IEEE SPECTRUM

FOR THE TECHNOLOGY INSIDER | 01.15

FIBER ACROSS THE ARCTIC
Opportunity from sea-ice melt
P. 11

BACK TO THE MOON
Closing in on the Lunar XPrize
P. 30

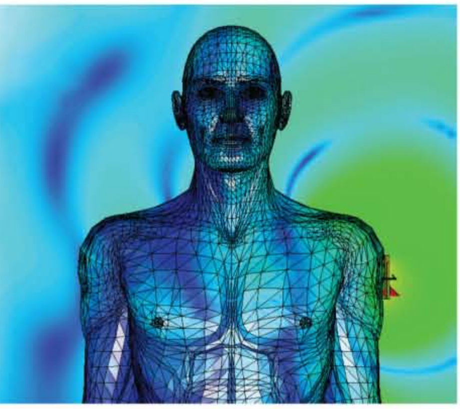
GOOGLE'S RAD NEW PHONE
It's modular and it's cheap
P. 42

HOME HUMANOID

CAN AN "EMOTION ENGINE" MAKE PEPPER THE ROBOT ENDEARING? P. 26

Top Tech 2015

IEEE



Top Tech 2015

NEW BEST FRIENDS: Bruno Maisonnier, founder and CEO of Aldebaran Robotics, wants to bring friendly companion robots into people's homes.

On the Cover and Above **Photograph for *IEEE Spectrum* by Antoine Doyen**

DEPARTMENTS_01.15

IEEE SPECTRUM

ADDITIONAL RESOURCES

Tech Insider / Webinars

Available at spectrum.ieee.org/webinar

- Modeling Material Properties Based on Measured Data—Now Available on Demand
- Thinking Past the Plug: Integrating Electric Vehicles With the Smart Grid—Now Available on Demand
- OpenStack's Secrets to Success: Rapid Innovation and Community Growth—Now Available on Demand

NEW PRODUCT RELEASE LIBRARY
http://spectrum.ieee.org/static/new-product-release-library

WHITE PAPERS
http://spectrum.ieee.org/whitepapers

The Institute

Available 9 January at theinstitute.ieee.org

YEAR OF LIGHT The United Nations has declared 2015 the International Year of Light and Light-Based Technologies. The IEEE Photonics Society and more than 100 organizations will be holding events throughout the year to celebrate the important role played by light applications.

CONNECTING COUNTRIES An IEEE Milestone honors TPC-1, the first transpacific cable to connect Japan and the United States. Completed in 1964, the undersea cable greatly increased the communications capacity between the two countries and triggered a rapid development of networks throughout East Asia.

LEADERSHIP EVENT FOR WOMEN The IEEE Women in Engineering International Leadership Conference, to be held from 23 to 25 April in San Jose, Calif., will focus on innovation and entrepreneurship as well as helping attendees attain their career goals.

FROM LEFT: DAISY GILARDINI/CORBIS; RANDI KLETT; SQUADRONE SYSTEM

IEEE SPECTRUM
(ISSN 0018-9235) is published monthly by The Institute of Electrical and Electronics Engineers, Inc. All rights reserved. © 2015 by The Institute of Electrical and Electronics Engineers, Inc., 3 Park Avenue, New York, NY 10016-5997, U.S.A. Volume No. 52, issue No. 1, International edition. The editorial content of IEEE Spectrum magazine does not represent official positions of the IEEE or its organizational units. Canadian Post International Publications Mail (Canadian Distribution) Sales Agreement No. 40013087. Return undeliverable Canadian addresses to: Circulation Department, IEEE Spectrum, Box 1051, Fort Erie, ON L2A 6C7. Cable address: ITRIPLEE. Fax: +1 212 419 7570. INTERNET: spectrum@ieee.org. ANNUAL SUBSCRIPTIONS: IEEE Members: $21.40 included in dues. Libraries/institutions: $399. POSTMASTER: Please send address changes to IEEE Spectrum, c/o Coding Department, IEEE Service Center, 445 Hoes Lane, Box 1331, Piscataway, NJ 08855. Periodicals postage paid at New York, NY, and additional mailing offices. Canadian GST #125634188. Printed at 120 Donnelley Dr., Glasgow, KY 42141-1060, U.S.A. IEEE Spectrum circulation is audited by BPA Worldwide. IEEE Spectrum is a member of the Association of Business Information & Media Companies, the Association of Magazine Media, and Association Media & Publishing. IEEE prohibits discrimination, harassment, and bullying. For more information, visit http://www.ieee.org/web/aboutus/whatis/policies/p9-26.html.

IEEE SPECTRUM Previous Page | Contents | Zoom in | Zoom out | Front Cover | Search Issue | Next Page

BACK STORY_

SQUADRONE SYSTEM

Selfies on Steroids

THE FEDERAL AVIATION ADMINISTRATION prohibits people from operating even the smallest drones for business purposes in the United States, with few exceptions. Journalism is not among them. So how do you test a selfie-taking multicopter, the subject of one of the stories in our Top Tech 2015 special report?

One way is to send the reporter to France, which is exactly what we did. There, drone regulations allow you to test and demo such products, as long as you follow some sensible guidelines.

So Senior Editor David Schneider went to Grenoble, where he visited Squadrone System, makers of the Hexo+, a self-following video drone that garnered US $1.3 million in Kickstarter funding last year. Backers won't be receiving their drones until May and are no doubt curious about how development is progressing. We figured that an on-the-scene report, along with a discussion of the burgeoning activity in this realm, would please them.

After conducting formal interviews, Schneider accompanied three members of the Hexo+ team to a grassy park on the outskirts of Grenoble for a demo. At that time, the hardware for the company's six-bladed multicopter was still in development, so he was shown what could be done with the Hexo+ software installed on a 3D Robotics Iris quadcopter.

While running away from the little drone, Schneider, a Hitchcock fan, immediately recalled Cary Grant being chased by a crop duster in *North by Northwest*. "Trying to dodge the drone so reminded me of that scene, I couldn't help but take a dive at one point for dramatic effect," says Schneider. "It was completely stupid—and I ended up losing my phone—but I just couldn't resist."

Next time we send Schneider on such an assignment, we'll have to remind him to wear a gray suit. ■

CITING ARTICLES IN IEEE SPECTRUM *IEEE Spectrum* publishes an international and a North American edition, as indicated at the bottom of each page. Both have the same editorial content, but because of differences in advertising, page numbers may differ. In citations, you should include the issue designation. For example, And Now This… is in *IEEE Spectrum*, Vol. 52, no. 1 (INT), January 2015, p. 60, or in *IEEE Spectrum*, Vol. 52, no. 1 (NA), January 2015, p. 72.

01.15

IEEE SPECTRUM

EDITOR IN CHIEF
Susan Hassler, s.hassler@ieee.org

EXECUTIVE EDITOR
Glenn Zorpette, g.zorpette@ieee.org

EDITORIAL DIRECTOR, DIGITAL
Harry Goldstein, h.goldstein@ieee.org

MANAGING EDITOR
Elizabeth A. Bretz, e.bretz@ieee.org

SENIOR ART DIRECTOR
Mark Montgomery, m.montgomery@ieee.org

SENIOR EDITORS
Stephen Cass (Resources), cass.s@ieee.org
Erico Guizzo (Digital), e.guizzo@ieee.org
Jean Kumagai, j.kumagai@ieee.org
Samuel K. Moore (News), s.k.moore@ieee.org
Tekla S. Perry, t.perry@ieee.org
Philip E. Ross, p.ross@ieee.org
David Schneider, d.a.schneider@ieee.org

DEPUTY ART DIRECTOR Brandon Palacio, b.palacio@ieee.org
PHOTOGRAPHY DIRECTOR Randi Klett, randi.klett@ieee.org
ASSOCIATE ART DIRECTOR Erik Vrielink, e.vrielink@ieee.org

ASSOCIATE EDITORS
Ian Chant, i.chant@ieee.org
Rachel Courtland, r.courtland@ieee.org
Celia Gorman (Multimedia), celia.gorman@ieee.org
Eliza Strickland, e.strickland@ieee.org
ASSISTANT EDITOR Willie D. Jones, w.jones@ieee.org
SENIOR COPY EDITOR Joseph N. Levine, j.levine@ieee.org
COPY EDITOR Michele Kogon, m.kogon@ieee.org
EDITORIAL RESEARCHER Alan Gardner, a.gardner@ieee.org

EXECUTIVE PRODUCER, SPECTRUM RADIO Sharon Basco
ASSISTANT PRODUCER, SPECTRUM RADIO Francesco Ferorelli, f.ferorelli@ieee.org

ADMINISTRATIVE ASSISTANTS
Ramona Foster, r.foster@ieee.org
Nancy T. Hantman, n.hantman@ieee.org
INTERN Neel V. Patel

CONTRIBUTING EDITORS
Evan Ackerman, Mark Anderson, John Blau, Robert N. Charette, Peter Fairley, Tam Harbert, Mark Harris, David Kushner, Robert W. Lucky, Paul McFedries, Prachi Patel, Richard Stevenson, Lawrence Ulrich, Paul Wallich

DIRECTOR, PERIODICALS PRODUCTION SERVICES Peter Tuohy
EDITORIAL & WEB PRODUCTION MANAGER Roy Carubia
SENIOR ELECTRONIC LAYOUT SPECIALIST Bonnie Nani

SPECTRUM ONLINE
PRODUCT MANAGER, DIGITAL Shannan Brown
WEB PRODUCTION COORDINATOR Jacqueline L. Parker
MULTIMEDIA PRODUCTION SPECIALIST Michael Spector

EDITORIAL ADVISORY BOARD
Susan Hassler, *Chair*; Gerard A. Alphonse, Francine D. Berman, Jason Cong*, Sudhir Dixit, Limor Fried, Kenneth Y. Goldberg, Bin He, Robert Hebner, Chenming Hu*, Grant Jacoby, Christopher J. James, Norberto Lerendegui, John P. Lewis, Steve Mann, Jacob Østergaard, Umit Ozguner, John Rogers, Jonathan Rothberg, Umar Saif, Gaurav Sharma, Takao Someya, Sergio Verdú, Jeffrey M. Voas, Kazuo Yano, Larry Zhang*, Yu Zheng, Kun Zhou
* Chinese-language edition

EDITORIAL / ADVERTISING CORRESPONDENCE
IEEE Spectrum
3 Park Ave., 17th Floor
New York, NY 10016-5997
EDITORIAL DEPARTMENT
TEL: +1 212 419 7555 FAX: +1 212 419 7570
BUREAU Palo Alto, Calif.; Tekla S. Perry **+1 650 752 6661**
ADVERTISING DEPARTMENT +1 212 705 8939

CONTRIBUTORS_

Elie Dolgin

Dolgin, a freelance science journalist based in Somerville, Mass., writes in this issue about portable diagnostic devices that may soon have a real impact on global health [p. 34]. Before moving into journalism, Dolgin earned a Ph.D. in evolutionary genetics, studying the development of sex in the *Caenorhabditis elegans* worm. He now writes about human health and biomedical research, and he's thankful for his years in the lab, which he says taught him to "judge good science."

Matthew Hollister

Hollister is an illustrator based in Seattle whose work has been featured in *The New Yorker, The New York Times*, and *Wired*. Known for his clean and colorful designs, he illustrated the seven feature articles in this issue. Given the disparate range of topics, he aimed for a universal feel that was slightly abstract but cohesive. "I really wanted to push the ideas behind each article and draw readers in while retaining a common thread," Hollister says.

Peter Fairley

Contributing editor Fairley often covers conflicts between energy use and the environment. But while visiting Topaz Solar Farms, in California [p. 38], he was struck by their coexistence. Construction crews noticed that one of the endangered San Joaquin kit foxes would watch them work, and they gave it a wide berth. After the fox got trapped in a 5.5-meter-deep auger-drilled hole, the workers named it Auggie. "The fox came out unscathed and went right back to making his living on the Topaz site," Fairley says.

Amy Nordrum

Freelance journalist Nordrum has written for *The Atlantic Monthly*, *Popular Mechanics*, and *Scientific American*. Prior to moving to New York City, she lived in Alaska for three years, and she experienced firsthand the state's lack of communications infrastructure. In this issue, she reports on a new fiber-optic cable that will link the state's remotest regions [p. 11]. "Until you live in Alaska, you have no idea how deficient the infrastructure is," Nordrum says. "This new connection could make a huge difference for the state."

G. Pascal Zachary

In this issue, Zachary, a veteran journalist and a professor of practice at Arizona State University, considers health-care technology for sub-Saharan Africa [p. 10]. Last June, on a National Science Foundation grant to study computer science in East Africa, he met with Ugandan researchers who are developing mobile-phone apps for disease detection. While such technologies are promising, he notes, "they're just the first step in a whole chain of events that have to happen before we'll see real progress."

01.15

IEEE

IEEE MEDIA
SENIOR DIRECTOR; PUBLISHER, IEEE SPECTRUM
James A. Vick, j.vick@ieee.org
ASSOCIATE PUBLISHER, SALES & ADVERTISING DIRECTOR
Marion Delaney, m.delaney@ieee.org
RECRUITMENT AND LIST SALES ADVERTISING DIRECTOR
Michael Buryk, m.buryk@ieee.org
BUSINESS MANAGER Robert T. Ross, r.ross@ieee.org
IEEE MEDIA/SPECTRUM GROUP MARKETING MANAGER
Blanche McGurr, b.mcgurr@ieee.org
IEEE MEDIA GROUP DIGITAL MARKETING SENIOR MANAGER
Ruchika Anand, r.t.anand@ieee.org
LIST SALES & RECRUITMENT SERVICES PRODUCT/ MARKETING MANAGER Ilia Rodriguez, i.rodriguez@ieee.org
REPRINT SALES +1 212 221 9595, EXT. 319
MARKETING & PROMOTION SPECIALIST Faith H. Jeanty, f.jeanty@ieee.org
SENIOR MARKETING ADMINISTRATOR Simone Darby, simone.darby@ieee.org
MARKETING ASSISTANT Quinona Brown, q.brown@ieee.org
RECRUITMENT SALES ADVISOR Liza Reich +1 212 419 7578
ADVERTISING SALES +1 212 705 8939

ADVERTISING PRODUCTION MANAGER Felicia Spagnoli
SENIOR ADVERTISING PRODUCTION COORDINATOR
Nicole Evans Gyimah
ADVERTISING PRODUCTION +1 732 562 6334

IEEE STAFF EXECUTIVE, PUBLICATIONS Anthony Durniak

IEEE BOARD OF DIRECTORS
PRESIDENT & CEO Howard E. Michel, president@ieee.org
+1 732 562 3928 FAX: +1 732 465 6444

PRESIDENT-ELECT Barry L. Shoop
TREASURER Jerry L. Hudgins **SECRETARY** Parviz Famouri
PAST PRESIDENT J. Roberto B. de Marca

VICE PRESIDENTS
Saurabh Sinha, Educational Activities; Sheila Hemami, Publication Services & Products; Wai-Choong "Lawrence" Wong, Member & Geographic Activities; Bruce P. Kraemer, President, Standards Association; Vincenzo Piuri, Technical Activities; James A. Jefferies, President, IEEE-USA

DIVISION DIRECTORS
Ellen J. Yoffa (I); Hirofumi Akagi (II); Harvey A. Freeman (III); William W. Moses (IV); Susan K. Land (V); Rob Reilly (VI); Wanda K. Reder (VII); John W. Walz (VIII); Marina Ruggieri (IX); Kazuhiro Kosuge (X)

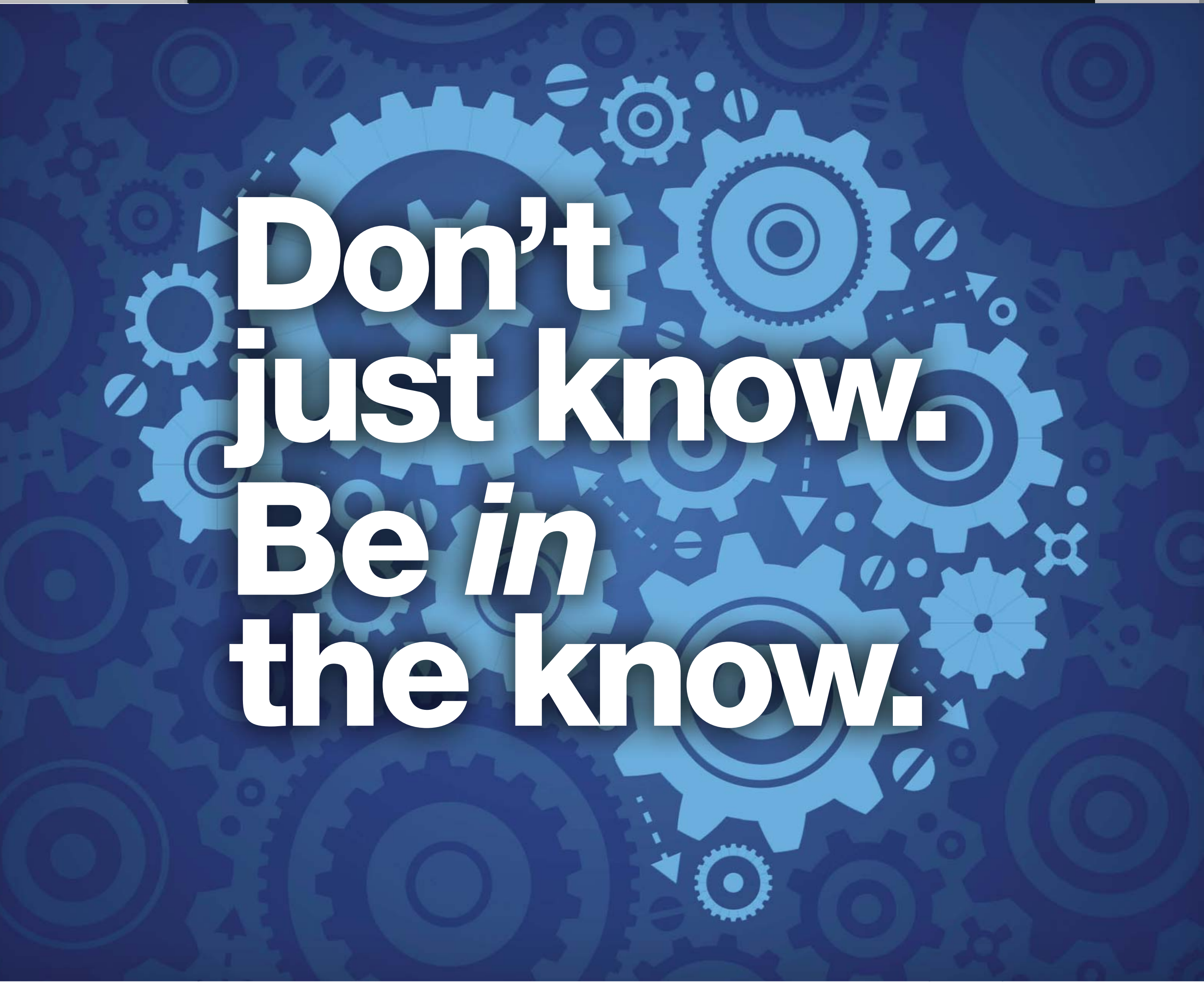
REGION DIRECTORS
Vincent P. Socci (1); Timothy P. Kurzweg (2); Mary Ellen Randall (3); Robert C. Parro (4); J. Derald Morgan (5); Thomas Coughlin (6); Amir G. Aghdam (7); Costas M. Stasopoulos (8); Norberto M. Lerendegui (9); Ramakrishna Kappagantu (10)

