from ABS to polycarbonate. A single mating screw completes the joining process. The microPEM (Type MSIB) inserts will install in either straight or tapered mounting holes.



PNEUMATIC VALVE

SCHUNK GMBH & CO, MORRISVILLE, N.C.

The micro valve MV 10 is designed for pick-and-place applications for small parts. The small pneumatic valve can be integrated directly on grippers or other pneumatic actuators and can be plugged or screwed into actuator ports. Traditional systems use valves located in a control cabinet some distance from the gripper and use tubing from the valve to the gripper.

QUARTER HP GEARMOTOR

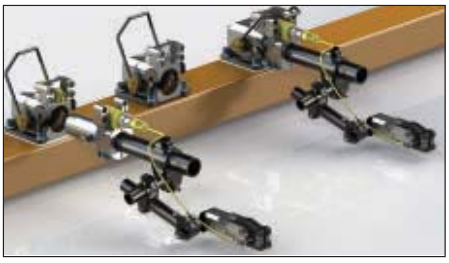
BODINE ELECTRIC CO., NORTHFIELD, ILL.

The new type 34B4/FV-5N gearmotors combine Bodine's 34B brushless DC motor with a right-angle gearhead, a built-in PWM speed control, and an optical encoder. Gearmotor power is 1/4 hp (187 watts), with continuous torque up to 104 lb-in. (12 Nm) and rated output speeds from 63 to 500 rpm. Gear ratios range from 5:1 to 40:1. Integrated Control uses a pulse width modulation interface for voltage control, amplifier enable, direction, and dynamic braking inputs. Closed-loop feedback to the external control is provided by an enclosed 1024 PPR, two-channel quadrature, optical encoder.

LIGHTWEIGHT END EFFECTORS

DE-STA-CO, AUBURN HILLS, MICH.

The Accelerate Collection is a line of components designed for lighter weight and faster production line speeds. The company claims increases in line speed can range between 25 and 30 percent. Accelerate components have trimmer shapes than their predecessors. Greater flexibility provided by CNC machines, tooling, and fixtures permitted contouring of components to eliminate unnecessary bulkiness and weight, the company said. Further weight savings come from specifying thin-wall extruded tube for accelerate end effector frames.



SET SCREWS

J.W. WINCO, INC., NEW BERLIN, WIS.

These RoHS-compliant set screws are a shielded magnetic assembly. The set screws can serve as workpiece stops, with the magnet holding the workpiece in place. The set screws are made of steel with a zinc plated, blue passivated finish. The retaining magnet element is neodymium, iron and boron NdFeB (ND type). Thread diameters from M6 to M16 are offered, with thread lengths from 12 to 80 mm.

FAU FLORIDA ATLANTIC UNIVERSITY

Tenure-Track Assistant Professor Position
Department of Ocean and Mechanical Engineering

The Department of Ocean and Mechanical Engineering at Florida Atlantic University invites applications and nominations for a Tenure Track Assistant Professor Position. Research expertise in any of the following areas is of special interest. Experimental combustion: The department is interested in developing an advanced diagnostic facility to complement its programs in CFD with a focus on low emission engines and gas turbines. Sensor technologies and microfluidic devices: Development of novel technologies for sensing with applications in bio-engineering, optical measurements, acoustics or ocean measurement techniques. Advanced multi-scale or sustainable manufacturing technologies: Improvement of product and manufacturing processes through more accurate experimental and modeling framework. We wish to fill the position as soon as possible.

Applicants must have earned a doctoral degree in a field of engineering by the time of appointment (August 2014) and possess demonstrated hands-on laboratory experience. Successful candidates must have the potential for excellent teaching at both the undergraduate and graduate level, and for developing a strong, externally-funded research program. Excellent oral and written communication skills are essential.

