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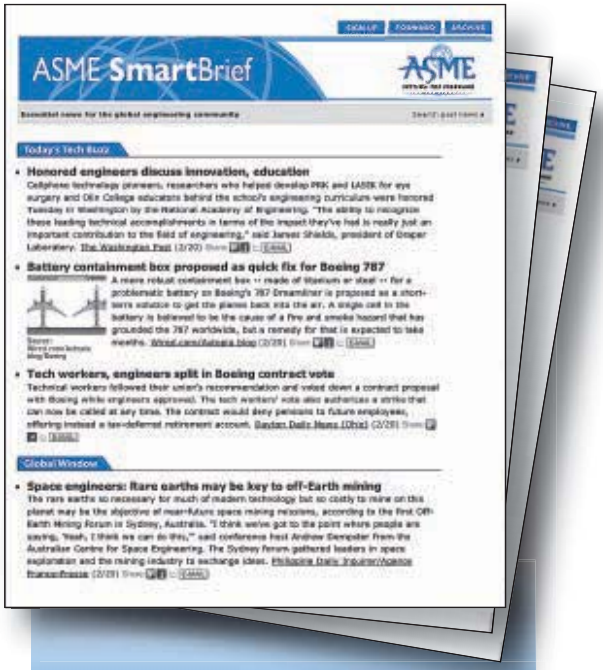

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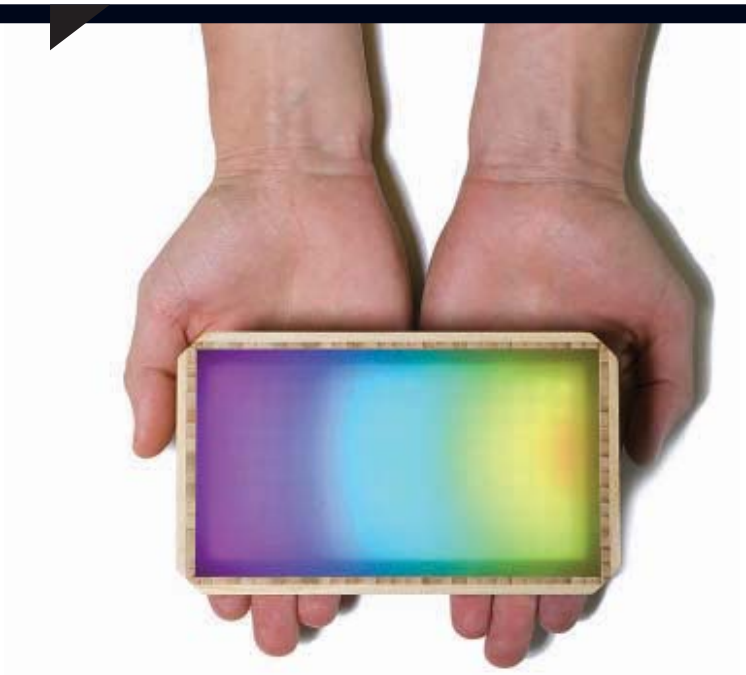

ENGINEERING ENLIGHTENMENT

SOME SPEND A FEW DECADES MEDITATING. OTHERS SPEND AN indeterminate amount of time inquiring after their true selves. Still others ingest ayahuasca or other intense psychoactive drugs. All are seeking the same thing: in a word, enlightenment. Now a robotics engineer out of California is hoping to help seekers find it another way, with technology. Under the Bio-Fluent banner, engineer Mikey Siegel has created three products to help induce meditative states in their users.

BIOSENSOR TO GO

Engineers have taken a biosensor technology that quickly detects a virus, bacteria, or toxin and have greatly expanded its uses by packaging it in a portable "suitcase."

OCTO-BOTS IN THE E.R.

Allen Jiang turned to granular jamming to make the Stiff-Flop, a surgical robot that can worm its way to a target spot and then stiffen to get to work.

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

A CHARGE FOR THE POWER HUNGRY

Students at Dartmouth Humanitarian Engineering have created a hydropower system that runs on waterfalls so villagers in rural Rwanda can charge batteries and power their phones.

NEXT MONTH ON ASME.ORG

WEBINAR: ENGINEERING THE MAKER MOVEMENT
Jason Dunn, CTO of Made in Space, and Manu Prakash, inventor of the Foldscope, discuss the Maker Movement, which is giving many hope that a new era in U.S. manufacturing is under way.

VIDEO: WHAT'S NEXT FOR 3-D PRINTING?
Bre Pettis, CEO of MakerBot, discusses the future outlook for 3-D printing and how it can be used as an essential tool for STEM education.

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SETTING THE STANDARD

AN INDUSTRY OF R&D

Singapore banks on ingenuity and human brain power to compensate for a shortage of other natural resources.

BY HARRY HUTCHINSON

THE TESLA PHENOMENON

The man responsible for alternating current and the induction motor is a bigger celebrity than ever before.

BY JAMES PERO

INSIDE

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

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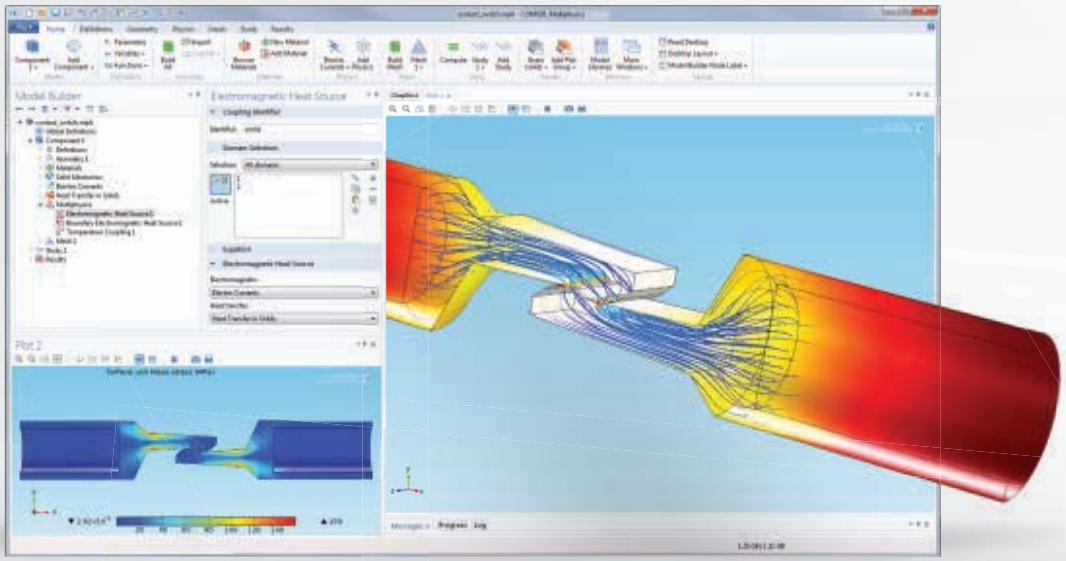
CONTACT SWITCH: Model of the electrical current and heat flow through the contacting surfaces of a switch.



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COMSOL

John G. Falcioni
Editor-in-Chief

IT'S A BIRD, IT'S A PLANE, IT'S A NEW FLYING MACHINE

By the year 2154, humans will have severely depleted Earth's natural resources.

This isn't a prognostication or a personal political proclamation, it's the premise on which the hugely successful 2009 film Avatar is based.

If the notion of Earth's depleted natural resources weren't enough, the plot gets unimaginably more intriguing from there. Those who saw the movie know what I'm talking about, but even if you didn't see it, you might remember watching some of the spectacular footage from the film in ads showing aerial battles waged in futuristic helicopters over the varied, extraterrestrial terrains. The film's creative team was rewarded for its imagination and imagery by winning Oscars for best art direction, best cinematography, and best visual effects.

These images stirred the imagination. Blog posts following the movie's release marveled at the mighty looking mechanical systems that lift vertically and whip around with power and might. Some bloggers speculated whether elements of these helicopters already existed and wondered whether such high-powered vehicles could ever be manufactured.

The U.S. Army wondered the same thing, but its concerns are, obviously, much more serious than those of bloggers or movie producers. Current military helicopters are based on designs of the 1970s and 1980s, while faster and durable civilian rotorcraft have been ushered by advances in engines and other technologies.

In 2008, the U.S. Department of Defense began defining the scope of a project to replace the legacy helicopter fleet with next generation vertical lift aircraft. The initiative, called Future Vertical Lift (FVL), represents a family of platforms across all of the U.S. defense departments. The DOD brass believes that some of the technology developed under FVL will also help civilian industry in the form of advances in rotating machinery and operating efficiencies.

Two years ago, the Army funded a program called Joint Multi-Role (JMR) Technology Demonstration "to inform future acquisition programs that fulfill the FVL initiative," said retired Lt. Col. Dan Bailey at a keynote session a few weeks ago during ASME's Design and Manufacturing Impact Forum. Bailey is the program director for JMR and FVL and, having logged more than 325 hours of combat duty in Apache and Black Hawk helicopters, certainly knows a thing or two about the topic. He said the goals of the program are air vehicle demonstration and mission systems architecture demonstration.

Around the same time as Bailey's speech, the Army selected two industry teams to develop this new type of helicopter. The Bell unit of Textron Co. in partnership with Lockheed Martin Corp. represents one team; the other is a team of Boeing Co. and Sikorsky Aircraft Co. Analysts say that, by creating a competition, the Pentagon is testing a new way to develop and purchase weapon systems.

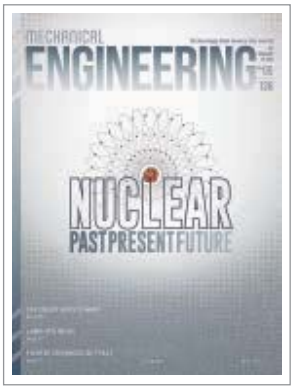
If development of these advanced aircraft ultimately gets the green light, we won't have to wait until the Avatar year of 2154 before they're flying around, but it won't be before the mid-2030s either. By then, Earth's natural resources won't likely be depleted (this month's power and energy articles provide some insight on that), but there's no word yet from the DOD if the Avatar brain link project will have gotten the go-ahead. **ME**

FEEDBACK

If films provide the context for technology, what will come next? Email me.

falcionij@asme.org

LETTERS & COMMENTS



MAY 2014

Reader Tom Luther questions the role of human activity in global warming.

Two readers comment on energy-related articles: one approving coverage of a plan to extend the life of U.S. nuclear power plants, and the other objecting to a report on numbers of wind turbines.

GREEN GLOSS

To the Editor: The production tax credit subsidy has grossly distorted the energy supply market. Green energy plants have been built because of the inequities that are inherent in the decisions to build, related specifically to the production tax credit. For example the May issue of *Mechanical Engineering*, includes an article (Trending) that is a model of obfuscation. In a letter to the editor, Frederick Willis illuminates the lack of clarity and incompleteness of the article.

In that same issue, "Nuclear's Next 40 Years" by Barbara R. Snyder, Theodore A. Meyer, and Kenneth R. Balkey discusses the issues confronting the nuclear industry for license renewal beyond 60 years of operation and the electrical capacity implications. No attempt is made to gloss over questions to be answered in order that operation beyond 60 years is viable.

Vogtle 3 and 4 nuclear units are being constructed in Georgia at an existing plant site, where Vogtle 3 is reaching the 65 percent completion milestone. About four years ago, Georgia Power applied for a U.S. Department of Energy loan guarantee, not a loan, for Vogtle 3 and 4. Recently, the DOE granted the request and received a 45 percent lien on the two units. In addition, there is a finder's fee that will be levied and payable to the DOE. So far, there is no information in the public domain related to the amount of the finder's fee.

There is no production tax credit for these electrical capacity units. Moreover, the combined load factor of all of the nuclear units has been about 89 percent for several years. I suspect that the load factor for wind and solar would be about 25 percent if they ran at rated output under the most favorable conditions.

The article by Snyder et al. lets the facts speak for themselves. Sadly, the article on wind does not meet that standard.

George J. Silvestri Jr., ASME Life Fellow, *Souderton, Pa.*

MISSING FROM THE WIND

To the Editor: The May 2014 *ME* wind article (Trending, "Wind Energy Set to Soar") presents one fact, installed wind capacity, and draws erroneous conclusions from it.

Installing wind turbines does not necessarily produce power or provide power at an economical cost. What is the operating capacity of the 61,108 MW of installed wind power? The operating capacity ratio provides the generated and available consumable power, yet it is omitted from the article.

The assertion wind power prices have fallen 43 percent, from an unknown value, is irrelevant.

The important issue is the delivered cost per kilowatt-hour to the grid. This information is also not provided in the article.

Wind power exists because of the production tax credit subsidy. Perhaps wind power will be economical and reliable in the future, but with its current subsidies and enforced purchase to meet the states' renewable energy standards, it is an ideologically driven energy source, not an economical one.

Frederick Willis, *Haddonfield, N.J.*

NATURAL OR MAN-MADE?

To the Editor: My biggest problem with the global warming juggernaut is the failure to separate the anthropogenic claims against immense natural variation. The planet has seen total variation in sea levels over 100 meters. I have serious doubts that a predicted centimeter or two can be measured accurately, much less be attributed to humans. The same goes for temperature variation. Plot the total natural variation over a hundred million years and then show the current data at the same scale. It is invisible.

We are just exiting an ice age, so of course the glaciers are melting. Time delay between cause and effect is the

hardest task for a control output. Ten or 15 centuries is quite a challenge for a control algorithm. Fundamentally, the war on weather is arrogant. When ranked against war, poverty, disease, and a number of other human ills, the war on weather just does not rank very high.

My high school physics class received an analog computer from the DOE in 1980 which modeled energy usage. No matter how you played the game (and I played endlessly; the class was way too slow) all worldwide natural gas and oil was completely gone by 2001. Only coal remained. Imagine my surprise as I bought gas for my truck while driving home with a new natural gas heating system.

I submit that modeling life itself is far more difficult than any fluid dynamics software. I read yesterday of a unique waterborne fern that first evolved the ability to fix nitrogen. This organism's evolution may well have cooled the entire planet while trapped in the Arctic Ocean, before ocean currents changed. Model that.

I agree that energy efficiency in production and consumption will be critical in the future, but this has been true for the past several thousand years and is a basis for our profession. I hope to see many ME's involved in pricing and delivering decentralized, customer-focused, unsubsidized energy—from whatever source derived. Let the customers lead, not the bureaucracy.

Tom Luther, *Raleigh, N.C.*

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.

Doug Neidich's company, Solarity, holds four patents on the LCCM NanoCell Architecture of its thin-film photovoltaic panels.

TRAPPING SUNPOWER

After getting his B.S.M.E. from Penn State, Doug Neidich started designing high-speed, high-density connections for computers. In doing this, he could easily see the value of packing a lot of components and memory into a small space in the world of solid-state electronics. Little did he know that he would see the same thing today in a totally different form: thin-film photovoltaic panels made possible by nanotechnology. It took a roundabout path for him to get there.

NEIDICH WENT TO WORK FOR DUPONT/BERG Electronics in Lewisberry, Pa., and worked his way into development engineering and got to do original concept work. The first project he handled involved a connector system for Cray Research, the Seattle-based company that develops advanced supercomputers. "I worked very closely with Cray doing interconnect schemes," Neidich said.

Then at the age of 27, Cray asked him to consider starting a company to do more specific development work for them. It was an easy decision for Neidich. He founded InterCon Systems, a developer and manufacturer of high-density, high-speed electronic connector systems. They started in a garage in 1987 at his partner's house and spent several months there. Once they developed the first successful product and got production established, they moved into leased space.

The first couple of years, the startup did work exclusively for Cray, but then it expanded and started doing work for other companies. After ten years, it had about 400 customers and $25 million a year in revenues. Customers included Hewlett-Packard, IBM, Motorola, Sharp, Panasonic, and Mitsubishi.

Then Neidich sold InterCon Systems to the Amphenol Corp. in 2005. With cash from the sale, Neidich proceeded to start not one but two new companies, GreenWorks Development and Solarity.

GreenWorks Development integrates urban communities in central Pennsylvania by revitalizing older, blighted neighborhoods. The firm has developed over $25 million worth of projects since 2005, focusing largely on educational facilities in Harrisburg.

Neidich gained insight into solar energy, because GreenWorks often installed solar panels on the roofs of buildings in order to make them sustainable. These conventional panels were made of thick semiconductor materials and mounted with structural metals and heavy hardware.

QUICK FACTS:

WHAT IT IS: Flexible photovoltaic film with a nano-scale array that traps light.

DEVELOPER: Solarity.

POTENTIAL END USE: Integration with conventional building materials .

NEXT STEP: Reducing the cost/watt ratio.

Solarity evolved from a chance meeting when Neidich went to the Penn State campus in State College to look at a nanotechnology business and ran into Stephen Fonash, director of the Penn State Center for Nanotechnology Education and Utilization. Fonash showed him the work he did with nano photovoltaic technology.

They started Solarity in 2006 and were joined by another Penn State professor, Wook Jun Nam, who is director of research. Today, they hold four patents and have more pending.

Now Neidich finds himself packaging a lot of components into small spaces. "It's the same as solid state electronics," he said. "We're not reinventing the wheel; we're applying nanotechnology to energy. It's fun looking at the limitations of solar while developing this new technology."

According to Neidich, "Conventional photovoltaics are Model T technology. We've got to bring more elegant solutions to the problem."

He sees thin-film technology yielding a flexible final product that can be produced by an automated roll-to-roll process and integrated with conventional building materials such as shingles, membrane roofs, and siding. Like many advances in technology, it packs more capability into a much smaller package.

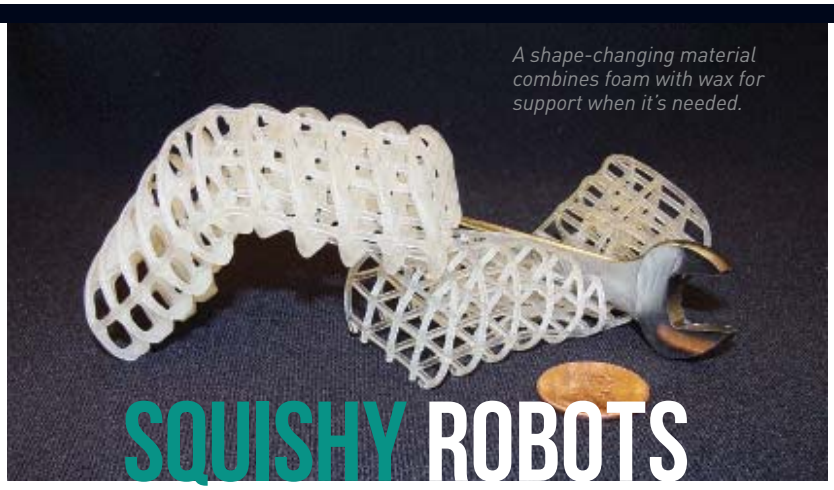
With Solarity's LCCM (Light and Carrier Collection Management) NanoCell Architecture, a nanostructured array forms on a lower electrode through high-density plasma deposition on metal foil, creating a silicon film with rod-like columns. In a self-assembly process, nanodomes form around each nanostructure-array element to create the LCCM structure.

The structure traps light as it transmits through each dome to the array and into the cell's absorber. A film 1.4 thousandths of an inch thick will pack 625 million domes in an area of 1 square centimeter.

Conversion rates of light to electricity are at least 15 percent with thin-film silicon. The company says it is working on refining the product and processing to bring down the cost per watt.

"I think we're very close to a commercially viable technology," Neidich reports. **ME**

TOM GIBSON, P.E., is a consulting mechanical engineer specializing in machine design and green building, and a freelance writer. He publishes Progressive Engineer, an online magazine and information source.



A shape-changing material combines foam with wax for support when it's needed.

SQUISHY ROBOTS

AN INTERNATIONAL COLLABORATION HAS DEVELOPED A material made from wax and foam that is capable of switching between hard and soft states. Its developers say it could result in low-cost robots that can squeeze through small spaces and then regain their shapes.

The material could be used to build deformable surgical robots that could move through the body to reach a particular point without damaging organs or blood vessels along the way. It was developed by Massachusetts Institute of Technology mechanical engineering professor Anette Hosoi and her former graduate student, Nadia Cheng, alongside researchers at the Max Planck Institute for Dynamics and Self-Organization in Göttingen, Germany, and Stony Brook University in New York.

Working with robotics company Boston Dynamics of Waltham, Mass., the researchers began developing the material as part of the Chemical Robots Program of the Defense Advanced Research Projects Agency. The agency wanted robots capable of squeezing through tight spaces and then expanding again to move around a given area, much as octopuses do, Hosoi said.

"But you can't just create a bowl of Jell-O, because if the Jell-O has to manipulate an object, it would simply deform without applying significant pressure to the thing it was trying to move," Hosoi said.

Controlling a very soft structure is extremely difficult: It is much harder to predict how the material will move and what shapes it will form than it is with a rigid robot, she added.

To build such a shape-shifting material, the researchers coated a foam structure in wax. Foam can be squeezed into a small fraction of its normal size and will bounce back to its original shape once released.

The wax coating, meanwhile, can change from a hard outer shell to a soft, pliable surface with moderate heating. Running a wire along each of the coated foam struts and then applying a current can heat and soften the surrounding wax, Hosoi said.

"This material is self-healing," she said. "So if you push it too far and fracture the coating, you can heat it and then cool it, and the structure returns to its original configuration."

To build the material, the researchers placed a polyurethane foam lattice in a bath of melted wax. They squeezed the foam to encourage it to soak up the wax, Cheng said.

They used a 3-D printer to build a second version of a foam lattice, to allow them to carefully control the position of each of the struts and pores.

The printed lattice was more controllable than the original polyurethane foam, but would cost more. The first version works, but the printed lattice can be refined by analysis and changed according to need.

The wax coating could also be replaced by a stronger material, such as solder, she added. ■

Nuclear engineer Mark Delgado, co-founder and chief executive of Koyr Engineering, holding the KoyrGeiger Android-enabled Geiger counter that he designed. Image courtesy: Mark Delgado.

RADIATION MEETS THE ANDROID

THE IDEA CAME TO MARK DELGADO, AN UNDERGRADUATE NUCLEAR engineering student at North Carolina State University, in his dorm room. After learning that radiation detection technology hadn't really changed for more than 40 years, Delgado decided to make something better.

"In terms of technological innovation, the industry still uses radiation detectors based on a 1970s design," he said. "The user spins a dial in order to give measurements. Companies must then record measurements by hand, enter them into a data analysis program by hand, file all paperwork by hand, and finally input the results into a database by hand."

To improve this process, Delgado built his own "very simple" ionization chamber out of some scraps, tape, and a breadboard. After some refinements, he created a small, portable, wireless radiation detector that connects with wireless devices to transmit data.

Delgado's KoyrGeiger connects with Android devices and turns them into advanced radiation detectors with GPS capability to log data and calculate numbers. All the standard data analysis, paperwork, and data entry can be done automatically, saving the operator time and money.

One possible application is for nuclear energy and medical facilities to monitor radiation levels and transmit that data to a central computer system, providing an effective way to identify any radiation leaks in real time. It could also be used to monitor radiation in larger areas, where detectors are carried by employees or inspectors. This would be a way to rapidly identify the limits of larger radiation leaks that could harm larger populations or communities, using real-time data analysis with a central computer. For example, if a radioactive act of terrorism occurred, first responders using these devices would be "live" points in a real-time detection network that could quickly identify the source of the radiation, and any danger zones.