DIRECTORS EMERITUS Eric Herz, Theodore W. Hissey

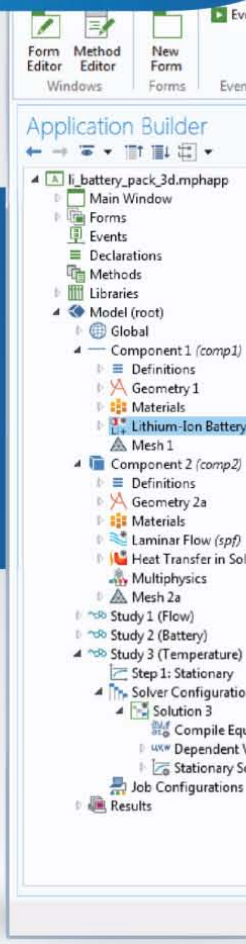
IEEE STAFF
EXECUTIVE DIRECTOR & COO James Prendergast
+1 732 502 5400, james.prendergast@ieee.org
PUBLICATIONS Anthony Durniak
+1 732 562 3998, a.durniak@ieee.org
CORPORATE ACTIVITIES Elena Gerstmann
+1 732 981 3452, e.gerstmann@ieee.org
EDUCATIONAL ACTIVITIES Douglas Gorham
+1 732 562 5483, d.g.gorham@ieee.org
ACTING CHIEF INFORMATION OFFICER Donna Hourican
+1 732 562 6330, d.hourican@ieee.org
MEMBER & GEOGRAPHIC ACTIVITIES Cecelia Jankowski
+1 732 562 5504, c.jankowski@ieee.org
HUMAN RESOURCES Shannon Johnston, SPHR
+1 732 562 6343, s.johnston@ieee.org
STANDARDS ACTIVITIES Konstantinos Karachalios
+1 732 562 3820, constantin@ieee.org
GENERAL COUNSEL & CHIEF COMPLIANCE OFFICER
Eileen M. Lach, +1 212 705 8990, e.m.lach@ieee.org
CHIEF MARKETING OFFICER Patrick D. Mahoney
+1 732 562 5596, p.mahoney@ieee.org
CHIEF FINANCIAL OFFICER Thomas R. Siegert
+1 732 562 6843, t.siegert@ieee.org
TECHNICAL ACTIVITIES Mary Ward-Callan
+1 732 562 3850, m.ward-callan@ieee.org
MANAGING DIRECTOR, IEEE-USA Chris Brantley
+1 202 530 8349, c.brantley@ieee.org
IEEE PUBLICATION SERVICES & PRODUCTS BOARD
Sheila Hemami, *Chair*; John Baillieul, Jennifer Bernhard, Jean-Luc Gaudiot, Ron Goldfarb, Glenn Gulak, Lawrence Hall, James Irvine, Hulya Kirkici, Carmen Menoni, Paolo Montuschi, Michael Pecht, Michael Polis, Tariq Samad, Fred Schindler, Gianluca Setti, Gaurav Sharma, Curtis Siller, David Tian, Joel Trussell, Leung Tsang, Stephanie White, Steve Yurkovich

IEEE OPERATIONS CENTER
445 Hoes Lane, Box 1331, Piscataway, NJ 08854-1331 U.S.A.
Tel: +1 732 981 0060 Fax: +1 732 981 1721

PHOTO-ILLUSTRATIONS BY **Gluekit**


Don't
just know.
Be *in*
the know.

FROM MODEL



Verify and Optimize your Designs with COMSOL Multiphysics®

NOW FEATURING THE APPLICATION BUILDER

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

Visit comsol.com/release/5.0

PRODUCT SUITE

COMSOL Multiphysics
COMSOL Server

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

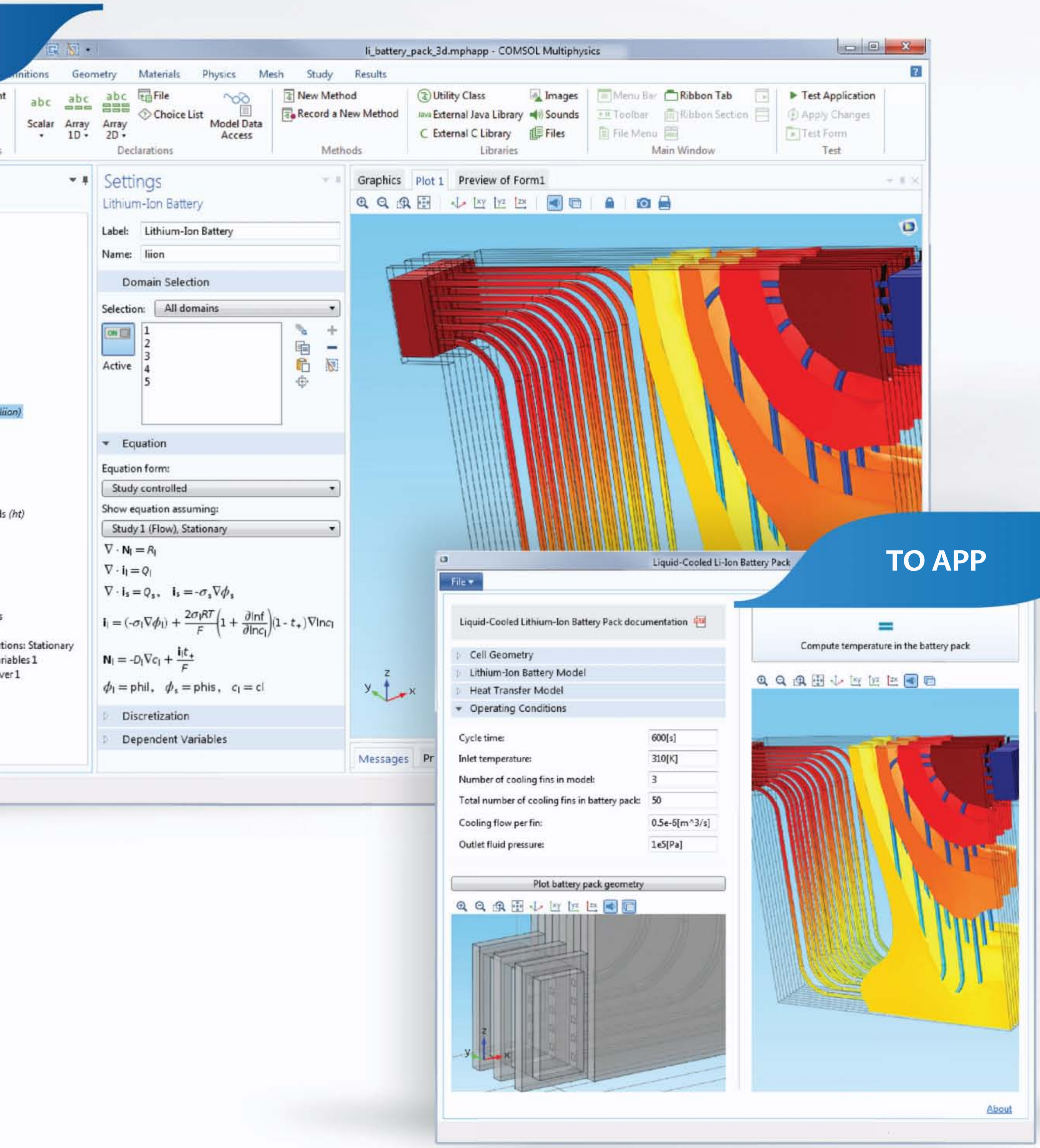
MECHANICAL
Heat Transfer Module
Structural Mechanics Module
Nonlinear Structural Materials Module
Geomechanics Module
Fatigue Module
Multibody Dynamics Module
Acoustics Module

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

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

MULTIPURPOSE
Optimization Module
Material Library
Particle Tracing Module

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


li_battery_pack_3d.mphapp - COMSOL Multiphysics
Geometry
Materials
Physics
Mesh
Study
Results
New Method
Record a New Method
Utility Class
External Java Library
External C Library
Images
Sounds
Files
Ribbon Tab
Test Application
Settings
Lithium-Ion Battery
Label: Lithium-Ion Battery
Name: liion
Domain Selection
Equation
Study controlled
Study 1 (Flow), Stationary
Discretization
Dependent Variables
Graphics
Plot 1
Preview of Form1
Liquid-Cooled Li-Ion Battery Pack
Liquid-Cooled Lithium-Ion Battery Pack documentation
Cell Geometry
Lithium-Ion Battery Model
Heat Transfer Model
Operating Conditions
Cycle time: 600[s]
Inlet temperature: 310[K]
Number of cooling fins in model: 3
Total number of cooling fins in battery pack: 50
Cooling flow per fin: 0.5e-6[m^3/s]
Outlet fluid pressure: 1e5[Pa]
Plot battery pack geometry
Compute temperature in the battery pack
About

KEN SAKWA, a Ugandan with AIDS, is ambivalent about antiretroviral drugs. "They make you sick, and if they don't work...I will die anyway," he says.

G. PASCAL ZACHARY

Technology Alone Won't Improve Health in Africa

Engineers deploy new apps and devices, but much remains to be done

THE SWIFT TECHNOLOGICAL RESPONSE to the deadly Ebola virus highlights the power of new technologies to engage urgent human problems–and also reveals the limits to engineering solutions to emerging diseases.

Crises spawn innovations. In the face of seemingly unstoppable threats, new technologies are rushed into service, aided by removing normal constraints on adoption. New clinical trials are planned, resources mobilized. More risks are taken because humans facing death accept novel improvisations.

In the case of Ebola, the results are heartening. Enough infected people have been saved to raise the hope of a general cure. Yet the lessons aren't clear. Ebola and other lethal infectious diseases confuse as much as they clarify the potential for technology to improve the health of sub-Saharan Africans, who live under the highest incidence of infectious diseases in the world.

Even if Ebola is knocked down, Africans face chronic ailments such as diabetes and heart disease, which arise as more Africans prosper and adopt sedentary, calorie-rich lifestyles. They still fight malaria and many neglected tropical diseases. And they also suffer from a high rate of HIV/AIDS.

The mobile phone, Africa's most important digital technology, is boosting African health as it emerges as a platform for diagnosis and treatment. In 2000, few Africans had a phone; today, about three-quarters do. Mobile phones also give Africans the chance to engineer their own solutions. At Uganda's Makerere University, for instance, researchers are designing software that turns phones into microscopes. Others are using computers to predict the spread of malaria and to translate medical advice from English into local languages.

In parallel, a slew of global innovators are bringing instant diagnostics to market. Like Daktari Diagnostics [see "Portable Pathology for Africa," in this issue], they target Africa and other regions where medical care is often absent or of poor quality. Yet information isn't enough. Treatment costs money. Fake medicines reduce confidence in therapies. Disease is often viewed as a personal failing and a source of shame. Even when patients do everything right, they may die, sowing suspicion.

These complex factors play on the mind of Sakwa, a successful 44-year-old farmer in eastern Uganda whom I've known since 2006. Last June, when I reached his home for a visit, his mother greeted me, and I immediately feared that Sakwa had become a widower.

Jessica, his wife, had indeed died of AIDS, despite receiving antiretroviral (ARV) drugs. She may have begun treatment too late or perhaps failed to take the required doses. Her death makes Sakwa question the power of medicine, which is unfortunate–because he has AIDS, too.

On a cool morning, Sakwa drives a 2000 Toyota Corona from his village in the foothills of Mount Elgon to the city of Mbale. He picks me up and we go to the regional hospital, where he must decide whether to begin ARVs. "They make you sick, and if they don't work, my life will be ruined and I will die anyway," he says.

Sakwa has much to live for. He is well funded, thanks to a boom in cash crops. He owns a tractor, a truck, two small shops, and his Toyota. He doesn't fit the stereotype of the poor, uninformed African. Yet even with a diagnosis of HIV/AIDS and tests revealing a weakened immune system, he's uncertain.

I sit with him as he talks with a counselor. She asks him to start ARV treatment despite worries that he has waited too long to begin. "It's worth a try," she says. He agrees to start.

Sakwa's predicament is Africa's writ large. Health outcomes depend on human choices. Technologies create options, but they don't automatically deliver benefits. New digital devices are revolutionizing our *understanding* of disease in Africa. That helps, but it doesn't guarantee a revolution in health outcomes.
–G. PASCAL ZACHARY

NEWS

24

24 MILLISECONDS: HOW MUCH FASTER DATA CAN GET FROM JAPAN TO THE U.K. ONCE THE ARCTIC CABLE IS BUILT

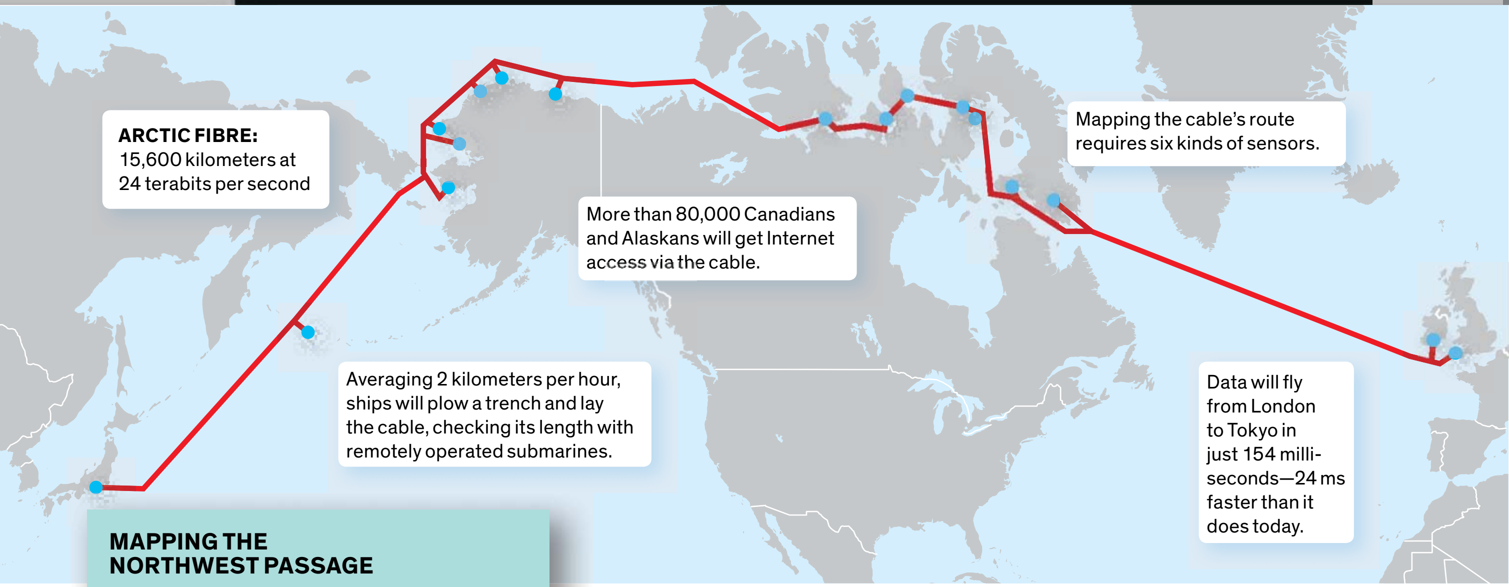
DAISY GILARDINI/CORBIS

FIBER OPTICS FOR THE FAR NORTH

A 24-terabit-per-second undersea cable will connect Japan and the U.K. and also bring broadband to remote Arctic communities

Meter by meter, a slim vein of fiber-optic cable will soon start snaking its way across the bottom of three oceans and bring the world a few milliseconds closer together. The line will start near Tokyo and cut diagonally across the Pacific, hugging the northern shore of North America and slicing down across the Atlantic to stop just shy of London. Once the cable is live, light will transmit data from one end to the other in just 154 milliseconds—24 ms less than today's speediest digital connection between Japan and the United Kingdom. That may not seem like much, but the investors and companies eager to send information—stock trades, wire transfers—are so intent on earning a fraction-of-a-second advantage over competitors that the US $850 million price tag for the approximately 15,600-kilometer cable may well be worth it.

Arctic Fibre, the Toronto-based company building the cable, is the first to try to connect the globe's economic centers by laying fiber optics through the long-sought Northwest Passage—the pinhole of open water that warmer temperatures have brought to the Arctic. British Telecom, China Unicom, Facebook, Google, Microsoft, and »



MAPPING THE NORTHWEST PASSAGE

A Canadian company called Arctic Fibre is planning to thread the Arctic with the region's first fiber-optic cable. Climate change has melted the ice that once covered much of the cable's 15,600-kilometer proposed route, which stretches from Japan to the United Kingdom. As Arctic Fibre plots the cable's underwater path, the company has to create new, detailed maps of the seafloor, once entombed in ice.

This summer, a survey crew will set out on a ship like the RV *Geo Explorer*, owned by EGS Group, which is one of the world's premier marine surveying companies. Aboard will be up to six types of sonar and mapping tools, each with a distinct role in deciding the cable's perfect course. The sonars will gather data on seismic activity, identify seams of rock in the seafloor, and warn surveyors to steer clear of subsea hazards. —A.N.

SUBSEA SENSORS

Side scan: Uses variations in the strength of echoes from the seafloor to sketch a black-and-white image that reveals crevasses or volcanoes to avoid.

Single beam: Measures depth to seafloor in a straight line by shooting a single beam of sound down from the ship. This records the exact depth for each inch of the cable's intended course.

Multibeam: Measures depth to the seafloor in a wider swath than single-beam sonar does, which helps the survey team identify alternate paths (if the cable must be rerouted) and potential rock-slide risks.

Sub-bottom: Deploys a low-frequency sonar to detect patterns in the sediment below the seafloor. This data tells the crew whether to expect sand or rock when digging a 1-meter trench for the cable.

Ultrashort base line: Integrated into an underwater vehicle tethered to a ship. The vehicle is equipped with attitude sensors to detect pitch and roll and also a transceiver to send and receive acoustic signals. The tethered vehicle tracks the location of a remotely operated vehicle that digs the trench or inspects the cable.

Magnetometer: Measures the magnetic field of the seafloor and can help find abandoned pipelines or old cables that must be avoided.

Read more at http://spectrum.ieee.org/arcticfibre0115

TeliaSonera are watching closely, but so are tens of thousands of Canadians and Alaskans who stand to gain a huge boost in Internet access.

Marine surveys will plot the cable's route this summer, and the line will be custom built to the surveyors' specifications. The installation is scheduled to start a year from now, and the cable could be in service by the end of 2016.

Along its route, the cable will pass directly through seven Alaskan communities and cross 25 more communities in Canada. Those connections will bring 57,000 Canadians and 26,500 Alaskans online, most of whom have never before had access to broadband.