A competitive start-up package will be available for this position. The Department has over 400 undergraduates and 80 Ph.D. and M.S. students. Research and teaching activities are conducted at two locations: at the main FAU Campus in Boca Raton, FL and at the SeaTech Institute for Ocean Systems Engineering in Dania Beach, FL. Further information about the Department of Ocean and Mechanical Engineering may be found at **http://www.ome.fau.edu**.

All applicants must apply online by completing the Faculty, Administrative, Managerial & Professional Position Application form available on-line through the office of Human Resources: **https://jobs.fau.edu** (reference position **# 978808**) and submitting the related documents. A complete application package must include a cover letter; curriculum vitae; copies of official transcripts scanned into an electronic format; a statement of teaching and research goals; and names, addresses, phone numbers, and email addresses of at least three references. The selected candidate will be required to pass the University's background check. Screening of applications will begin immediately and will continue until the position is filled. While applications will be accepted until the position is filled, interested applicants are urged to apply before March 2014 to assure optimal consideration.

Florida Atlantic University takes pride in having a diverse population of students and faculty, and is an Equal Opportunity/Equal Access institution. Minorities and members of underrepresented groups are encouraged to apply. Individuals with disabilities requiring accommodation, call 561-297-3057. TTY/TDD 1-800-955-8771.

POSITIONSOPEN

ASSISTANT PROFESSOR—TWO POSITIONS AVAILABLE (9-month, tenure-track, start date Aug. 22, 2014). Department of Mechanical Engineering, South Dakota State University.Teach courses and conduct research in one of the following fields: (1) solid mechanics/machine design, (2) thermal sciences/biofuels production. For a full list of qualifications and application process, visit https://yourfuture.sdbor.edu. Position is open until filled, with full consideration given to applications received by March 21, 2014. For questions on the electronic employment process, contact SDSU Human Resources at (605) 688-4128. SDSU is an AA/EEO employer.

THE UNIVERSITY OF TEXAS AT TYLER PROFESSOR AND CHAIR OF MECHANICAL ENGINEERING. Expected qualifications include strong leadership skills, excellence in teaching, and strong external funding and scholarships, preferably in biomedical or energy engineering. For a full prospectus, visit http://www.uttyler.edu/cecs/. Position is open until filled, with full consideration given to applications received by March 1, 2014. The University of Texas is an Equal Opportunity Employer.

PARTS TRANSFER SYSTEM

ABB ROBOTICS, AUBURN HILLS, MICH.

The Twin Robot Xbar (TRX) is a fast and flexible parts transfer system with an output rate of up to 16 parts per minute for big panels in tandem press lines. The TRX can be retrofitted to existing press lines. Utilizing two robots optimally distributes the total power and load, while minimizing the inertia in demanding press automation applications.

DC MOTOR

JOHNSON ELECTRIC, HONG KONG.

The Compact P - XC8 motor is designed for powering battery-operated tools. The XC8 motor has high power density and a proprietary heat-rejection system. According to the manufacturer, the motor has 15 percent more power than comparable motors, and the temperature rise is 20 °C less, resulting in longer run times and more work per battery charge.

UNLV

Entertainment Engineering Faculty

The College of Engineering & College of Fine Arts, University of Nevada Las Vegas (UNLV) invites applications for a full-time, non-tenure, tenure-track, or tenured position at the Assistant/ Associate level in the area of automation, embedded control system design, motion control systems design, and mechatronics related to Entertainment Engineering and Design commencing Fall 2014.

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EEO/AA Employer

FAU FLORIDA ATLANTIC UNIVERSITY

Charles E. Schmidt Eminent Scholar Department of Ocean and Mechanical Engineering

The Department of Ocean and Mechanical Engineering at Florida Atlantic University is seeking an internationally known researcher whose focus lies at the intersection of engineering and medicine. Research areas of special interest include sensors (MEMS, Microfluidics), nanotechnology, biomaterials, drug delivery devices, imaging and spectroscopy, tissue engineering/tissue scaffold design, and micro-biomechanics. Candidates that employ integration of multiple bioengineering disciplines in their research programs will be given special consideration. The Charles E. Schmidt Eminent Scholar in Engineering is a high-salary and high visibility position designed to attract strategic hires in cutting-edge priority areas of research.