After several rounds of funding, including $23,000 from the National Collegiate Inventors and Innovators Alliance, Delgado was able to commercialize his product. He launched his start-up company, Koyr Inc., in Raleigh, N.C., with the goal continued on page 14»

AUTOMATION COMPANY BUYS SOLAR POWER FIRM

YASKAWA ELECTRIC CORP., KNOWN in the U.S. primarily as a supplier of automation equipment and motors, has agreed to acquire Solectria Renewables LLC, a manufacturer of power electronics for photovoltaic systems.

Yaskawa Electric, based in Japan, plans to complete the acquisition through its U.S. subsidiary, Yaskawa America Inc.

Solectria Renewables will operate as a wholly owned subsidiary under its current management. Solectria, a 10-year-old company in Lawrence, Mass., manufactures photovoltaic inverters for residential, commercial, and utility use.

According to Yaskawa America's president, Mike Knapek, the acquisition will strengthen Yaskawa's position in the renewable energy market. Yaskawa Electric is a leading supplier in the low-power PV inverter market in Japan.

REMANUFACTURING EXPANSION

A WISCONSIN-BASED MANUFACTURER of hydraulic cylinders has opened a separate plant devoted to cylinder remanufacturing. JARP Industries, headquartered in Schofield, opened the 25,000 square foot stand-alone remanufacturing site in Wausau.

The company calls its remanufacturing business JARP/RE. According to the company's CEO, Kevin Kraft, the expansion will allow JARP/RE to reach new customers and markets.

HIGHEST RAILS EXTENDED

A SECOND LINE HAS BEGUN OPERATIONS in Tibet's rail system, the world's highest, according to Xinhua, China's state news agency. The line links Lhasa, the capital, with Xigase, Tibet's second-largest city.

Rail service cuts travel time between the cities to two hours, down from four hours by highway.

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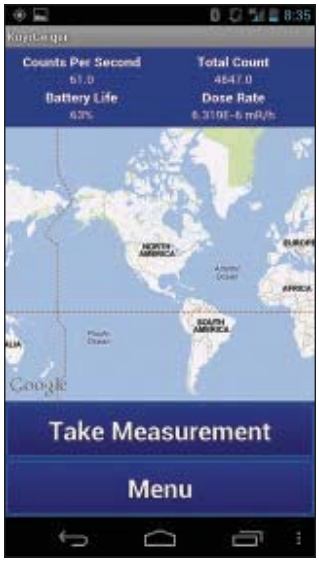
RADIATION MEETS THE ANDROID



The KoyrGeiger connects to Android devices to provide data logging and analysis capabilities.

of developing solutions for customers who require radiation detectors capable of GPS coordination, data logging, and data analysis. "Our device combines the accuracy and reliability of LND tubes with the power and capability of an Android device," Delgado said.

Koyr is marketing KoyrGeiger to nuclear power plants to improve workflow automation. "We're currently focusing on using software and hardware to automate labor-intensive tasks and paperwork for nuclear power plants, starting with low-risk tasks to further show credibility of the device," Delgado said. "We have also successfully completed a pilot program with a nuclear power plant of a very large utility company, and are hoping to have some big announcements very soon."

Delgado said he plans eventually to expand the types of products his company provides. "The first product focuses on the inventory and upkeep of several important items on site," he said. "We're currently working with radiation protection teams; however, we'd like to grow into fire protection, chemistry, operations, and any other team that could have a use for us. Eventually, we would like to be in a position in which we could drive innovation in the industry, and be the Google or Apple of nuclear power."

Delgado said he is excited to be in a creative space where he can build products at the intersection of hardware and software.

"Think of it as combining hardware and software to add features and capabilities that were previously not possible," he said. "The exciting part is seeing how far we can push the hardware and how innovative we can get when solving problems. For example, if we can solve three problems with one scalable solution, then all parties win and the industry can advance more rapidly." ME

MARK CRAWFORD, ASME.ORG

A REIMAGINED DESIGN

THE TEAM AT HATCH INTERNATIONAL'S BIOD PROJECT has developed a home-scale biodigester that can turn farm waste into usable energy.

BioD has reimagined the biodigester for homes and plans to introduce it in Madagascar, said Caroline Angelo, electrical engineer and co-director at BioD. Hatch International of Washington, D.C., creates self-sustainable technologies for developing communities worldwide through a number of projects, such as BioD.

Biodigesters work, after a fashion, the way a stomach works. Shovel manure, food scraps, and other organic material into a closed container, let bacteria and other microbes break it down, then harvest the methane gas that they produce in the process, Angelo said. If they're used properly, they can cut down on the amount of wood burned for cooking, which can reduce deforestation, clean up the air in the kitchen, and help families save money.

A Hatch International engineering team poses with BioD, a low-cost and effective biodigester that converts organic waste into methane gas, which can then be used as a cooking fuel.

FOR THE BIODIGESTER

They also produce organic fertilizer that can be spread on local crops.

But many biodigesters are large, underground structures made from concrete. And they can cost upwards of $1,000 in parts of Africa. They're expensive for poor families and difficult to install and maintain, Angelo said.

BioD has made a smaller, less expensive digester using materials, such as farm waste, that can be found locally in Madagascar, home to about 22 million people.

"Our design is unique in that it's small enough to serve a single household, and could even be picked up and moved around," Angelo said. "Since everything is above ground it's easy to troubleshoot and repair if necessary."

The BioD team set out to make biodigesters more accessible in 2010 by attempting to build on existing designs.

"After several iterations and frustrations we decided to start from scratch, focusing on the biological processes and materials that are locally available in developing countries," Angelo said.

Now the team plans to head to Madagascar to test its newest prototype and research the market for training, distribution and sales. The team will train local entrepreneurs to build and sell the biodigesters, and they'll help families to afford them through financing. But they won't do it alone.

"The key to our success has been local partnerships," Angelo said. "We have established strong relationships in Madagascar with civil society organizations and university students. That has ensured that our product is not just technically appropriate, but is culturally sensitive and harnesses local skills and materials." ME

The BioD is designed to utilize materials commonly available in the developing world.

ENGINEERINGFORCHANGE.ORG

OBSTRUCTION AND EVASION

Passive aggression in the workplace can take **different forms in different people.**

I had a friend at a company who was perhaps the ultimate example of passive aggression. He did not really like working for the company and eventually left. He was one of the more intelligent and capable individuals in our organization, but he despised the corporate management.

We were at a company that rewarded absolute loyalty above all else, including competence. It was not an oppressive organization, however, just somewhat archaic.

As with many passive aggressive individuals in the workplace, he was extremely sullen in his demeanor. Once I was standing beside one of the managers and we watched my friend walk across the floor. Without looking at me the manager said, "I find it depressing to watch him walk through the building." As I opened my mouth to retort, the manager pre-empted me and said "I know, I know, you keep telling me that he is one of our top technical people." Even though I was his friend, I also found it depressing to watch him walk through the building.

His passive aggression manifested itself primarily in his almost complete inability to submit work on time. In fact, one time he was on one of the projects that I was leading. I let him know that he had four weeks to get me results to include in our quarterly report and that if he did not, I would have to include the results without his interpretation or even his consent.

There, that sounded far better than just taking the results, did it not? At the end of the four weeks, after a two-week reminder, he still did not provide the results that were needed for the report. Our mutual manager wished me luck in getting the results and commented on his personal frustration with my friend's chronically late submittals.

When I included the data in the report, my friend became extremely angry and confronted me, asking how I could backstab him that way, as he was not finished digesting the data. Despite being very religious, he used a few words that I had not heard him use before or since.

I looked him in the eye and told him that of all the people in the company, I had his back and including his data was helping, not hurting him. I also tried to talk to him about his habitual late submittals, but to no avail.

Passive aggression takes different forms in different people. Another individual at the same company was passive aggressive in other ways.

He was all smiles and would tell you, that you could trust him, and then he would throw you under the bus whenever he had the slightest opportunity to do so. Here is an example of one of his behaviors.

He had given a presentation to some people outside the company and when we returned he gave that same presentation to the other engineers in our company. When the other engineers asked if he had presented something to those outside the company that was presented internally, the other individual said no. After the meeting, this individual told me not to worry, that he would not lie to me.

DON'T EAT AT A PLACE CALLED MOM'S; DON'T PLAY CARDS WITH A GUY NAMED POPS, AND NEVER, EVER TRUST SOMEONE WHO SAYS, 'YOU CAN TRUST ME.'

Since I had been at the company approximately six months, I was certain that this was not true. This led to the family mantra that I passed on to my son before he went out into the world: "Don't eat at a place called Mom's; don't play cards with a guy named Pops, and never, ever trust someone who says, 'You can trust me.' "

Oddly enough, both of these individuals had far above average intelligence. As I write this, I have to wonder if that may be a prerequisite for this behavior.

Whether an individual is your friend or not, it is disheartening to see a talented individual waste his talent. ME

RONALD A.L. RORRER is the director of motorsports in the Department of Mechanical Engineering at the University of Colorado Denver.

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Q&A WAYNE CLOUGH

BORN IN RURAL DOUGLAS, GA., G. Wayne Clough rose to become president of Georgia Institute of Technology, where he remade the college into a major research university while raising $1 billion to upgrade the school's facilities. After retiring at age 67, he began a second career as leader of the Smithsonian Institution. There, he brought one of the world's preeminent museums into the digital age while emphasizing its teaching mission. He is retiring from the Smithsonian this month.

Photo: Carl C. Hansen, Smithsonian

ME: What led you to engineering?

G.W.C: Blood. I wanted to be a veterinarian until I first saw a dog being operated on. I grew up in a rural area, and loved nature and building things, so it was natural for me to become a civil engineer.

ME: After teaching at Stanford, you eventually rose to dean of engineering at Virginia Tech and provost at University of Washington. What skills did you bring to administration?

G.W.C: I always loved to read, and I found that all that reading allowed me to communicate with non-engineers in ways many engineers could not do. I also found, from watching, that folks who didn't have engineering skills could have used a more structured way to make decisions and take action. So I had a combination of skills that were a little bit unique.

ME: You were first alumnus to become president of Georgia Tech. What were your goals?

G.W.C: There were immediate needs. Georgia Tech was building facilities for the 1996 Olympics, but didn't know how to manage the process. I had done a lot of consulting and had managed big construction projects. I also told the trustees that the school was too narrow, and that we needed to emphasize the humanities and educate our students to speak to a broader audience. I believed that the educational process involved the right and left side of the brain, and I wanted to teach both. Joining a university in a leadership position is a two-way street. I had to be a fit for them, and they had to accept my goals.

ME: The Smithsonian Institution named you secretary in 2008, after its previous leader was forced to resign. Why you?

G.W.C: The Smithsonian has one of the largest research science programs in the world, and as president of a major research university, I understood that. It needed to raise money, and I had done that. Also, there was a lot of disarray here, and I had shown that I could bring more discipline to the decision-making process at Georgia Tech.

ME: You've spent a lot of time focusing on the Smithsonian's teaching mission. Why?

G.W.C: When I came here, I thought a lot about the Smithsonian's purpose. James Smithson founded it "for the increase and diffusion of knowledge." We increase knowledge through scholarship and research, and diffuse it through education.

ME: How?

G.W.C: Every year, 30 million people come to our museums, but many more do not. So why not try to share our collection with everyone? We're using our digital capabilities for outreach. Our website use was up 60 million people in the past three years. We had 400,000 downloads last year. We're creating education centers in our museums, and lesson plans for teachers. I grew up in a rural area and didn't know this institution even existed. Our taxes help support it, so why shouldn't we all get some benefit out of it?

ME: You have had an exceptional public career. Why are so many engineers not engaged with the public?

G.W.C: I don't think they prepare themselves. They let themselves become highly specialized, and so they can't contribute when we talk about the world's larger issues. Universities are partly to blame, because they reward specialization and care less about general knowledge. There's also the fear factor. Engineers are often afraid to get out of their comfort zone. To be successful in the larger sense, you have to get out of your comfort zone. I am out of my comfort zone every day I'm here. **ME**

Spanish researchers are developing a system that can tell when a driver is dangerously fatigued.

CARS THAT KEEP DRIVERS AWAKE

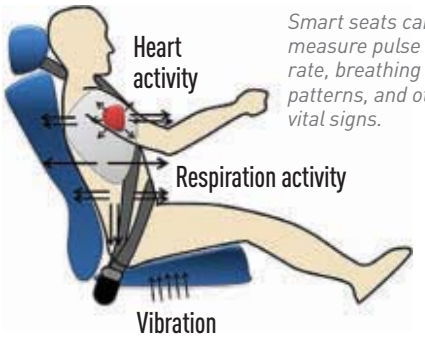
THE MOST DANGEROUS DRIVER ON THE ROAD IS THAT ONE SO fatigued that he can barely stay awake. Now, researchers report that they are developing a system that would enable a vehicle to monitor a driver's vital signs and warn him if he shows signs of fatigue.

According to European statistics, fatigue is implicated in more than 8 percent of all car crashes and as many as 35 percent of serious accidents. This implies nearly 100,000 accidents and about 125,000 injured people in the European Union every year.

To guard against fatigue, the newly developed system measures when a driver is falling asleep and can then sound an alarm.

The system employs sensors embedded into the seat cover and the seat belt that can measure the driver's pulse and respiratory rates, together with a signal-processing unit to process the data in real time. Pressure exerted by the weight of the driver's body against the cushion and back of the car seat can be used to measure the flow of blood as the heart beats. Though not as accurate as an electrocardiogram, the data is detailed enough to show changes in heart rate.

According to researchers at the Instituto de Biomecánica de Valencia in Spain, where the system was developed, variations in heart rate and breathing patterns can indicate whether a driver is becoming drowsy.



Smart seats can measure pulse rate, breathing patterns, and other vital signs.

The system uses smart textile materials, composed by a combination of fibers and yarns with electrical properties, supported by the standard textiles of the seat and belt, to measure blood flow and breathing rates.

In addition to the Instituto de Biomecánica de Valencia, the University of Manchester in England, the Eesti Innovatsiooni Instituut in Estonia, and the auto parts manufacturer Fico Mirrors, S.A., contributed to the research. ME

JEFFREY WINTERS

AUTOMAKERS TO DRIVE STRONG GROWTH IN METROLOGY

COORDINATE MEASURING MACHINES will account for about two thirds of a more than $1 billion dimensional metrology market in the automobile industry, according to a recent analysis from Frost & Sullivan.

The overall dimensional metrology market in the automotive industry is forecast to rise from a 2013 baseline of $949 million to more than $1,225 million in 2018, an increase of 29 percent. The factors driving this demand, Frost & Sullivan reports, include the growth in automation of automotive manufacturing plants and a renewed focus on reducing the weight of cars and trucks.

Frost & Sullivan sees a trend toward more use of inline metrology, in which automated measurements are integrated into the production line. That segment of the metrology market is expected to grow at a 12 percent annual rate. Inline metrology is compatible with assembly lines using robots rather than workers. The trend toward automation will see inline metrology replacing coordinate measuring machines, though CMMs will continue to dominate the market.

INLINE METROLOGY WILL GAIN ON COORDINATE MEASURING MACHINES.

Other metrology market segments for the automobile industry include vision measuring machines, measurement gauges, and optical digitizers and scanners.

Also, the report forecasts that the Asia-Pacific automotive industry will see the largest growth in dimensional metrology sales. As of 2013, the European, North American, and Asia-Pacific markets were roughly equal, with each region accounting for between 29 and 33 percent of global sales.

The report, "Analysis of the Dimensional Metrology Market in the Automotive Industry," was published by Frost & Sullivan in June.

Penn State professor Jack Langelaan (right) helps a graduate student attach the wings to the fuselage of a robotic glider in the Air Vehicle Intelligence and Autonomy Lab.

ABOVE THE EARTH

The unmanned aerial vehicle can be used for more than military service. One laboratory seeks ways to keeps drones aloft for a long time on their own so they can serve to monitor weather or crops. Another lab looks at a quiet, efficient means of thrust for airplanes.

FLOAT LIKE AN ALBATROSS

THE LAB The Air Vehicle Intelligence and Autonomy Lab, Pennsylvania State University, State College; Jack Langelaan, associate professor.

OBJECTIVE To create planning and control algorithms for the autonomy of robotic flight vehicles.

DEVELOPMENT Working to derive algorithms that allow aerial gliders to ride without human help on vertical wind shear or on thermals.

Jack Langelaan and his team at Penn State see many civilian possibilities for robotic flight vehicles, or drones: from crop surveys to low-altitude meteorology. But those uses will require planes that can glide on their own for long periods of time.

To get there, Langelaan and his team are working with colleagues at Lehigh University of Bethlehem, Pa., to make dynamic soaring autonomous. The goal is to develop software on board the drones that will allow them to fly for long periods of time without stopping, Langelaan said.

The team first looked to the albatross, which takes advantage of vertical wind shear—the difference in wind speed with the changing altitude—to stay aloft for days and fly thousands of miles over open ocean while hardly flapping its wings.

Starting under its own power in the calm trough between waves, the albatross climbs above the wave, where the increasing headwind boosts its speed in relation to the air. Then, turning, it dives back down,

again using the change in wind velocity to increase airspeed.

"Our part is, given data that we can measure from the airplane, to build up a computer map of what the wind field looks like so that we know the wind velocity as it changes," Langelaan said. "Then we can use that information to figure out the best way to fly."

The other avian technique that Langelaan's lab seeks to imitate is soaring on thermals, the way hawks and vultures do. A thermal occurs where the sun heats up the ground unevenly, resulting in hot spots that combine with an unstable atmosphere to create pockets of rising air.

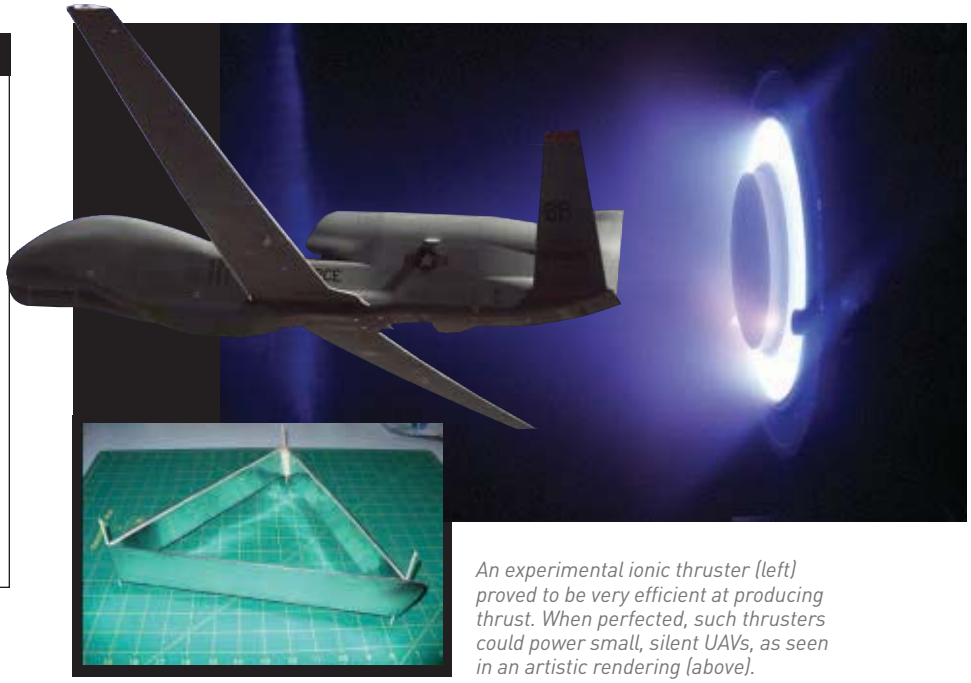
Langelaan's lab is working to deploy planes in flocks whose individual members can communicate via software to share information on thermal locations.

SILENT FLIGHT

THE LAB Laboratory of Aviation and the Environment, Massachusetts Institute of Technology, Cambridge; Steven Barrett *(left)* director.

OBJECTIVE To better understand how to minimize the environmental impacts of aviation.

DEVELOPMENT The first steps toward electrohydrodynamic thrust for air propulsion, especially for surveillance vehicles.



An experimental ionic thruster (left) proved to be very efficient at producing thrust. When perfected, such thrusters could power small, silent UAVs, as seen in an artistic rendering (above).

Ionic wind could be used as a silent, efficient propulsion system for small, lightweight aircraft, according to Steven Barrett at MIT.

When a current passes between two electrodes—one thinner than the other—it creates a wind in the air between. If enough voltage is applied, the resulting wind can produce a thrust without the need for propellers or jet engines. This phenomenon is called electrohydrodynamic thrust, or ionic wind.

Experiments run in Barrett's Laboratory of Aviation and the Environment have found ionic thrusters may be a far more efficient source of propulsion than conventional jet engines. In their experiments, the researchers found that ionic wind produces 110 newtons of thrust per kilowatt, compared with a jet engine's two newtons per kilowatt, Barrett said.

In addition to their relatively high efficiency, ionic thrusters are ideal for surveillance vehicles as they are silent and do not give off heat, making them invisible in infrared. To measure an ion thruster's efficiency, the team built a simple ionic thruster setup and hung it under a suspended digital scale. They applied tens of thousands of volts. They altered the distance between the electrodes, and recorded the thrust as the device lifted off the ground.

Barrett has acknowledged one big obstacle to ionic wind propulsion: thrust density, or the amount of thrust produced per given area. Ionic thrusters depend on the wind produced between electrodes; the larger the space between electrodes, the stronger the thrust produced. That means lifting a small aircraft and its electrical power supply would require a very large air gap. Electrodynamic thrusters for aircraft—if they work—would encompass the entire vehicle, he said.

Another drawback is the voltage needed to get a vehicle off the ground: Small, lightweight balsa models require several kilovolts. A small craft with onboard instrumentation and a power supply would need hundreds or thousands of kilovolts, he said.

"The voltages could get enormous," Barrett said. "But I think that's a challenge that's probably solvable." Power might be supplied by lightweight solar panels or fuel cells, he added. ME

TRASH CAUSES MORE POLLUTION

GETTING RID OF TRASH IS NOT JUST A NEVER-ENDING CHORE; it is a health priority. But one common method for disposing of waste—open burning—is a bigger threat to human health and the global climate than previously thought.

That's the conclusion of a team of researchers from the National Center for Atmospheric Research in Boulder, Colo., who have published the first country-by-country estimates of pollutants such as particulates, carbon monoxide, and mercury that are emitted by trash burning.

Unlike emissions from commercial incinerators, trash burned in open fires is generally done by individuals and is not reported to local authorities. This means it is left out of many inventories of national air pollution and is not incorporated into policy making.

To estimate emissions from trash fires, chemical engineer Christine Wiedinmyer and her colleagues at NCAR compared population figures and per capita waste production with official figures of trash disposal. They estimated that each year 1.1 billion tons, or 41 percent of the total waste generated worldwide, is disposed of through unregulated burning.

The study found that unregulated trash burning emits vast amounts of pollution—as much as 29 percent of the reported global levels for small particulates (those less than 2.5 micrometers in diameter) and 64 percent of reported levels for polycyclic aromatic hydrocarbons. In China, the emissions are equivalent to 22 percent of reported emissions of particles larger than 10 micrometers.

Those pollutants have been linked to heart disease, respiratory illnesses, and cancer.

The levels of greenhouse gas emissions appears to be lower, with trash burning accounting for about 5 percent of human-related emissions.

The researchers stressed that this estimate is still rough, and could be higher or lower by a factor of two.

The study was published in August in the journal, *Environmental Science and Technology.*

EASIER THINKING INSIDE THE BOX

TWO RESEARCHERS SAY THEY MAY have quantified why it's so hard for humans to "think outside the box."