"The thing about Alaska is, it's so big," says Katie Reeves, program coordinator with Connect Alaska, a broadband advocacy group based in Anchorage. "The distance between communities is hundreds of miles, and there might only be a few people there. They deserve Internet, but it's hard for [local service provider] GCI or other carriers in the state to justify building out to those communities, because they don't think they're going to get a return on their investment."

Though the United States' Federal Communications Commission recommends access to download speeds of at least 4 megabits per second, the average download speed in rural areas of Alaska rarely tops 3 Mbps. Plus, there are still 21,000 households and 6,000 businesses without any access to broadband at all.

Across the border in northern Canada, the Internet is sent down from Anik F2, a telecommunications satellite owned by Telesat Canada. On paper, Anik F2 provides access at 5 Mbps, the minimum download speed recommended by Industry Canada, the nation's economic development agency. But in reality, that connection is often plagued by long delays and poor reliability due to the distance the signal must travel. (In 2011, a technical problem with Anik F2 knocked out service for thousands of people in 39 communities.)

Doug Cunningham, president and CEO of Arctic Fibre, knows this misery all too well: Because upload speeds were too slow, he had to use a courier to send his 227-page environmental report on the cable to the review board in Cambridge Bay, a hamlet in Canada's most northern province.

"The biggest benefit [of the cable] is really to those residents in communities in Alaska and to the Canadian Arctic who will be released from their satellite captivity," he says. "For many people in the Canadian North, YouTube is a dream."

Arctic Fibre, the cable's owner, will not sell broadband directly to homes and businesses; it will provide only the backbone from which carriers will siphon these services. But the company predicts that prices could be slashed by 75 percent for equivalent service or that northern customers might receive six to seven times as much bandwidth for the current price.

The new broadband will easily transmit classes from the University of Alaska or permit researchers at the Canadian High Arctic Research Station to upload large data sets. Telemedicine recently debuted at four health-care systems, including the U.S. Department of Veterans Affairs in Alaska, and better broadband could keep patients from having to travel hundreds of kilometers to seek services. Access will also be a boon to rural businesses.

All of these benefits stem from a 4-centimeter cable. Barges will lay it along most of the route. But to prevent a 1,800-km detour by sea, there is a 51-km section that must cross the Boothia Peninsula, a roadless scrap of tundra in northern Canada. Cunningham says that laying this stretch will require stuffing four large reels of cable through the door of a Hercules aircraft, flying onto a remote airstrip, packing the cable onto sleds, and pulling it across a frozen lake. The crew must then snowmobile along the cable's intended route, cutting a trench about 30 cm deep through permafrost to bury the line.

That's all far more work than any company would do to just to serve rural communities in the far north. And with an end-to-end capacity of 24 terabits per second, it's far more than Arctic residents need. After having so little access for so long, they will be awash in broadband. "The capacity is incredible. They'll never use all of that capacity," says Desiree Pfeffer of Quintillion Networks, the Alaska-based arm of Arctic Fibre.

Even though the main point of Arctic Fibre is to connect two of the world's busiest hubs, Cunningham is pleased that his fellow Canadians will benefit from the project. "I've been building systems and financing them for over 20 years, and I'm 63 years old, so this is probably one of my last projects and certainly the largest one," he says. "This is something I've come back to Canada to do." —AMY NORDRUM

NEWS

WHEN WILL WE HAVE AN EXASCALE SUPERCOMPUTER?

2023 if we do it right; tomorrow if we do it crazy

The global race to build more powerful supercomputers is focused on the next big milestone: a supercomputer capable of performing 1 million trillion floating-point operations per second (1 exaflops). Such a system will require a big overhaul of how these machines compute, how they move data, and how they're programmed. It's a process that might not reach its goal for eight years. But the seeds of future success are being designed into two machines that could arrive in just two years.

China and Japan each seem focused on building an exascale supercomputer by 2020. But the United States probably won't build its first practical exascale supercomputer until 2023 at the earliest, experts say. To hit that target, engineers will need to do three things. First they'll need new computer architectures capable of combining tens of thousands of CPUs and graphics-processor-based accelerators. Engineers will also need to deal with the growing energy costs required to move data from a supercomputer's memory to the processors. Finally, software developers will have to learn how to build programs that can make use of the new architecture.

"To some degree it depends on how much money a country is willing to spend," says Steve Scott, senior vice president and chief technology officer at Cray. "You could build an exaflop computer tomorrow, but it'd be a crazy thing to do because of the cost and energy required to run it."

Simply scaling up today's supercomputer architecture to build an exascale supercomputer would lead to a machine that requires the »

SUPERCOMPUTER, SUPERCEDED: Lawrence Livermore National Laboratory, home to Sequoia [below], will host a much more powerful machine in 2017.

LAWRENCE LIVERMORE NATIONAL LABORATORY

equivalent of a gigawatt-scale nuclear power plant, wrote Peter Kogge, a computer scientist and engineer at Notre Dame University, in *IEEE Spectrum* in January 2011. Instead, the U.S. government hopes to achieve practical exascale supercomputing in the 2020s at a cost of about US $200 million and 20 to 30 megawatts of power, says Horst Simon, deputy director at Lawrence Berkeley National Laboratory, in California. (One megawatt could cost a U.S. national lab about $1 million annually.)

The U.S. Department of Energy recently announced that it will invest $325 million in a pair of supercomputers–capable of performing one-tenth of an exaflops or more–being developed by IBM, Mellanox, Nvidia Corp., and other companies for a 2017 debut. The planned supercomputers, named Summit and Sierra, will rely on a new computer architecture that stacks memory near the Nvidia GPU accelerators and IBM CPUs. That architecture's method of minimizing the energy costs of moving data between the memory storage and processors is a big step toward exaflops supercomputers, experts say.

Practical exascale computing will need additional development of stacked memory and faster, more energy-efficient interconnects to boost the performance of densely packed supercomputer chips, Simon explains. But he anticipates the need for other technological tricks too. One such technology–silicon photonics–would use lasers to provide low-power data links within the system.

Power and cost aren't the only problems preventing practical exascale systems. The risk of hardware failures grows as new supercomputers pack in a greater number of components, says Bronis de Supinski, chief technical officer for Livermore Computing at Lawrence Livermore National Laboratory, in California. His lab's IBM Blue Gene/Q supercomputer, named Sequoia, currently has a mean time between failures of 3.5 to 7 days. Such a window could shrink to just 30 minutes for an exascale system.

That's hardly enough time for researchers to run complex simulations or other applications. But software capable of automatically restarting programs could help supercomputing systems recover from some hardware errors. "This is an instance in which the physical realities of hardware...end up creating challenges which we have to handle in software," De Supinksi says.

Experts also point to the challenge of writing software applications that work for tens or hundreds of thousands of CPUs running in parallel. The programming becomes even more complex for the newer supercomputing architecture that includes GPU accelerators. That's why Nvidia, based in Santa Clara, Calif., and its partner companies working on the planned Summit and Sierra machines have already reached out to thousands of software developers at universities around the world to begin teaching them about its accelerators.

Beyond Sierra and Summit, the U.S. Department of Energy has invested an additional $100 million in paving the way toward exascale supercomputing. But such investments won't benefit just the few big U.S. government labs that can afford such machines. The new computer architectures needed to make an exascale supercomputer could also make supercomputing more widely accessible, says Sumit Gupta, general manager for the Tesla accelerated computing business at Nvidia.

"One thing I'm always intrigued by is, once we have an exascale machine, how small will a petaflop machine be?" Gupta says. "Will it fit in a backpack or under my desk? What is the research that the average graduate student could do that they can't do today? I always find that aspect much more intriguing."

–JEREMY HSU

The Sequoia supercomputer has a mean time between failures of 3.5 to 7 days. That could shrink to just 30 minutes for an exascale system

AN ULTRASONIC SCALPEL FOR BRAIN SURGERY

Focused ultrasound lets surgeons treat brain diseases without opening the skull

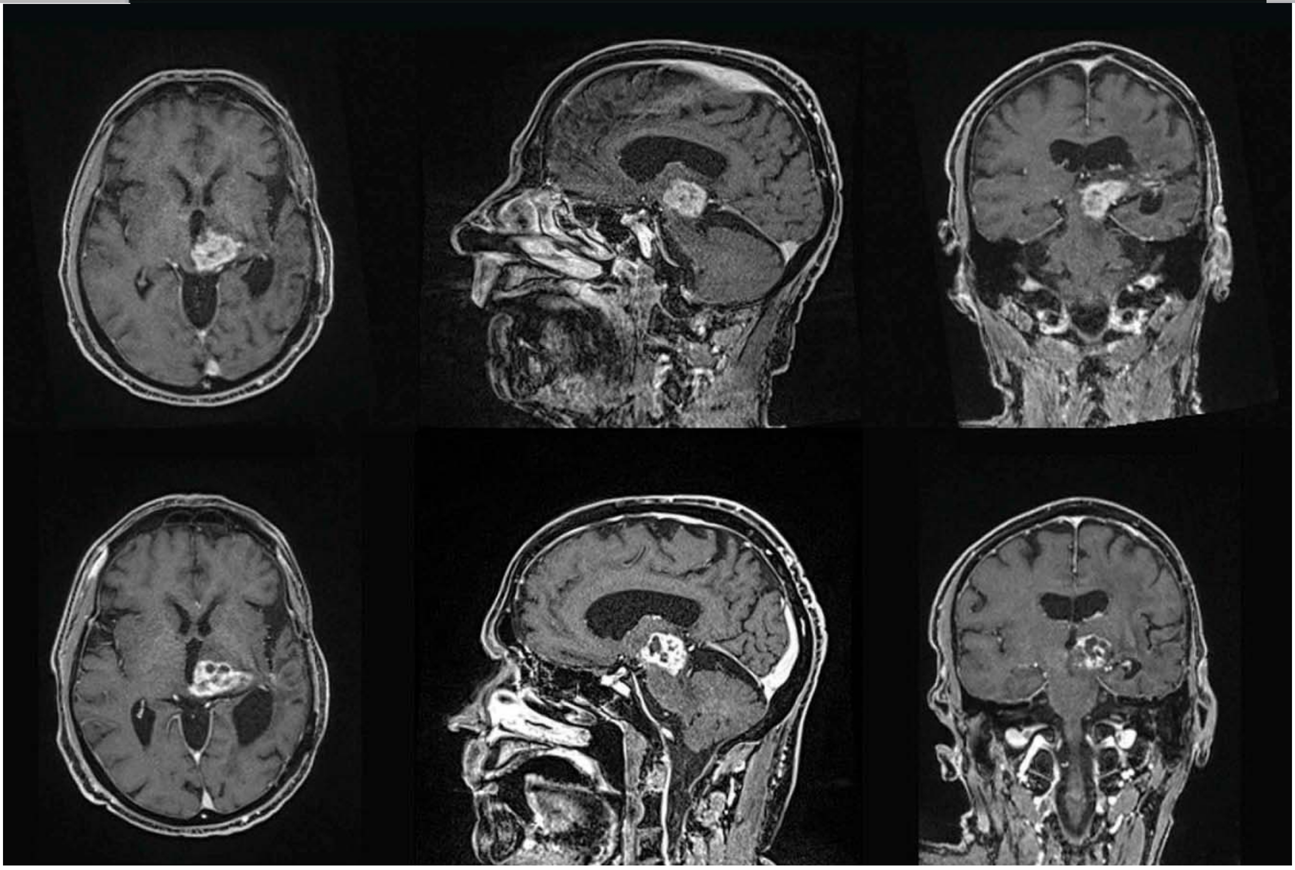
Brain surgery is fraught with huge risks and uncertainty. Parts of the skull (and sometimes most of it) need to be removed, a lengthy and harrowing procedure that could expose the brain to infection and almost always results in significant postoperative pain. Once the surgeon makes the first incision, the smallest error could have devastating consequences–seizure, loss of sensory or motor function, stroke, or even coma. But what if you could slice through the brain without removing any of the skull–create incisions inside the brain from the outside?

Through "transcranial focused ultrasound," physicians can now use high frequencies of ultrasound (typically from 650 to 710 kilohertz) to create discrete lesions in brain tissue without making direct physical cuts. Patients and doctors alike hope this could be a transformative tool for treating many different psychiatric and neurological disorders more easily and more effectively.

In fact, focused ultrasound has already proved successful in treating patients with the condition known as essential tremor. Neurosurgeons at the University of Virginia's Focused Ultrasound Center, in Charlottesville, saw tremor rates fall by more than 50 percent in patients treated with ultrasound. The surgeons are currently finishing the final round of patient testing before seeking U.S. government approval as a prescribed treatment of essential tremor. The same clinical team is conducting trials for Parkinson's patients as well.

"Ultrasound is able to move through obstructions, like the skull," explains psychiatrist Alexander Bystritsky, of the University of California, Los Angeles. "It's noninvasive. You simply have to focus ultrasound much like you would focus a light."

Actually, it's a bit more complicated than that. Ordinarily ultrasound passes through body tis-



BEFORE AND AFTER: Doctors focused ultrasound inside the brain of a patient with essential tremor, creating lesions [bottom row] deep within the brain [black spots inside white mass at center].

FOCUSED ULTRASOUND FOUNDATION

sue without any effect. But in the same way that rays of sunlight can be focused by a magnifying glass to start a fire, beams of ultrasound can be focused to converge on a specific target, raising temperatures and destroying tissue. This three-dimensional "thermal ablation" can be anywhere between 1 and 15 millimeters in diameter, and it can be localized to a specific target deep in the brain without affecting the surrounding tissue. It's like performing surgery with a heat ray instead of a knife, but with the same precision and deep brain penetration—all without opening up a person's skull.

The initial problem with the transcranial delivery of ultrasound was that sound waves would lose focus and reflect off the skull. A section of skull would have to be removed to deliver the ultrasound deep into the brain. If part of the skull had to be removed, there was little real advantage to ultrasound over conventional surgery.

Robert Dallapiazza, a neurosurgeon at the University of Virginia, says phased-array systems developed decades later meant that "instead of just two or three ultrasound sources, they started using 200, 500, and 1,000 elements, all focused into one discrete spot." Combined with a machine-mediated correction algorithm that informs doctors how the energy would be reflected or how its transmission would be altered through the skull, there is now no need to carve a window into the cranium.

Of the multitude of ultrasound applications being researched, one of the most promising is the treatment of motor disorders. Dallapiazza and his colleagues are currently researching the surgical applications of MRI-guided high-frequency focused ultrasound. A patient enters an MRI machine, and an ultrasound transducer is placed over his head. The whole setup, Dallapiazza says, "kind of looks like a hair dryer at a beauty salon." Within the MRI, low-energy ultrasound is applied to verify the machine's alignment with the targeted brain region. Amplitudes are then increased to generate a more intense beam that results in lesions. Patients are awake during the entire procedure and can usually feel the effects instantaneously. "They can really tell when they got the treatment," he says. "People are really brimming with excitement over focused ultrasound, because it doesn't require awake surgery or electrode implantation for potentially the rest of their lives."

Dallapiazza is optimistic about using ultrasound as a way to treat other diseases too, such as cancer. In March 2014, neurosurgeons at the University Children's Hospital Zurich used ultrasound to treat a brain tumor for the first time. Much more research will be needed to assess the efficacy of such a procedure, but the surgery was a milestone nonetheless.

"In the next five or 10 years, I think there are going to be a lot of breakthroughs of what we're actually able to do with this technology," says Dallapiazza. "It's an exciting time." —NEEL V. PATEL

NEWS

FLYWHEELS GET THEIR SPIN BACK

Grid stabilization energizes flywheel pioneer Beacon Power and a host of new competitors

Flywheel-based energy storage got a black eye with the 2011 bankruptcy filing of Beacon Power Corp., a leading energy storage company, based in Massachusetts, whose technology upgrades pushed flywheels to grid-scale applications. But that blemish proved ephemeral. New investors pulled Beacon Power out of bankruptcy, and last July the firm started a second commercial facility, in Hazle, Pa., to provide power-grid-regulation services. Beacon is attacking new markets that would take the technology in a new direction, followed closely by new grid-scale flywheel competitors.

Recent entrants in the flywheel field include Boston's Helix Power, cofounded by former Beacon Power chief technical officer Matt Lazarewicz, and Williams Advanced Engineering, based in Wantage, England, which is scaling up technology from the flywheel-based hybrid drivetrains it built for Formula One race cars.

The quick revival of Beacon–and of flywheels' reputation–was a direct result of a change in the way grid operators in the United States pay for frequency regulation. To prevent damage to equipment, the frequency of an AC grid must not deviate by much more than 1 hertz. But when loads are added or subtracted from the grid, it can reduce or increase the frequency. Energy storage systems can bring the frequency back in line by quickly adding or subtracting power. Under the new "tiered pricing" regulations, begun in 2012 after years of consideration, Beacon earns a premium, because the 200 flywheels in each of its plants correct frequency deviations on the grid far more quickly than the power plants that have traditionally regulated AC grids can. Each plant can release or absorb up to 20 megawatts of power.

WHIRLING WATTAGE: Beacon Power built a 20-megawatt plant in Hazle, Pa. It started regulating grid frequency in July 2014.

While competitors offering fast-acting, battery-based facilities also earn that premium, they are less well adapted to repeated cycling. What's more, flywheel costs are dropping fast, according to proponents. Beacon Power CEO Barry Brits says the company's next plants, two of which are in advanced planning, will cost less than half as much as the new plant in Pennsylvania. Another difference is that Brits plans to find buyers for those plants, rather than continuing to act as an owner-operator, thus reducing Beacon Power's financial needs.

Recent entrants in flywheel development are adopting the same risk-limiting approach. Canadian start-up Temporal Power's first facility–a 2-MW frequency-regulation plant in Minto, Ont., that started stabilizing for the provincial grid operator last year–is owned and operated by another firm. "We're in the business of producing turnkey facilities. That's less risky and less capital intensive," says Temporal Power cofounder and chief technology officer Jeff Veltri.

Flywheel competitors are similarly tracking Beacon's expansion into new markets. For example, a slew of recent flywheel installations by Beacon, Temporal, and others help grids cope with intermittent renewable energy. One such project on Alaska's Kodiak Island showcases the flywheel's ruggedness relative to batteries, according to Darron Scott, CEO of the local utility, Kodiak Electric Association.

KEA's 2-MW flywheel system is being installed by Zurich-based ABB, which acquired Australian flywheel manufacturer Powercorp in 2011. Scott says the flywheel system will become KEA's first line of defense against varying power flows from wind turbines, relieving a 3-MW battery system that is wearing out faster than expected. "We use our batteries a couple of hundred times of day–a lot more than we'd modeled," says Scott.

Beacon is working on a similar project designed to allow Alaska's Saint Paul Island–smaller than Kodiak Island–to run exclusively on wind power about 15 percent of the time, with Beacon's flywheels providing all of the grid's voltage and frequency regulation.

Applications such as these are driving a trend toward flywheels with larger motor generators, which can push and pull energy out of the spinning rotors faster. Brits says Beacon is testing a larger motor that nearly doubles its flywheels' 160-kilowatt charge/discharge capacity. Temporal Power's flywheels already operate at plus or minus 500 kW.

Helix Power is developing 1-MW machines to target yet another grid-scale energy-storage application: capturing energy from braking electric trains as they enter the approximately 9,000 mass-transit stations worldwide. The opportunity has been proven with other technologies, such as the combination of ultracapacitors and batteries that is capturing energy from trains in Philadelphia. But Helix Power's Lazarewicz bets that its flywheels will be more cost effective.