Candidates are expected to have an international reputation in their respective fields as evidenced by publications, citations and peer recognition. In addition, a current and substantive record of acquiring external resources to support research, team building, and mentoring of associates and graduate and undergraduate students is necessary. The holder of the Charles E. Schmidt Eminent Scholar will be expected to establish vibrant research activities between FAU's College of Engineering and College of Medicine, build a community of scholars at Florida Atlantic University and a world-class research program. Qualified Associate and Full professors, as well as other research professionals are encouraged to apply for this position. The appointment will be at the full-professor rank. An appropriate start-up package will be available.

Applicants for the position must have earned a doctorate in Biomedical Engineering or a relevant field that contributes to the strategic initiatives of the university. The department has a strong research and educational track record in traditional areas of engineering but is making a commitment to expand into multi-disciplinary fields of research in bioengineering. The departmental research facilities are located in the main campus at Boca Raton and in Dania Beach in a state-of-the-art research facility called SeaTech (**http://www.ome.fau.edu/seatech-the-institute-for-ocean-systems-engineering**). We are seeking candidates who will complement the existing research activities at the department, college, and the university. The successful candidate will have the opportunity to develop research collaborations with various FAU centers of excellence and affiliated institutions including Scripps Research Institute (Scripps Florida), and Max Plank Florida Institute (MPFI).

The department of Ocean and Mechanical Engineering consists of twenty two faculty members from diverse backgrounds who are committed to excellence in research and education. The department has a thriving research program (~2.5M annually), an undergraduate population of approximately 490 students and a graduate student population of 95 (50 MS and 45 PhD). Details of department and college research activities can be obtained at the department's and College's websites: **www.ome.fau.edu/** and **www.eng.fau.edu/**.

The beautiful city of Boca Raton, called a city for all seasons, is the home of the main campus of Florida Atlantic University. The city, located in Palm Beach County, South Florida, has an excellent school system, and is a scenic and exciting town with easy access to diverse cultural activities. Boca Raton boasts a strong, diverse economy that is grounded in high tech industry, tourism, finance, and healthcare. Boca Raton's location makes it uniquely suitable for outdoor recreational activities.

All applicants must complete the Faculty Position Application form available on-line through the office of Human Resources: **https://jobs.fau.edu** (Position **980043**) and apply for the currently posted position. Please upload online, at the above address, the complete application package including:a cover letter; curriculum vitae; copies of official transcripts scanned into an electronic format; a statement of teaching and research goals; names, addresses, phone numbers, and email addresses of at least three references.

Screening of applications will begin in January of 2014 and will continue until the position is filled. The anticipated starting date is as soon as possible. For assistance and other information regarding this position, contact Ms. Lise Proulx via email at proulx@fau.edu or phone at 561-297-3549.

Florida Atlantic University takes pride in having a diverse population of students and faculty and is an Equal Opportunity/Equal Access institution. All minorities and members of underrepresented groups are encouraged to apply. Individuals with disabilities requiring accommodation, call 561-297-3057. TTY/TDD 1-800-955-8771.

American Bureau of Shipping (ABS) Chaired Professor in Maritime Technology

The Singapore University of Technology and Design (SUTD), established in collaboration with the Massachusetts Institute of Technology (MIT), is seeking an exceptional candidate for the American Bureau of Shipping Chaired Professor in Maritime Technology (the ABS Chair). The ABS Chair was enabled by a generous endowment from ABS and the Maritime and Port Authority of Singapore (MPA) as part of an ambitious goal to initiate and build world-class capabilities related to and applicable for maritime and offshore technology education and research at SUTD.