They found monkeys could learn a concept more easily when it only requires nerve cells to rearrange existing patterns than when it requires the nerve cells to generate new patterns. Meaning it's easier to learn something new when you've already mastered a skill pretty close to what you're learning. A concept or process that doesn't call on any skill set you already have will take longer to master.

Aaron Batista, an assistant professor of bioengineering at the University of Pittsburgh, worked with Byron Yu, assistant professor of electrical, computer, and biomedical engineering at Carnegie Mellon University to explore the brain's capacity to learn through recordings of electrical activity of brain cell networks.

The findings may eventually lead to new treatments for stroke as well as other neurological disorders, he said.

The human brain contains nearly 86 billion neurons, which communicate through intricate networks of connections. So understanding how the neurons and the networks collaborate to learn something new can be challenging.

The researchers combined brain-computer interfaces and machine learning to study patterns of neurons among monkey brains. As the animals learned to use their thoughts to move a computer cursor, the scientists recorded how their neurons fired.

They found the animals used a small set of favored firing patterns to move the cursor.

When the team reprogrammed the link between brain and cursor movement they found monkeys easily relearned how to move the cursor if they could use a pattern within their favored firing patterns. So if a firing pattern originally caused the cursor to move to the top of the screen, the interface would move the cursor to the bottom. The change was easy for the monkeys.

They had a much harder time when the interface required patterns of neural activity that were outside their favored firing patterns.

The researchers speculated that, for humans, thinking outside the box requires more difficult changes in neural activity. ■

GONE THE WAY

DURING ONE WINTER ABOUT SIX YEARS AGO, Brian Nagamatsu realized he had a problem. "I was actually living at the time in Glenville, N.Y.—upstate New York where they get lots of snow," he said.

What was a typical situation for millions of Americans living in snow- and ice-prone regions became grounds for a challenge for Nagamatsu. As a self-described inventor with a B.S.M.E. from Union College and an M.S.M.E. from the University of Illinois, Nagamatsu didn't sit by while snow collected around his home. Instead, he took his leaf blower and went outside. "I was interested in seeing how a leaf blower would do blowing snow," he said. "So, I took my leaf blower and I stuck it into a big snow pile."

Unfortunately for Nagamatsu, the snow blew back and turned him into a living snowman. Rather than give up, Nagamatsu continued tinkering with his new idea. "I started thinking, 'What happens if I put a blade on the end so that the snow wouldn't blow back towards me [but instead] would blow away from me and move the snow?' "

"I WAS INTERESTED IN SEEING HOW A LEAF BLOWER WOULD DO BLOWING SNOW. SO ... I STUCK IT INTO A BIG SNOW PILE."

Six years later, the AirJet Shovel had a home on Amazon and Home Depot's websites.

The AirJet Shovel is an extension piece designed to fit the round exhaust pipe of a leaf blower with an ideal output of 400 CFM or more. The shovel utilizes the powerful air flow of leaf blowers to disperse snow and clear the ground. Its blade and skids assist in navigating surfaces such as sidewalks and decks. The shovel is held to the snow blower pipe by a Velcro tape fastener.

The idea sounds simple enough, but the path to production required several versions of the AirJet Shovel. From a simple prototype of a single outlet port hole in a piece of flat board, the AirJet Shovel evolved to include two, and even four, ports for air. As Nagamatsu streamlined back to a single port for manufacturing, he also added and later removed wheels on the shovel, according to the AirJet Shovel's website. They were replaced by skids. The final result is a simple tool that extends the useful season of a leaf blower from autumn into winter.

OF THE LEAVES

The AirJet Shovel is designed to blow away light accumulations of snow.

Now that he lives in Utah, Nagamatsu said he found the AirJet Shovel worked well in clearing powder snow. "You want to use it in the lighter snow and also for cleanup from heavy snow," he said. "But don't expect it to replace a two-stage, six-horsepower snow blower."

With winter right around the corner, Nagamatsu said the shovel would make a great gift. "The kids will be fighting over it! It's totally different and fun for using," he said. "If someone has a leaf blower, then it's kind of a no-brainer."

Up next: Nagamatsu said his company was looking at getting the AirJet Shovel into retail outlets and taking the AirJet Shovel to the streets—as a snowplow attachment for pickup trucks. **ME**

B.L. LOGAN is a journalist who is studying at the Institut d'études politiques de Paris.

CRYOGENIC REFRIGERATOR

BY WALTER H. HOGAN, MEMBER ASME, AND ROBERT W. STUART, DIVISION 500, ARTHUR D. LITTLE INC., CAMBRIDGE, MASS.

Freezing below 100 K has seen a range of applications, from superconductivity to cryonics, the preservation of the dead until they can be cured of what killed them. Two experts in the field looked at options 50 years ago.

During the past decade, basic research has uncovered many opportunities for commercial devices that require liquid-helium temperatures. In response to this challenge, some engineers are facing problems of designing suitable refrigeration equipment, and others the arduous task of evaluating the potential success, reliability, and ultimate cost of competing systems for both laboratory and field applications. This paper discusses some of the more important design considerations peculiar to miniature (below 10 W) refrigeration at liquid-helium temperatures.

Since only a few materials remain fluid in the region below 100 K, the choice of refrigeration means and refrigerants is limited. All systems depend on gas expansion, either (a) isenthalpic (Joule-Thomson) with no work removal, or (b) one of the systems utilizing work extraction to reduce the energy content and therefore the temperature of the gas. The latter systems always provide more refrigeration per unit of power input and per unit of gas circulated. However, because of its extreme mechanical simplicity, Joule-Thomson expansion still remains one of the primary mechanisms for refrigeration production. A combination of both systems is normally used for helium temperature refrigeration. ...

An ideal Carnot refrigerator would require 75 W input to support a 1 W refrigeration load at 4 K. In a real situation, however, heat exchanger, expansion engine, and compressor inefficiencies and other losses result in a practical input of 2,000 W to achieve the same refrigeration load capability.

Compared with the ideal system, the practical system has a thermal efficiency of less than 5 percent, and this seemingly poor efficiency is obtained even though the engineer can assume good efficiency in heat exchangers, expansion engines, and compressors. Thus it should be readily apparent that even small departures from ideality can have serious consequences in the design of real systems.

The two most successful miniature liquid-helium temperature refrigerators developed to date both depend on reciprocating expansion engines to refrigerate an external Joule-Thomson loop. ...

Since refrigeration is so difficult to achieve at low temperatures, it is necessary to conserve refrigeration to the maximum extent. The design of the insulation for a cryogenic system is a special field in itself.

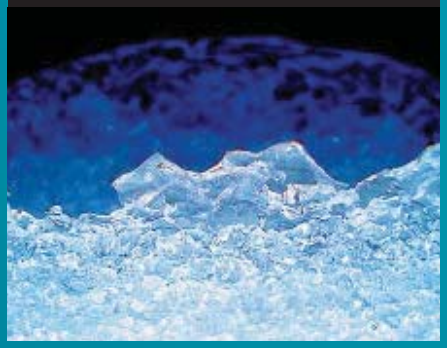
The types of insulation used are gas-filled powders and foams, evacuated powders, radiation shields, and super-insulation (made of layers of a reflecting foil separated by poorly conducting spacers). Gas-filled systems are used only at high temperature, because most gases liquefy below 77 K. ME

LOOKING BACK

Cryogenics was an emerging field when this article appeared in October 1964.

CRYOGENIC IMMORTALITY

In December 1963, 10 months before "Cryogenic Refrigerator" appeared in *ME* magazine, Evan Cooper, author of *Immortality: Physically, Scientifically, Now,* formed the Life Extension Society, the world's first cryonics organization. By 1970, perhaps discouraged by the belief that cryonic preservation would not be practical in his lifetime, Cooper abandoned the field and took up sailing. He was lost at sea in 1983.



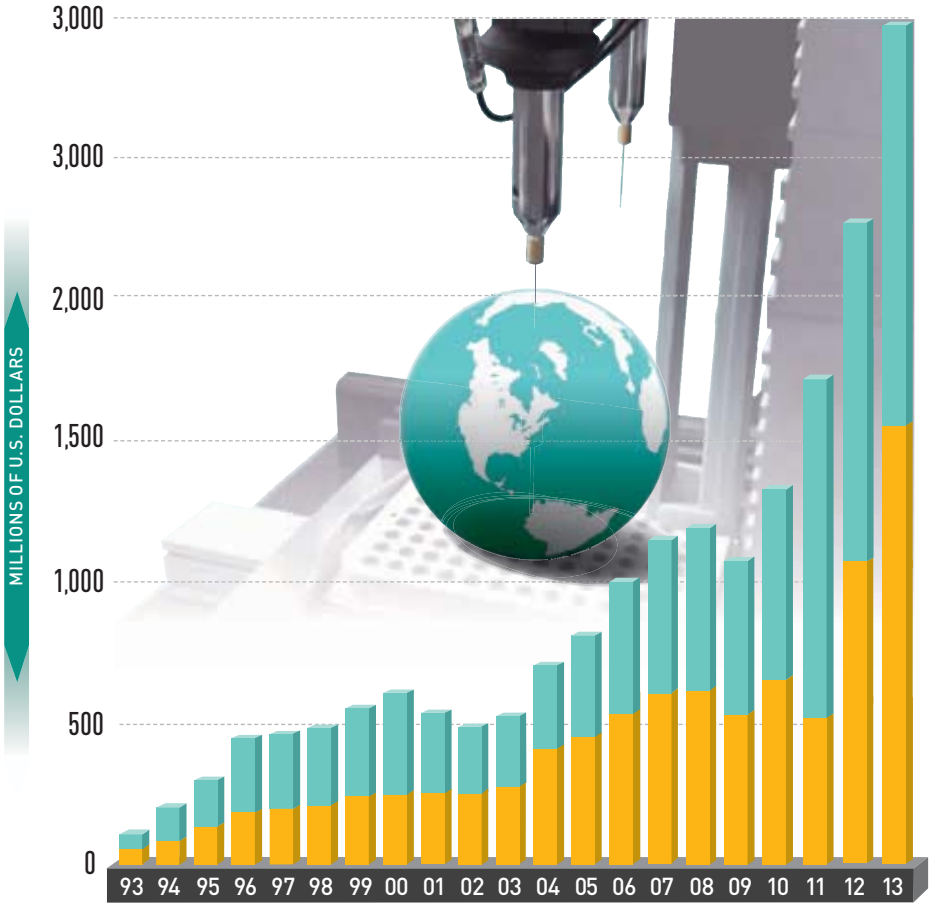
BY THE NUMBERS: GROWTH BY ADDITION

Whether it's referred to as additive manufacturing or three-dimensional printing, the sector continues to surge.

GRAPH 01

1993–2013 WORLDWIDE ADDITIVE MANUFACTURING REVENUES IN MILLIONS OF U.S. DOLLARS

SOURCE: *Wohlers Report 2014*



GRAPH 1 Revenues for additive manufacturing products and services worldwide over the past four years are up significantly from previous years and the market has nearly tripled over that time. In this chart, the lower segment of the bars represents products, while the upper segment represents services. Neither category includes secondary processes such as tooling, molded parts, or castings.

Additive manufacturing systems for metal parts are increasingly popular, according to *Wohlers Report 2014*. The additive manufacturing market in 2013, consisting of all additive manufacturing products and services worldwide, grew 34.9 percent, to $3.07 billion. This compares to growth in 2012 of 32.7 percent, to $2.3 billion. Industry-wide growth in 2011 and 2010 was 29.4 percent and 24.1 percent respectively, according to the report.

Terry Wohlers, founder and president of Wohlers Associates of Fort Collins, Colo., is principal author of the report, which includes an analysis of additive manufacturing and 3-D printing—terms that are used interchangeably, Wohlers said. The process is used for a range of applications across a number of industries.

The report was based on feedback from 82 service providers, 29 system manufacturers, and 70 co-authors in 24 countries, Wohlers said.

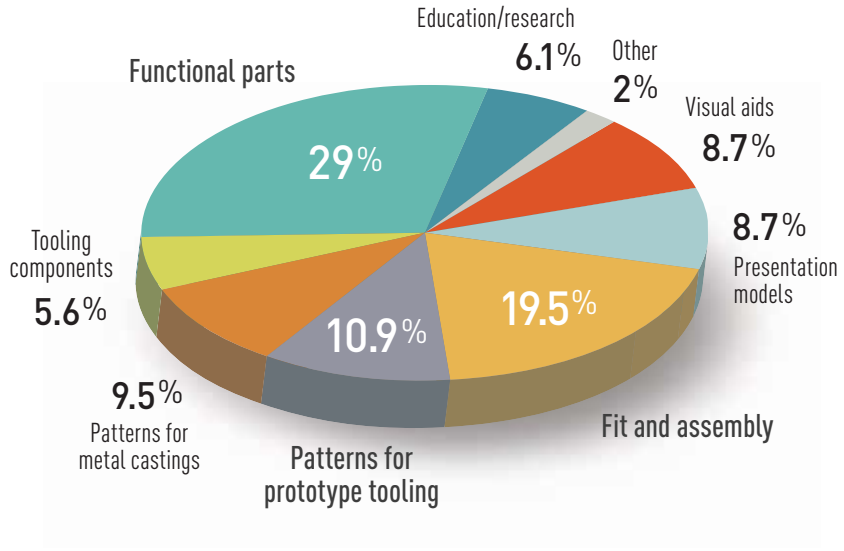
The estimate of $3.07 billion comprises revenues generated in the primary additive manufacturing market. This segment consists of all products and services directly associated with additive manufacturing processes worldwide. Products include additive manufacturing systems, system upgrades, materials, and items such as software and lasers. Services include parts produced on additive manufacturing machines and consulting services.

When broken out to look at revenues worldwide strictly from additive manu-

GRAPH 02

ADDITIVE MANUFACTURING BY APPLICATION

SOURCE: *Wohlers Report 2014*

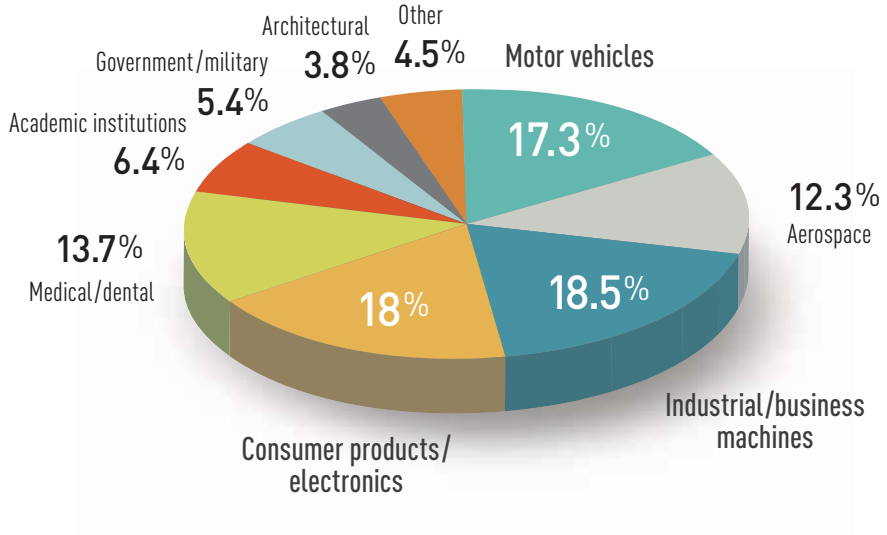


GRAPH 2 Customers of additive manufacturing companies are finding a wide range of uses for the 3-D printed parts. Functional parts account for 29 percent of the uses, but tooling and casting applications together account for almost as much.

GRAPH 03

INDUSTRIES SERVED BY ADDITIVE MANUFACTURING

SOURCE: *Wohlers Report 2014*



GRAPH 3 Half the revenues for additive manufacturing came from three industries: Motor vehicles, industrial/business machines, and consumer products. Total is less than 100% because of rounding.

facturing systems and materials, the report cited revenues at an estimated $1.5 billion in 2013, an increase of 44.5 percent, from $1.1 billion in 2012. This market segment grew by 28.8 percent in 2012, 28 percent in 2011, and 22.9 percent in 2010.

The report also looked at the emerging category of metal-based additive manufacturing. The report noted that 348 metal-based additive manufacturing machines were sold in 2013 compared to 198 in 2012, a 75.8 percent increase. The report first considered this segment in 2000, when fewer than 25 of these machines had been sold.

"Companies such as Airbus, General Electric, and Lima Corp. are using these machines to produce complex metal parts for next-generation aerospace and medical products," Wohlers said.

The 29 system manufacturers and 82 service providers interviewed for the report were asked which industries they serve and the approximate percentage of their revenues that they receive from each industry channel.

Industrial and business machines is the leading sector, growing 5.1 percent over 2012 and nudging past consumer products and electronics, the leading sector for the previous eight years.

The motor vehicles sector and medical and dental sector are third and fourth, respectively. The motor vehicle industry continues to use additive manufacturing for product development, although production volumes are typically too high to use the method for most final part applications, according to the report.

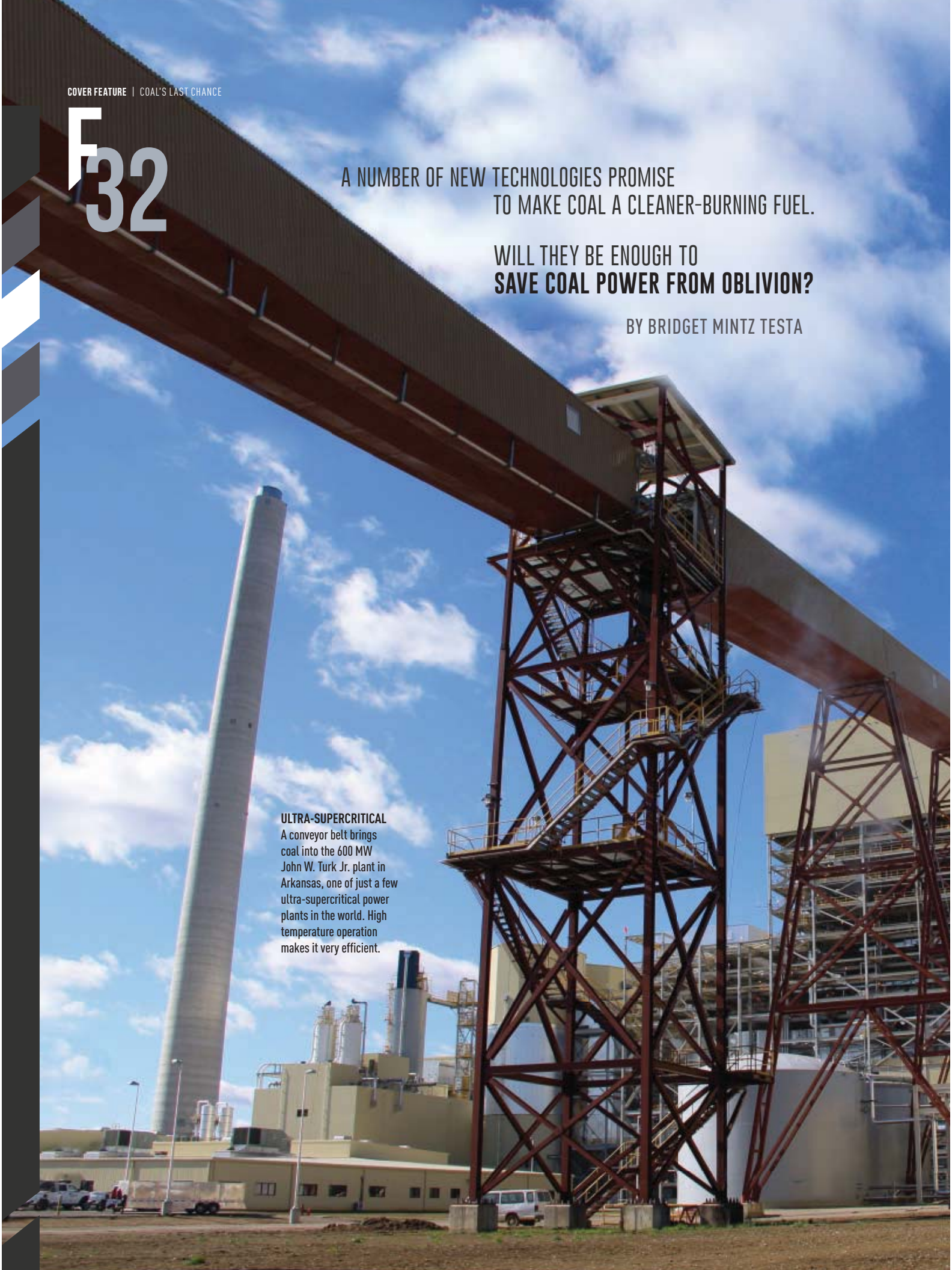
The consumer products and electronics category covers a range of products, including mobile phones, home electronics, and computers. **ME**

JEAN THILMANY

A NUMBER OF NEW TECHNOLOGIES PROMISE TO MAKE COAL A CLEANER-BURNING FUEL.

WILL THEY BE ENOUGH TO **SAVE COAL POWER FROM OBLIVION?**

BY BRIDGET MINTZ TESTA



ULTRA-SUPERCRITICAL
A conveyor belt brings coal into the 600 MW John W. Turk Jr. plant in Arkansas, one of just a few ultra-supercritical power plants in the world. High temperature operation makes it very efficient.

COAL'S LAST CHANCE

Hard as it may be to believe, some people see pollution as a positive.

In 1913, for instance, John J. O'Connor Jr., an economist with the Mellon Institute of Industrial Research, observed, "Because of the important part that coal has played in the industrial development of Pittsburgh and because the coal has been so poorly burned that it has given off great quantities of black smoke, Pittsburghers have come to regard smoke as a sign of prosperity."

But attitudes change, and in time smoke and soot were seen as a problem with coal that had to be cleaned up. The coal power industry responded with measures to reduce visible smoke and soot pouring out of industrial chimneys. A lot of other coal users, however, switched to cleaner-burning oil. Coal survived and remained dominant in the power industry, but lost its status as the ubiquitous fuel of American industry.

Today, pollution from coal is again a problem. It's not dark clouds of soot and smoke this time, but rather invisible emissions—toxins like mercury and sulfur dioxide and greenhouse gases such as carbon dioxide. Federal regulations now restrict the amount of toxins that coal plants can emit, and newly built power plants face strict carbon-emission limits. In June, the Environmental Protection Agency proposed carbon emission standards for the power industry that may make existing coal-fired thermal generating stations uneconomical. Before that, many older coal plants were already scheduled for retirement.

And just like a century ago, pollution concerns aren't the only thing squeezing coal. A bonanza of

clean-burning natural gas unlocked by hydraulic fracturing has utilities and merchant generators adding capacity via gas-fired boilers and turbines. Between 2014 and 2017, the power industry intends to add more than 22,500 MW of net gas-fired generating capacity; coal is scheduled to lose more than 21,000 MW of net capacity.

Stricter regulations and fierce competition from gas don't necessarily spell the end of coal, but any new coal-fired power plants likely will be different from the fleet we have today. If coal power can be saved, it will be through so-called clean coal technologies that promise to produce electricity with fewer emissions.

Whether these technologies can compete in the market with natural gas and fulfill promises of pollution-free power remains to be seen.

In the flatlands of southwest Arkansas between Hope and Texarkana rises one of the new plants that the coal industry is pinning its hopes on. The 600 MW John W. Turk Jr. power plant built by American Electric Power near Fulton is the first "ultra-supercritical" electric-generating clean coal unit in the U.S. There are just a few in the world.