He adds that this and other industrial applications can operate "behind the power meter," remaining largely immune to regulatory hang-ups such as the multiyear wait for tiered pricing on frequency regulation that Lazarewicz lived through at Beacon Power. –PETER FAIRLEY

BEACON POWER

RESOURCES

BKSGK ABYFF LUJAR JZ

1.58 X 10[20]: THE NUMBER OF POSSIBLE WAYS THAT A THREE-ROTOR ENIGMA MACHINE CAN ENCODE A MESSAGE

RESOURCES_HANDS ON

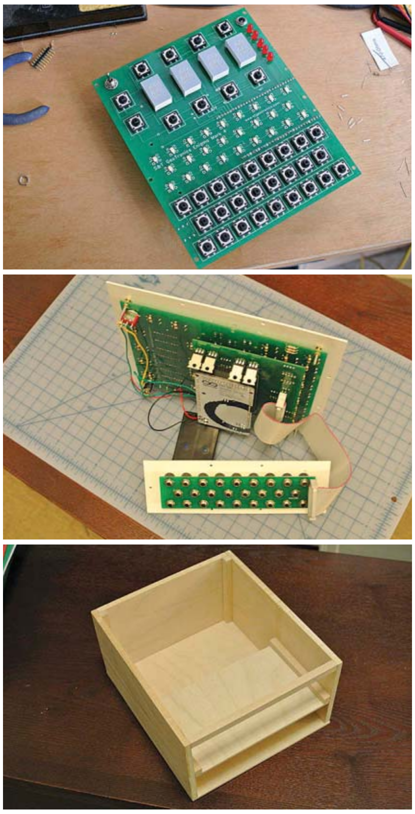
A SIMPLE ENIGMA

A KIT REPLICATES THE INFAMOUS CIPHER MACHINE

NEARLY A CENTURY AFTER ITS INVENTION, THE ELECTROMECHANICAL ENIGMA CIPHER machine still strikes a deep chord among the digerati. Used by the German military to encode communications in the run-up to and during World War II, the Enigma has achieved a mythic quality in computing history—the Medusa slain by the hero Turing with the new weapon of digital logic. • Consequently, original Enigma machines are now collector's items that sell for tens of thousands of dollars. Even replicas are pricey. So the only alternative for those wishing to get to grips with this machine—and to better understand the mathematical, engineering, and operational feats that defeated it—has been to use one of a number of software emulators. But now there's a middle ground: a hardware kit that duplicates the physical operation of the Enigma's keyboard, display, and plugboard while replacing the rotating metal discs at the machine's heart with an Arduino Mega microcontroller. • The kit—called the Enigma Mark 4—was created by S&T Geotronics as an open-source project with development funded by a Kickstarter campaign. It's available in three versions—one that has just the printed-circuit boards and basic components for US $200, one that includes a top panel and an Arduino Mega for $300, and a version that also includes a plugboard front panel for $425. I built the plugboard version for maximum verisimilitude and ease of use, but users of kits without this panel can program plugboard settings into the Arduino software. • Assembling the Mark 4 was mostly a straightforward exercise in soldering, but there were a few places where the instructions were a little unclear, such as how to wire up the battery pack or how to hold the faceplate of the plug-▸

PHOTOGRAPH BY Randi Klett

IEEE SPECTRUM | Previous Page | Contents | Zoom in | Zoom out | Front Cover | Search Issue | Next Page | Qmags THE WORLD'S NEWSSTAND®



SPINNING ELECTRONS: The keyboard and displays of the Enigma are replaced by buttons and LEDs [top], while its mechanical rotors are simulated by an Arduino Mega [blue and white circuit board, middle]. I built a simple wooden case to house the circuitry [bottom].

board in place. Still, there was nothing that couldn't be figured out with a little thought.

The only truly fiddly part of this stage of construction was soldering the LED lights that form the Enigma machine's alphabet display. These are small surface-mount LEDs and can easily slip out of place during assembly. I found that prizing the contacts a little off the body of each LED made them much easier to solder to the right spot on the motherboard. Once the various mother- and daughterboards were populated and connected together, I downloaded the software from the Open Enigma website and installed it via a USB cable connected to the Arduino Mega.

The Mark 4 does not come with a case, so I had to make my own (although you can now buy hand-built cases from S&T Geotronics for an additional $350). I built mine from basswood, making it a few centimeters taller than it needed to be so that I could have a space for storing unused plugboard cords underneath.

Initially—taking my lead from online pictures of some fully assembled kits—I built my case with the intent of mounting the plugboard immediately in front of the top plate. Unfortunately, when I tried to fit everything into the case, I discovered that the plugboard cable connector was pressing against the daughterboard that holds the Arduino Mega underneath the top panel. This made it impossible to fit the plugboard into place until I provided additional clearance by extending the front of the case with some spare beams of basswood.

At the core of an original Enigma machine lies a set of three or four rotors. Each rotor hard-wires pairs of letters together in its own unique pattern. This acts as a basic substitution cipher, so that A becomes H, for instance. When a key is pressed, a corresponding electrical signal is fed to the first rotor, whose output is used as the input for the next rotor. At the end of the series of rotors, a "reflector" passes the signal back through the rotors, where it then illuminates one of the letters on the Enigma's display. Every key press advances the first rotor one notch (so that now A becomes G, while B becomes H, for example), and after a certain number of steps, each wheel advances the next rotor along a notch. The upshot is that every letter is encoded using a different combined substitution cipher, one that is not easily predictable without knowing the exact settings of the rotors.

On the Mark 4, you enter the various settings using buttons above and below four 16-segment LED displays. Operating the Mark 4 kit also requires you to decide how you are going to set up the plugboard, which lets you connect up to 10 letter pairs using patch cords. (The plugboard added significantly to the cryptographic strength of Enigma machines, being, in effect, a user-programmable rotor.) Depending on the settings, the Mark 4 can act as either a four-rotor navy Enigma or a three-rotor army machine, and it can code and decode genuine wartime messages.

Cracking the Enigma code required exploiting technical weaknesses of the rotor system, such as the fact that the reflector design means no letter can be encoded to itself. But the code breaking also critically relied on instances of operator error to provide insight into the machine's settings. It's much easier to understand these operator failures—such as only slightly varying rotor settings between messages—when one is confronted with a physical version of an Enigma.

Much more could be said about the operation and mechanism of an Enigma machine, but for now, let's end with a message (Enigma purists will note that I'm dispensing with the initial three-letter session key used by World War II operators): Tweet the solution to @stephencass, and we'll randomly select a winner for some *IEEE Spectrum* swag at the end of January. Plugboard settings: SC, HT, AL. Reflector: B. Rotors: B817. Inrings: IEEE. Outrings/rotor start positions: ALAN. Message: BKSGK ABYFF LUJAR JZ. —STEPHEN CASS

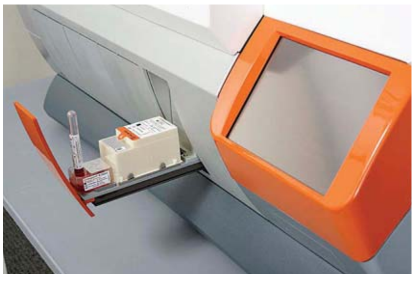
A WAR MACHINE: This Enigma can be identified as once belonging to the German navy, as it uses four encoding rotors—army Enigmas had only three.

LEFT: STEPHEN CASS (3); RIGHT: SSPL/GETTY IMAGES

T2 BIOSYSTEMS
ITS DESKTOP DEVICE CAN QUICKLY IDENTIFY PATHOGENS

When a patient is brought to an emergency room with a virulent fever, the body shutting down from infection, doctors can make only an educated guess on treatment. Blood culture tests to determine the pathogen take days. Until the results are in, patients are pumped with antibiotics and antifungals that may or may not fight the disease.

T2 Biosystems in Lexington, Mass., plans to change that with a printer-size device that can identify microbes in 3 to 5 hours. The company's initial system can identify five strains of candida, a fungus that's a leading cause of sepsis-induced death. With an exact diagnosis in hand, doctors can prescribe the best possible drug regimen. Such precise treatment within 12 hours can reduce the mortality rate from 40 percent to 11 percent, says T2's CEO, John McDonough. Treating patients with the right antifungals immediately would also save hospitals US $30,000 per patient, he says. For those who test negative for candida, ruling out the infection would save thousands of dollars more by preventing the use of unnecessary drugs.



MICRO MEDICINE: Magnetic nanoparticles bind to specific pathogens. A nuclear-magnetic-resonance sensor can detect the clusters of these particles in a blood sample.

T2 BIOSYSTEMS (2)

In a trial that involved over 1,500 patients at seven hospitals, the device correctly identified 91 percent of the people who had a candida infection. This led to the U.S. Food and Drug Administration's taking just three months—record time for a new technology—to approve T2's instrument and candida test.

The company is now developing a test to spot common sepsis-causing bacteria. It's also developing a 20-minute test to help doctors detect faulty hemostasis—the process that coagulates blood to stop bleeding—in trauma patients. In theory, the technology can identify cancer-indicating proteins, hormones—pretty much anything with DNA. It isn't a stretch to imagine a device like this being used in the fight against epidemics like Ebola, says Michael Cima, a materials science and engineering professor at MIT, one of the cofounders of the company.

Cima and five other researchers from MIT and Harvard Medical School came up with the technology when they were putting together an unrelated cancer research proposal in 2006. Cima and Ralph Weissleder, a professor of systems biology at Harvard Medical School, had been working on sensors that allowed smaller and simpler versions of the nuclear-magnetic-resonance systems used in magnetic resonance imaging.

The founders devised a technique that combines their mini-NMR sensors with magnetic nanoparticles. The iron-oxide nanoparticles are coated with molecules that bind to a specific target, such as a protein's or a pathogen's unique DNA. If the target molecule is present in a test sample, the nanoparticles cluster around it, which causes a detectable change in the sample's magnetic response.

T2 started as a company with a technology looking for an application. McDonough, who took over the CEO

IEEE SPECTRUM Previous Page | Contents | Zoom in | Zoom out | Front Cover | Search Issue | Next Page Qmags THE WORLD'S NEWSSTAND®

helm in 2007, was the one who identified the unmet need for rapid candida diagnostics. With FDA approval in its pocket, the company is now gearing up its sales force, and McDonough wants to get the first few machines into hospitals early this year.

So far, T2 has raised $150 million between private equity financing and its August IPO. Dan Leonard, an analyst with investment bank Leerink Partners, says the company has "novel technology with very good market potential." He estimates that the company can generate revenue of $3.4 million in 2015, going up to $36.5 million in 2016 and $111 million in 2017.

According to Cornelius Clancy, an associate professor of medicine at the University of Pittsburgh division of infectious diseases who was involved in T2's clinical trials, the new technology will complement traditional blood culture diagnostics, not replace them (traditional cultures let you grow the pathogen for further study, for example). While the bean counters at his hospital system will ultimately decide whether to invest in the instrument, he says, T2 Biosystems has come up with a "new diagnostic paradigm for infectious diseases."
—PRACHI PATEL

Company: T2 Biosystems **Founded:** 2006 **Headquarters:** Lexington, Mass. **Founders:** Michael Cima, Tyler Jacks, Lee Josephson, Robert Langer, W. David Lee, and Ralph Weissleder **Funding:** US $150 million **Employees:** 75 **Website:** http://www.t2biosystems.com

CROWDFUNDING FOR HARDWARE
THINGS TO CONSIDER BEFORE LAUNCHING THAT KICKSTARTER CAMPAIGN

CROWDFUNDING—COLLECTING MONEY FROM A BUNCH OF people to fund a project—has in the last few years gone from "doable but tough" to "so easy we can't remember how we lived before," thanks to sites like Kickstarter and Indiegogo. Particular beneficiaries of the new era are those wanting to make physical devices, who have often struggled for funding because of the higher risk and capital requirements of hardware development over software. "Crowdfunding validates the product-market fit early in the development cycle, before you've spent millions of dollars creating something nobody wants," says Scott Miller, CEO and cofounder of Dragon Innovation, in Cambridge, Mass., which offers certification and manufacturing expertise. "It provides the capital essential for buying the tools and inventory. And it's the most efficient form of marketing: It creates an informed community who then evangelizes," says Miller. ● Notable hardware crowdfunding successes include the Oculus Rift VR headset and the Pebble e-watch, which raised US $2.4 million and $10.2 million, respectively. But crowdfunding campaigns can be helpful to hardware developers in ways that go beyond just money and marketing—if they know how to take advantage of the opportunities.

ILLUSTRATION BY Erik Vrielink

First, leverage the communities and knowledge bases growing up around crowdfunding sites: "We have seen a lot of hardware projects using a software development mindset—winging it, since software can be fixed after the fact," says Miller. "But the decisions you make early in the hardware design process cast a long shadow." For example, a shape that's easy to hand cut or 3-D print may be costly to make using injection molding. Kickstarter, Indiegogo, and other crowdfunders offer documents, experts, events, and other resources to cope with issues such as manufacturability and how to obtain compliance certificates for things like safety, radio frequency/electromagnetic interference, and environmental impact. Compliance testing takes time and money, which need to be factored into the schedules presented to backers.

Getting manufacturing right is key to having a final product that works well for more than just the handful of users comfortable with your prototype: "It's important to make sure the manufactured product will be reliable," says Charles Edward Pax, founder of Pax Instruments, who successfully completed a Kickstarter campaign for his T400, an open-source Arduino-based data logger for four channels of thermocouple temperature data. "If you make ten units and one fails, it's not a big deal, but if one in ten of 10,000 units fail, you have a lot of disappointed customers."

Secondly, a crowdfunding campaign can help developers understand their customers' desires, which in turn can help focus feature and style development. "The feedback you get during a campaign can improve your market traction," says Kate Drane, head of hardware at Indiegogo. "It might be as simple—but important—as learning that case-color preferences are 80 percent for black and 10 percent each for red or blue. So when you go to production, you can make informed order estimates."

Thirdly, backers can help spot problems and suggest solutions: "Transparency is probably one of the greatest things about crowdfunding campaigns," says John Dimatos, Kickstarter's lead for tech and design partnerships. "For an engineer to be able to speak at length about what components they chose, how they did the circuitry for the project, the manufacturing process they are using...these details are very important to their backers, and there are few other places you can talk in such detail."

HARDWARE HELPER

Some of Kickstarter's biggest tech campaigns

PonoMusic hi-fidelity portable music player: Raised US $6,225,354

Micro Consumer 3-D printer: Raised $3,401,361

Form 1 professional 3-D printer: Raised $2,945,885

SCiO pocket chemical spectrometer: Raised $2,762,571

FROM TOP: PONOMUSIC; M3D; FORMLABS; CONSUMER PHYSICS

Recognizing the challenges faced by inexperienced hardware developers, some crowdfunding sites are seeking out those most likely to be dreaming up the next great gadget. "I spend a lot of time talking with organizations like the IEEE and with organizations that make up the ecosystem around hardware—like schools that have engineering and design students—explaining what a campaign is like and what resources are available," says Dimatos.

"We have live Hardware Happy Hours with industry experts like lawyers and tax accountants that hardware developers can talk with," says Indiegogo's Drane. "And we hired an experienced product creator to be a mentor-in-residence." Indiegogo also created the free *Hardware Handbook for Crowdfunding*.

Once you've decided to go forward with a campaign, check to see if there's a site that's particularly suited to your project's goals or that will connect you with the backers most likely to fund you. Besides Kickstarter and Indiegogo, well known crowdfunding sites include Fundable and RocketHub—but there are many more. According to Leigh Lepore, founder of Crowdfunding Strategy & Information, there are over 800 crowdfunding sites and services. And if you don't find one you like, you can crowdfund from your own WordPress blog, using IgnitionDeck, or create a site using the open-source Selfstarter. There are even crowdfunding events where you can raise money in person, like the OneSpark Festival.

Indiegogo's Drane offers some final words of advice: "Take good care of gathering documentation and other assets," Drane stresses. "This is so you can showcase prototypes and what you've done when you are ready to start the campaign. Hardware development involves all sorts of tasks. Being open and transparent with the campaign page will go a long way to building trust with your backers." —DANIEL DERN

CARS WEIGH TOO MUCH

A CENTURY AGO THE BEST-SELLING CAR in the United States, Ford's Model T, wrung a watt from every 12 grams of its internal-combustion engine. Now, engines in best-selling American cars are getting a watt per gram—a 92 percent improvement. That is the one bit of happy news I am going to impart today. • Now for the bad news: In the past 100 years average engine power has increased more than 11-fold, to about 170 kilowatts. This means that despite a huge drop of mass/power density, today's typical car engine is hardly lighter than it was a century ago—and the average car itself has become much heavier: Its mass has roughly tripled, reaching more than 1,800 kilograms (the average for all light-duty vehicles, nearly half of which are pickups, SUVs, and minivans). • And because more than three-quarters of U.S. commuters drive alone, you get the worst ratio of vehicle-to-passenger weight since a mahout last rode a bull elephant to work. • That ratio is what matters. Because for all the auto industry's talk about "lightweighting"—using aluminum, magnesium, and even carbon-fiber polymers to reduce total weight—this ratio ultimately limits the energy efficiency you can achieve. • Here, in ascending order, are a few of the weight ratios that a 70-kg passenger can achieve:

- 0.1 for a 7-kg bicycle.
- 1.6 for Italy's 110-kg Vespa scooter.
- 5 or less for a modern bus, such as those based on New Flyer's designs (and that's just if you count sitting passengers).
- 7.3 for France's 510-kg Citroën 2CV ("*deux chevaux*," or two horses), back in the 1950s.
- 7.7 for the Model T and also for Japan's Shinkansen, or bullet train, which celebrated its 50th anniversary in October. The train's frugal ratio owes as much to design as it does to a high ridership rate.
- 12 for a Smart car, 16 for a Mini Cooper, 18 for my own Honda Civic LX, 20 and change for the Toyota Camry.
- 26 for the average American light-duty vehicle in 2013.
- 28 for the BMW 740i.
- 32 for the Ford F-150, the best-selling American vehicle.
- 39 for the Cadillac Escalade EXT.

Of course, you can get quite spectacular ratios by pairing the right car with the right driver. I regularly see a woman driving a Hummer 2 that easily weighs 50 times as much as she does. That's like going after a fly with a steam shovel.

To put it all in perspective, consider that the latest Boeing, the 787-9, does better than a small Citroën. Its maximum takeoff weight is 253 metric tons; with 280 passengers weighing 20 metric tons and another 20 metric tons of cargo, the overall weight-to-payload ratio comes to just 6.3.

Cars got heavy because part of the world got rich and drivers got coddled. Light-duty vehicles are larger, and they come equipped with more features, including automatic transmissions, air conditioning, entertainment and communication systems, and an increasing number of servomotors. And new battery-heavy hybrid drives and electric cars will not be lighter: The small all-electric Ford Focus weighs 1.7 metric tons, General Motors' Volt is more than 1.7 metric tons, and the Tesla is just above 2.1 metric tons.