The ABS Chair will serve as SUTD's focal point in maritime technology, interacting with relevant industrial, academic, and government stakeholders, and provide enthusiastic leadership to the program development including: i) maritime and offshore technology educational and co-curricular components, and ii) a contemporary research program in maritime-technology related/relevant topics that endeavor to bring cutting-edge technology to the maritime and offshore industries. This will include regular interfacing with the ABS Singapore Innovation and Research Center and ABS Corporate Technology organization to explore opportunities for R&D collaboration.

The strongest candidates for the ABS chair will be internationally-renowned experts, widely published in his/her field of specialization which may be in marine engineering, naval architecture, maritime security, ocean, mechanical, environmental, civil, or systems engineering or other engineering or computer science disciplines. Particular expertise should have maritime and offshore technology relevance in areas including, but not limited to:

- Computational hydrodynamics, fluid dynamics and/or solid mechanics, particularly that applied to ships and offshore facilities, structural analysis, failure, and fluid-structure interaction.
- Optimal design, particularly that related to performance optimization of marine and offshore structures and systems.
- Clean energy in shipping, energy systems engineering, particularly that related to internal combustion engines, thermal efficiency and emissions, energy management; electrical engineering for marine and offshore facilities.
- Offshore structures design, analysis, operations.
- Marine infrastructure, ports, marine logistics and traffic, techno-economic modeling, management, enterprise systems.
- Sensor technologies, especially related to structural health monitoring, nondestructive evaluation, etc.
- Marine robotics; advanced materials and manufacturing for marine and offshore technologies.
- Software engineering, integrity, safety for marine and offshore technologies.

Applications/Nominations

Candidates should submit a letter of interest, a complete CV, and statements of research and teaching interests to the Senior HR Director, Jaclyn Lee (jaclynlee@sutd.edu.sg). Inquiries about the position, as well as nominations, should be directed to Professor Martin L. Dunn, Associate Provost for Research (martin_dunn@sutd.edu.sg).

Additional information about the university can be found at www.sutd.edu.sg

About SUTD

SUTD, the first university in the world with a focus on design accomplished through an integrated multi-disciplinary curriculum, has a mission to advance knowledge and nurture technically grounded leaders and innovators to serve societal needs. SUTD is characterized by a breadth of intellectual perspectives (the "university"), a focus on engineering foundations ("technology") and an emphasis on innovation and creativity (design). The University's programs are based on four pillars, Architecture and Sustainable Design, Engineering Product Development, Engineering Systems and Design, and Information Systems Technology and Design, each leading to a separate degree program.

MIT's multi-faceted collaboration with SUTD includes curriculum development and initial course deployment, faculty and student recruiting, mentoring, and career development, and collaboration on joint research projects, through a major new international design centre, a joint post-doctoral scholar program, a dual MS program, and student exchanges.

About ABS

Founded in 1862, ABS is a leading international classification society devoted to promoting the security of life and property and preserving the natural environment through the development and verification of standards for the design, construction and operational maintenance of marine-related facilities.

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Required Qualifications: Ph.D. in Engineering with specialization in engineering mechanics and composite materials with experimental and modeling experience. **Preferred Qualifications**: A proven record in the mechanics, manufacturing and/or synthesis of composite materials, including smart, self-healing composite materials and the associated manufacturing processes; experience with applications relating to lightweight piping, pressure vessel and automotive and aero structures; balanced experience in experimentation and modeling.

Salary and rank are commensurate with qualifications and experience. An offer of employment is contingent on a satisfactory pre-employment background check. Application review will begin March 15, 2014 and continue until a candidate is selected. Apply online and view a more detailed ad at: **www.lsusystemcareers.lsu.edu**. Position #008843.

Quick link at ad URL:
https://lsusystemcareers.lsu.edu/applicants/Central?quickFind=56970

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FUNDAMENTAL EXAMS ARE NOW COMPUTER-BASED

IN A CHANGE INTENDED TO MAKE TAKING THE EXAMS Fundamentals of Engineering and Fundamentals of Surveying easier, the National Council of Examiners for Engineering and Surveying is now offering the exams at approved Pearson VUE computer-based testing centers.