"Conventional, pulverized coal technology dominates the market," said Howard Herzog, a senior research engineer at the Massachusetts Institute of Technology in Cambridge and head of its Energy Initiative, which focuses on clean coal. "Ultra-supercritical is just the most efficient subset of those plants."

Conventional power plants start by grinding coal to the consistency of baby power. That coal is then blown into the boiler (or furnace), which is lined with water-filled tubes. The burning coal boils the water to produce steam, which turns turbines, which spin a generator, which produces electric power. One drawback is the energy it takes to boil the feedwater, since while water changes phase its temperature remains constant.

"A conventional sub-critical unit operates at 2,400 psig to 2,600 psig and at around 1,000 °F," said Turk plant manager Tim Gross. "If you could go from water to steam—skipping the boiling period altogether—you'd save lots of energy."

Plants that do just that operate at temperatures between 1,000 °F and 1,050 °F and at pressures above 3,500 psig. Under these conditions, water exists in a state that is neither liquid nor gas, but in a "supercritical" state that allows for the flash generation of steam without the energy-absorbing step of boiling. As a thermodynamic concept, supercritical steam generation has been around for many decades, but it wasn't until the 1990s and early 2000s that carbon steel alloys were available that could handle those supercritical conditions.

But Turk is ultra-supercritical, which means even higher temperatures. "Turk's main steam is at 1,100 °F, and the reheat steam is at 1,125 °F," Gross said. "The metallurgy wasn't there for the long 15-year lifespan of a power plant. The integrity of the metal wouldn't support those [ultra-supercritical] extremes of operation."

Modern chromium- and nickel-based "super" steel alloys can withstand prolonged exposure to the brutal conditions without deforming. Turk's steam generator, steam turbine, and piping system all include components made of these metals.

The new alloys require equally new welding techniques, including special "filler" materials and careful, precise pre-weld heating and post-weld cooling. Gross said the new steels and welding processes were the biggest challenges during plant construction. But the exotic materials have a direct pay-off.

"You increase efficiency by going to

NIFTY: The 260 MW Polk Power IGCC Station in Florida uses a multistep process to turn coal into a syngas suitable for burning in a highly efficient gas turbine.

higher steam temperatures," Herzog said. Turk's efficiency is 39 percent to 40 percent, versus about 35 percent for conventional plants. Turk burns roughly 11 percent less coal than a subcritical plant would need to produce the same amount of power.

Less coal means fewer emissions, and what's left—aside from carbon dioxide—is further reduced by state-of-the-art emissions control technologies. Gross said that Turk is "as tight as or tighter than any other plant in the U.S."

And if one day the plant needs to capture its carbon dioxide emissions, the design allows for retrofits to accomplish that.

Ultra-supercritical plants are rare—another clean coal technology has seen wider adoption. The technology, circulating fluidized bed combustion, is found at 75 furnaces at 49 plants in the U.S., for a total capacity of 9,500 MW, according to Ventyx, an enterprise software provider for energy, mining, chemical, and other industries. There are hundreds more CFBC plants worldwide.

With CFBC, limestone (or some other sulfur-binding substance) and crushed coal are blown into a furnace by themselves or onto a bed of sand. Jets of hot air support the solids, allowing them to float on the hot air like a fluid, hence the adjective "fluidized."

The solids rise, ignite, and burn slowly at temperatures just under 1,600 °F—low enough to prevent nitrogen oxides from forming. Not all the coal is burned on the first pass. Partly burned coal, ash, and other bed material are carried along with the flue gases until they reach a cyclone, which extracts the larger particles and returns them to the combustion chamber. Coal particles may recirculate dozens of times until they are completely combusted.

"The hot flue gas [travels] from the cyclone to heat transfer units external to the furnace—superheater, reheater, and economizer—which produce steam for power," said Tim Fout, general engineer in the Systems Analysis Performance Division at the Department of Energy's National Energy Technology Laboratory. "The gases then flow to air preheating systems and additional environmental controls, if needed."

One of CFB'S greatest advantages is that since the furnaces burn at low temperatures, it can use very low-quality fuel, such as waste piles left over from mining and even chicken litter.

The EPA's Mercury and Air Toxics Standards, which earlier this year withstood a legal challenge, calls for some 40 percent reductions in sulfur dioxide emissions and 90 percent reductions in mercury.

Unfortunately, CFBC offers no special magic when it comes to mercury; conventional mercury emissions technology will be needed to meet the MATS. The news is better for sulfur dioxides, though. Limestone in a CFB is a sorbent for sulfur dioxide. Dolomite is another. Thanks to the long times that the bed particles, including the limestone, remain in the furnace, as much as 95 percent of the sulfur dioxide produced by burning coal in a CFB can be captured.

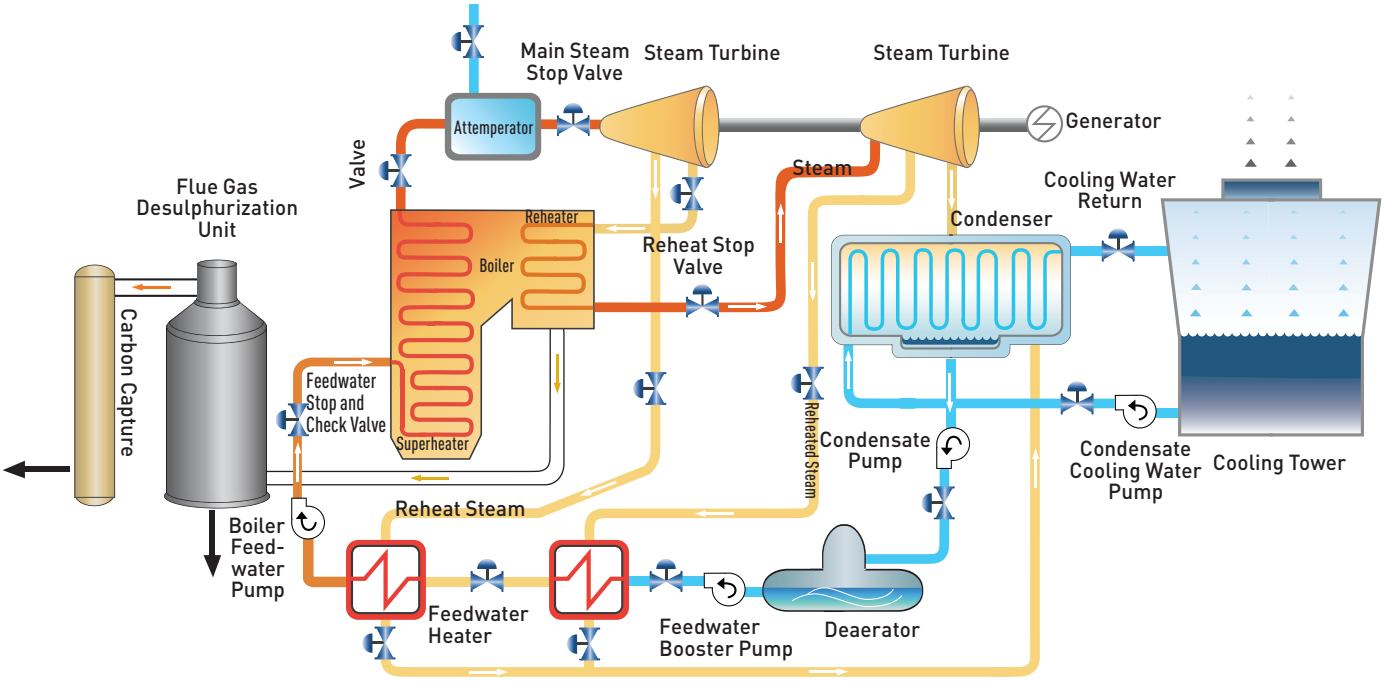
For some people, that's clean enough. But if coal power is to thrive in a landscape where carbon dioxide is treated as pollution, then other technologies may be in order.

Gasification is one of those technologies. The process itself is centuries old. By the start of the 20th century, gas works were found in just about every major city, converting coal into a number of industrial products—coke, tar, ammonia, to name a few—by heating the mineral in a low-oxygen environment. Instead of burning, oxygen and steam reacted with the carbon to make a gas mixture that could feed other industrial processes or be piped to customers for lighting and heating purposes. This was the town gas of the "gaslight" era.

Natural gas supplanted town gas from coal, though gasification was still used to produce chemical feedstocks. In the 1990s, however, NETL helped fund some demonstration plants to test a technology called integrated gasification combined cycle, or IGCC.

One was the Polk Power IGCC Station in Mulberry, Fla. Tampa

ULTRA-SUPERCRITICAL STEAM GENERATOR



COAL'S LAST CHANCE

CLEAN COAL TECHNOLOGIES PROMISE TO GENERATE ELECTRICITY

Electric started construction in 1994. "First fire" was in July 1996, and commercial operations began on Sept. 30, 1996.

Polk's IGCC design—an "entrained-flow downward fire system"—is both complicated and ingenious. Power generation starts with two concurrent steps. The components of air are separated cryogenically, with oxygen sent in one direction and nitrogen in another. Meanwhile, coal and water are mixed into a slurry. Next, valves carefully meter the oxygen and the slurry as they enter the gasifier, which is about 35 feet tall and 15 feet in diameter. It operates at 375 psig and an average 2,500 °F.

"Partial combustion of the slurry and oxygen in the gasifier produces carbon monoxide and hydrogen," said Mark Hornick, director of engineering and project management at Tampa Electric. "Both are fuel gases, and hydrogen is used as a fuel in the combustion turbine."

It can't go there yet: the 2,500 °F raw syngas from the gasifier is too hot to travel. It is also anything but pure, containing fly ash, chlorides, water, sulfur, and particulates. If that gunk went through the combustor to the gas turbine, it would "be like sand in an engine," Hornick said. "A combustion turbine is like a jet engine bolted to the ground. You have to have clean fuel."

The next step, then, for the syngas is a byzantine, multi-step journey through the plant involving various coolers and mechanical and chemical scrubbers. Along the way, up to 15 percent of the heat energy from the hot syngas gets recovered. By journey's end, the syngas reaches ambient temperature and perfect purity, and it's ready to enter the combustor to drive the gas turbine.

And the nitrogen? This wholly non-combustible gas also plays a vital role in power generation.

"The biggest challenge with coal gasification is that it produces one-third of the BTUs that natural gas does," said Hornick. "The nitrogen from the air separation unit goes through the combustion turbine. The additional mass flow from the nitrogen produces power. But because it's introduced right at the combustion chamber, it also moderates the peak flame temperature. Nitrogen oxide production is very strongly related to the combustion temperature. By using that nitrogen, we lower that peak flame temperature and therefore have lower emissions of nitrogen oxides."

After exiting the turbine, the still-hot gases are sent to a heat recovery system to produce steam to power a second turbine. Between the two turbines, 260 MW is generated, and at higher efficiency than a conventional plant. But IGCCs are not as efficient as combined cycle gas turbines running on natural gas. That's because some of the coal's energy is needed to run the gasification process. Depending on the type of coal and the specifics of the plant, efficiencies can run anywhere between 38 and 43 percent.

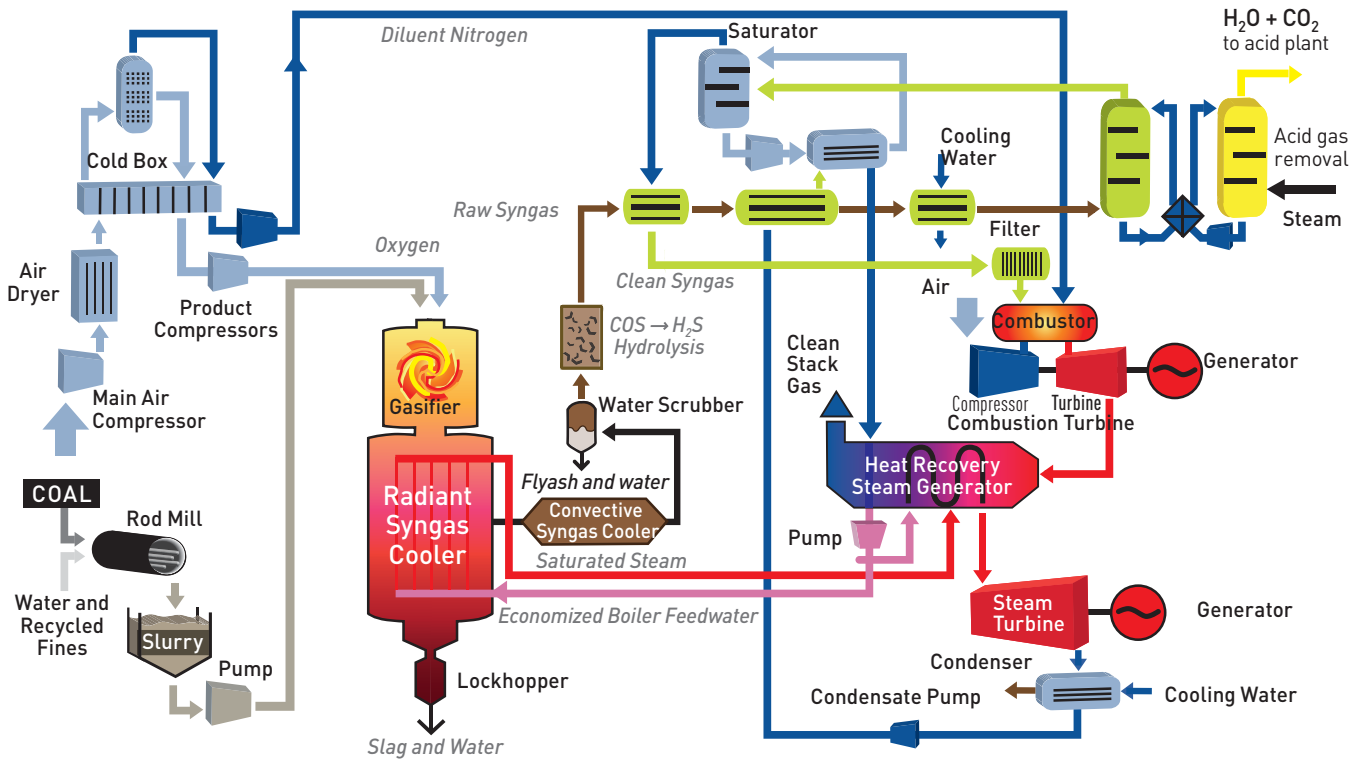
On paper, it makes for a nifty process. But a look at the sporadically updated DOE Gasification Database indicates that nearly all proposed IGCC plants in the U.S. have been indefinitely delayed or canceled. The two currently active American IGCC projects, Duke Energy's Edwardsport Plant in Indiana and Southern Company's Kemper Plant in Mississippi, have encountered not only repeated delays but also cost overruns.

Southern Company's initial cost estimate for the Kemper plant was $2.97 billion; by 2013, the price had ballooned to $5.04 billion. The plant's start date, originally scheduled for May 2014, has been pushed back to December.

Edwardsport's cost estimate ran from an initial $1.9 billion to the latest figure of $3.5 billion. The plant "fired up" for just six days in June 2013, and then intermittently for the rest of that year. In February 2104, it briefly started up again, though power production was less than 1 percent of capacity. As of May, the plant was not operating.

Kemper and Edwardsport's problems aren't unusual. A 2013

INTEGRATED GASIFICATION COMBINED CYCLE



WHILE PRODUCING FEWER EMISSIONS.

report from the International Energy Agency's Clean Coal Centre described typical IGCC problems—plant complexity, high expenditures, equipment and materials costs, market risks from natural gas, and up to five years of shake-down and troubleshooting.

"IGCC needs a long wait before it's commercially viable," said Sowmya Srinivasan, an energy analyst for U.K.-based Global Data.

MIT's Herzog agrees. "Experiences with gasification plants haven't been great," he said. "I don't see people going to gasification unless it's cogeneration with electricity."

An IGCC plant may produce less carbon dioxide than most other coal-fired power plants, but it could still emit a lot. Ultimately, the solution for coal power plants may be to divert greenhouse gas emissions before they enter the atmosphere and lock them away, which is colloquially known as carbon capture and storage.

In some ways CCS is like natural gas production in reverse. The carbon dioxide stream is compressed and pumped down a pipe to a deep geological stratum under an impervious layer. In theory, the gas would stay locked down there pretty much forever.

"CCS has been tried and tested in a segmented fashion for enhanced oil recovery," said Srinivasan. "But large-scale implementation of the technology for power production has never been done." One plant intended to demonstrate the technology, called FutureGen, has yet to get off the drawing boards.

In the oil and gas industry, "the streams coming out are relatively pure carbon dioxide," said Richard Esposito, an engineer and geologist with Southern Company who also works closely with the Southeast Regional Carbon Sequestration Partnership program, funded by the U.S. Department of Energy. "In the power industry, you have to pull the carbon dioxide out of the flue gas," he said. "Only 6 percent to 8 percent of the stream is carbon dioxide." The rest is made up of the chemicals in the air that the coal was combusted in: mainly nitrogen, but also oxygen and some trace components.

Burying carbon dioxide isn't so simple, either. According to Esposito, a power plant could emit up to five million tons of carbon dioxide a year for 40 to 50 years. That's up to 250 million tons of the gas from one power plant. You'd need a big carbon sink for that, and sometimes, there just isn't one.

The Southeast Regional Carbon Sequestration Partnership program is one of seven similar partnerships in the United States and Canada. Its goal is to find and investigate suitable, safe geological formations for long-term carbon dioxide storage. "Saline reservoirs and oil and gas fields are probably the best," Esposito said. "They provide relatively low-risk storage."

The ability to monitor stored carbon dioxide is critical. "You monitor the pressure and temperature in the reservoir," Esposito said. "Get a baseline, inject the carbon dioxide and watch the pressure rise. But you don't want to see any increase in pressure in the reservoirs above." Monitoring also includes seismic profiling and the resulting predictive models.

"CCS still has a lot of unproven technology," Srinivasan said. "Governments are keen on it, but power companies are backing away."

That statement could apply to clean coal technology in general, and so could this one: "If it were economical and technically feasible," said Dan Aschenbach, senior vice president of global project and infrastructure finance at Moody's Investment Service, "there would be people lining up to do it." ME

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

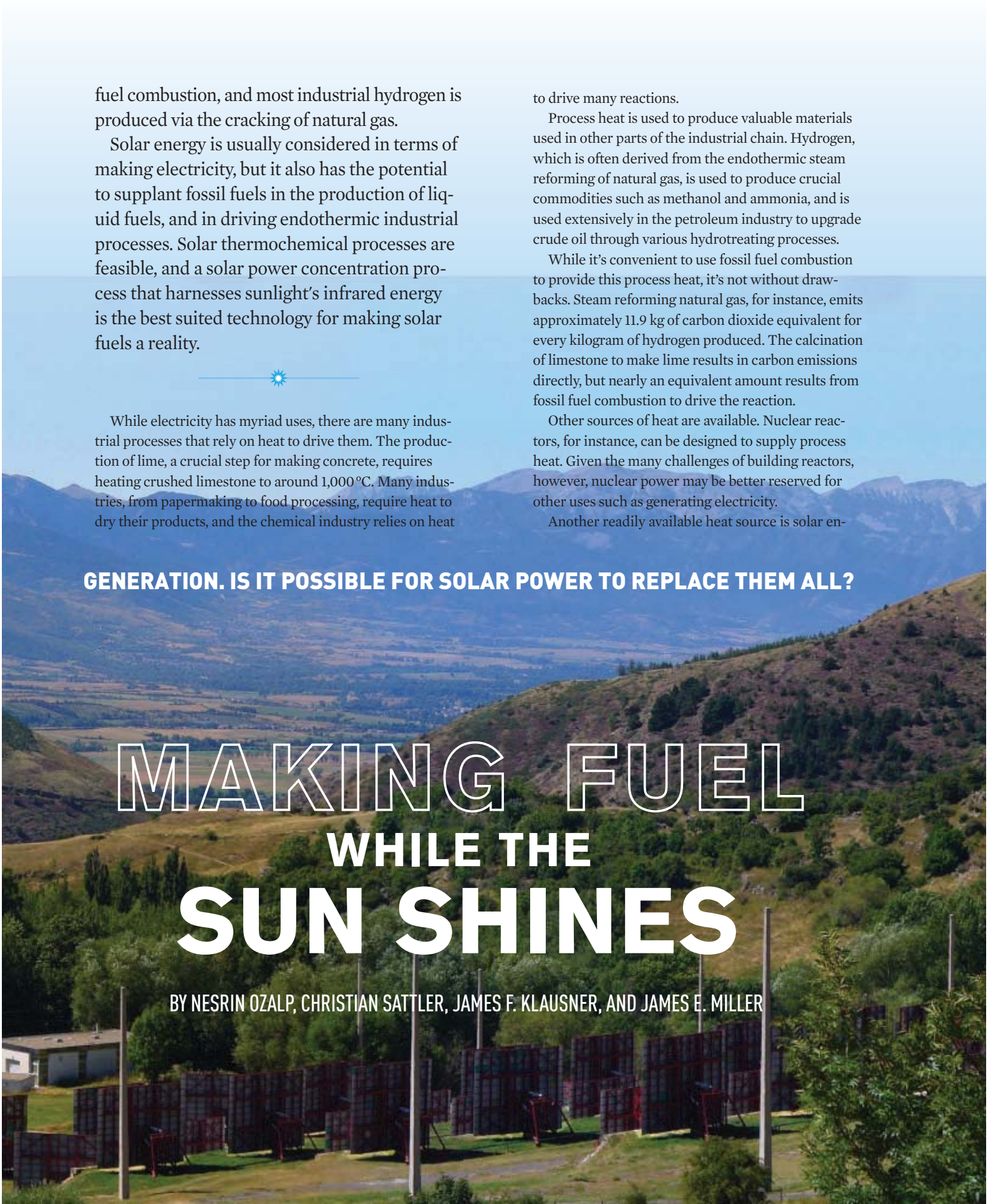
SOLAR ENERGY WAS ONCE VIEWED AS PIE IN THE SKY. Photovoltaic cells might be suitable for running pocket calculators or communications satellites, but they could not compete with electricity from conventional power plants.

BUT RECENT ADVANCES in the production of photovoltaic panels have driven down the cost of solar power. Estimates for the levelized cost of electricity from PV range from 10 to 30 cents per kWh. And though this is still higher than the cost of generation from a newly built coal-fired thermal power station, solar power could be the cheapest electricity available in some areas within a few years, according to data from the Energy Information Agency.

Solar energy supplanting coal in producing electricity would be a milestone, but it would scarcely be the end of fossil fuel. Of the nearly 80 quadrillion Btu of oil, gas, and coal that the U.S. consumes each year, only 25 quads—about 31 percent—are used to generate electricity.

Carbon-based fuels are critical to many sectors, such as transportation. Even if electric vehicles become common, it seems unlikely that airplanes will ever be battery powered. Process heat is another important application for fossil

FOSSIL FUELS HAVE A NUMBER OF INDUSTRIAL USES BEYOND ENERGY



MAKING FUEL WHILE THE SUN SHINES

GENERATION. IS IT POSSIBLE FOR SOLAR POWER TO REPLACE THEM ALL?

BY NESRIN OZALP, CHRISTIAN SATTLER, JAMES F. KLAUSNER, AND JAMES E. MILLER

fuel combustion, and most industrial hydrogen is produced via the cracking of natural gas.