Lighter designs would help, but obviously, nothing could halve (or quarter) the ratio as easily as having two or four people in a car. And yet in the United States, that is the hardest thing to enforce. The latest commuting survey from the U.S. Census Bureau shows that in 2012, the percentage of Americans who drove to work alone was 76 and that carpooling was down from 20 percent in 1980 to just 12 percent, as was the use of public transportation (down from 6 percent to 5 percent).

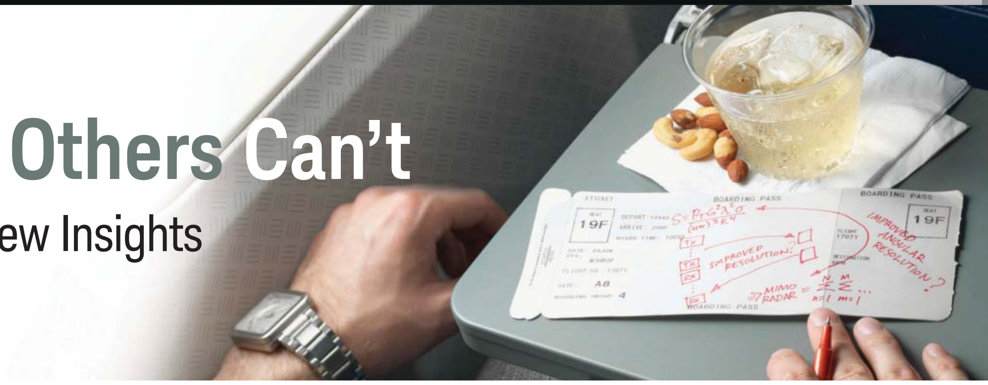
And so the outlook is for ever-better engines or electric motors in heavy vehicles used in a way that results in the worst weight-to-payload ratios for any mechanized means of personal transportation in history.

These cars may be, by some definition, smart—but they are not wise. ■

ILLUSTRATION BY Harry Campbell

Seeing What Others Can't

The Key to Unlocking New Insights



Mark Wallace
Vice President and General Manager
Keysight Technologies, Inc.

You've known us as Hewlett-Packard, Agilent Technologies and, now, Keysight Technologies. For more than 75 years we have been helping you unlock measurement insights.

There have always been two sides to the story. One is the work we do, creating innovative instrumentation and software. The other is the work you do: design, develop, debug, troubleshoot, manufacture, test, install and maintain components, devices and systems.

Those seemingly separate activities are connected by something profound: the "A-ha!" that comes with a moment of insight. When those happen for us, the results are innovations that enable breakthroughs for you.

Enabling the right idea at the right time

This is our legacy. Keysight is a company built on a history of firsts, dating back to the days when Bill Hewlett and Dave Packard worked in the garage on 367 Addison Avenue in Palo Alto, California. Our firsts began with U.S. patent number 2,268,872 for a "variable-frequency oscillation generator." Appropriately, the centerpiece of Bill's design was a light bulb, which is often used to symbolize a new idea.

Our future depends on your success, and our vision is simple: by helping engineers find the right idea at the right time, we enable them to bring next-generation technologies to their customers—faster.

Offering expertise you can leverage

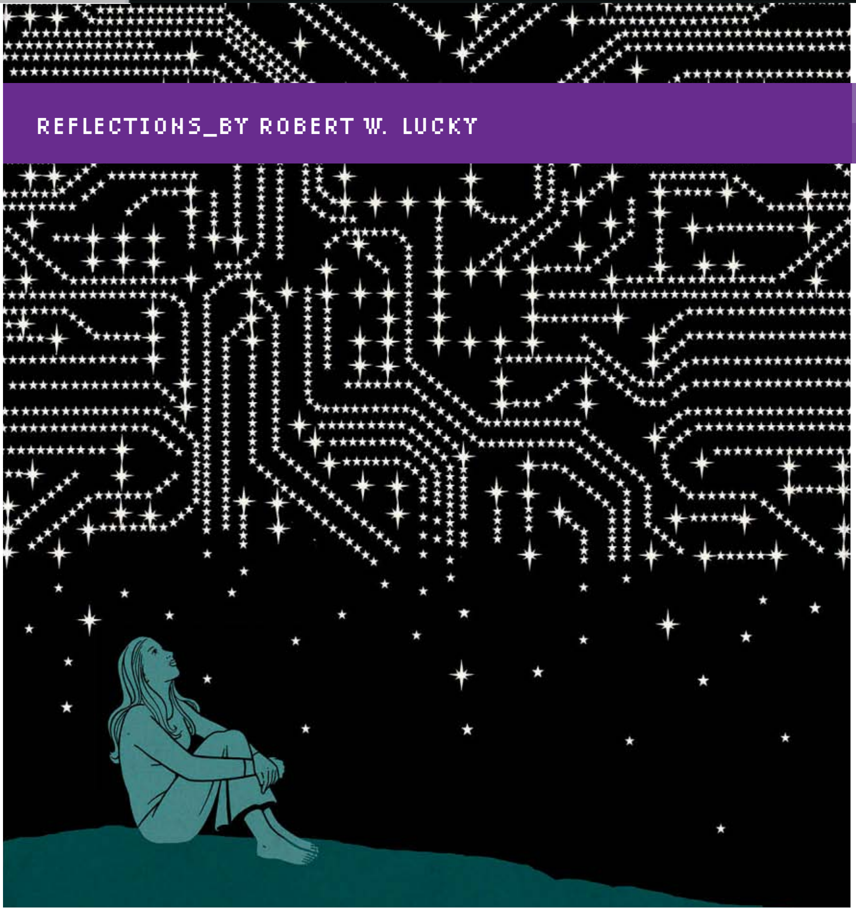
This is happening in aerospace and defense applications where increasingly realistic signal simulations are accelerating the development of advanced systems that protect those who go in harm's way. It's happening in research labs where our tools help turn scientific discovery into the discovery of new sciences. It's taking place with DDR memory, where our line of end-to-end solutions ranges from simulation software to protocol-analysis hardware. And in wireless communications we're providing leading-edge measurement tools and sophisticated, future-friendly software that support the development and deployment of LTE-Advanced.

Within those systems, there are more standards than a single engineer can keep up with. That's why so many of our engineers are involved in standards bodies around the world. We're helping shape those standards while creating the tools needed to meet the toughest performance goals.

Enabling your next breakthrough

To help Keysight customers continue to open new doors, we're concentrating our effort and experience on what comes next in test and measurement. Our unique combination of hardware, software and people will help enable your next "A-ha!" moment, whether you're working on mobile devices, cloud computing, semiconductors, renewable energy, or the latest glimmer in your imagination. Keysight is here to help you see what others can't—and then make it reality.

KEYSIGHT TECHNOLOGIES



LOOKING BACK ON THE FUTURE

The technologies of 1914 might give a hint of the future

WHEN I WAS YOUNG, MY PARENTS WOULD TELL ME OF the hardships of their own childhoods. These were spent at the beginning of the last century in a world with no electricity, lights, cars, airplanes, radio, or television. Of course, in the way of children, I wasn't impressed at the time. • Then, many years later, I helped choose the U.S. National Academy of Engineering list of engineering's greatest accomplishments of the 20th century. My parents' stories came back to me with new meaning. In choosing and ordering the list of achievements, we weighed arguments about how much each achievement had improved the quality of life. But beyond the details of any single achievement, I was simply proud of how dramatically we engineers had bettered the way people live. • Of course, in the way of parents, I have told my offspring of the hardships of my own childhood. But I have the sense that maybe it wasn't all that different from what they were experiencing themselves, give or take an Internet. And now, in thinking about the future, I sometimes wonder if technology will continue to make the same degree of improvement in quality of life that it did in the last century. Could it be that there are diminishing returns with technological solutions to the often-intractable problems of the human condition on Earth? • Perhaps at the end of the 21st century, the National Academy will put together another list of achievements. I would love to know what would be on it, but it's unlikely that any practicing engineer of today will be alive then. Nonetheless, we are now 14 years into this century, and there may already be some trends that can be extrapolated into predictions. • Think of what we knew in 1915 of the achievements that would come to be listed in 2000. It's actually quite a bit. We can group these achievements into three categories: those that had already happened or were well under way, those that were anticipated (or at least would have been unsurprising), and finally, those that could not possibly have been predicted by anyone in 1915.

A handful of achievements belong in the first category. No. 1–electrification–was already progressing rapidly in 1915. Power stations were being built throughout the world, and alternating current had become the preferred mode of transmission. No. 2–the automobile–was well into its development with the production of the Model T Ford in 1908. And No. 3–the airplane–was already being pressed into military service above Europe. Radio (listed with television at No. 6) was invented right before the turn of the century and had risen into prominence with the sinking of the *Titanic* in 1912. Finally on this list, the evolution of the telephone network, at No. 9, would become a century-long task, but it was also advancing swiftly as of 1915.

In the category of anticipated or unsurprising achievements, I would place highways (11), agricultural mechanization (7), household appliances (15), air conditioning and refrigeration (10), and water supply (4). But the third category, the surprises, is the most interesting: Who could have predicted integrated circuits and lasers, and who would have believed that before the century was out, a man would walk on the moon?

Applying this reasoning to the current day lets me suggest some possibilities for the year 2100 list of achievements. Wireless technology is already under way and will be an ongoing theme for the century. In the anticipated category I would put machine intelligence and 3-D printing. By definition, though, the technological surprises are beyond my imagination. I even wonder if the inventions of such fundamentally transformative devices as the integrated circuit and laser are rarities that might not be seen in every century. Or perhaps the engineers of the future will look back on these words wryly after a raft of transformative technologies push wireless or 3-D technologies below the cutoff point of significance. But I'll never know! ■

ILLUSTRATION BY Dan Page

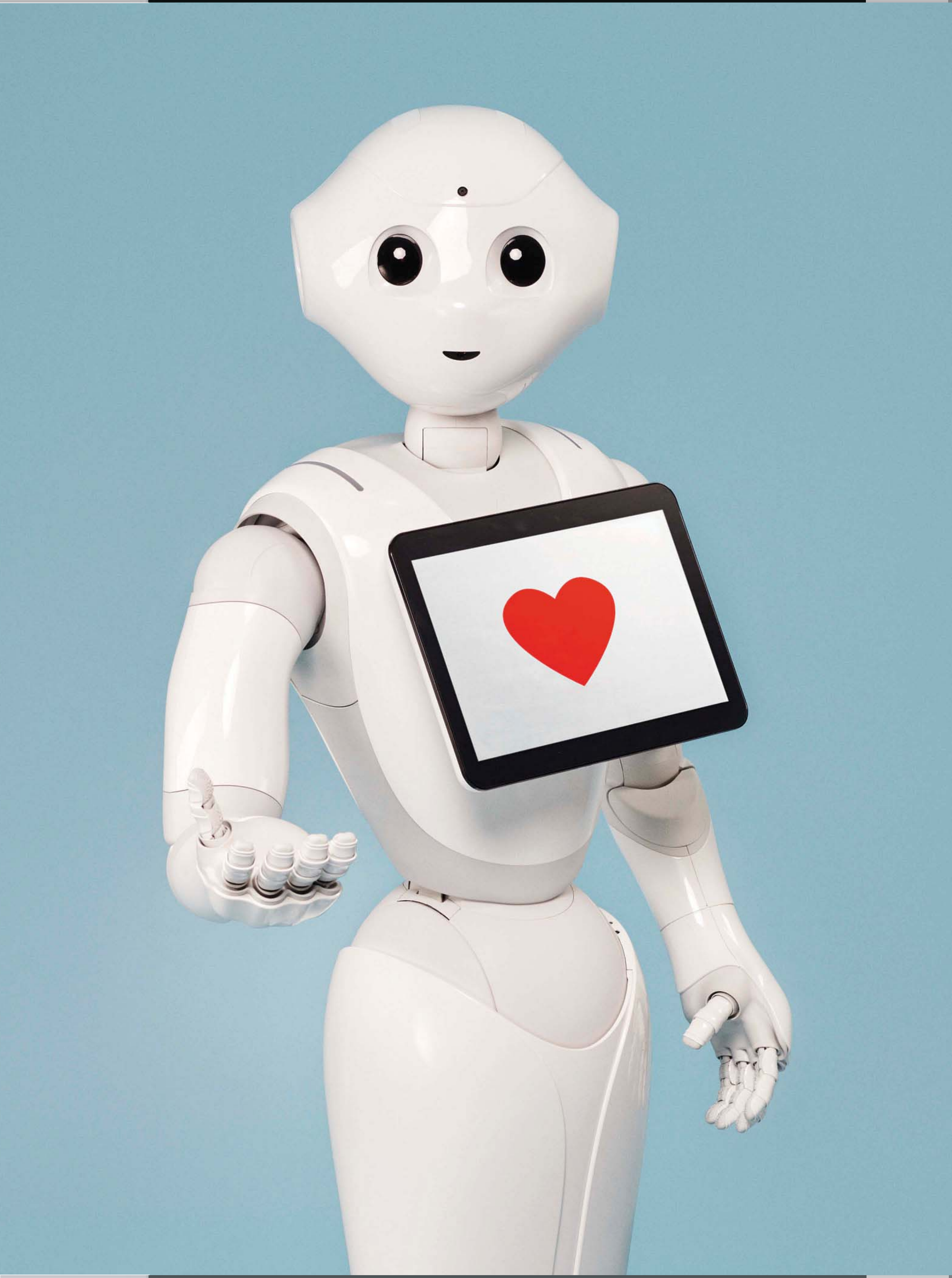
2015

Robots
Space
Medicine
Energy
Telecom
Drones
Transportation
Top Tech to Watch

Illustrations by **Matthew Hollister**

HERE'S WHAT YOU'LL BE READING ABOUT— OR BUYING— THIS YEAR

SNIFFING OUT TECHNOLOGICAL DEVELOPMENTS that we expect to be in the news is never a problem for *IEEE Spectrum*'s editors. What's hard is paring down the list. In this special report, we give emphasis to technologies we anticipate will not only make headlines but also make it into consumers' hands in 2015: robots for the home, modular smartphones, personal video drones, and more. We also highlight some big projects–involving solar power and lunar exploration in particular–that won't significantly affect ordinary people for a while but will achieve important breakthroughs this year. ▶



A Robot in the Family

Pepper can't cook or clean, but many people will welcome this friendly humanoid into their homes

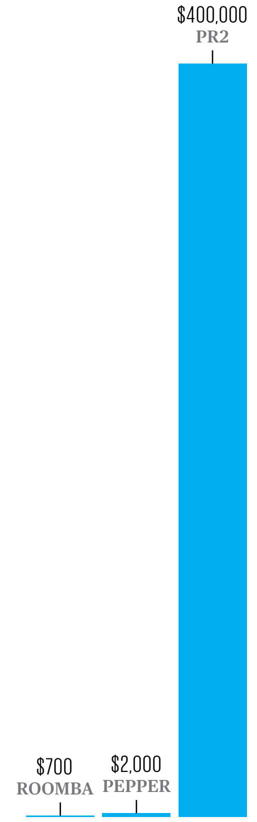
THE ROBOT SEEMS determined to put a bigger smile on the man's face. "Are you smiling from the bottom of your heart?" it asks. The man chuckles. "That's what I'm talking about," the robot quips in a high-pitched voice. Then, just for good measure, it bows its plastic head and apologizes for being "too bossy to our CEO."

The CEO is Masayoshi Son, founder and chairman of telecom giant SoftBank and Japan's richest person. As such, he has overseen the development of hundreds of new products as part of a vast conglomerate of mobile-phone carriers, Internet ventures, and media companies. But last June, at a press conference outside Tokyo, Son climbed onstage to unveil a pet project: a humanoid robot named Pepper [photo, left]. Designed to be a companion in the home, it is the world's first full-scale humanoid to be offered to consumers. In February, SoftBank plans to start selling it in Japan for 198,000 yen (less than US $2,000), plus a monthly subscription fee. Taiwanese electronics manufacturer Foxconn, known for building iPhones for Apple, will produce the robots.

For that kind of money, don't expect anything like Rosie, the robot maid from "The Jetsons." What you'll get is a two-armed, 1.2-meter-tall robot that rolls around on a wheeled base. It can dance and gesture with some grace, but its manipulation skills are limited, and it's unclear how much autonomy the robot has; at the launch event, most of its actions were clearly preprogrammed. At home, Pepper won't be able to fold your laundry or clear the dinner table.

And that's fine with SoftBank, which says Pepper is not a utilitarian automaton. It is designed to provide advice and company: It'll tell you jokes, play games with you, teach you a new subject, and help you communicate with family and friends. Pepper will read a recipe aloud while *you* do the cooking. Onstage with Son, it spoke Japanese, but it is also fluent in English, French, and Spanish.

To do all that, the robot is equipped with an "emotion engine"– software that attempts to infer how a user is feeling based on facial expressions, tone of voice, and speech, allowing the robot to respond accordingly. If you arrive home and look a bit down, Pepper will play your favorite song, for instance. "We want to have a robot that maximizes joy and minimizes sadness," Son said.

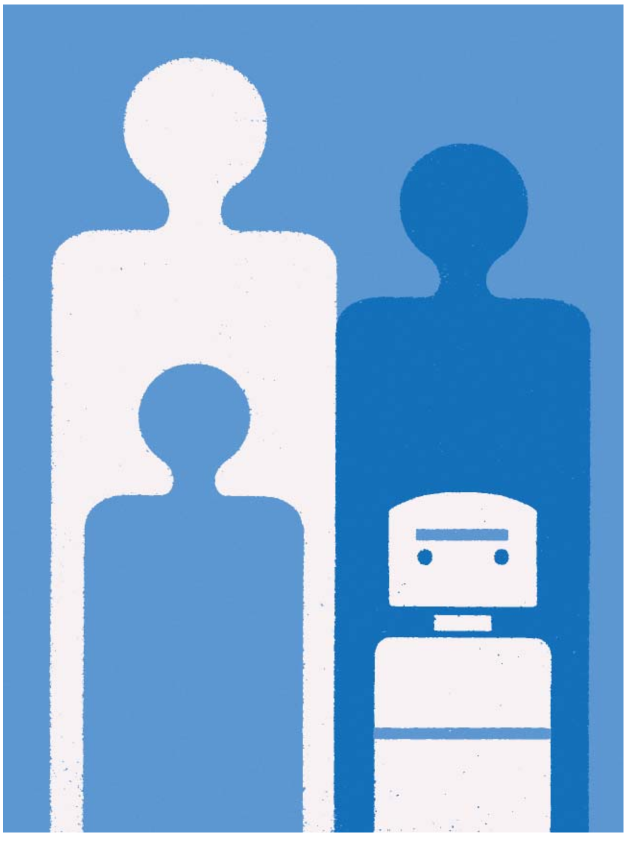


COST OF THREE NOTABLE ROBOTS (U.S. DOLLARS)

While single-task robots like the Roomba vacuum are becoming more popular (and affordable), general-purpose robotic platforms like the PR2, which can fold laundry and fetch you a drink, are still costly laboratory playthings.

DATA SOURCES: IROBOT; SOFTBANK; WILLOW GARAGE

PHOTOGRAPH BY Antoine Doyen



SoftBank is betting that people are ready for that kind of experience. Humanoids have long captured our imaginations, but until now they've been notably absent from our homes, where the only robotic inhabitants you'll find today are small mechatronic toys and Roomba vacuum cleaners. It's still too early to tell whether Pepper will be a hit, but its arrival may be a sign that robotics technology is beginning to catch up with science fiction.