Until now, the tests were only offered two times a year in the traditional pencil-and-paper format.

Computer-based testing benefits both examinees and NCEES, the council said. Test takers can schedule their exam at a convenient time and location and receive their results within seven to ten days. In addition, the move to computer-based testing ensures enhanced security and better uniformity in testing conditions, according to NCEES.

The Principles and Practice of Engineering Exam, which engineers take after the FE exam in order to become a Professional Engineer in the United States, will still be offered in the pencil-and-paper format. To learn more about the FE and FS exams, visit **http://ncees.org/exams.**

IPTI, ASME T&D TO HOST PIPELINE TRAINING WEEK EVENT IN DENVER

UPDATES TO ASME CODES, SAFETY ISSUES, AND INDUSTRY technical challenges are topics to be covered at a weeklong training program on onshore pipeline engineering scheduled in Denver next month. ASME's International Petroleum Technology Institute (IPTI) and Training & Development department will host the event.

Engineers can learn from experts at Pipeline Training Week, which will run from April 14 to 18. The five-day event will feature 10 training courses tailored specifically for engineers and project managers involved in the design, operation, maintenance, and integrity assurance of piping systems.

The courses, taught by ASME committee members responsible for writing codes and standards, include *B31.4 Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids; B31.8 Gas Transmission and Distribution Piping Systems; Bolted Joint Assembly Principles Per PCC-1-2013;* and *Composite Repair Solutions for Pipeline Anomalies.*

Other courses on offer during the event address defect assessment, inline inspection, integrity management, onshore design and construction, practical welding technology, and pipeline pressure testing.

Course instructors include Larry Decker of RCP Inc., Tom Bubenik of Det Norske Veritas Inc., David Lay of Hytorc, E. Shashi Menon from SYSTEK Technologies, Chris Alexander of Stress Engineering Services, Michael Rosenfeld from Kiefner/Applus-RTD, Albert Moore Jr. of Marion Testing and Inspection, and Carolyn Kolovich and Martin Phillips from Kiefner and Associates.

For more information on Pipeline Training Week, download the event brochure at **http://calendar.asme.org/EventDetail.cfm?EventID=25751.** ■

EGYPTIAN ENGINEERING SOCIETY HONORS KOTB

IN JANUARY, THE EGYPT SECTION OF ASME held a joint meeting with the Egyptian Society of Mechanical Engineering at that society's headquarters in Cairo. During the meeting, the engineering societies discussed potential areas of collaboration and honored ASME President **Madiha El Mehelmy Kotb**, who was in attendance.

The ASME Egypt Section announced its plan to establish an award named after Kotb that recognizes female engineering professionals in the Middle East and Africa. With the award, which will be given to early career ASME members in Egypt, the section hopes to encourage more women to become involved in both ASME and their local communities.

Approximately 120 people, including members of ESME, the ASME Egypt Section, and a number of engineering students from nearby universities, attended the meeting. ESME and the ASME Egypt Section called the meeting to honor Kotb, who was visiting her homeland on vacation for the holidays, as the first ASME president of Arab descent and only the fourth female leader of the Society since its inception in 1880.

Others in attendance at the meeting included **Moustafa Chaaban**, former president of ESME, **Tarek**

ASME'S EGYPT SECTION WILL ESTABLISH AN AWARD NAMED AFTER KOTB IN RECOGNITION OF FEMALE ENGINEERING PROFESSIONALS IN THE MIDDLE EAST AND AFRICA. IT WILL BE GIVEN TO EARLY CAREER ASME MEMBERS IN EGYPT.

STUDENTS CHALLENGED TO CREATE DESIGN SIMULATIONS

ASME IS NOW ACCEPTING ENTRIES FOR THE SECOND NEW COMPETITION EVENT FOR UNDERGRADUATE STUDENTS THE SOCIETY HAS LAUNCHED FOR THIS YEAR.