Solar energy is usually considered in terms of making electricity, but it also has the potential to supplant fossil fuels in the production of liquid fuels, and in driving endothermic industrial processes. Solar thermochemical processes are feasible, and a solar power concentration process that harnesses sunlight's infrared energy is the best suited technology for making solar fuels a reality.

While electricity has myriad uses, there are many industrial processes that rely on heat to drive them. The production of lime, a crucial step for making concrete, requires heating crushed limestone to around 1,000 °C. Many industries, from papermaking to food processing, require heat to dry their products, and the chemical industry relies on heat to drive many reactions.

Process heat is used to produce valuable materials used in other parts of the industrial chain. Hydrogen, which is often derived from the endothermic steam reforming of natural gas, is used to produce crucial commodities such as methanol and ammonia, and is used extensively in the petroleum industry to upgrade crude oil through various hydrotreating processes.

While it's convenient to use fossil fuel combustion to provide this process heat, it's not without drawbacks. Steam reforming natural gas, for instance, emits approximately 11.9 kg of carbon dioxide equivalent for every kilogram of hydrogen produced. The calcination of limestone to make lime results in carbon emissions directly, but nearly an equivalent amount results from fossil fuel combustion to drive the reaction.

Other sources of heat are available. Nuclear reactors, for instance, can be designed to supply process heat. Given the many challenges of building reactors, however, nuclear power may be better reserved for other uses such as generating electricity.

Another readily available heat source is solar en-

ergy. The sun provides an average of around 1,000 watts per square meter of power during daylight hours, which by itself provides enough for some low-temperature processes such as food drying. (Some tomatoes are marketed as "sun-dried" for good reason.) Small reflectors have enabled solar-powered water heaters to be economical for domestic use.

To obtain the temperatures needed for large industrial processes, however, large arrays of mirrors are necessary. These arrays collect the sunlight falling on many square meters or even hectares and reflect it on receivers that heat up. A concentration factor of 500 to 1,000 can yield a temperature at the receiver well over 700 °C. A solar furnace in Odeillo, France, for instance, focuses light from about 2,000 square meters of mirrored surface onto a spot 60 cm across to produce temperatures in excess of 3,200 °C—easily hot enough to vaporize iron or nickel.

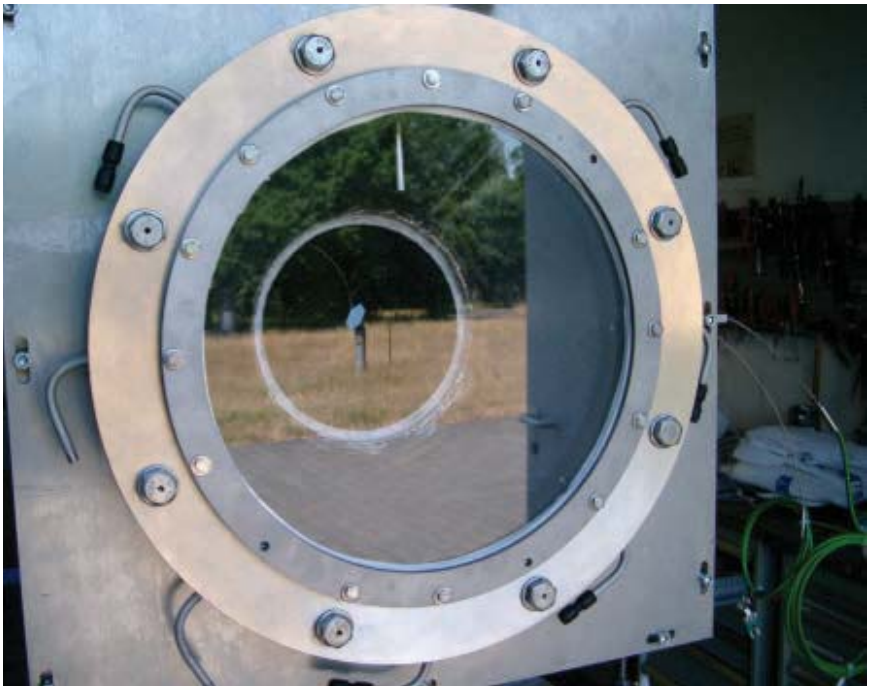
Vaporizing iron may have limited practical uses, but many industrial processes can be driven by heat from a large solar concentrator. Several research teams—including some that we have participated in—have shown the practicality of making hydrogen from water splitting via solar thermal reactions. In the most basic framework, steam flows over a high temperature metallic substrate, and as steam oxidizes the metal, hydrogen is released. Concentrated solar energy is then used to reduce the metal so that the cyclical steam oxidation can be repeated.

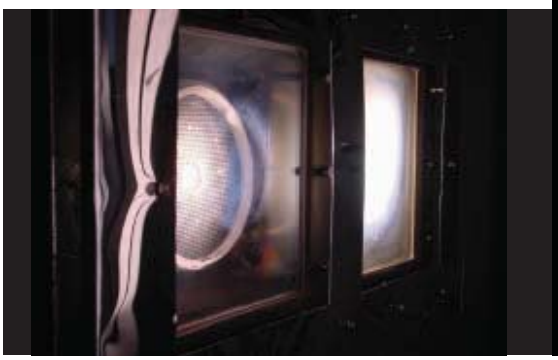
Such processes could entirely eliminate the emissions of carbon dioxide associated with fuel combustion. Other groups are working to use solar heat to crack methane for hydrogen production, which would produce fewer carbon and other hazardous emissions than current industrial practices.

One route to making hydrogen from natural gas via solar thermochemical processes produces carbon black instead of carbon dioxide as a byproduct. Carbon black is the most important technical carbon product after metallurgical coke. An important additive for rubbers, inks, batteries, and several polymers, it is also used in power generation, soil amendment, and environmental remediation. This method of hydrogen production could potentially provide the double benefit of being both CO_2-free and cost-effective, with the production of marketable carbon products defraying the expense of hydrogen. It is also possible to produce carbon nanotubes from natural gas by tuning the cracking process conditions.

Another area in which solar commodity production may have advantages over traditional industrial practice is in the separation of pure metal and oxygen from metal oxides found naturally in many ore deposits. For example, the use of solar thermochemistry to produce metallic magnesium from magnesium oxide appears to be quite promising. Advanced aluminum-magnesium alloys are essential in keeping vehicles, such as the new Ford F150

Solar reactors up close: A single-chamber reactor (below) for thermochemical reduction of metals; a two-chamber reactor at the German Aerospace Center (below right) for producing hydrogen; an iris mechanism (above right) for controlling incoming thermal power.





Facilities such as the Mont-Louis Solar Furnace (above) and the Odeillo Solar Furnace (right and on the opening pages) concentrate sunlight to conduct thermochemical experiments.

SOLAR FUELS CAN PROVIDE A STABLE AND STRATEGICALLY IMPORTANT ENERGY RESOURCE; SOME MAY CONSIDER THEM TO BE THE IDEAL SOLUTION FOR SUSTAINABLE ENERGY INDEPENDENCE.

production model, as lightweight as possible.

Solar thermochemistry could potentially have the biggest impact in the production of hydrogen-derived fuels which would be capable of replacing those derived from fossil fuels. Hydrogen can be used directly as a fuel, and advances in fuel cell technology may one day make it an attractive substitute for gasoline or diesel. But it is also possible to use solar heat to drive processes to create fuels that are compatible with the existing hydrocarbon infrastructure.

For example, methanol is readily produced via the catalytic reaction of hydrogen with carbon dioxide. This process has been commercialized with renewable hydrogen and recovered CO_2 by Carbon Recycling International.

Alternatively, solar thermochemical processes can produce carbon monoxide from carbon dioxide and hydrogen from water, or both can be produced from the solar steam reformation of methane, and the resulting gas mixture can be used to produce more conventional liquid fuels via the Fischer-Tropsch process. (That process is used today to make synthetic fuels, but the heat to drive the reactions comes from the combustion of a portion of the fossil fuel feedstocks.) Solar thermochemistry could plausibly produce a significant fraction of the world's transportation fuels in the long-term, as technological advancements continue increasing efficiencies and driving down costs.

IN SPITE OF THEIR APPEAL, solar thermochemical processes have the same drawback that direct solar power has: the transient and diurnal nature of sunshine. Fossil fuel-powered process heat provides the sort of constant temperatures and continuous operation that simplify industrial processes and controls. Fluctuations of available solar radiation—over the course of a day, across different types of weather, and from season to season—present considerable challenges for potential solar-thermal systems. Although there are economically affordable and commercially available solutions to some of those problems, substantial research and development is still required.

One common approach to dealing with fluctuations of solar energy is storing a fraction of the solar radiation as thermal energy. This can be done at a scale that manages short-term, transient variability such as the passing of a cloud or, if more energy is stored, to allow continued production for several hours after sunset. High temperature sensible heat storage in ceramic powders would enable such a process.

Several non-storage solutions can control the power and temperature of endothermic processes rendered through concentrated solar energy approaches that reduce peak power include the partial focusing/defocusing of the sun-tracking mirrors and the use of shuttering devices that can block a fraction of the sunlight entering the receiver. Varying the mass flow rate according to the incident solar flux is another widely used technique to maintain semi-constant temperature inside a reactor.

It would be best not to simply waste the solar power. The heliostat array can account for up to 60 percent of the capital costs of a solar thermal facility; so if possible, facilities should be designed to make full use of the light falling on the mirrors.

One promising approach to obtain semi-constant temperatures inside a solar reactor is an iris-like aperture mechanism that adjusts

the area of the opening through which solar energy enters the reaction chamber. The mechanism can dynamically increase or decrease the aperture as the solar flux changes. Such a mechanism has the potential to stabilize internal reactor operating conditions by minimizing radiation losses through the aperture and by responding to the fluctuations in solar flux by regulating the aperture area.

The optimum aperture size depends on the magnitude of direct normal insolation. For a particular time of the day, depending on the magnitude of direct normal insolation, there exists an optimum aperture size that can maintain the desired level of temperature inside the reactor. The power intercepted by the aperture as a function of its diameter can be calculated using the mean concentration ratio of the paraboloidal concentrator and the normal beam insolation.

An aperture size of 4 cm, for instance, intercepts a maximum of about 5.5 kW for a peak noon-time normal beam insolation of 981 W/m^2; in the morning and evening, when the insolation drops to 200 W/m^2 the same aperture size intercepts only 1.12 kW—a reduction of a factor of 5. To compensate, the aperture could open up to let in more radiation in the morning and evening, or conversely could iris down at midday so as to have a constant flux all day.

In order to compensate this dramatic change in power intercepted from morning to evening, a variable aperture might be used where the optimum size is set according to the incoming power level. Such a mechanism would conveniently work for smaller concentrating devices, such as solar furnaces.

When coupled with an energy recovery system that absorbs the sunlight that doesn't pass through the aperture, such a mechanism could make full use of the installed capacity of the heliostats irrespective of fluctuating solar radiation. For commercial solar tower installations, however, the proper control of the heliostat field will be more economical.

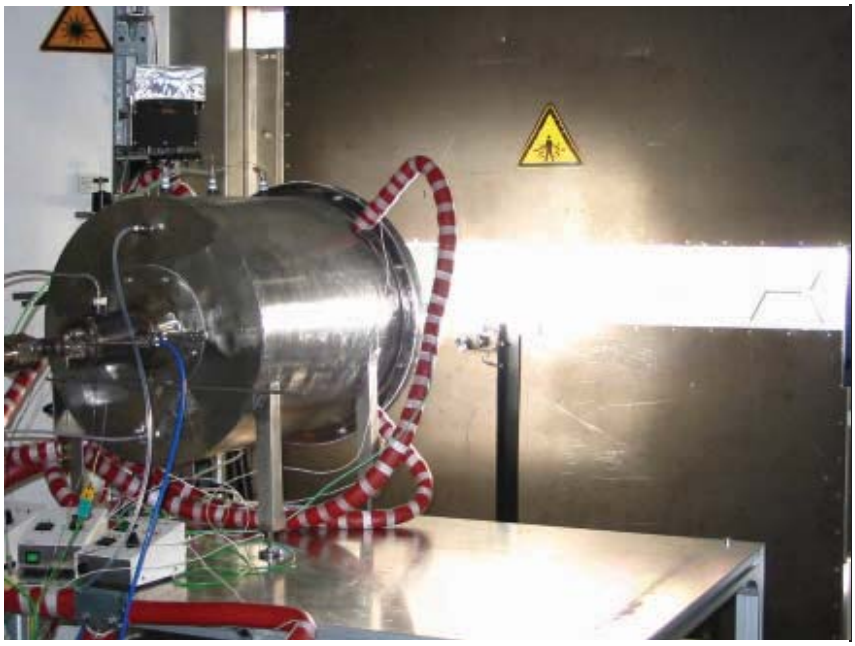
WHILE TECHNICAL CHALLENGES CAN BE MET, the factors that will ultimately determine whether solar fuels and commodities gain widespread acceptance are mostly economic. That's not the same as pure cost considerations: In markets where cheaper competitors are available, it's possible for a technology to gain an economic advantage if it meets other goals.

For solar fuels, one key benefit is the security of supply. Unlike fossil fuels, which are subject to depletion and to wide swings in prices due to the international nature of their markets, solar radiation will be available indefinitely and therefore is not dependent on economic and political changes. This means solar fuels can provide a stable and strategically important energy resource; some may consider them to be the ideal solution for sustainable energy independence.

Another strong case for solar-driven endothermic processes to supplement or even replace (over time) fossil-fueled endothermic processes concerns health. In many urban areas around the world, air pollution due to the combustion of carbon fuel is a major issue. Cleaner burning fuels from solar thermochemical processing would likely be welcomed in many places, especially China, which has notoriously opaque air.

One way in which air quality has been improved over the past century is the gradual replacement of carbon with hydrogen in commonly used fuels. Coal, which is mostly carbon by weight, was supplanted by oil and gasoline, mixtures that contain around twice as many hydrogen atoms as carbons, and then by methane, which has a hydrogen-to-carbon ratio of 4 to 1.

A solar fuel process to produce a syngas could increase the hydrogen ratio to around 6 to 1, or even remove the carbon component entirely if pure hydrogen was the final product. The benefit for society in the reduction



To Learn More

The following publications discuss many of the topics covered in this article.

M. Roeb and C. Sattler, "Isothermal water splitting," *Science*, 341, 470–471 (2013).

A. Singh, F. Al-Raqom, J. Klausner, J. Petrasch, "Production of hydrogen via an iron/iron oxide looping cycle: Thermodynamic modeling and experimental validation." *International Journal of Hydrogen Energy*, 37, 7442–7450 (2012).

E.B. Stechel and J.E. Miller, "Re-energizing CO_2 to fuels with the sun: Issues of efficiency, scale, and economics," *Journal of CO_2 Utilization*, 1, 28–36 (2013).

N. Ozalp, A. Toyama, D. Jayakrishna, R. Rowshan, and Y. Al-Hamidi, "Effect of camera-like aperture in quest for maintaining quasi-constant radiation inside a solar reactor." *ASME Journal of Mechanical Design*, 133, 021002–021008 (2011).

R.E. Bird and R.L. Hulstrom, "Simplified Clear Sky Model for Direct and Diffuse Insolation on Horizontal Surfaces," Technical Report No. SERI/TR-642-761, Golden, Colo. (1981).

S. Usman and N. Ozalp, "Numerical and optical analysis of solar power level adaptable solar reactor." *Heat Transfer Engineering*, 35(16/17), 1405-1417 (2014).

or elimination of carbon pollution, both in terms of local health effects and global climate issues, may more than outweigh the price differential between solar fuels and the existing fossil fuels.

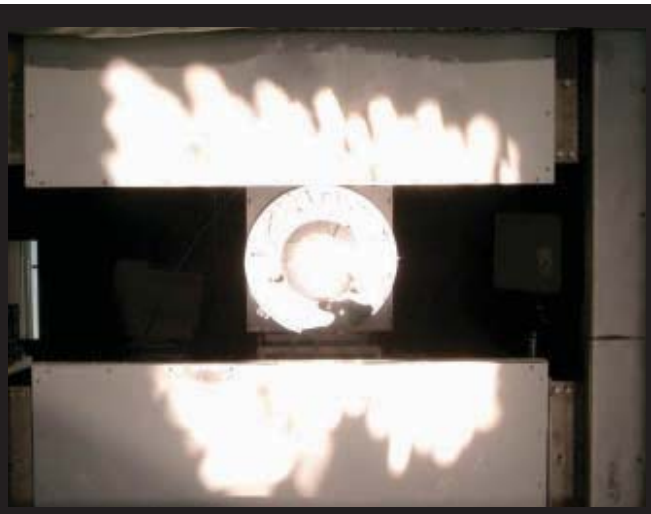
Solar fuels can also perform in places where electrical power is difficult or impossible to tap. Battery-powered airplanes may be impractical, but in the 1980s, when the oil crises of the 1970s were still a fresh memory, researchers demonstrated the practicality of hydrogen-fueled aircraft. It would take an effort to create a hydrogen-powered air fleet because the existing infrastructure would take decades to replace, but converting aviation to clean fuels would be a major step toward reducing global air pollution. In the meantime carbon-based solar fuels for aeronautic applications could be produced using the Fischer-Tropsch process.

Although much work still needs to be accomplished to make solar fuels and commodities readily and easily available, research into solar thermal processes has been marked by rapid progress in recent years, with interest in the field steadily growing.

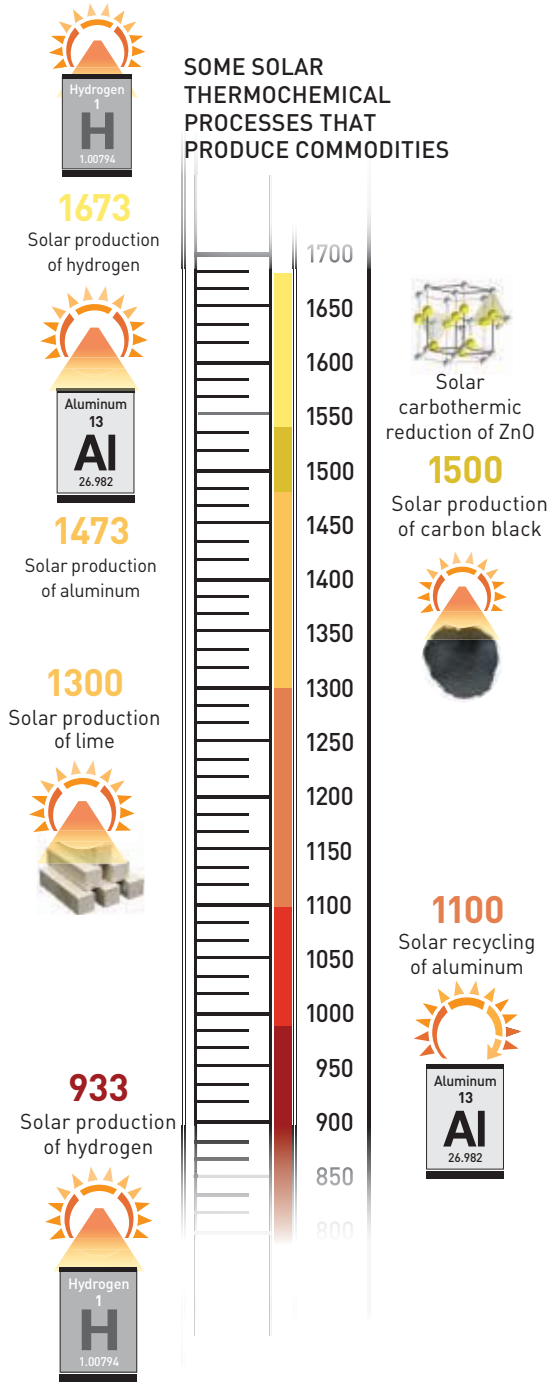
ASME has a major role in making the technology viable. This article is a follow up to the Heat Transfer Division-sponsored panel, "Clean energy as a building mark of this millennium," held at ASME IMECE in November 2013. ASME journals, such as the *Journal of Solar Energy Engineering* and the *Journal of Heat Transfer,* among many others, have recently published groundbreaking research advancing the field.

The first law of thermodynamics states that energy cannot be created. But if mechanical engineers apply themselves to optimizing processes to make thermochemically derived solar fuels and commodities viable, it will be the next best thing. They will have transformed a ubiquitous but diffuse resource into the backbone of a clean and green economic future. ME

NESRIN OZALP is an associate professor of mechanical engineering at the Katholieke Universiteit Leuven in Belgium. **CHRISTIAN SATTLER** is head of solar chemical engineering at the German Aerospace Center in Cologne. **JAMES F. KLAUSNER** is Ebaugh Professor of mechanical engineering at the University of Florida in Gainesville and an ARPA-E program director. **JAMES E. MILLER** is a chemical engineer in the Advanced Materials Laboratory at the Sandia National Laboratories in Albuquerque.



At left, a thermochemical reactor splitting water to make hydrogen. Above, a high-temperature solar reactor producing fuel.



Various thermochemical processes can be driven by the heat obtained via concentrated solar power. Because some reactions are possible through different chemical pathways, there may be more than one temperature at which a commodity material can be produced. (All temperatures in Kelvin.)

A SMALL COUNTRY IS AMASSING A BRAIN TRUST TO COMPENSATE FOR RESOURCES THAT NATURE DIDN'T PROVIDE. BY HARRY HUTCHINSON

AN INDUSTRY OF R+

Singapore as seen from partway up the CREATE Tower: The climate supports growing things on the ground and on buildings. The structure covered by photovoltaic panels is one of the tower's wings.

THE GREEN IS SO INTENSE ON THE CAMPUS OF THE NATIONAL UNIVERSITY OF SINGAPORE THAT IT CAN STARTLE YOU. ESPECIALLY WHEN YOU STEP OUT OF AN AIR-CONDITIONED CAB AND SMELL THE HUMIDITY IN THE AIR.

On reflection, though, that shouldn't be surprising. The entire city state of Singapore was once a rainforest. There were tigers here in the old days.

The forest and a convenient location for a port were just about the only natural resources enjoyed by this tiny island country that was once part of Malaysia. But so far, Singapore has developed strategies to prosper in spite of its shortage of natural opportunities. This university is one of the key parts of its latest scheme.

The university's roadways wind among buildings, trim lawns, and graceful trees. Every detail seems calculated and carefully tended.

The campus buildings look serious, intended for learning and research. But there is one in particular we came to see—a 17-floor structure capped with photovoltaic panels, the CREATE Tower.

Standing on a terrace outside one of the upper floors of the tower, an observer can peer down on the roofs of three separate buildings, which are referred to as wings. A government agency plans to fill all three wings with research laboratories.

The complex is the home of CREATE, or "Campus for Research Excellence and Technological Enterprise." It is probably the most ambitious project to date of Singapore's National Research Foundation. The agency, which answers directly to the office of the Prime Minister, is one of the primary engines for creating a fundamental resource in the country: an infrastructure—or more appropriately, an industry—based on R&D skills and services.

Chief executive officer of the National Research Foundation, Low Teck Seng, has his office in the CREATE Tower, and sees Singapore's universities as "emerging" research institutions. CREATE is one of the plans in progress to leverage that research capability.

The National Research Foundation oversees programs that offer substantial grants and university positions to Ph.D.s under 40 from anywhere in the world. Another program, Corporate Laboratory @ University, encourages private companies to establish research laboratories at Singapore's universities.

The EVA electric taxi, designed for service in the tropics, can run 200 km on a 15-minute charge.

CREATE seeks to unite Singapore's universities with world-class research institutions to study issues ranging from urban planning to medical treatment. The organization has partnerships with 10 foreign universities, including Massachusetts Institute of Technology, the Technical University of Munich, Cambridge University, and the Swiss Federal Institute of Technology.