It seems natural that Japan, a nation known for its love of everything robotic, would be the first market for a home humanoid. But it may come as a surprise that SoftBank, as it sought partners to develop Pepper, didn't join forces with Honda, Sony, Toyota, or any other big Japanese company with robotics expertise. Instead, it turned to a much smaller and lesser-known French robotics firm called Aldebaran.

TUCKED IN A NARROW tree-lined street on the southwest edge of Paris, Aldebaran's headquarters occupies several floors of a modern office building. Robots and humans mingle casually as if in a scene from *Star Wars*. A Pepper robot greets employees near the coffee machine. Another–wearing a blond wig that someone thought would make for a stylish upgrade–watches people going by in a hallway. In a glass-walled room, a dozen robots speak and roam aimlessly, testing their own endurance.

I approach a Pepper and strike up a conversation, but the robot doesn't seem to get what I'm saying. An employee comes over and tells the robot to speak English. *Voilà!* Now Pepper and I can understand each other–sort of. When I ask the robot what it is capable of doing, it responds by describing a game it wants to play. The employee shows me how to improve my human-robot interaction skills: I have to look at Pepper's face and speak more clearly. I ask again what it can do. "I can do lots of things," this Pepper tells me, "because the engineers who programmed me are very smart."

SoftBank seems to agree. Four years ago, Masayoshi Son decided he wanted robotics to be part of his vast business empire, and he sent emissaries to evaluate the world's top robotics companies. Aldebaran, despite being relatively small, stood out in its ability to design robots that offer a highly interactive experience. Aldebaran's flagship robot is a knee-high humanoid called Nao. More than 6,000 Naos are now used in research labs,

UPDATE

Titans Vied for Titan

Google outbid Facebook for Titan Aerospace

***IEEE SPECTRUM*'S** prediction that Titan Aerospace's solar-powered "atmospheric satellites" (which are in truth fixed-wing aircraft) would make news ["Solara Takes Off," January 2014] was right on one hand and wrong on the other. In March of last year, rumors surfaced that Facebook was attempting to acquire the company—in hopes that Titan's long-duration stratospheric drones could serve as high-altitude wireless relays, allowing millions to plug into the Internet without having to wait for conventional terrestrial infrastructure to be rolled out. Then in April, Google shouldered Facebook out of the way and purchased Titan for an undisclosed amount.

So there was quite a bit of news about Titan's business dealings, if not its technology, early in the year. But in the months since Google acquired the company, there's been little for anyone to report, as is only to be expected when a start-up gets absorbed by a tech giant in this way. ■

ILLUSTRATIONS BY Matthew Hollister, Greg Mably schools, and hospitals in 70 countries. Longer term, the company is also developing a 1.4-meter-tall legged humanoid called Romeo.

"The most important role of robots will be as kind and emotional companions to enhance our daily lives, to bring happiness, to surprise us, to help people grow," says Aldebaran founder and CEO Bruno Maisonnier, an executive who quit a career in finance to pursue his dream of creating robots for everyone.

Son and Maisonnier met and realized they shared the vision of taking robots out of the lab and into everyday life. In early 2012, SoftBank acquired a majority stake in Aldebaran and agreed to fund the company's growth. For Aldebaran, the acquisition meant that nearly overnight, the company had to focus almost exclusively on the Pepper project.

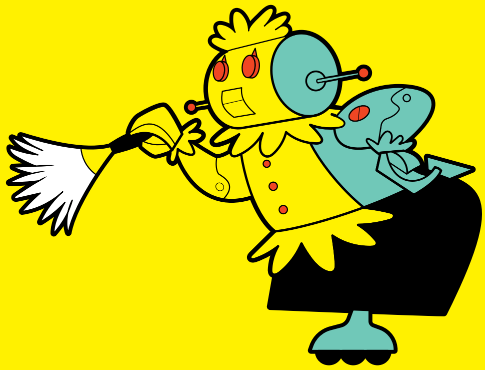
SOFTBANK GAVE Aldebaran just three months to build the first prototype, and after that it demanded to see a demonstration every two or three months. Aldebaran's strategy was to build on its experience with Nao and develop a "stretched up" version of the smaller humanoid. As an example, Rodolphe Gelin, Aldebaran's research director, says the engineers adapted the joint mechanisms in Nao's arms for use in Pepper. "Our robots share many things in common, and that allowed us to do things in a time frame that otherwise would be impossible," he says.

A team of designers and artists created a sleek, friendly looking shell for the robot. And the engineering team stuffed its body with 20 electric motors, an Intel Atom-based computer, two cameras, a 3-D sensor, four microphones, and a lithium-ion battery that lets Pepper run for 12 hours. A tablet on the robot's chest displays information and provides another way to interact with the robot.

Gwennael Gate, one of the software directors, says that a big challenge was dealing with the robot's huge computing needs while "making sure that the CPU is not exploding." Each function is controlled by one of about 20 software engines. If you're standing far from the robot, for instance, its awareness engine makes the robot move its head and emit sounds to try to get your attention. If you come closer, a dialogue engine kicks in, so you and Pepper can have a conversation. If you ask the robot to dance, a motion engine takes over.

In Aldebaran's first trip to SoftBank's Tokyo headquarters, in April 2012, the engineers gathered in a room filled with Japanese executives.

CONTINUED ON PAGE 54



FAST FORWARD

When Will We Have Robot Servants?

Not anytime soon, but personal robots will invade our homes

BY 2020 **PEPPER APPEARS** to be the first of a new breed of personal robots designed to be helpers and companions in the home. In the next five years, several others will become available. One of them, set to ship later this year, is Jibo, a chatty, coffee-machine-size robot created by Cynthia Breazeal, a pioneer of social robotics at MIT. Another robot that will likely hit the market before 2020 is a larger, mobile machine developed by Hoaloha Robotics, a Seattle start-up that targets the health-care market. What we believe Pepper, Jibo, and the Hoaloha robot will have in common is that they'll be interactive, expressive robots that communicate with users through voice and touch screens; in addition to their built-in functionalities, they'll also run third-party applications. So with this first generation of home robots, we should see the emergence of a community of developers focused on robot applications. These robot apps will revolve around entertainment, communication, and education, so don't expect the robots to take over your domestic chores just yet.

BY 2025 **WITHIN THE NEXT** 10 years, more personal robots—with different sizes, capabilities, and prices—will arrive in our homes, offered by established robot makers, big electronics companies, and new robotics start-ups. More robo-companions will mean greater demand for robot applications, and a growing population of developers will strive to build the most compelling—and profitable—apps. But the biggest shift will be in the robots' vision and manipulation skills, which will be vastly improved and allow our robotic cohabitants to begin to perform some useful tasks for us. They still won't be able to cook or clean as well as a human, but they might help you chop some veggies or pick up toys from the floor. This generation of robot helpers will still be slow and imperfect, but they'll be smarter than their predecessors. At least when they break, they'll be able to call customer service themselves. *—E.G.*

ILLUSTRATION BY MCKIBILLO

IEEE SPECTRUM Previous Page | Contents | Zoom in | Zoom out | Front Cover | Search Issue | Next Page Qmags THE WORLD'S NEWSSTAND®

The XPrize's Lunar Deadline Drifts

Aspiring moon explorers now have until 2016 to win a top prize of $20 million from Google

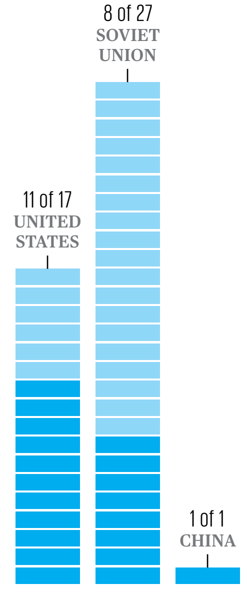
GRIFFIN IS A PACK mule with a mission. The four-footed spacecraft is designed to carry 1.7 metric tons of fuel in its belly. It's girded by wide aluminum deck plates, from which robotic rovers can hang like sleeping bats. It's built to carry time capsules and cremated remains, among other potential payloads. And one day, in the not-too-distant future, a Pittsburgh-based start-up plans to send it to the moon.

One of 18 competitors remaining in the Google Lunar XPrize, the Pittsburgh company, Astrobotic, hopes to be the first private team to make a moon landing, move 500 meters across the lunar soil, and send high-definition images and video back to Earth. If it can do all of this before any of its competitors, it stands to claim a top prize of US $20 million, provided by Google.

But they don't call it a moon shot for nothing. Now in its eighth year, the competition has seen 15 of the original 33 teams drop out. In 2009, the prize administrators moved to extend the deadline by three years, to the end of 2015. And just a few weeks before this issue of *IEEE Spectrum* went to press, the Google Lunar XPrize team informed us that the deadline would be extended by another year, to 31 December 2016.

For many prize participants and space-news enthusiasts, the change likely comes as little surprise. Aspiring explorers face some daunting hurdles between Earth and lunar glory. First, there's the technical challenge involved in building a lunar spacecraft capable of reaching the moon and then performing a soft landing—a feat that has so far been accomplished by only three nations: the United States, the Soviet Union, and China. Then, and perhaps even more crucially, there are the financial and logistical obstacles associated with getting to space. A rocket launch can easily cost tens of millions of dollars, and it's not easy to coordinate, particularly if you're trying to launch on short notice or save money by piggybacking on an existing mission.

The mission is "extremely difficult and unprecedented," both technically and financially, the XPrize Foundation said in an e-mail to *Spectrum*. But it's clear that it wants competitors to get serious about leaving Earth. In addition to an extension, the new guidelines will disqualify teams that do not show proof of a launch agreement by the end of 2015. No teams have yet shown such



SUCCESSFUL SOFT LANDINGS

Three nations have landed spacecraft on the moon, with varying rates of success.

DATA SOURCES: JONATHAN MCDOWELL; ANATOLY ZAK/RUSSIAN SPACE WEB

proof, an XPrize representative added.

A spin-off of Carnegie Mellon University, in Pittsburgh, Astrobotic hopes to go to the moon by selling berths on its Griffin lander and the SpaceX Falcon 9 rocket it aims to use to get to space.

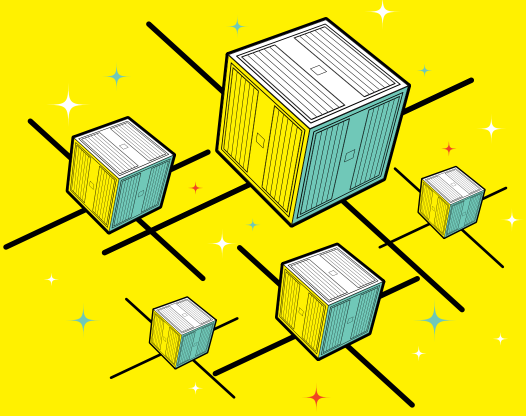
The company plans to offer delivery services to three unique locations: on a lunar trajectory near Earth, an orbit around the moon, and the lunar surface. Transport all the way down is currently priced at about $1.2 million per kilogram, says CEO John Thornton.

For its maiden voyage, Astrobotic aims to send Griffin to Lacus Mortis, where there is a roughly 150-meter-wide opening in the surface, first spotted several years ago by NASA's Lunar Reconnaissance Orbiter. The pit, which is collapsed on one side, could potentially provide an easy-to-access shelter that could shield future lunar explorers from radiation and micrometeorites.

Astrobotic has already penned agreements to deliver cremated remains managed by the space-burial company Celestis, based in Houston, and a time capsule made by a Singapore-based company, Astroscale. The capsule will contain messages from children and a Japanese sports drink called Pocari Sweat. But the XPrize will be a big part of the financing for the first mission, says Thornton. SpaceX's "front-door" price for a Falcon 9 is about $60 million, he says. To make up for the cost, Astrobotic aims to use Griffin to deliver the company's own rover and vehicles of other lunar XPrize teams. So far, one competitor has signed on, Thornton says, and there should be space for more than half of those teams still participating.

Astrobotic now has many of the ingredients needed to perform a safe lunar landing. Building off work done more than 10 years ago for the DARPA Grand Challenge, an autonomous-vehicle competition, chief technology officer Kevin Peterson and his colleagues have built a computer-vision system designed to help the spacecraft track its progress toward the lunar landing site by comparing real-time images taken by Griffin with reference pictures of the surface.

The team has made feature-recognition algorithms that allow the spacecraft's computer–a garden-variety, military-grade motherboard with an Intel i7 core–to process images at the speed required for a moon touchdown: roughly 10 frames per second. In June 2014, the team used this system, in concert with a scanning



FAST FORWARD

Dips Into Deep Space

Private firms will make excursions beyond Earth orbit

BY 2020 **THE MOON WON'T** be forgotten. At the very least, China plans to send a sample return mission to the lunar surface in 2017, following on its successful robotic landing in 2013.

As for private exploration, even if a lunar landing remains elusive, the next five years could bring at least a few forays beyond geosynchronous orbit. The spacecraft making these trips will likely be small. They could be standardized vehicles such as CubeSats, which consist of cube-shaped modules that measure 10 centimeters on a side. Hundreds of CubeSats have now been launched into space, but so far none past low Earth orbit.

That situation could change in just a few years, with the launch of NASA's new heavy-lift rocket, the Space Launch System. The rocket, which will be the most powerful yet constructed, is designed to carry astronauts to asteroids and potentially to Mars. But on its maiden voyage in 2018, it will take a relative baby step, carrying an uncrewed space capsule on a three-week test flight beyond the moon.

NASA has set aside 11 berths for CubeSat missions that would piggyback on the launch. One mission that's already been selected, called Lunar Flashlight, would hunt for evidence of water ice at the moon's south pole. Two other missions aim to test the effect of space radiation on cell growth and to inspect a near-Earth asteroid. The agency has opened a competition for three to six other slots.

BY 2025 **BY THIS TIME,** several nonprofit and commercial outfits will be sending their own small spacecraft into deep space. This exploratory push will likely get a boost from newly miniaturized propulsion systems, such as the CubeSat Ambipolar Thruster, a small plasma thruster developed at the University of Michigan.

Ten years from now, says space historian Jonathan McDowell, "we could see the first [private] interplanetary survey probes sent to asteroids," a first step in exploring the profitability of asteroid mining. This may ultimately pave a path for the financially sustainable exploration of space beyond Earth orbit. *—R.C.*

ILLUSTRATION BY MCKIBILLO

laser, to guide a rocket-powered vehicle built by Masten Systems down to a landing from some 260 meters in the air. The combination could also detect surface obstacles as small as a soccer ball.

To win the lunar XPrize, Astrobotic must incorporate this capability into a fully integrated lander–and get it off the ground well before the end of 2016. Astrobotic says its technology will be ready to go by the deadline. But much will depend on whether it can cobble together funding for the mission and reserve a rocket in time.

"The biggest challenge of this prize is the financing," Thornton says. What's more, he says, there is the possibility that SpaceX's 2016 launch manifest will fill before Astrobotic is ready to claim a spot. But even if Astrobotic can't get customers in line in time to make a bid for the lunar XPrize, he says, it will still aim for a launch: "We're not driven by a particular date or prize. We're out to make a sustainable business operation where we're regularly transporting payload to the surface of the moon."

A WORLD AWAY: Astrobotic's Griffin lander, photographed in 2014 at a "mooncast" at the LaFarge slag heap in West Mifflin, Pa.

Astrobotic isn't the only team with a go-for-it-regardless stance. Another is the Penn State Lunar Lion team, based at Pennsylvania State University and still at the beginning stages of fund-raising and spacecraft construction. The extension will surely allow the Lunar Lion team to stay in the running for at least a bit longer, but making the deadline doesn't concern team leader Michael Paul. The Google Lunar XPrize is "a great fire in the belly," Paul says, but his main goal is to grow aerospace talent for the university. Already, he says, "there are companies that are coming here to recruit from the team."

Competitor SpaceIL, an educational nonprofit in Israel, is also set on the moon, prize or no. "We're 100 percent going to the moon," declares director of business development Daniel Saat. Getting the prize would just be a bonus: "At the end of the day, the prize is dessert," he says.

SpaceIL wants to give Israel its own Apollo moment. "Our mission is to land the first Israeli spacecraft on the moon," Saat says. It's a goal that's resonated with many Israelis. SpaceIL has already raised $36 million–enough, Saat says, for them to get to the moon. The team has made outreach a priority and has so far reached some 60,000 schoolchildren through in-class presentations, he adds.

Now with more than 30 full-time staff, the group is just beginning work on flight hardware,

CONTINUED ON PAGE 55

UPDATE

Electric Car Racing Runs Fast and Quiet

The first Formula E race ripped up the streets of Beijing

NICK AND DREW HAGELIN

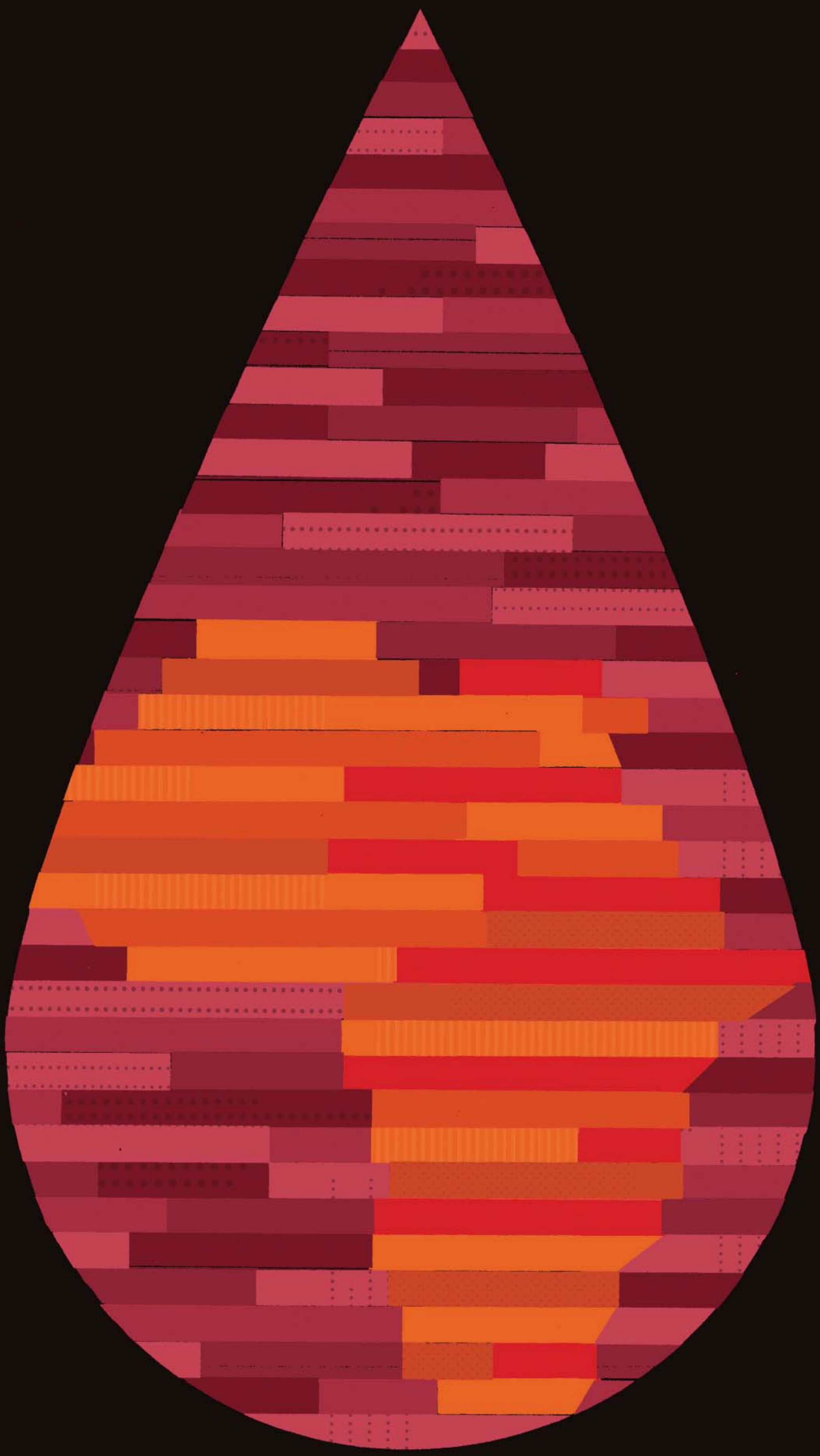
THE FORMULA E racing circuit that *IEEE Spectrum* previewed last year ["The Fast and the Formula E," January 2014] went pretty much as planned in its inaugural run on the streets of Beijing. The cars had lower top speeds but faster acceleration than Formula One cars, and they were safe—but not too safe.