The ASME Innovative Design Simulation Challenge gives mechanical engineering and multi-disciplinary undergraduates worldwide an opportunity to showcase their skills in developing and deploying simulations or simulation frameworks and environments. Students can showcase their knowledge and creativity in design simulations that address a range of academic, industrial, manufacturing and humanitarian challenges.

The simulations created for the challenge should enable predictive models capturing systemic or service behavior for the needs of product or service design, maintenance, qualification, or certification in all areas of engineering.

Students may register, either as individuals or in teams of up three members, until May 31. Twelve finalists, selected by a reviewing committee, will be announced by June 30. The finalists will present their simulations to a panel of judges in Buffalo, N.Y., at ASME's 2014 International Design Engineering Technical Conference and Computers and Information in Engineering Conference, scheduled for August 17 through 20. The winners will be announced at the event.

Two $2,000 prizes will be awarded in each of the IDSC's three categories: custom, open, and commercial

Madiha El Mehelmy Kotb (in red jacket) at the joint meeting in Cairo.

Hatem, assistant professor at the British University in Egypt and current interim chair of the ASME Egypt section, and **Maher Younan**, professor and chair of mechanical engineering department at the American University in Cairo.

Kotb spoke during the event. She discussed her experiences during her long and distinguished career, which began as a student at the American University in Cairo and led to her current position as head of the Pressure Vessels Technical Services Division for Regie du batiment du Quebec. Kotb also spoke on the importance of encouraging young women to pursue careers in engineering, particularly in the Middle East and Africa, and ASME's role in addressing future engineering challenges in Egypt and throughout the world. ME

ePoster Deadline This Month for ASME's Advanced Design and Manufacturing Impact Forum

The deadline is fast approaching for submitting ePosters to be showcased this summer, **August 17 through 20,** at ASME's **Advanced Design & Manufacturing Impact Forum**. **SUBMISSIONS MUST BE RECEIVED BY MARCH 15.**

ePosters will be displayed on monitors, *not* printed on paper. Themes and subject matter for ePosters should address the forum's session topics, which include design and advanced manufacturing, additive manufacturing and 3-D printing, aerospace, automotive, medical devices, life sciences, computer aided engineering, and robotics.

To learn how to get your work on view before an audience of more than 1,000 leaders in these fields, visit: **go.asme.org/ImpactForum.**

simulations. Other prizes include $1,000 honoraria and complimentary five-year ASME memberships for selected team faculty member advisors, and travel subsidies for semi-finalists to attend the Challenge finals at the IDETC/CIE.

The ASME Innovative Design Simulation Challenge is the second competition event for undergraduate students that the Society has launched for 2014, following the new ASME Innovative Additive Manufacturing 3D Challenge that was announced in December. ■

To learn more about the ASME **Innovative Design Simulation Challenge**, or to register, visit **https://www.asme.org/events/competitions/idsc-challenge.**

PART OF A SERIES IN WHICH ASME PAST PRESIDENTS DISCUSS KEY ISSUES.

Presidential Oral Histories:

Inspiring Future Engineers

DAN KOENIG

ASME PRESIDENTS The Oral History Archives

Promoting STEM education has been a hallmark of ASME programs for decades. Dan Koenig, ASME president during the 1995-1996 fiscal year, played a significant role in linking ASME to one of the most successful STEM initiatives, the FIRST Robotics Competition.

FIRST ("For the Inspiration and Recognition of Science and Technology") is the brainchild of **Dean Kamen**. Believing young people need engagement with hands-on projects involving science and engineering, he made it a sport.

Past President **Keith Thayer** in an oral history interview said Koenig was one of the catalysts for building the relationship between ASME and FIRST.

Koenig was introduced to FIRST by **Vince Wilczynski** of the U.S. Coast Guard Academy, who was running a FIRST team for graduate students. After that contact, ASME provided volunteers as judges, mentors, and event supporters at the regional level, and began supporting FIRST teams.