"We created CREATE," Low said. As there is with any new and ambitious venture, there is a bit of a gamble about it. But Low aims to make it a key pillar supporting Singapore's goal of establishing itself as the go-to venue for research in southeastern Asia.

The city state, which has a population of 5.5 million, is in the process of spending the equivalent of about $12 billion over five years to make that happen.

Part of the country's research budget passes to sister organizations, the Agency for Science, Technology, and Research, known as A*STAR, and the Ministry of Education.

A*STAR's projects cover a broad range of subjects, as diverse as biomedical sciences, green buildings, and additive manufacturing. The agency's dozens of research partners have included University College London, Stanford University, Carnegie Mellon University, Karolinska Institute, and the U.S. National Energy Technology Laboratory.

Singapore is busy building a brain trust that can bring in research dollars from around the world. One of the natural attractions it will use to compete for clients is its position in the tropics, less than 2 degrees north of the Equator.

According to Low, if a project plans to research diseases commonly found in Asia, such as dengue fever, there would be advantages in doing the work in Singapore rather than in Massachusetts.

He makes a similar argument for studies of urban planning. The differences between cities in the tropics and those in the temperate zones are not only cultural. There are numerous issues to be addressed in the urbanization that is occurring all over the world.

The question of energy use differs between tropical and temperate climates. In the North, for example, heating is a major energy issue in the winter, while cooling is the main issue in the tropics. Singapore could be a natural laboratory for studying solutions for tropical cities, said Low.

A current project of CREATE, in concert with one of its European academic partners, the Technical University of Munich, is to study the implications of introducing the widespread use of electric cars in Singapore.

"It is difficult for a scientist with a post at Cambridge and 2 million pounds a year for research to give it up and come back to Singapore."

—Low Teck Seng, CEO
National Research Foundation

The advantages of doing so include a quieter city, and net fewer emissions. It is easier to control emissions from a central source than from a million tailpipes.

But energy is a big question. The country is powered by imported fossil fuels and has limited wind and no significant hydroelectric resources. In spite of Singapore's equatorial location, its climate is so cloudy that it gets less energy from the sun than Amarillo, Texas. Indeed, technicians told us that the solar panels covering the roof of the CREATE Tower would provide perhaps 1 percent of the building's electricity.

According to Low, research is needed before any decision can be made to electrify cars in Singapore on a large scale.

The partnership, TUM-CREATE, has developed EVA—a taxi designed specifically for conditions in tropical megacities, where heat and humidity pose challenges to electric vehicles.

Taxis make up about 3 percent of the Singapore's vehicle fleet, but account for 15 percent of the distance covered by motor vehicles in the country.

EVA has four seats and a curb weight of 1,500 kg. Maximum power is electronically limited to 60 kW. It has a range of 200 km after 15 minutes of what TUM-CREATE calls "super-fast charging." Energy storage consists of 216 lithium polymer cells with a capacity of 50 kWh. According to TUM-CREATE, "Developing the electric taxi in Singapore was a feat in itself, given the country's small automobile industry."

There are several other projects under the CREATE umbrella. One example is a partnership of the local Nanyang Technological University, the National University of Singapore, and the Technion-Israel Institute of Technology to explore tissue engineering as an approach to cardiac restoration.

The University of California, Berkeley, has two research programs with CREATE. One aims to improve the efficiency of buildings in the tropics, and the other is working on raising the electrical output of photovoltaic devices.

There are five research groups in CREATE's partnership with Massachusetts Institute of Technology. The research areas are infectious diseases, environmental sensing and modeling, biosystems and micromechanics, urban mo-

Rolls-Royce has availed itself of a government program that provides funding for opening a research lab in collaboration with one of the country's universities.

bility, and low-energy electronic systems.

A separate National Research Foundation initiative, known as the Corporate Laboratory @ University program, has reinforced a relationship that already existed between Rolls-Royce and Singapore. The company has established a corporate laboratory that will combine its resources with the research capabilities of Nanyang Technological University.

Singapore has become one of three major hubs for Rolls-Royce, along with the U.K. and the U.S.

According to Kurichi Kumar, director of research and technology for Rolls-Royce in Asia, the company has a history with NTU. In 2003 and '04, representatives of the company and the university researched fuel cells. A two-year project begun in 2008 considered electrical systems, data management, and analytics.

The new Rolls-Royce @ NTU Corporate Lab will operate under a five-year renewable contract. Initial funding is about $59 million, provided jointly by the company, the university, and the National Research Foundation.

The lab is expected to launch more than 30 projects over the next five years focusing on three core research areas—electrical power and control systems, manufacturing and repair technologies, and computational engineering.

Kumar said the work at the university will develop ideas as far as a lab demonstration. The most promising will move inside Rolls-Royce for possible commercial development.

Rolls-Royce has 31 university technical centers around the world. The lab at Nanyang could involve as many as 300 people, a mix of Rolls-Royce employees, university faculty, Ph.D. candidates, and other students and researchers.

Faculty involved include Subodh Mhaisalkar, executive director of ERI@N, the Energy Research Institute at the university, and Leong Kah Fai, head of the university's division of systems and engineering management.

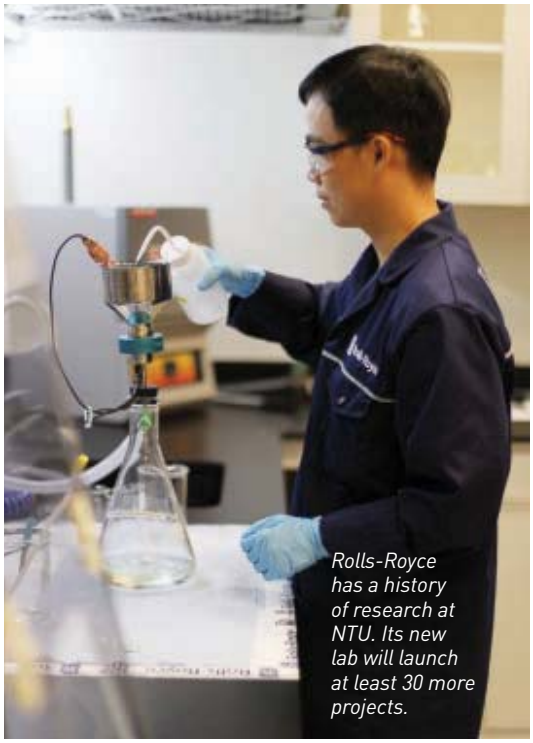
According to Kumar, Singapore has become one of three major hubs for Rolls-Royce, along with the U.K. and the U.S.

The company began manufacturing its wide-chord fan blades in Singapore, the first time that the secret proprietary process has been conducted outside the U.K. The company is building Trent 900 and 1000 engines there as well.

Singapore is also accelerating the staffing of its universities through a research fellowship program administered by the National Research Foundation. Fellowships are open to Ph.D. degree holders under the age of 40 who are willing to conduct research in Singapore for at least five years. Singapore will fund successful fellowship candidates and will offer them faculty positions at the university of their choice.

The fellowships are open to candidates in a range of fields and of any nationality, and are intended to offer "independence to pursue path-breaking research."

A National Research Foundation Fellow since 2009, Hilmi Volkan Demir is an associate professor at Nanyang Technological University and directs his own lab, Luminous! Center of Excellence for Semiconductor Lighting and Displays. The lab focuses on digital lighting and display technologies and has received close to $8 million from the NRF Fellowship and other programs in the past five years.



Rolls-Royce has a history of research at NTU. Its new lab will launch at least 30 more projects.

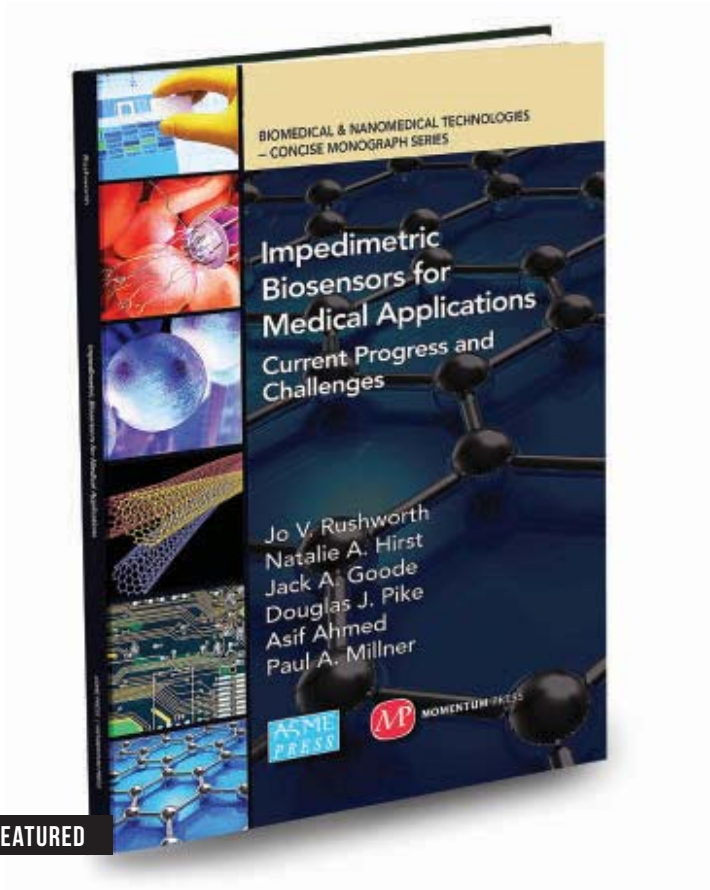
Demir said he finds feedback one of the advantages of his fellowship. In an e-mail, he wrote: "NRF not only provides funding, but also looks at our annual progress, and we receive periodic feedback from NRF. The quality and impact of our work is evaluated by an International Scientific Advisory Board. Various performance indicators are used, which help measure the success and progress of our research work."

According to Low, a new program in development aims to bring back Singaporean researchers now working in other countries. How many may choose to return, he can't predict, but believes as few as 10 would be a satisfactory number.

"It is difficult for a scientist with a post at Cambridge and 2 million pounds a year for research to give it up and come back to Singapore," Low said.

Singapore's Prime Minister, Lee Hsien Loong, who is chairman of the Research, Innovation, and Enterprise Council, summed up the reason for all this investment during a speech to dedicate the CREATE program in November 2012. According to Lee, "R&D is integral to Singapore's development strategy. It gives us an edge against larger and better-resourced countries." **ME**

HARRY HUTCHINSON is the executive editor of *Mechanical Engineering.*



FEATURED

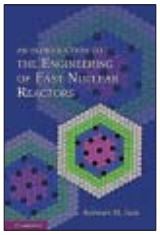
IMPEDIMETRIC BIOSENSORS FOR MEDICAL APPLICATIONS: CURRENT PROGRESS AND CHALLENGES

JO V. RUSHWORTH, NATALIE A. HIRST, JACK A. GOODE, DOUGLAS J. PIKE, ASIF AHMED, AND PAUL A. MILLNER

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

The authors of this book, No. 8 in the BioNano Monographs Series, discuss the current progress in the medical application of impedimetric biosensors, along with the key challenges in the field. They begin with a general overview of biosensor development, structure, and function. They follow with a detailed discussion of impedimetric biosensors and the principles of electrochemical impedance spectroscopy. They review the current state of the art in terms of the science and technology underpinning impedance-based biosensors. They also describe layer-by-layer construction of impedimetric sensors, including the design of electrodes, their nano-modification, transducer surface functionalization, and the attachment of different bioreceptors.

78 PAGES. $89.95; ASME MEMBERS, $72. ISBN: 978-0-7918-6024-3.

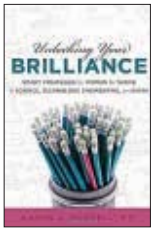


AN INTRODUCTION TO THE ENGINEERING OF FAST NUCLEAR REACTORS

Anthony M. Judd
Cambridge University Press, 32 Avenue of the Americas, New York, NY 10013-2473. 2014.

The author intends this text as a resource for both graduate-level engineering students and practicing nuclear engineers who want to expand their knowledge of fast nuclear reactors. The book covers topics including neutron physics; neutron flux spectra; flux distribution; Doppler and coolant temperature coefficients; the performance of ceramic and metal fuels; the effects of irradiation and corrosion on structural materials; heat transfer in the reactor core and its effect on core design; coolants and coolant circuits; pumps; heat exchangers and steam generators; and plant control. The book also includes new discussions on lead-alloy and gas coolants, metal fuel, the use of reactors to consume radioactive waste, and accelerator-driven subcritical systems.

299 PAGES. $135. ISBN: 978-1-1070-3464-8.



UNLOCKING YOUR BRILLIANCE: SMART STRATEGIES FOR WOMEN TO THRIVE IN SCIENCE, TECHNOLOGY, ENGINEERING, AND MATH

Karen Purcell
Greenleaf Book Group LLC PO Box 91869, Austin, TX 78709. 2014.

Tackling an important social issue from a personal perspective, Karen Purcell describes the trajectory of her career in engineering, including the struggles she endured. Purcell, an electrical engineer, has established a company, PK Electrical, and a foundation called STEMspire that encourages young women to pursue STEM careers. She tells her story and shares stories from women in other fields. The book identifies hurdles that confront women in the STEM world and offers pragmatic strategies for moving beyond them. The author discusses such issues as earning the respect of male colleagues and balancing a personal life with career pressures.

145 PAGES. $21.95. ISBN: 978-1-6083-2376-0.

PATH PLANNING

SIEMENS PLM, PLANO, TEXAS.

KineoWorks 3.0 is a software component for collision-free path planning in a range of applications, including robotics, human accessibility studies, and assembly-and-disassembly verification. This version simplifies the planning of complex motion in offline and online machine control applications and provides new tools for generating optimum manufacturing and inspection sequences. Many complex path-planning problems in welding, painting, cutting, and related manufacturing processes can be solved with new algorithms that account for complex tool trajectories. The same developer has also released Kineo Collision Detector version 3.0, which enables high-speed collision checking in motion studies and point cloud applications.

With the software application KineoWorks engineers can plan collision-free paths for a number of workplace issues, including robotics and assembly-and-disassembly verification. Image: Siemens PLM

ELECTROMAGNETICS SIMULATION

ESI GROUP, PARIS.

CEM Solutions 2014 is an integrated software environment for the virtual prototyping of electromagnetic phenomena. The suite integrates computational electromagnetics time and frequency methods within a simulation platform, giving users the ability to simulate electromagnetic phenomena using coupled and hybrid techniques. Components in the suite include electromagnetic compatibility and electromagnetic interference with cable networks, antenna placement, and radar signatures. Capabilities include enhanced virtual testing with a dedicated radio noise process and the ability to investigate the performance of radar sensors behind plastic bumpers.

CAD VIEWER

KISTERS, AACHEN, GERMANY.

The application 3DViewStation version 2014.1 is used to view CAD designs in 3-D and for digital mock-up. Images can be imported into the application from many popular CAD systems, including Catia, NX, Creo, SolidWorks, JT, 3D-PDF, and STEP. The application includes a Microsoft Office 2013-compliant user interface. Catia 2-D drawing support has been added to this update, with more 2-D file formats to be added in the future. Also, 2-D drawings and 3-D designs and assemblies can be printed from the application. The prints can include grids, markups, and stamps to add printing time or document name. This version allows users to undo selections, color changes, movements, dimensions, and other items.

CAD CONSOLIDATION AND COLLABORATION

PTC, NEEDHAM, MASS.

PTC Creo with Unite Technology allows users to consolidate CAD systems. Design teams working in multiple systems can collaborate across CAD platforms. CATIA, NX, SolidWorks, Autodesk Inventor, and SolidEdge files can be imported and opened directly in the PTC Creo design application. Users can also convert legacy CAD files to PTC Creo files using the Unite application and can convert only the data they need converted rather than all the information in the legacy file.

CAM FOR REVERSE ENGINEERING

DELCAM, BIRMINGHAM, ENGLAND.

The 2015 version of PowerShape Pro CAD for computer-aided manufacturing systems is used for modeling, for manufacture, and for reverse engineering. The release includes improvements to direct modeling, surface modeling, and reverse engineering capabilities as well as support for data from HandySCAN hand-held scanners from Creaform of Lévis, Québec. Having various technologies in the same package reduces the need to transfer data among multiple programs, according to the developer. A new smart-feature manager allows users to identify all the features, such as fillets, slots, and bosses, within a solid in a single operation. A smart-feature selector then allows multiple similar features to be found and selected using either a specific value or a range of values. Another potential application for the software is in tidying up models created by reverse engineering, where features that are intended to be identical, such as a series of holes, will often show small variations. In such cases, all the items within a specified tolerance band can be selected and then all adjusted together to the same precise size.

INVENTOR T-SPLINE TUTORIAL

INFINITE SKILLS, OAKVILLE, ONTARIO.

"Mastering Autodesk Inventor—T-Splines" is a video tutorial series that helps users build skills in creating T-splines in the CAD program. It includes practice files to provide retention. Subjects are divided into simple tutorial videos so users can learn at their own pace.

SUBMISSIONS

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

VISION-GUIDED TOOL HANDLING

ABB ROBOTICS INC., AUBURN HILLS, MICH.

The FlexMT, a flexible, pre-engineered system is designed to load and unload machine tools using vision-guided robotics. Designed for both small batch and high volume production, the FlexMT increases spindle utilization by up to 60 percent over manual machine tending. The system can handle many sizes and types of parts, and is compatible with a wide range of machine tools, including horizontal and vertical lathes, machining centers, 5-axis machines and grinders.

LOW DP TRANSMITTER

ASHCROFT INC., STRATFORD, CONN.

The new GL42 low differential pressure indicating transmitter mates a four-digit LCD to a stable transmitter to provide a local reading as well as a 4-20 mA output. These features allow communication with a remote data acquisition device as well as a visual reading at the pressure source. Selectable engineering units, adjustable display response times, an IP65 enclosure, and several mounting options allow the GL42 to be applied to a variety of installations. A choice of ranges from 0/0.1 to 0/25 in. H_2O and bidirectional to ±30 in. H_2O are available.

SIX-AXIS POSITIONER

PHYSIK INSTRUMENTE, AUBURN, MASS.

A high load hexapod is available for loads to 500 kg (1,100 pounds). The H-850KMLD provides 1 µm minimum incremental motion over a 100 mm travel range in XY and of 0.5 µm over a 50 mm travel range in the Z direction. The linear repeatability is ±1 µm. The maximum tilt and rotation angle is ±30 degrees. An absolute encoder option is also available. The encoder detects the actual position of the axes after power up, eliminating reference moves.

PRESSURE TRANSMITTER

OMEGA ENGINEERING, STAMFORD, CONN.

The new series of rangeable, very low differential pressure transmitters can output either static (gauge) pressure or differential pressure. The PX2600 series has four unidirectional and four bi-directional ranges, three selectable outputs (0 to 5 V dc, 0 to 10 V dc, 4 to 20 mA two-wire), pushbutton or remote zero, four-digit LCD with the ability to show either static or differential pressure. The CE compliant product comes with a durable glass-filled polyester case.

LINEAR AXIS

SCHUNK INC., MORRISVILLE, N.C.

The ELB linear axis combines a linear motor drive with a smooth pre-loaded roller guide. It can position high loads with an accuracy of 0.01 mm. Maximum acceleration is 100 meters per second and maximum speed is 4 meters per second. It is offered in three stroke variants—50, 75, and 100 mm. The unit is controlled either by the Bosch Rexroth IndraDrive controller or by the Siemens SINAMICS inverter. Standard controller interfaces can integrate the module into higher-level control systems.

PLASTIC HINGES

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

RoHS-compliant hinges are stable and notable for a high resistant torque of 3 Nm in four indexing positions. All detent positions have a guaranteed resistant torque of about 3 Nm (which is the torque that must be applied to free the detent device of the hinge). This hinge has been tested with more than 20,000 opening and closing cycles, and the value of the resistant torque was unchanged. Hinges are made of matte black glass fiber reinforced plastic (Polyamide PA Series 303).

PRECISION MACHINING CENTER

KERN PRECISION INC., WEBSTER, MASS.

The KERN EVO machining center provides high productivity through fast acceleration, feed rates, and spindle speeds up to 50,000 rpm. The machining center's polymer concrete mono-block frame absorbs forces and vibrations that occur during operation. Positioning accuracy is ±0.5 µm (0.00002 in.). The EVO's advanced machine technology also provides superb surface finish quality down to 0.1 µm Ra or less.

BAR FEEDER

LEXAIR INC., LEXINGTON, KY.

Multi Mini Rhinobar bar feeder makes multi-diameter bar stock processing faster with a feed tube cartridge that automatically centers and feeds three sizes of small-diameter bar stock to Swiss-style CNC screw machines and sliding-head lathes. Cartridges are available in three size ranges: 0.25 in./0.375 in./0.5 in., 0.25 in./0.5 in./0.75 in. and 0.375 in./0.5 in./0.635 in. Each three-tube cartridge is enclosed in a standard aluminum barrel.

MINI DRIVE

WEG ELECTRIC, ATLANTA.

The new CFW100 mini drive is a single-phase variable-speed drive offered to OEMs and end users. The compact drive is designed to handle 150 percent overload for 60 seconds in an ambient temperature of 50 °C. The drive has power ranges from 0.25 to 1 hp at 230 V ac with single-phase in and 1.5 A to 4.2 A three-phase output current.

ROTARY ACTUATORS

BIMBA MANUFACTURING CO., UNIVERSITY PARK, ILL.

The new MHRQ double-rack, rack and pinion series includes a robust, clean and compact extruded aluminum body for maximum mounting efficiency. A magnetic piston for position-sensing is included on all models along with multiple port locations for flexibility with plumbing. The actuators are available with four bore sizes, offering a range of torque output to 85 in.-lbs. They are interchangeable with popular international brands. The MHRQ line is suited to a broad range of general light-duty automation processes, including material transfer.

ROTARY ENCODERS

LEINE & LINDE, SCHAUMBURG, ILL.

Leine & Linde's 800 rotary encoder series now includes an integrated over-speed capability with programmable switching speeds. In industrial applications like wind turbines or loading cranes, it is common for an incremental encoder signal to be complemented with a separate relay output for over-speed indication. This is typically used to avoid loss of control in order to protect personnel and equipment.