Indeed, they provided the 70,000-odd attendees with the ideal crash. One of the two leaders bumped the other, went flying into a crash barrier, and landed upside down. Its driver emerged angry but unscathed. A third driver, Audi Sport ABT's Lucas di Grassi, took first place.

The only thing lacking was noise. A Formula E car puts out a modest 80 decibels, like a hair dryer, compared with the gas-burning Formula One car's 130 to 140 decibels, which is somewhere between a jackhammer and a jet engine. The organizers addressed the deficiency, if such it was, by supplying music.

Formula E is supposed to overcome the golf-cart image of electric cars, but that image has already been revised. In October, Tesla Motors previewed a dual-motor version of its all-electric Model S, which goes from 0 to 60 miles per hour (97 kilometers per hour) in about 3.6 seconds. The final version is supposed to do it in 3.2 seconds—very much on par with what Formula E cars can manage. ■

ILLUSTRATION BY **Greg Mably**



Portable Pathology for Africa

Diagnostic medicine goes mobile, thanks to new microfluidic tools

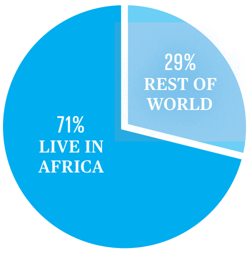
WHEN JOHN BARBER, a project manager at Daktari Diagnostics, sought to test his company's instrument, he went to the type of place where the technology might have the most impact: a small fishing village on the shores of Lake Victoria in Uganda. He awoke at dawn on a November morning in 2013, tossed a few Daktari devices into a backpack, and, together with a team of HIV-treatment specialists, drove 2 hours to the village of Kasensero, where the first Ugandan case of HIV was reported more than 30 years ago. Driving a Jeep along dirt roads with more cows than traffic, "we were off the grid," Barber recalls.

Barber and his team showed up at 8 a.m. and found about 20 people already waiting for them. Dozens more arrived within the hour. An estimated 43 percent of people in Kasensero are HIV-positive, and these patients wanted to know whether the virus had started to damage their immune systems. The medical team was there to check the patients' CD4 counts, a measure of immune cells that indicates how well the body can stave off opportunistic infections such as tuberculosis. Based on test results, some people would need to start antiretroviral therapy. Others might need their medications adjusted.

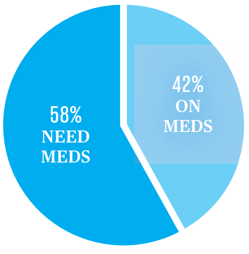
The villagers didn't get answers that day. While the Daktari device is capable of providing same-day results, it was only being tested during Barber's visit to Uganda. So the Kasensero patients had to settle for the standard CD4 diagnostic procedure: testing on a large and expensive desktop instrument called a flow cytometer, which requires dedicated laboratories, highly trained technicians, and infrastructure for shipping refrigerated reagents long distances. Because the nearest flow cytometer was in a town 80 kilometers away, the HIV-treatment team had to collect and transport vials of blood for testing and couldn't inform villagers of their CD4 levels until they returned for their next scheduled visit months later. At worst, patients were lost to follow-up. At best, critical medical decisions got delayed. Either way, the virus became tougher to fight.

In 2015, Daktari will enter the fray. The company is planning to roll out its portable CD4 tester this year across sub-Saharan Africa—first in Kenya, then in Ethiopia, South Africa, and practically every country in between. The Daktari device is part of a new wave of lab-in-a-backpack instruments that can bring diagnostic testing directly to patients and health workers in the developing world.

The device looks like a vintage Fisher-Price tape



PEOPLE LIVING WITH HIV



HIV MEDICATION IN AFRICA

The World Health Organization recommends that adults with HIV begin taking antiretroviral medications when their CD4 cell counts fall to 500 cells per cubic millimeter.

DATA SOURCE: WORLD HEALTH ORGANIZATION

THE MOVABLE LAB: In Kasensero, Uganda, doctors tried out the Daktari Diagnostics device, which can provide HIV patients with on-the-spot test results.

DAKTARI DIAGNOSTICS

player, with test cartridges taking the place of audiocassettes. But that appearance belies a sophisticated piece of equipment that can provide CD4 counts in less than 15 minutes, all from a simple finger prick. "Our goal is that you have a CD4 count and you can make a decision before the patient leaves the doctor's office," says Aaron Oppenheimer, vice president of product design and development at Daktari, as he demonstrates the instrument at the company's headquarters in Cambridge, Mass. "There really aren't products like this on the market. In fact, there really isn't a market. There's a need, but being able to do real diagnostics at the point of care is new."

Oppenheimer acknowledges that a few rival companies already have grab-and-go tests available for CD4 monitoring in rural Africa. But these competing devices are essentially portable versions of flow cytometers, which rely on imaging fluorescent proteins bound to CD4 cells. Daktari's CD4 reader instead measures the electrochemical signal of the cells, and

Oppenheimer says this distinction is important. Without optical detection, he says, the Daktari device has a longer battery life–up to two days or about 50 runs–and requires less maintenance than other systems. "We believe that our product will go where other products that we're competing with can't go," Oppenheimer says.

DOCTORS HAVE LONG talked of the promise of point-of-care diagnostic tools that can provide near-instant results at hospital bedsides and doctors' offices. In recent years, that talk has turned into real products. Most of these portable devices rely on new microfluidic technologies, which manage how tiny samples of bodily fluid move through pieces of equipment. They also make use of miniaturized electronics developed for cellphones and other consumer electronics. According to a recent report on microfluidic diagnostics by Yole Développement, a consulting firm in France, the worldwide market will grow rapidly: from US $1.6 billion in 2013 to a projected $5.6 billion in 2019.

It's in global health that point-of-care diagnostics could arguably do the most good. In countries like Uganda, where many people don't have access to hospitals and labs, these tools could empower a distributed, mobile system of health-care delivery. Just as African telecommunications largely skipped over landline infrastructure and went straight to mobile phones, some experts say African medicine can skip over centralized labs.

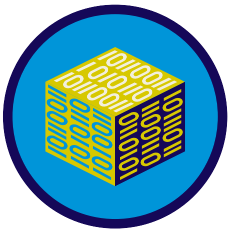
Device makers are working on a wide range of disease applications, with HIV-management tests at the forefront. In high-income countries, doctors routinely check the amount

---

UPDATE

3-D Memory on the Rise

Vertical designs for more density and bandwidth are getting off the ground



TURNING LINES OF memory cells on their side, so that they stand straight up, lets chipmakers save money by packing more bits into a given space. Last year, we predicted that 2014 would be the banner year for such 3-D memory ["Memory in the Third Dimension," January 2014]. And we were partly right.

Samsung already had a 3-D NAND flash-memory chip for data centers under its belt. In May, the company released a second offering, targeted at high-end PC users. These chips soon found their way into consumer-level solid-state drives, but less was heard from the other memory makers that aimed to release their first 3-D NAND products in 2014. Still, momentum is building: In November, Intel announced that it, too, has plans for the technology.

We also predicted that 2014 would be a big year for a vertical sort of dynamic RAM. Boise, Idaho–based Micron Technology has developed the Hybrid Memory Cube (HMC), a pile of DRAM chips that talk via chunky connections to a logic chip on the bottom of the stack. Micron hoped these designs would go into full production in 2014. But testing took longer than anticipated, says the company's HMC technology strategist, Mike Black. He says production should ramp up by the middle of this year. ■

ILLUSTRATION BY Greg Mably

of virus present in an HIV patient's blood (in addition to counting CD4 cells) to guide treatment decisions, such as when to switch from one drug to another. But costs and equipment demands have precluded running viral-load tests in most of the developing world. "The existing systems are not anywhere near good enough to do the job" in resource-limited settings, says Daniel Laser, CEO and president of the diagnostics company Wave 80 Biosciences, in San Francisco.

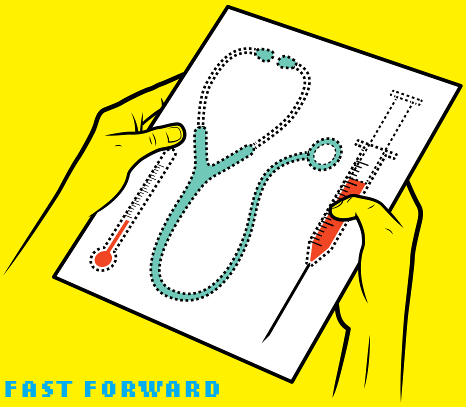
For newborn babies, the viral-load count is critical. Doctors can diagnose HIV in adults and older children with simple flow tests that identify the presence of antibodies directed against HIV, but these same antibodies diffuse across the placenta and can persist for up to 15 months in an infant's blood. Thus, their presence confirms that a mother is HIV-positive but doesn't reveal a newborn's HIV status.

A number of companies are now introducing devices that can check viral load in this vulnerable population. Wave 80, for example, has invented a handheld device called the Eoscape-HIV, which uses disposable cartridges that incorporate micropistons. It can measure viral loads on-site in less than an hour. The Massachusetts-based company Alere also has a new viral-load-testing device, which it's launching in late 2015. "The clinical reality is, if we don't get a [HIV-positive] baby on treatment within the first 8 to 12 weeks of life, the mortality is quite bad," says Willem Pretorius, global product manager for HIV care at Alere. "If we bring a point-of-care early-infant diagnostic test to the primary health-care setting, where the mother can actually wait for the result, that could have quite a big impact on getting those babies who test positive on antiretroviral therapies."

Many of these same HIV-monitoring technologies can be refashioned for other diagnostic purposes. Wave 80, for example, is looking also to detect chlamydia, gonorrhea, and other pathogens with its Eoscape. And Alere is adapting its new machine to test for tuberculosis, including drug-resistant strains. These portable systems may soon allow health-care workers to test for many infectious diseases in the remotest regions of the globe.

In 2015, "the bottleneck is not really in the technology" anymore, says Benjamin Roussel, an analyst with Yole. "It's mainly in the user, the doctor, and the medical world. Getting them to adopt the technology could take some time." Fortunately, that adoption process has begun.

—ELIE DOLGIN



FAST FORWARD

Stripping Away the Instruments

Paper-based tests and cellphones will replace dedicated devices

BY 2020 **TO MAKE DIAGNOSTICS** even easier in the developing world, some innovators are creating tools that require no maintenance and no power source.

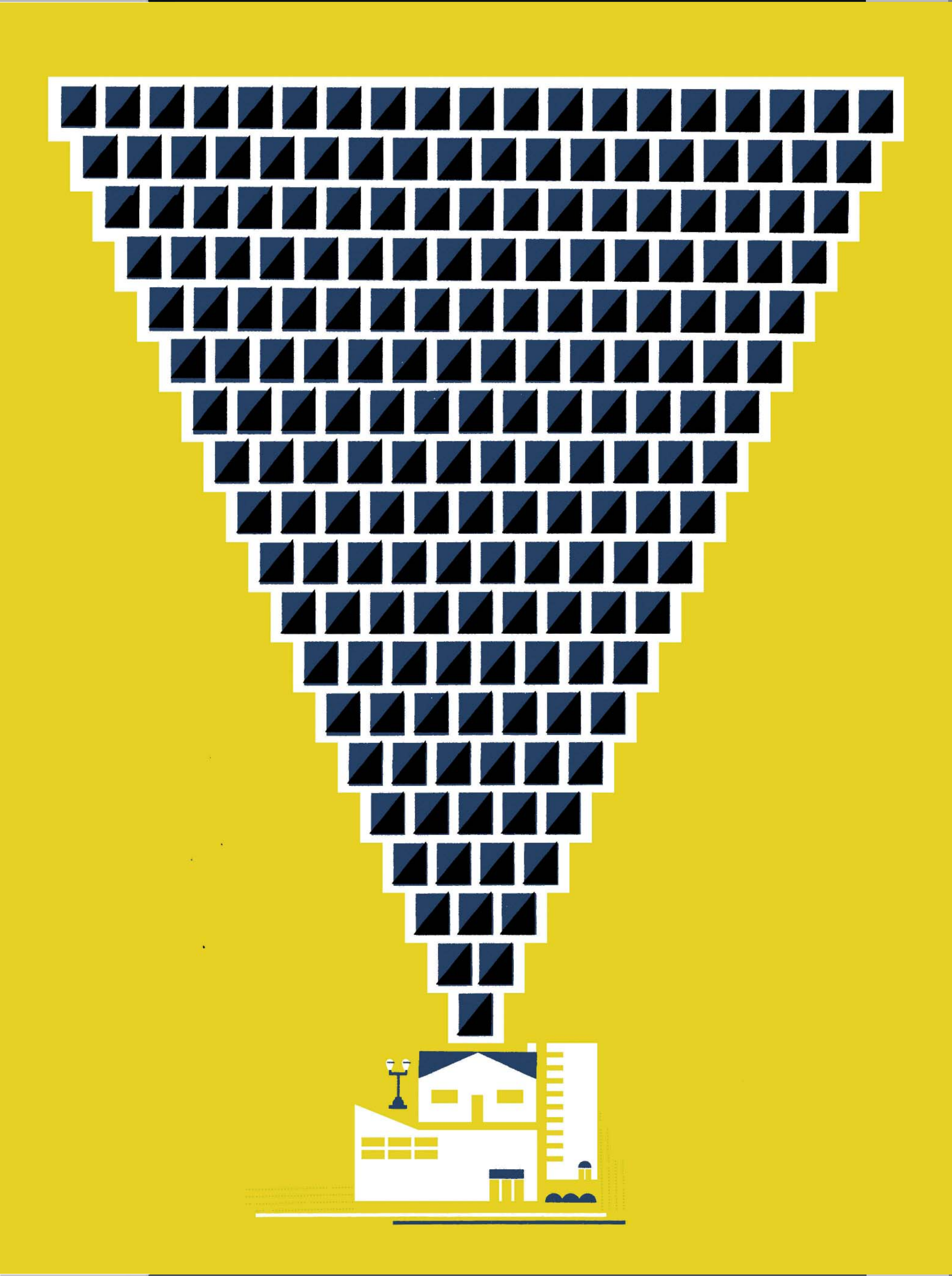
A forthcoming CD4-counting tool from Scotland-based Omega Diagnostics, for example, takes the same approach used in a pregnancy test, wicking blood through paper and capturing proteins from CD4 cells at a sample line. This is checked against a reference line to give a visual "treat or no-treat" result, explains the device's inventor, David Anderson. "It can be read by eye," he says. "You don't need anything except the disposable that comes in the box to get a result."

Omega has also created an app to allow more precise quantification with a smartphone camera. Other companies are coupling cellphones with paper-based microfluidics to detect levels of blood sugars, micronutrients, and pathogenic bacteria. "Cellphones are ubiquitous," says Elain Fu, a bioengineer at Oregon State University, so there's little sense in building a dedicated read-out tool for every test. Within five years, Fu expects most paper-based microfluidic tests to be read by smartphones.

BY 2025 **AT THE NONPROFIT** Diagnostics for All, based in Cambridge, Mass., CEO Marcus Lovell Smith is looking further ahead. His team is blending disposable electronics, including LEDs, light detectors, and transistors, into paper-based microfluidic tests. "We are absolutely averse to instruments because we feel that anything that plugs into a wall, or requires some sort of calibration or servicing, is just not feasible," he says. "But that doesn't mean that we wouldn't use sophisticated but very inexpensive electronics." Those hybrid systems are maybe a decade from commercialization.

Bernhard Weigl, who works on diagnostic technology at Path, a Seattle-based nonprofit, says scientifically sophisticated paper tests could be the world-changing advance the global health community has been waiting for. This is "quantum-leap-type stuff," he says. *—E.D.*

ILLUSTRATION BY MCKIBILLO



Big Solar's Big Surge

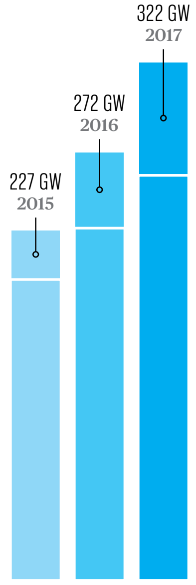
With the completion of the world's largest photovoltaic power plant, grid operators must figure out how to integrate more solar

SILENCE GENERALLY reigns across California's Carrizo Plain, about 160 kilometers northwest of Los Angeles. But for much of the past three years, this expanse of grassland and farms was anything but silent, as up to 880 people trucked out each day to the plain's sparsely inhabited northern end to build a hefty power plant. On a bright October afternoon, only a handful of construction workers remain, and the nearly completed plant is generating at close to full tilt. And yet it makes nary a click, buzz, or whir, even as it pumps hundreds of megawatts of electricity into California's power grid.

The utter quiet is a facet of the technology. This is the world's largest solar power plant, Topaz Solar Farms, where First Solar, based in Tempe, Ariz., has erected nearly 9 million of its cadmium-telluride thin-film photovoltaic panels across 19 square kilometers of former ranchland. This sea of panels and the associated inverters and transformers are designed to deliver 550 megawatts of low-carbon AC power, enough to service 180,000 homes. The site will reach its full design capacity early this year.

Topaz marks the pinnacle in a massive scale-up of grid-connected solar power across the United States. As recently as 2009, rooftop systems accounted for nearly 90 percent of U.S. solar capacity. While installation of rooftop PV continues to expand, utility-scale solar has come to dominate the market. This year, plants like Topaz will add more megawatts than the entire U.S. solar market did in 2013, according to projections by Boston-based green-tech consultancy GTM Research. Indeed, First Solar is also nearing the completion of another massive PV plant, its 550-MW Desert Sunlight Solar Farm, in Southern California.