When Thayer made a bid for ASME's presidency that year, he asked Wilczynski to draft a document for ASME leadership outlining the FIRST program. "How to Start a FIRST Team" is still in use today.

According to Thayer, "Because of that document, we cemented the relationship between FIRST and ASME."

Today, FIRST is celebrated by government, industry, NASA engineers, inventors, and major media outlets. There are now over 150 providers funding over $15 million in scholarships in 2013. They include ASME, which offers the Lucy and Charles W.E. Clarke FIRST Scholarship.

In 1996, when Koenig learned of the competition, FIRST had fewer than 100 teams. More than 10,000 students filled the floor of a huge domed stadium in St. Louis for the 2013 FIRST National Championships. In this "Varsity Sport for the Mind," teams demonstrated robots designed to roam a field, place discs inside a goal post, and climb a pyramid.

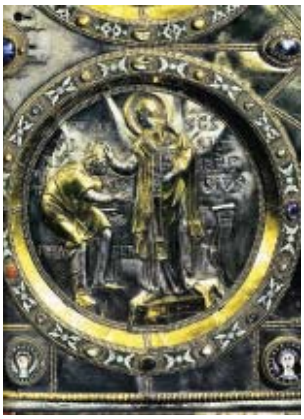
Among those present to offer support were several ASME past presidents, including Thayer, **Sue Skemp**, **Robert Simmons**, and **Marc Goldsmith**. Thayer served as a judge, and was joined by several other volunteers, including ASME Governor **Betty Bowersox**, Auxiliary President **Kay Simmons**, member **Nina Webb**, and **Willard Nott**, past vice president of the Board on Public Outreach.

According to Thayer, "ASME and FIRST share an important goal, which is to raise awareness among young people about the role of science in everyday life and about the enrichments—and fun—of a career in the field." ■

WIL HAYWOOD/ ASME PUBLIC INFORMATION

NEW VIEWS INTO AN OLD CRAFT

Nanotech methods provide new insight into the methods of ancient gilders.



The altar of Holy Ambrogio in Milan, right, and a close-up of the gilder's art. Nanoscale methods gave researchers a new understanding of the surfaces of the work. Photos: Giovanni Dall'Orto

PRECIOUS-METAL PLATING AND COATINGS on valuable objects have been under examination for centuries and under scientific analysis for decades, but the research has reached a new, intimate scale in Italy. Case in point is the research into thin metal plating on Roman coins, ancient and medieval artwork, and jewelry produced 1,200 to 2,000 years ago.

Their artistry and durability have aroused the curiosity of scientists at Italy's Institute for the Study of Material Nanostructures in Rome, which is part of Italy's National Research Council (Consiglio Nazionale delle Ricerche). Researchers at the institute are finding that state-of-the-art investigative technologies such as scanning electron microscopy are able to "see" beneath surfaces in depths measured in nanometers.

The investigations are the work of a team of scientists and chemists led by Gabriel Maria Ingo, senior scientist at the Instituto per lo Studio dei Materiali Nanostrutturati. In addition to SEMs, researchers used selected area X-ray photoelectron spectroscopy, energy-dispersive spectroscopy, secondary ion mass spectrometry, and glow discharge optical emission spectrometry.

The results of the team's investigations were reported in a paper, "Ancient Mercury-Based Plating Methods," in the July 2013 *Accounts of Chemical Research*, published by the American Chemical Society.

Ingo's team examined coins from Carthage (circa 240 B.C.) and from the Roman Republic; a silver-coated fragment of a statue of a lion from the Roman Republic; and a gold- and silver-plated altar from the Holy Ambrogio basilica in Milan made around 850 A.D.

They looked at specimens coated with processes using mercury, a technique that may have originated in China and moved west along the Silk Road. One object of the study, a Roman copper coin coated in silver from the first century B.C., is one the oldest European artifacts coated by a mercury-based method. The mercury method lasted until the 19th century when it was phased out by electroplating.