SUBMISSIONS

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

RESOURCEFILE

- Instrumentation & Control
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MASTER BOND

NEWARK ELEMENT 14

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TORMACH

YASKAWA

OMEGA

OMEGA

SMALLEY

TSUBAKI

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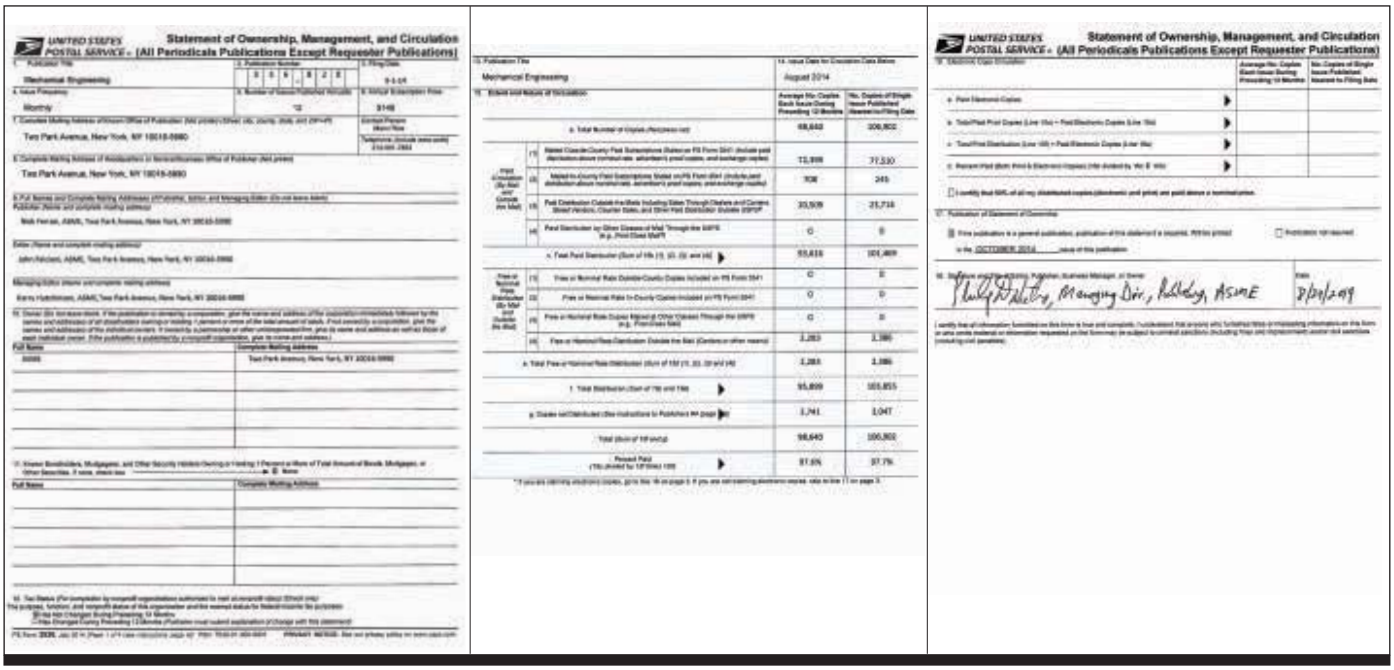
EXPERIMENTALIST POSITION ANNOUNCEMENT The Composites Branch of the Structural Materials Division, Materials and Manufacturing Directorate, Air Force Research Laboratory, Wright-Patterson Air Force Base, Ohio is seeking a materials research engineer with experience in experimental quantification and simulation of polymer matrix and ceramic matrix composite materials and their constituents in representative Air Force system environments. Responsibilities include conducting in-house research that is both modeling and experimental in nature as well as some external contract management. Strong analytical skills and the ability to apply analyses to experimental data are desired as is an understanding of Integrated Computational Materials Engineering/Integrated Computational Materials Science and Engineering principles. Candidates should have a background in polymer matrix and ceramic matrix composites, finite element analysis, fracture modeling, digital image correlation (or equivalent), X-ray computed tomography, and a working knowledge of the validation and verification process. An advanced degree in Aerospace, Mechanical, Materials, or Civil Engineering is preferred and U.S. Citizenship is required. For consideration, qualified candidates should submit resumes to Donna.Ballard@us.af.mil

THE DEPARTMENT OF MECHANICAL ENGINEERING at the California State University, Los Angeles, invites applications for a full-time tenure-track Assistant Professor position in Mechanical Engineering. The position is in any single or combination of three Aerospace specializations: Aerospace Engineering, Control Systems, or Solid Mechanics. Applicants must have an earned doctorate degree in Mechanical Engineering or closely related field by the start date of their appointment. The successful candidate has a strong primary commitment to excellence in teaching at the undergraduate level, but is also committed to graduate courses and research, and will be able to take advantage of the College's strong, well established ties to local industry. Faculty candidates must have an appreciation for undergraduate teaching and learning at an urban serving institution and must be capable of developing a research and development program in their field that integrates research and development into teaching and learning. Faculty must also be willing to engage in STEM related activity with the local community colleges and K-12. Applicants should have the ability to relate well to others within the academic environment, and demonstrate ability and/or interest in working in a multiethnic, multicultural environment. Preference will be given to those candidates with teaching experience, registration as a professional engineer, experience in either industry, a national laboratory, or as a post-doctorate researcher. The successful candidate will teach in an ABET accredited ME bachelor's program and an ME master's program and will be expected to establish externally funded research programs. Email a PDF a letter of application, curriculum vita, official transcripts, three letters of recommendation and the University's Application for Academic Employment form (http://www.calstatela.edu/univ/hrm/forms/appl_emp.xls) to Dr. Darrell Guillaume, Department Chair, at dguilla@calstatela.edu. Review of applications will begin on October 1, 2014, and continue until the position is filled. The complete position announcement is available at http://web.calstatela.edu/academic/position/2014_ecst/me_asst_prof.php

LEHIGH UNIVERSITY DEPARTMENT OF MECHANICAL ENGINEERING & MECHANICS Lehigh University is accepting applications for faculty positions at the Assistant or Associate Professor level in two fields: 1) Mechanical Systems, including the areas of systems, dynamics and controls and 2) Solid Mechanics, with an emphasis on structural failure and fracture mechanics. The ideal candidate will have a doctoral degree in Mechanical Engineering or a related field with a strong background in the experimental or theoretical/computational aspects of one or more of the areas, and will be expected to develop a vigorous research program, accompanied by excellence in teaching at both the graduate and undergraduate levels. Multidisciplinary research programs are an important priority at Lehigh University, and include strong interactions with government agencies, industry, and existing research centers on campus. Candidates should provide curriculum vitae that include: a statement of professional experience and goals; detailed plans for research and funding; a list of prefered publications and presentations; a summary of teaching experience and plans; and the names and contact information of four references. This material should be submitted electronically using our online application found at https://academicjobsonline.org/ajo/jobs/4403. For questions regarding this position, please contact Barbara McGuire, bcm208@lehigh.edu. Review of applications will begin upon receipt and will continue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Mechanical Engineering

August 2014

Statement of Ownership, Management, and Circulation (All Periodicals Publications Except Requester Publications)

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until the position is filled. Lehigh University is an affirmative action/equal opportunity employer and does not discriminate on the basis of age, color, disability, gender, gender identity, genetic information, marital status, national or ethnic origin, race, religion, sexual orientation, or veteran status. Lehigh University provides comprehensive benefits including partner benefits. Lehigh is a NSF ADVANCE Institution. http://www.lehigh.edu/luadvance/Lehigh offers excellent benefits including domestic partner benefits. http://www.lehigh.edu/~inprv/faculty/worklifebalance.html. Lehigh Valley Inter-regional Networking & Connecting (LINC) is a network of diverse organizations designed to assist new hires with dual career, community and cultural transition needs. infdcap@lehigh.edu

SOUTHERN METHODIST UNIVERSITY, DEPARTMENT OF MECHANICAL ENGINEERING invites applications for a full-time tenure-track faculty position at the rank of assistant professor (Position No. 52632). We are seeking a highly qualified faculty member in the area of Solid Mechanics with particular focus on experimental and/or computational biomechanics, mechanobiology, and micro- and nano-mechanics. Candidates must have a Ph.D. degree in mechanical engineering or a closely related field, and will be expected to teach undergraduate and graduate courses, develop and sustain internationally recognized active research programs, and participate in multi-disciplinary research projects in the Lyle School and the university. Exceptionally qualified candidates may also be considered for a position at associate or full professor level. With over 10,000 students, SMU is a leading private University located in the Dallas –Fort Worth Metroplex, a dynamic region with leading high-technology companies and research institutes in the aerospace, defense, energy, information technology, life sciences, semiconductors, telecommunications, transportation, and biomedical industries. Some of these companies and research institutions include Texas Instruments, Raytheon, Bell Helicopter, Lockheed-Martin, Turner Construction, Trinity Industries, Baylor Research Institute, and the University of Texas Southwestern Medical Center. Supercomputing facility at SMU currently has over 11,000 CPUs, and is capable of supporting large-scale modeling and simulations. The Mechanical Engineering Department resides within the Lyle School of Engineering and offers B.S., M.S., and Ph.D. degrees in mechanical engineering. The ME Department is home to the Research Center for Advanced Manufacturing, the NSF Industry/University Cooperative Research Center for Lasers and Plasmas for Advanced Manufacturing. It is also the home of several other research laboratories in the areas of mechanics of materials; dynamics, systems and controls; biomedical instrumentation and robotics; porous materials applications; nanoscale electro-thermal sciences; opto-electronics packaging; laser micromachining; micro-optical

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sensor technology, bio-microfluidics; 3-D printing/additive manufacturing; and experimental fluid mechanics (http://www.lyle.smu.edu/me/). Applications received by December 15, 2014 will be given full consideration, but the search committee will continue to accept applications until the position is filled. Curriculum vitae, statement of teaching and research plan, and a list of four references should be sent to Mechanics-Search@lyle.smu.edu. Hiring is contingent upon the satisfactory completion of a background check. SMU will not discriminate in any employment practice, education program, or educational activity on the basis of race, color, religion, national origin, sex, age, disability, genetic information, or veteran status. SMU's commitment to equal opportunity includes nondiscrimination on the basis of sexual orientation and gender identity and expression. The Associate Vice President, Office of Institutional Access and Equity, has been designated to handle inquiries regarding the nondiscrimination policies.

SOUTHERN METHODIST UNIVERSITY, DEPARTMENT OF MECHANICAL ENGINEERING invites applications for a full-time tenure-track faculty position at the rank of assistant professor (Position No. 52680). We are seeking a highly qualified faculty member in the area of Dynamic Systems and Control with particular focus on micro- and nano-systems, biomechanics, robotics, or closely related research fields. Candidates must have a Ph.D. degree in mechanical engineering or a closely related field, and will be expected to teach undergraduate and graduate courses, develop and sustain internationally recognized active research programs, and participate in multi-disciplinary research projects in the Lyle School and the university. Exceptionally qualified candidates may also be considered for a position at associate or full professor level. With over 10,000 students, SMU is a leading private University located in the Dallas–Fort Worth Metroplex, a dynamic region with leading high-technology companies in the aerospace, defense, energy, information technology, life sciences, semiconductors, telecommunications, transportation, and biomedical industries. Some of these companies and research institutions include Texas Instruments, Raytheon, Bell Helicopter, Lockheed-Martin, Turner Construction, Trinity Industries, Baylor Research Institute, and the University of Texas Southwestern Medical Center. Supercomputing facility at SMU currently has over 11,000 CPUs, and is capable of supporting large-scale modeling and simulations. The Mechanical Engineering Department resides within the Lyle School of Engineering and offers B.S., M.S., and Ph.D. degrees in mechanical engineering. The ME Department is home to the Research Center for Advanced Manufacturing, the NSF Industry/University Cooperative Research Center for Lasers and Plasmas for Advanced Manufacturing. It is also the home of several other research laboratories in the areas of mechanics of materials;

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dynamics, systems and controls; biomedical instrumentation and robotics, porous materials applications; nanoscale electro-thermal sciences; opto-electronics packaging; laser micromachining; micro-optical sensor technology, bio-microfluidics, 3-D printing/additive manufacturing, and experimental fluid mechanics (http://www.lyle.smu.edu/me/). Applications received by December 15, 2014 will be given full consideration but the search committee will continue to accept applications until the position is filled. Curriculum vitae, statement of teaching and research plan and a list of four references should be sent to Dynamics-Search@lyle.smu.edu. Hiring is contingent upon the satisfactory completion of a background check. SMU will not discriminate in any employment practice, education program, or educational activity on the basis of race, color, religion, national origin, sex, age, disability, genetic information, or veteran status. SMU's commitment to equal opportunity includes nondiscrimination on the basis of sexual orientation and gender identity and expression. The Associate Vice President, Office of Institutional Access and Equity, has been designated to handle inquiries regarding the nondiscrimination policies.

THE DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING at the Missouri University of Science and Technology (formerly the University of Missouri - Rolla) invites applications for a full-time tenure-track Assistant Professor position. Applications are sought in all fields of aerospace engineering; however, preference will be given to candidates with expertise in materials and structures for spacecraft and super/hypersonic vehicles, multifunctional material systems, hybrid-material structures, morphing structures, and controlled-flexibility distributed-actuation smart structures. The successful candidate will complement the department's existing strengths in nano/cubesat technology, unmanned air vehicles, composite materials, and aerospace structures. Applicants must have a Ph.D. in Aerospace Engineering or closely related fields. This opening is anticipated to be filled at the Assistant Professor level, although qualified applicants will be considered for appointment to a higher level. The successful candidate will demonstrate the potential to establish and grow a strong research program and will participate in all aspects of the Department's mission, which includes research, teaching and service.The department currently has 38 full-time faculty members, over 800 undergraduate and approximately 200 graduate students. The Department offers the B.S., M.S., and Ph.D. degrees in Mechanical and Aerospace Engineering. The Department seeks to significantly increase the national visibility of its research and graduate program while maintaining its high standards of teaching. Details regarding the department can be found at http://mae.mst.edu/. In addition, details of research centers on campus can be found at http://www.mst.edu/research/. Candidates should include the following with

College of Engineering: Open Rank Faculty

Department of Aerospace Engineering

College of Engineering

University of Illinois at Urbana-Champaign

The Department of Aerospace Engineering at the University of Illinois at Urbana-Champaign is seeking highly qualified candidates for multiple faculty positions with emphasis on the areas of space systems/propulsion, autonomous aerospace systems, multi-disciplinary design optimization, aeroelasticity, and aerospace materials and structures. Particular emphasis will be placed on qualified candidates who work in emerging areas of aerospace engineering and whose scholarly activities have high impact.

Please visit http://jobs.illinois.edu to view the complete position announcement and application instructions. Full consideration will be given to applications received by November 3, 2014. Applications received after that date will be considered until the positions are filled.

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Illinois is an EEO Employer/Vet/Disabled - www.inclusiveillinois.illinois.edu and committed to a family-friendly environment (http://provost.illinois.edu/worklife/index.html).

THE UNIVERSITY OF HONG KONG
香 港 大 學

Founded in 1911, the University of Hong Kong is committed to the highest international standards of excellence in teaching and research, and has been at the international forefront of academic scholarship for many years. The University has a comprehensive range of study programmes and research disciplines spread across 10 faculties and over 140 academic departments and institutes/centres. There are over 27,800 undergraduate and postgraduate students who are recruited globally, and more than 2,000 members of academic staff coming from 50 countries, many of whom are internationally renowned.

Tenure-Track Professor/Associate Professor/Assistant Professor in the Department of Mechanical Engineering (Ref.: 201400297)

Applications are invited for a tenure-track appointment as **Professor/Associate Professor/Assistant Professor in the Department of Mechanical Engineering**, Faculty of Engineering, in additive manufacturing, focusing on the technique development and advanced applications of direct digital manufacturing or 3D printing of near-net shapes of metallic, composite or ceramic materials, to commence as soon as possible, on a three-year fixed-term basis, with the possibility of renewal, or on tenure terms for exceptionally outstanding candidates for Associate Professor or above.

The Department offers B.Eng., M.Sc., M.Phil. and Ph.D. degree programmes. The Department also contributes to the Medical Engineering programme, which is jointly offered by the Faculties of Engineering and Medicine. The Department employs about 30 full-time faculty and has well-equipped teaching and research facilities and support. The Department has a vibrant research environment and promotes cutting-edge research in strategic areas including materials and nanotechnology, design and manufacturing, control and robotics, biomedical engineering, and energy and environment. Information about the Department can be obtained at http://www.mech.hku.hk/. The Faculty of Engineering has recently secured a sizable University Development Fund to purchase a state-of-the-art 3D printer.

Applicants should possess a Ph.D. degree in Mechanical Engineering, Materials Science and Engineering, or a closely related field with an excellent research record. The appointee is expected to conduct frontier research in additive manufacturing and related areas, and be responsible for quality teaching in relevant subjects at both undergraduate and postgraduate levels, and other fundamental engineering courses at the undergraduate level.

A globally competitive salary commensurate with qualifications and experience will be offered. At current rates, salaries tax does not exceed 15% of gross income. The appointment on fixed terms will attract a contract-end gratuity and University contribution to a retirement benefits scheme, totalling up to 15% of basic salary, as well as annual leave, and medical benefits. Housing benefits will also be provided as applicable.

Applicants should send a completed application form together with an up-to-date C.V. to mepost@hku.hk. Please indicate clearly which field and level they wish to be considered for and the reference number in the subject of the e-mail. Application forms (341/1111) can be obtained at http://www.hku.hk/apptunit/form-ext.doc. Further particulars can be obtained at http://jobs.hku.hk/. **Review of applications will start from September 1, 2014 and will continue until November 30, 2014.** The University thanks applicants for their interest, but advises that only shortlisted applicants will be notified of the application result.

The University is an equal opportunity employer and is committed to a No-Smoking Policy

UNIVERSITY OF ILLINOIS AT CHICAGO
DEPT. OF MECHANICAL & INDUSTRIAL ENGINEERING
FACULTY POSITION • MECHANICAL ENGINEERING

The Department of Mechanical and Industrial Engineering at the University of Illinois at Chicago invites applications for tenure-track faculty positions in various areas of Mechanical Engineering. Individuals will also be considered at associate or full professor rank if they possess outstanding qualifications commensurate with the rank. Successful applicants are required to have an earned PhD in Mechanical Engineering or a related field, and are expected to develop and maintain an active, externally-funded research program as well as teach courses at both the undergraduate and graduate levels. The Department offers BS, MS, and PhD degrees in Mechanical Engineering, and Industrial Engineering and Operations Research, and currently has an undergraduate enrollment of about 640 and a graduate enrollment of about 200. More information about the Department can be found at http://www.mie.uic.edu. Applicants are required to send aletter of application indicating their qualifications, an up-to-date CV including the names and contact information of three references, and separate one-page statements outlining their future teaching and research plans. For fullest consideration, applications must be submitted online at https://jobs.uic.edu/job-board/job-details?jobID=43717 by January 2, 2015. Applications will be accepted until the positions are filled. Expected starting date is August 2015.

The University of Illinois at Chicago is an affirmative action, equal opportunity employer, dedicated to the goal of building a culturally diverse and pluralistic faculty andstaff committed to teaching and working in a multicultural environment. We strongly encourage applications from women, minorities, individuals with disabilities and covered veterans.

VANDERBILT UNIVERSITY • FACULTY POSITION
MECHANICAL ENGINEERING DEPARTMENT

The Department of Mechanical Engineering at Vanderbilt University invites applications for a faculty position to begin in the fall of 2015. Applications will be considered for positions at all ranks commensurate with qualifications. Applicants must possess a Ph.D. in Mechanical Engineering or related field. We are particularly seeking candidates with research interests in **rehabilitation engineering**. The School of Engineering and the Department of Physical Medicine and Rehabilitation (within the School of Medicine) at Vanderbilt are in the process of establishing an interdisciplinary research program with the mission of collaboratively pursuing the development of innovative methodologies, interventions, and assistive devices to improve the quality of care and quality of life for persons with physical disabilities. The collaborative program will occupy dedicated space that will physically integrate resources and personnel from engineering and medicine such that technological innovation will be thoroughly informed by clinical expertise. We are seeking candidates who will work within this collaborative center, and in particular will pursue innovative and impactful research toward the development of assistive or therapeutic devices or methods that improve functional or health outcomes of individuals with physical disabilities, including but not limited to individuals with stroke, spinal cord injury, MS, CP, or limb loss. Successful candidates will be expected to build a strong, externally-funded research program and make significant contributions to the Department's research activities. The Department of Mechanical Engineering has a student body of approximately 300 undergraduates and 50 Ph.D. students, and candidates should have a marked interest in teaching both undergraduate and graduate students. Applications consisting of a cover letter, a complete curriculum vitae, statements of teaching and research interests, and the addresses of four references (include email address) should be submitted on-line at https://academicjobsonline.org/ajo/jobs/4299. *Vanderbilt University is an Affirmative Action/Equal Opportunity Employer. Women and minorities are especially encouraged to apply.*

SAN JOSÉ STATE UNIVERSITY

ANNOUNCEMENT OF POSITION AVAILABILITY | Subject to Budgetary Approval

Assistant Professor, Tenure-Track

(two positions) - *Job Opening ID (JOID): 22970*

Mechanical Engineering / Department of Mechanical Engineering
Charles W. Davidson College of Engineering

Qualifications: The Department of Mechanical Engineering at the San Jose State University (SJSU) invites applications for two tenure-track faculty positions at the rank of Assistant Professor. Applicants must have strong academic background and advanced knowledge in mechanical engineering, as evidenced by a Ph.D. or equivalent degree in mechanical engineering or closely related field. The mechanical engineering curriculum at SJSU is organized in three major stems in (1) mechanical systems design, (2) thermal & fluids engineering, and (3) mechatronics, dynamics, & controls. The candidates accordingly are expected to contribute their specialized expertise in one or more of these areas. Candidates must demonstrate potential for excellence in scholarly research, with an expectation of peer-reviewed publications and professional presentations. Both positions require excellent communication, teamwork, and interpersonal skills. The successful candidates must be aware of and sensitive to the educational goals of a multicultural population as might have been gained in a cross-cultural study, training, teaching, or other comparable experience. The candidates must also be sensitive to the needs of a student population that is very diverse in age, ethnicity, cultural background, socioeconomic status, and level of prior academic preparation.

Responsibilities: Providing quality education is a top priority for the Department of Mechanical Engineering. In addition to teaching engineering courses, faculty members in the department are expected to develop curricula and laboratories and should plan to establish externally funded research programs. Faculty members advise undergraduate and graduate students via project mentorship as well as academic planning. They also serve on committees and task forces under shared governance to improve policies and resources for the betterment of education.

Salary Range: Commensurate with qualifications & experience

Stating Date: August 18, 2015

Eligibility: Employment is contingent upon proof of eligibility to work in the United States.

Application Procedures: For full consideration, by February 15, 2015, submit in pdf format at letter of application, curriculum vitae, statement of teaching interests/philosophy and research plans to: **me-search-group@sjsu.edu**. In addition, arrange for at least three original letters of reference with contact information to be submitted to: **tai-ran.hsu@sjsu.edu**.

SAN JOSÉ STATE
UNIVERSITY

Please include JOID # on all correspondence. The position remains open until filled.

San José State University is California's oldest institution of public higher learning. The campus is located on the southern end of San Francisco Bay in downtown San José (Pop. 1,000,000), hub of the world-famous Silicon Valley high-technology research and development center. Many of California's most popular national, recreational, and cultural attractions are conveniently close. A member of the 23-campus CSU system, San José State University enrolls approximately 30,000 students, a significant percentage of whom are members of minority groups. The University is committed to increasing diversity of its faculty so our disciplines, students and the community can benefit from multiple ethnic and gender perspectives.

San José State University is an Affirmative Action/Equal Opportunity Employer. We consider qualified applicants for employment without regard to race, color, religion, national origin, age, gender, gender identity/expression, sexual orientation, genetic information, medical condition, marital status, veteran status, or disability. This policy applies to all San José State University students, faculty, and staff as well as University programs and activities. Reasonable accommodations are made for applicants with disabilities who self-disclose. Note that all San José State University employees are considered mandated reporters under the California Child Abuse and Neglect Reporting Act and are required to comply with the requirements set forth in CSU Executive Order 1083 as a condition of employment.

The latest San José State University Safety 101 Uniform Campus Crime and Security Report is available. You may request a copy of San José State University's annual safety report by contacting the University Police Department at (408) 924-2222 or by visiting the University Police Department website at www.sjsu.edu/police

their letter of application: current curriculum vitae, statement of research plans including areas of potential collaboration with other faculty, statement of teaching interests and philosophy, and names and contact information for at least three references. Applications will be accepted and reviewed until the position is filled. All application materials must be electronically submitted to the Missouri University of Science and Technology's Human Resource Office at http://hraadi.mst.edu/hr/employment/. All submitted application materials must have the position reference number in order to be processed. Acceptable electronic formats that can be used for email attachments include PDF and Word; hardcopy application materials will not be accepted. The final candidate is required to provide an official transcript showing completion of the terminal degree listed in the application materials submitted. Copies of transcript(s) must be provided prior to the start of employment. In addition, the final candidate may be required to verify other credentials listed in application materials. Failure to provide the official transcript(s) or other required verification may result in the withdrawal of the job offer. Missouri S&T is an AA/EO Employer and does not discriminate based on race, color, religion, sex, sexual orientation, national origin, age, disability, or status as Vietnam-era veteran. Females, minorities, and persons with disabilities are encouraged to apply. Missouri S&T is responsive to the needs of dual-career couples. Missouri University of Science and Technology participates in E-Verify. For more information on E-Verify, please contact DHS at: 1-800-464-4218. NOTE: All application materials must have appropriate position reference number in order to be processed.

NANJING TECH UIVERSITY FACULTY POSITIONS in College of Mechanical and Power Engineering This announcement invites applications for tenure-track faculty positions in: Mechanical Engineering, New Energy Science and Engineering, Welding Technology and Engineering, Mechanical Design Manufacturing and Automation, Vehicle Engineering, Process Equipment and Control Engineering. Required Qualifications: Ph.D. in Mechanical Engineering or a closely related field is required. Initial appointments are at the assistant professor level. Exceptionally qualified candidates at the associate or full professor level may also be considered. Rank and salary are commensurate with experience and accomplishments. Candidates should send application to chunlei-shao@njtech.edu.cn. A CV, list of publications, statements of research and teaching plans are required. Applications received before December 31, 2015 will be guaranteed full consideration. Additional infor-

LSU

(NUCLEAR ENGINEERING: THERMAL HYDRAULICS/TENURE-TRACK)

DEPARTMENT OF MECHANICAL AND INDUSTRIAL ENGINEERING
COLLEGE OF ENGINEERING

The Department of Mechanical and Industrial Engineering (MIE) at Louisiana State University invites applications for a tenure-track Assistant Professor position starting in August 2015. The department seeks to build on a strong track record in the thermal/fluids area and to further strengthen current activities in energy research by adding expertise relevant to nuclear energy.

Duties include undergraduate and graduate level teaching; initiating and sustaining independent, externally-funded research, and supervising graduate students. Successful candidates are expected to teach nuclear reactor theory/design and nuclear reactor systems design, among other topics, and to have the potential to develop substantive collaborations within MIE, other engineering/science departments, and LSU's Center for Computation and Technology (CCT). Indeed, the opportunity exists for applicants involved in computationally intensive research to be offered a joint position between MIE and the CCT. The position supports a recently established Nuclear Power Minor to the BS in Mechanical Engineering with funding from the U.S. Nuclear Regulatory Commission.

The MIE Department realizes Mechanical and Industrial Engineering education, research and scholarship and advances professional frontiers within a creative, multi-disciplinary and diverse atmosphere that promotes discovery, creativity and innovation. It is the largest of seven departments in the College of Engineering at LSU. The College is experiencing a period of unprecedented growth, which involves an investment of a $100M new engineering complex, a result of a public-private partnership. The new engineering complex will come on line in 2017.

The CCT is an innovative research environment, advancing computational sciences, technologies and the disciplines they touch. Researchers at CCT use the advanced cyberinfrastructure – high-performance computing (HPC) and networking, advanced data storage and analysis, and hardware and software development – available at LSU and across LONI (the Louisiana Optical Network Initiative) to enable research in many different fields. By fostering interactions and collaborations among researchers from diverse disciplines, the CCT facilitates the dissemination of ideas and expertise across disciplinary backgrounds to foster knowledge and invention.

Required Qualifications: Ph.D. in nuclear engineering or a related discipline. **Preferred Qualifications:** Applicants with a strong research background and interests in thermal/fluids research (thermal hydraulics), or nuclear propulsion are encouraged to apply, especially if their research and background is in computation/simulation related to these areas. Applicants with exceptional qualifications in experimental research related to these areas of emphasis will be given serious consideration. Women and minority candidates are encouraged to apply.

An offer of employment is contingent on a satisfactory pre-employment background check. Applications will be accepted until the position is filled and those received before December 15, 2014 will be guaranteed full consideration. Apply online and view a more detailed ad at: **www.lsusystemcareers.lsu.edu**. Position #036921.

Quick link at ad URL: **https://lsusystemcareers.lsu.edu/applicants/Central?quickFind=57968**

LSU IS AN EQUAL OPPORTUNITY/EQUAL ACCESS EMPLOYER

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mation is available at http://www.njtech.edu.cn. Title: Assistant or Associate Professor of Biomedical Engineering Job Category: Faculty Division: Shiley School of Engineering Department: Shiley School of Engineering Opened Date: 08/01/2014 Closed Date: 10/31/2014 Hours: Full time Benefits: Full time faculty Short Description: The Biomedical Engineering Graduate Program at the University of Portland seeks a faculty member for a tenure-track position at the assistant or associate professor level. Responsibilities: The University is launching a professional master's degree in biomedical engineering in Summer 2015. The selected faculty member will be at the forefront of developing and implementing what is intended to be a signature program for the University. Requirements: The candidate is expected to have a Ph.D. in biomedical engineering, or related field with expertise in biomedical applications such as instrumentation, signal/imaging processing, tissue engineering, bio-transport, and/or related areas. Dedication to excellence in teaching is essential. Preference will be given to candidates with industrial experience. Primary duties include teaching graduate level courses, however the faculty member will be expected to contribute to the undergraduate program(s)

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closest to his/her specialty, School-wide service courses, as well as program development for the master's degree in biomedical engineering. Faculty members are also expected to be active with laboratory development, scholarship/research, and service. The deadline for submitting applications is October 31st and review will begin at that time. Only electronic applications will be considered. A background investigation check is required before final hiring can be completed. The selected candidate must be legally authorized to work in the United States and not require sponsorship. All applications must include a curriculum vitae, letter of interest discussing teaching and scholarship philosophy, and contact information for at least three references. Required Documents:

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Cover Letter, Curriculum Vitae Link to apply for the position: https://up.hiretouch.com/applicant-login?jobID=20209 A background investigation check is required before final hiring procedures can be completed. Founded in 1901, the University of Portland is a private, comprehensive, Catholic university of 3800 students, 3200 undergraduates and 600 graduates presently enrolled, with a mission of teaching and learning, faith and formation, service and leadership. We are an EQUAL OPPORTUNITY EMPLOYER striving to employ personnel at all levels who will support and enhance our educational mission and purpose. Please visit our website at www.up.edu for more information about this position and the University.

CONSULTING

PENNSYLVANIA STATE UNIVERSITY

NEW FACULTY SEARCHES IN MECHANICAL ENGINEERING AND NUCLEAR ENGINEERING

The Department of Mechanical and Nuclear Engineering at The Pennsylvania State University is pleased to announce a significant growth of faculty over the next three years. It is expected that the faculty will expand by 25% with ten new tenure-track positions in mechanical engineering. This year, the Department is seeking excellent applicants to fill five tenure-track positions in mechanical engineering and two tenure-track positions in nuclear engineering. The areas of interest for mechanical engineering include, but are not limited to: manufacturing and materials processing, cyber-physical systems, energy systems, multi-scale modeling, instrumentation and controls, biomechanics and biomedical devices, automation, and other emerging areas. The areas of interest for nuclear engineering include, but are not limited to: nuclear power and science, reactor physics, nuclear fuel cycle, nuclear materials, and other emerging areas. Applicants should have demonstrated outstanding scholarly research experience and teaching interests in mechanical engineering, nuclear engineering, or a related field.

The Department is home to 50 faculty, 270 graduate students, and 1000 undergraduate students. The faculty conduct in excess of $27M per year of funded research across a broad spectrum of traditional and emerging areas. Penn State actively encourages and provides resources for interdisciplinary research collaboration through university-level institutes primarily focused on materials, cyberscience, health, and energy. The Department offers separate B.S., M.S., and Ph.D. degree programs in both mechanical engineering and nuclear engineering, including distance graduate programs in both mechanical and nuclear engineering. Further information on the Department can be found at: **http://www.mne.psu.edu/**.

Qualifications for these positions include a doctorate in engineering or a related field. Successful candidates will be expected to teach courses at both the undergraduate and graduate levels, to develop an internationally-recognized, externally-funded research program, and to contribute to the operation and promotion of the department, college, university, and profession through service. Nominations and applications will be considered until the positions are filled. Screening of applicants will begin on October 15, 2014. **Applicants should submit a statement of professional interests, a curriculum vitae, and the names and addresses of four references. Please submit these three items in one pdf file electronically to job #52555 at http://www.psu.jobs**.

Employment will require successful completion of background check(s) in accordance with University policies. Penn State is committed to affirmative action, equal opportunity and the diversity of its workforce.

MECHANICAL ENGINEERING FACULTY—Washington State University Vancouver invites applications for a full-time tenure-track position at the assistant professor level beginning 8/16/2015. Candidates are sought with expertise in renewable energy related areas; thermal management of electronics; and/or micro/nano fluidic systems.

Required qualifications: Ph.D. in Mechanical Engineering by the employment start date and demonstrated ability to (1) develop a funded research program, (2) establish) contribute to our campus diversity goals (e.g. incorporate issues of diversity into mentoring, curriculum, service or research). **Preferred qualifications**: (1) already have published promising scholarly work in the field and (2) relevant industrial background. **Duties include:** (1) teaching at undergraduate and graduate levels, topics including thermodynamics, fluids, heat transfer and/or renewable energy; (2) participation and documentation of distinguished scholarly activities including research, innovative teaching and laboratory development; (3) securing external funding for research programs; and (4) service to the department and university through committee work, recruitment, and interaction with industry. WSU Vancouver serves about 3,000 graduate and undergraduate students and is **fifteen miles north of Portland, Oregon**. The rapidly growing School of Engineering and Computer Science (ENCS) equally values both research and teaching. WSU is Washington's land grant university with faculty and programs on four campuses. For more information: http://ecs.vancouver.wsu.edu. WSU Vancouver is committed to building a culturally diverse educational environment. **To apply:** Please visit www.wsujobs.com and search postings by location. Applications must include: (1) cover letter with a clear description of experience relevant to each of the required and preferred qualifications; (2) vita including a list of at least three references, and (3) A statement (two page total) of how candidate's research will expand/complement the current research in ENCS and a list of the existing ENCS courses the candidate can teach and any new courses the candidate proposes to develop. Application deadline is December 12, 2014.

WASHINGTON STATE UNIVERSITY IS AN EQUAL OPPORTUNITY/AFFIRMATIVE ACTION EDUCATOR AND EMPLOYER. Members of ethnic minorities, women, special disabled veterans, veterans of the Vietnam-era, recently separated veterans, and other protected veterans, persons of disability and/or persons age 40 and over are encouraged to apply. WSU employs only U.S. citizens and lawfully authorized non-U.S. citizens.

UNIVERSITY OF CENTRAL FLORIDA
MECHANICAL AND AEROSPACE ENGINEERING

PROFESSORSHIPS IN MECHANICAL AND AEROSPACE ENGINEERING

The University of Central Florida (UCF) announces two senior faculty positions at the rank of Professor to be filled by the Department of Mechanical and Aerospace Engineering (MAE) in the College of Engineering and Computer Science (CECS). This hiring program is part of an aggressive growth plan to form strategic partnerships with the recently announced Advanced Manufacturing Research Center (http://www.flbog.edu/pressroom/newsclips_detail.php?id=29466) and the newly established College of Medicine, with a focus on expertise that includes sensors and advanced manufacturing, bioengineering, aerospace systems engineering, and mechanical systems. Candidates with backgrounds in all other areas of mechanical and aerospace engineering will also be considered. Exceptionally well-qualified candidates will be considered for the Provost Professor positions. Preference will be given to candidates who can form and lead multidisciplinary research teams across academic fields, both within and outside of the College's domains. Women and individuals from underrepresented groups are encouraged to apply. Applications and nominations are solicited for these positions.

With this targeted hiring initiative, the University seeks to build on its existing strengths in the engineering and computing disciplines by adding senior faculty members who will make an immediate impact on the Department's and College's funded research activities and scholarly productivity.

Interested persons with questions about the positions may contact the Search Committee at maefacsearch@ucf.edu. For more information about the department, we invite all interested parties to visit MAE's website at www.mae.ucf.edu. Candidates must submit all documents on-line to http://www.jobswithucf.com/postings/39267. Review of applications will begin immediately until the positions are filled. We expect the selected candidates will start in August 2015.

UCF is an equal opportunity, affirmative action employer and encourages the candidacies of women, members of racial and ethnic minorities, and persons with disabilities. All searches and documents are subject to the Sunshine and public records laws of the State of Florida.

ADVERTISERINDEX

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NEW EDITORS FOR JOURNALS

WITH THREE NEW JOURNALS SET FOR RELEASE in 2015, seven new editors have joined the ASME Journal program in addition to the reappointment of an eighth. Two new appointments are for journals making their debut in January: **Igor Pioro**, editor of the *Journal of Nuclear Engineering and Radiation Science*, and **Bilal Ayyub**, editor of the *ASCE-ASME Journal of Risk Uncertainty in Engineering Systems Part B: Mechanical Engineering*. The *Journal of Verification and Validation*, to launch the first half of 2015, will be edited by **Ashley Emery.**

Editors making their debut include **Joseph Beaman**, *Journal of Dynamic Systems, Measurement, and Control*; **Vijay Kumar**, *Journal of Mechanisms and Robotics*; **Y.C. Lee**, *Journal of Electronic Packaging*; and **Steve Shen**, *Journal of Vibration and Acoustics*. **Malcom Andrews** has been reappointed for a second term as the editor of *Journal of Fluids Engineering*. To learn more about these ASME journals, visit **journaltool.asme.org.**

E4C WEBINAR: HUMANITARIAN USE OF UAVS

THE INCREASING USE OF UNMANNED aerial vehicles for disaster response and recovery projects by humanitarian organizations was the subject of the Engineering for Change webinar "Humanitarians in the Sky: How UAVs are Changing Disaster Response."

Patrick Meier, director of social innovation at QCRI, led the discussion. Recognized worldwide for his leadership in using new technologies to improve humanitarian response, he is the author of the widely read blog, iRevolution. For archived video of the webinar, visit **www.engineeringforchange.org/**.

ASME ENDORSES AFTERSCHOOL STEM BILL

A BILL PROMOTING AFTERSCHOOL and summer science, technology, engineering, and math programs—the Supporting Afterschool STEM Act—has been endorsed by ASME in a letter to Sen. **Jeanne Shaheen** of New Hampshire, who introduced the bill.

The bill is based on research by the Afterschool Alliance, which found that extracurricular STEM programs retain students from diverse populations in formal STEM education.

In the letter to Shaheen, ASME wrote, "Research has shown the importance of afterschool programs in engaging students in STEM fields and building STEM-relevant skills and proficiencies, especially for girls, students from populations traditionally underrepresented in STEM fields, and students from low socioeconomic circumstances. The Supporting Afterschool Act is a timely bill, which will help expand access to quality STEM experiences."

FOUNDATION JOINS NASA

THE ASME FOUNDATION HAS PARTNERED with NASA on a new program that gives K-12 students the chance to design items that could be manufactured on the International Space Station. Through the new Future Engineers program, the space agency and the foundation will develop a series of 3-D design challenges and curricula intended to inspire students to solve real-world challenges.

Future Engineers was announced in July at the White House Maker Faire.

A Zero-G Technology 3-D demonstration printer will launch to the station in the fall and will be the first printer to fly in space. It will produce a run of space station parts and tools to be tested, and print the Future Engineers competition's winning design.

A permanent 3-D printer, the Additive Manufacturing Facility, is in development and is expected to be installed on the ISS.

The program's inaugural challenge, begun in September, asks students to create 3-D models specifically designed to be used in space. The winning design will be uploaded to a 3-D printer on the International Space Station and printed by astronauts.

Future Engineers was conceived by a small team that included mechanical engineer and STEM advocate **Deanne Bell**, who is both a member of ASME and its Foundation's Board of Directors. The idea for the competition was sparked by an online video about the 3-D Printing in Zero G Experiment—a joint venture between NASA and Made in Space Inc. to launch 3-D printing equipment that can operate in microgravity.

Bell worked with **Niki Werkheiser**, NASA 3-D Printing in Zero-G project manager, to develop the program.

"As a member, I know that ASME has perhaps the largest network of advanced manufacturing and 3-D design experts in the world," Bell said. "It seemed like the perfect fit for a program aimed to teach students how to 3-D model their ideas within the context of space manufacturing."

Bell noted that the goal of the program is to connect Future Engineers challenges and curriculum with educators, museums, after-school programs, and maker-capable facilities in local communities. "It's a large

ASME AND GERMAN ENGINEERS PONDER

DEVELOPING ADVANCED MANUFACTURING content has been a top priority for ASME. Now, ASME is collaborating with the Association of German Engineers, known by its German initials VDI, on a project intended to obtain input from early career engineers regarding the types of advanced manufacturing technology programs the two societies should develop in the future.

ASME and VDI signed a memorandum of understanding earlier this year that called for a more collaborative approach to addressing the need for new advanced manufacturing technology. In July, members from the newly formed ASME-VDI Early Career Engineer Advanced Manufacturing Technology Project team, comprising five members from each society, met at the VDI headquarters in Düsseldorf to kick off the joint project.

ASME was represented by **Julie Kulik, Paul Moore, David Rule, Lakshmi Singh,** and **Matthew Standley**; **Dania Dawood, Christoph Bellmann, Lars Gehrke, Arno Kühn,** and **Sebastian Siemes** were the VDI team members. The team is supervised by **Michael Tinkleman**, ASME's director of research, and **Claudia Rasche**, the project coordinator from VDI.

During the kick-off meeting, team members selected "The Factory of the Future" as the theme of the project. Using background material provided by the ASME and VDI leaders on U.S. and European manufacturing initiatives—in particular Horizon

For more information on the ASME-VDI Advanced Manufacturing Project, contact:

Michael Tinkleman at **tinklemanm@asme.org**

TO LAUNCH STUDENT DESIGN CHALLENGE

To learn more, visit
www.futureengineers.org

Researchers monitor the performance of extruders inside the Made In Space experiment box during a microgravity portion of a flight aboard a modified Boeing 727 from the Zero G Corp.

Photo: Made In Space Inc.

endeavor. The ASME Foundation will need further sponsors and supporters to fully realize these goals," she said. **ME**

ADVANCED FACTORY

2020, which includes its own Factories of the Future program—the engineers will design an efficient, environmentally friendly facility that incorporates high-tech advanced manufacturing processes while addressing such human concerns as staff organization and structure, working environment, and work-life balance.

The ASME-VDI Early Career Engineer Advanced Manufacturing Technology Project is modeled after a previous team project, Leadership in Sustainability, which the two organizations pursued three years ago. A white paper compiling the current ASME-VDI team's findings will be presented next year at a number of conferences, including Hannover Messe 2015, VDI Automation 2015, and the August 2015 ASME Advanced Manufacturing and Design Impact Forum in Boston. The team is also expected to make recommendations on other advanced manufacturing opportunities.

NEW ASME PRESS BOOK CELEBRATES LANDMARKS

One hundred ASME engineering landmarks are the subject of a new book from ASME Press. *Machines That Made History — Landmarks in Mechanical Engineering* by Jennifer M. Black, features concise descriptions and photos of each landmark.

Sponsored by the ASME History and Heritage Committee, the book highlights the key devices and innovations that have shaped the mechanical engineering field and, in the process, have influenced modern civilization. Beginning with early breakthroughs in mechanical technology, such as the Archimedes screw pump, the Noria Al-Muhammadiyya water wheel, and the Newcomen engine, Black organized the selected landmarks into several chapters addressing specific themes, from energy and manufacturing to information, science, and medicine.

More recent innovations Black profiled include the Hanford B reactor, the Hughes two-cone drill, the ASME Boiler and Pressure Vessel Code, the Model T Ford, the Holland Tunnel ventilation system, the Holt Caterpillar tractor, the Tokaido Shinkansen railway, the Wright Flyer III, the Apollo Lunar Module LM-13, the Sholes & Glidden typewriter, and the Pierce-Donachy ventricular assist device.

The Noria al-Muhammadiyya, a water-powered pump more than 350 years old, is still in use.

Nikola Tesla, shown here in 1916 at about age 50, has been portrayed as a vampire scientist and now may get his own opera.

THE TESLA PHENOMENON

During his lifetime, Edison stole the limelight. So why is Tesla's reputation now bigger than ever?

IT WAS AN IGNOBLE END FOR A SELF-PROCLAIMED genius. Nikola Tesla died broke and alone (and maybe passionately in love with a pigeon) at the Hotel New Yorker in Manhattan in 1943. The prolific inventor had long been overshadowed by his rival, Thomas Edison, who had gained worldwide fame for the light bulb, the phonograph, and the motion-picture camera.

Today, more than 70 years later, there is a revival for the man responsible for alternating current and the induction motor. The name Tesla is now considered very cool.

Thomas Edison may have invented movies, and Mickey Rooney played *Young Tom Edison* while Spencer Tracy starred as *Edison, the Man*, but there hasn't been a film about him since 1940.

Tesla, on the other hand, is something of a pop-culture phenomenon. In the 2006 Christopher Nolan film, *The Prestige*, rock musician David Bowie played an eccentric version of Tesla capable of building a teleportation machine.

More recently, Jim Jarmusch (director of such films as *Mystery Train* and *Night on Earth*) and composer Phil Kline have been collaborating on a "modern baroque opera," *Tesla in New York*. Bernstein Artists Inc., the New York production company developing the project, describes the opera as "a 'more or less' true series of fantasies based on the incredible life of Nikola Tesla. ... A man has conversations with birds, invents electric ray guns, and makes a ship disappear. The reality presented will be that of dreams or memories. Or myths."

Tesla's even a television star. For four seasons of the SyFy series, *Sanctuary*, a fictional version of Tesla has appeared as a part-human, part-vampire scientist.

And celebrity industrialist Elon Musk named his high-end electric car company "Tesla." Would driving an Edison have the same flash appeal?

Maybe we should have seen this coming thirty years ago, when a rock band from Sacramento, Calif., named itself Tesla. Ten years later, New York City named the intersection of West 40th Street and Avenue of the Americas the Nikola Tesla Corner.

And anyone passing through can rent room 3327 at the Hotel New Yorker where Tesla died. There's a plaque on the wall verifying it. According to rumor, this is where Tesla, in declining physical and mental health, developed a romantic attachment to an all-white female pigeon.

For those eager for more things Tesla, there is the Tesla Memorial Society of New York. Its companion website, The Tesla Connection (teslacollection.com), hosts a searchable database of about 4,200 pages of documents relating to Tesla published in his lifetime. It claims to include every major newspaper article on Tesla from 1886 to 1920 and provides a look at the early days of X-ray, remote control, and robotics, and also at Tesla's efforts to develop wireless electricity.

Iwona Rudinska, editor of The Tesla Collection, says that part of Tesla's appeal and the reason that his memory is making such a comeback today is that "he is comparable to Steve Jobs in that he was a visionary who changed the world."

That's true of Edison, too.

Tesla, she added, was "not just an innovator, but a scientist whose mind operated within a philosophical framework that made his writings fascinating. He was a man who traveled his own road." ME

JAMES PERO