Observations of the coin showed the presence of mercury and small grains and subgrains of silver with diameters ranging from 100 nm to 1 µm. Areas lacking the silver coating contained copper corrosion products, including cuprite and atacamite.

The Holy Ambrogio altar is a rectangular wooden case measuring 250 x 150 x 130 centimeters. It is decorated with precious-metal enamels, filigrees, and gems such as emerald, topaz, amethyst, agate, and carnelian. The microchemical structure of the gold layers was revealed as well as the complex interface between painted-on gold layers and silver substrates.

The institute's work has led to a deeper understanding of the enameling and related techniques that used amalgams of gold and silver with mercury and several other elements.

Also revealed were the ways in which these objects' surfaces degraded over the past 1,200 to 2,000 years. The patinas, or precious metals in thinly plated or coated surfaces, suffered from exposure to oxides, sulfides, and chlorides stemming from the atmosphere, moisture, handling by humans, and long-term burial.

In the Holy Ambrogio altar, the team found "microcracks and a dense population of cuprite (Cu_2O) microglobules that formed during the manufacturing of the panel." The researchers found other cracks as well, which they attributed to brittleness caused by the aging of the ancient silver.

The goal of the institute's thin-metal-coatings analyses is to better understand the ancient techniques of goldsmiths and silversmiths and the complex processes of degradation since then. The findings are considered vital for the preservation of Italy's cultural heritage, and intriguing in terms of rediscovered trade secrets. **ME**

JACK THORNTON, a technology consultant in Santa Fe, N.M., is a frequent contributor to *Mechanical Engineering*.

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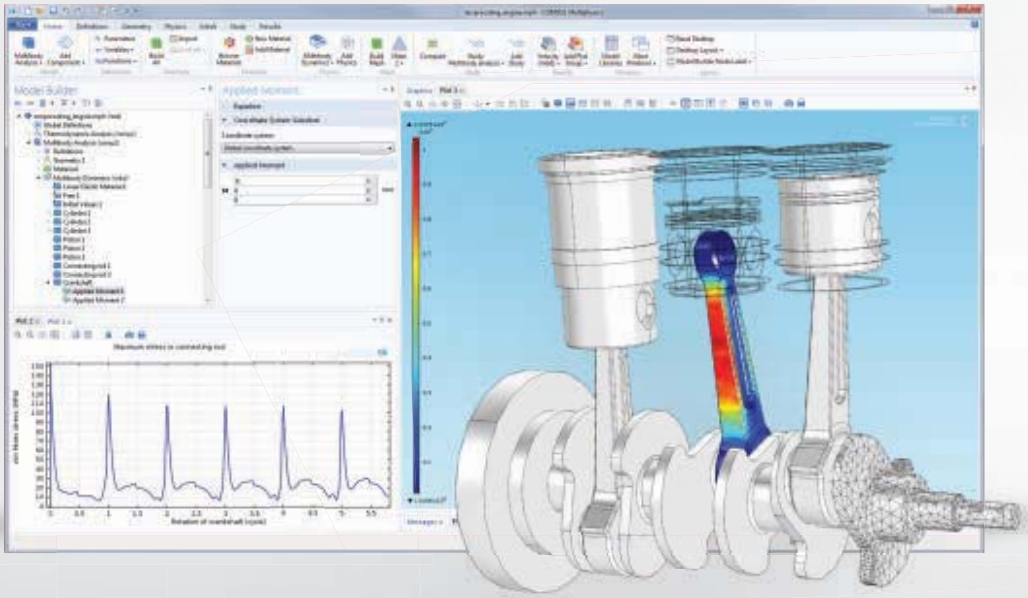
MULTIBODY DYNAMICS: Model of a three-cylinder reciprocating engine with both rigid and flexible parts is used for the design of structural components.



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