So far most grid operators are taking the "big solar" surge in stride, in part because PV plants like Topaz tend to produce the most electricity when demand is also high. But the commissioning of more plants, plus the proliferation of rooftop solar, could soon lead to days when generation exceeds demand, threatening to upset the grid's delicate balance. According to models commissioned by the California Independent System Operator (CAISO), which oversees the state's



ESTIMATED GLOBAL PHOTOVOLTAIC CAPACITY, 2015-17

Worldwide solar PV capacity could reach 282 to 362 gigawatts by the end of 2017. The low end of that estimate assumes that new markets in emerging countries will fail to take off, while the upper end assumes a robust PV market in emerging regions.

DATA SOURCE: EUROPEAN PHOTOVOLTAIC INDUSTRY ASSOCIATION

IEEE SPECTRUM Previous Page | Contents | Zoom in | Zoom out | Front Cover | Search Issue | Next Page Qmags THE WORLD'S NEWSSTAND®

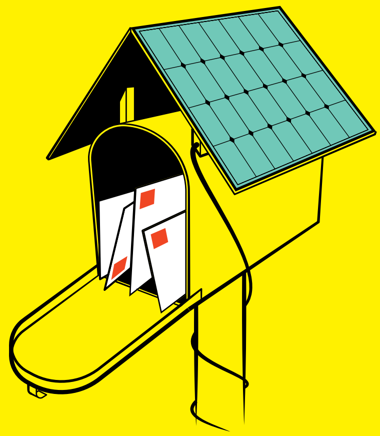
bulk electricity grid, some areas could suffer that very scenario by 2020 if current trends continue. This means that CAISO and other grid operators have just a few more years to figure out how to best integrate this new wealth of solar-generated power.

SOLAR'S SCALE-UP IN California has been a long time coming. One abortive start occurred right here in the Carrizo in 1983, when an oil company erected one of the first dedicated solar power stations. The 5.2-MW plant's time in the sun was cut short, however, as deterioration of the panels soon sapped their output. By 1995, the panels were gone. That same period saw the construction of even bigger solar plants that use mirrors to concentrate sunlight, raise steam, and drive turbines. Nine such solar thermal plants generating about 40 MW each were installed in the Mojave Desert before expiring incentives stalled that technology, too.

Then, in 2006 California passed a law mandating that utilities include at least 20 percent renewable energy in their retail electricity supply by 2010; three years later, the state added a mandate for 33 percent renewables by 2020. Energy officials figured that much of this green power would come from big solar plants. The state's best sites for wind turbines–that is, those having decent access to transmission lines–were already being maxed out, says Neil Millar, executive director for infrastructure development at CAISO. Top solar sites, in contrast, were largely untapped–including the Carrizo.

The Carrizo Plain, with 315 sunny days a year, offers some of the state's best sun, and it is conveniently bisected by an existing 230-kilovolt transmission line. In 2008, when the Topaz project was first proposed, San Francisco-based Pacific Gas and Electric Co. signed up to take the site's power at a guaranteed price of roughly 20 U.S. cents per kilowatt-hour for 25 years. By the time First Solar was ready to build Topaz in 2011, the alternative-energy investment arm of billionaire Warren Buffet's empire, known as MidAmerican Renewables, had bought the project and financed its construction. "All of the stars lined up for Topaz," says Gary Hood, MidAmerican's Topaz project manager.

Aligned stars or not, Topaz has taken many years to come together. Ironically, what held it up–and what has posed a challenge for many solar megastations–is its environmental footprint.



FAST FORWARD

Big Solar Slims Down

Although photovoltaic generation will grow, individual installations will get smaller over time

BY 2020 **MORE GRID-SCALE SOLAR** will continue to come on line over the next five years, but some "rightsizing" is already in the works. Many experts expect utility-scale plants in 2020 to be a lot smaller than the 550-megawatt Topaz Solar Farms. "We're looking at 20 to 80 MW as the sweet spot," says Mark Bolinger of Lawrence Berkeley National Laboratory.

That's because the economies of scale for gas, coal, and nuclear power plants don't apply to solar, Bolinger says. Instead, building bigger tends to complicate solar installations. While small photovoltaic plants can be easily slipped into unused tracts, such as abandoned farmland, larger parcels—like Topaz's 19 square kilometers—are harder to come by. Smaller projects can also connect with the power grid more quickly and cheaply. To hook up Topaz and another nearby solar farm, Pacific Gas and Electric Co. had to upgrade high-voltage transmission wires at a cost of US $35 million to $45 million.

BY 2025 **EXPECT THE TREND** toward smaller sizes to continue, with rooftop installations eventually retaking the lead. Electricity from rooftop solar systems may be pricier than that from utility-scale plants, but it already makes economic sense in an increasing number of states and countries that enjoy great sun and suffer from high grid-power prices. California is among them, with nearly a quarter of a million PV systems providing about 1 percent of the state's power. By 2025 the rooftop share could be 10 times as great, according to distributed-energy proponents.

James Fine, a San Francisco–based senior economist for the Environmental Defense Fund, says the rise of rooftop solar will come from consumers' desire for self-sufficiency as well as the growing number of third-party providers that lease PV systems to homeowners and businesses for no money down.

California may need that extra power by 2025. By then, the licenses are set to expire for its last nuclear power plant: PG&E's 2,200-MW Diablo Canyon facility, which lies on a seismically active stretch of coastline just 80 kilometers west of the Topaz solar plant. *—P.F.*

ILLUSTRATION BY MCKIBILLO

A FOX TALE: **Custom fences help endangered San Joaquin kit foxes coexist with the 500-megawatt Topaz solar power plant.**

MIDAMERICAN SOLAR (2)

Topaz lies within a critical habitat for several dozen protected species, including the longhorn fairy shrimp, the giant kangaroo rat, and the San Joaquin kit fox, one of California's most imperiled animals. "It's this great vast open area with very little growing over a foot tall, but there are some remarkable species out there," says Bruce Gibson, chairman of the San Luis Obispo County Board of Supervisors.

To win government approvals and avoid litigation, First Solar purchased another 70 square kilometers nearby to be conserved in perpetuity. The company also designed the Topaz site itself to function as wildlife habitat, both during construction and throughout its 35-year projected lifetime.

So far, no kit foxes have been harmed during construction. And Brian Cypher, an expert on these foxes at California State University's nearby Stanislaus campus, says that Topaz may even be improving the foxes' lot by providing refuge from predators. Small gaps in the fencing around the site let the house-cat-size foxes slip through while excluding the coyotes that hunt them.

Even if Topaz now passes environmental muster, other big-solar sites in California have not. Topaz's twin, Desert Sunlight, is one of several solar plants where endangered waterbirds have turned up dead. Ileene Anderson, a senior scientist for the Center for Biological Diversity who specializes in desert conservation, speculates that the birds are mistaking the polarized light reflecting off the panels for lakes. They may be injured when landing, she says, and may then be unable to take off. Anderson's group is reportedly planning a lawsuit over the dead birds.

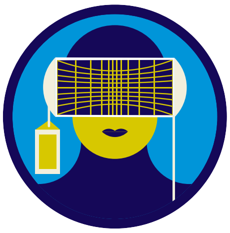
Facing even greater scrutiny are solar thermal power plants. Altogether, California's three recently completed projects–plus two more in Arizona and Nevada–have more than doubled the country's solar thermal capacity since 2012. But further development has all but stalled amid alarming reports of birds igniting as they fly through the plants' concentrated solar flux. "That market is at a standstill," says Mark Bolinger, a renewables expert at Lawrence Berkeley National Laboratory and coauthor of a recent analysis of utility-scale solar.

CONTINUED ON PAGE 56

UPDATE

Oculus Rift: It's getting better with time

The new dev kit from Oculus VR bodes well for the future of virtual reality



OCULUS VR, WHICH makes the best consumer virtual-reality headset that *IEEE Spectrum*'s editors have ever experienced, had a very big year in 2014. And we weren't the only ones impressed with this hardware: Facebook acquired the entire company in July for US $2 billion.

The latest Oculus Rift development kit improves substantially on the one described in these pages a year ago ["Virtual Reality's Moment," January 2014]. It features a higher-resolution, active-matrix organic LED screen with faster response times, new sensors that can track the position of your head (not just where you're looking), and various updates that reduce latency by 50 percent.

Spectrum got some eyes-on time with a prototype at the 2014 Consumer Electronics Show, in Las Vegas, and we found the experience a lot more immersive and a lot less virtual than what the preceding model provided.

Oculus is exploiting the consumer-electronics industry's rapid development cycle to improve its product. In September, Oculus and Samsung announced a collaboration on a virtual-reality headset based on the screen of Samsung's Galaxy Note 4. Although there is no official timetable for when this gadget will be ready for sale, our guess is that the long-awaited commercial release of the Oculus Rift—with even better hardware than what we tested—will take place sometime this year. ■

ILLUSTRATION BY Greg Mably

Your Phone Will Go to Pieces

Project Ara's modular smartphone design lets users swap parts like screens and cameras on the fly

THE MODERN SMARTphone is a masterpiece of adaptability. It lets you talk, snap photos, and tote around sprawling media collections. Downloadable apps let you do lots of other things, too, like track your workouts, monitor your diet, or remix a song. There's even an app that helps you find hidden treasure, thanks to software that turns your device into a metal detector using the magnetic-field sensors that make up your smartphone's compass.

But don't let this apparently awesome adaptability bamboozle you. For all its vaunted versatility, a smartphone is still only as good as its hardware. Though hundreds of new apps appear every day, your phone's hardware is unchangeable beyond perhaps the option of swapping in a more spacious memory card.

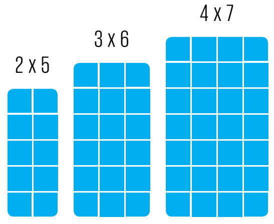
This inflexibility has two drawbacks. First, your phone cannot take advantage of the steady improvements to hardware that accrue from Moore's Law and other factors. Second, other than installing an app, you cannot modify your phone to fit your lifestyle or temporary needs.

Suppose you're finally going on that long-dreamed-of vacation to Indonesia and want a better camera in your phone. Add-ons can give you a new lens to work with, and photo-editing software can improve the resulting pictures, but these tweaks won't make a dramatic difference in your photos. If you really want to take better pictures with your phone, buying a new one is your only option.

Google hopes to change that this year when it releases the first iteration of Ara smartphones, which consumers will build and customize using hardware modules. At press time, Google hadn't disclosed many details about its plans, including the exact release date or the modules that will be available when Ara debuts. But the company intends to begin sales of a "market pilot" version of the phone in 2015.

Google also announced that Chinese chip manufacturer Rockchip will provide the central processor for the device, which will be housed in a single, removable "application processor" module alongside the graphics processor and main flash drive. It was unclear as of mid-December whether the cellular antenna and radio components that allow Ara to serve as a phone will be contained within a single module or spread out over several. However, Project Ara director Paul Eremenko tells *IEEE Spectrum* that the phone will be capable of 4G LTE connectivity when it launches. Other basic offerings are expected to include display modules that serve as the screen, as well as battery, microphone, speaker, and camera modules.

To turn this hodgepodge into a functioning smartphone, you'll plug everything into an "endoskeleton" that has



PROJECT ARA MODELS

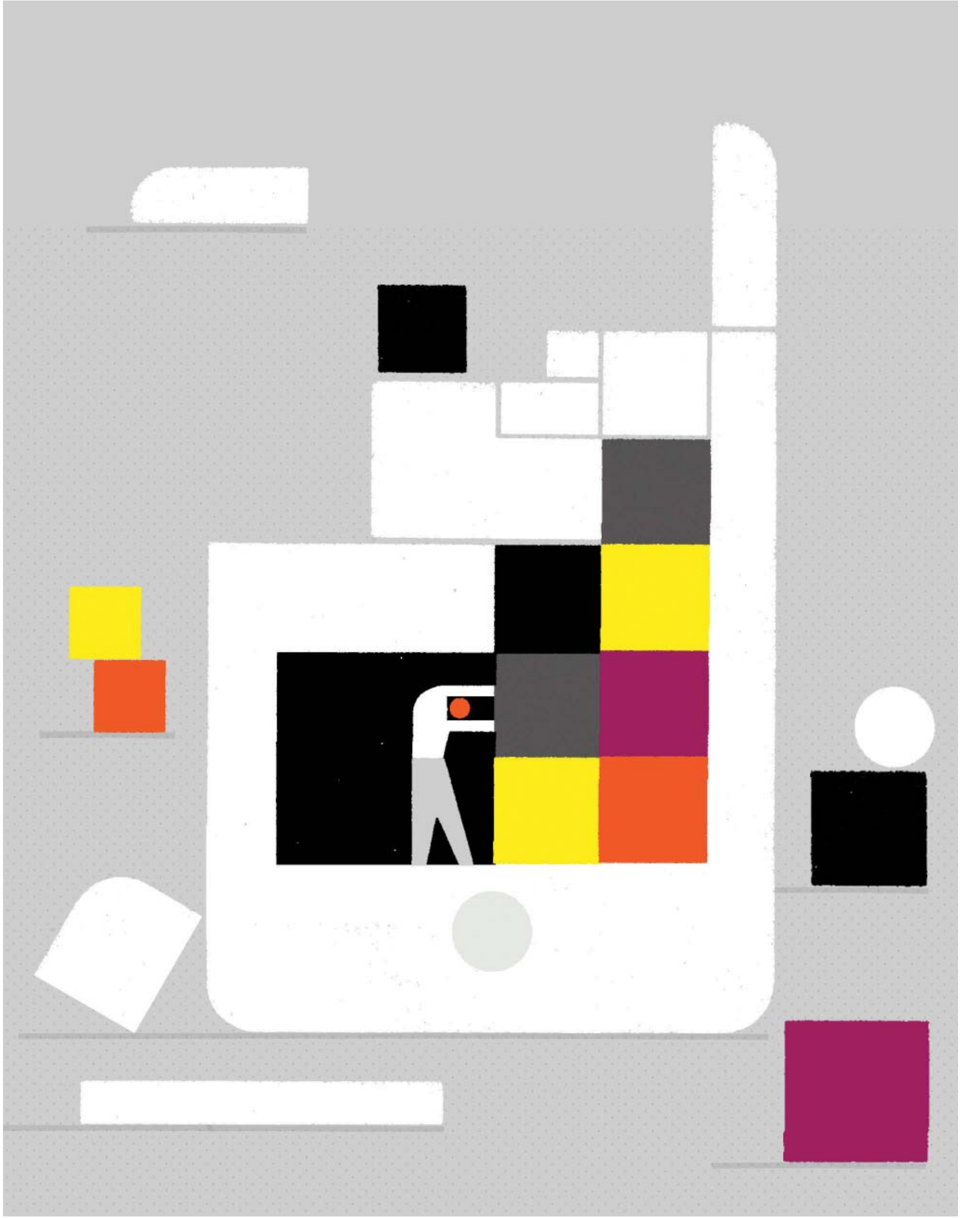
Ara endoskeletons will come in three sizes, measured in the spaces they offer for modules. Pocket-size versions will fit just a few modules at a time, while larger options can host many more devices simultaneously.

DATA SOURCE: GOOGLE

IEEE SPECTRUM Previous Page | Contents | Zoom in | Zoom out | Front Cover | Search Issue | Next Page Qmags THE WORLD'S NEWSSTAND®

built-in electronics to manage the flow of data and distribute power among modules. This supporting framework will also contain a tiny backup battery, which can keep the phone alive while you swap a dead battery module for a charged one. While Google will build the endoskeleton, the module design will be left to independent developers. Members of the design team expect that a basic Ara phone could be built from materials and components that cost between US $50 and $100. The retail cost of the phone could, of course, be more, depending on the specific modules the customer chooses.

The ultimate goal, Eremenko says, is a marketplace for hardware that rivals the vitality and diversity of offerings available now in app stores. Independent developers will create modules that are compatible with the phone's endoskeleton, in much the same way developers write apps for the Android operating system. Google has offered some initial ideas for these modules, such as a thermal imager and a pulse oximeter, which lets users measure their pulse rates and blood oxygen levels. And independent developers are brainstorming designs for a slew of other modules, including radiation detectors and haptic-feedback devices to enable the blind to read braille on their smartphones.



LAUNCHING A WIRELESS revolution isn't easy, and it's a task that not even a tech giant would take on alone. Google's Advanced Technologies and Projects group, which oversees the company's more far-out efforts, like the 3D-mapping Tango tablet, leads Project Ara. This small group is collaborating with companies including Toshiba and universities such as Carnegie Mellon. To build a version of Android that can operate a modular phone, Google has teamed with the nonprofit engineering consortium Linaro. This organization of engineers from around the world helps to develop open-source operating systems like Android and Ubuntu. The group also hosted the Linaro Connect USA conference in California where Eremenko laid out some of the details of Project Ara.

Speaking at that conference, Eremenko said that the device would initially target people without smartphones. "There are 6 billion people who are not connected to the mobile

FOR EVERY SEASON: Ara users will be able to modify their phones on the fly, customizing the device for work, play, and any other scenario.

GOOGLE

Internet," he told the audience. "Delivering the mobile Internet to those people could in fact be world changing."

Does Google have the muscle to get a new kind of smartphone adopted by billions of new users? Alan DeRossett, cofounder of the firm VOXearch, which makes portable medical devices, is optimistic. One of the reasons is the burgeoning market for self-diagnostic gadgets. An Ara phone, he says, could host a suite of standardized modules that will diagnose a variety of diseases using an assortment of already available lab-on-a-chip technologies.

The beauty of the scheme, he says, is that building a device to detect diseases in the developing world wouldn't mean abandoning other consumers who are interested in more mundane functions. "If you're in California, you may need a fitness-monitoring module," DeRossett notes. "In a developing country, the malaria monitor is going to be much more important to you."

CUSTOMIZING AN ARA phone starts with its endoskeleton. It will come in three sizes, letting users decide whether they want a device that's small, standard, or phablet size. The backbone of each model is laid out with a grid of slots, which can accommodate three different module shapes: small squares, large squares, and medium-size rectangles.

Every slot in the endoskeleton will have a pair of copper pins to convey power and four single-turn copper coils, each about 3 millimeters across. This layout is mirrored in each attached module, with a tenth of a millimeter between paired coils. Data is transferred across this small air gap by a technique known as inductive coupling–sending a current through one coil to induce a voltage in its partner. Because the coils don't make physical contact, frequent swapping of modules won't wear them down.

To manage the interchange of data between modules, Google chose an interface protocol called UniPro. Like USB, UniPro is a set of hardware and software standards that defines how devices communicate. Tech companies began developing UniPro almost a decade ago, under the auspices of the Mipi Alliance, which sets standards for mobile technology. Project Ara will be one of the first implementations of the protocol in the wild.

To make the most of its modular design, Ara will run a specialized version of the newly released Android 5.0 Lollipop operating system, which will allow for "hot swapping" of modules. With the exception of the screen and the application processor module, users will be able to remove a module and replace it with another without rebooting the phone. Want to use an Ara phone to share photos with friends? Remove the camera, plug in a pico-projector module, and start the show without ever powering down.

Battery life, which can make or break a smartphone, will be in the hands of Ara users. The device can be outfitted with more than one battery module at a time for greater capacity.

The Ara team had to come up with a connection system to ensure that modules stay firmly coupled to the phone while in use but are easy to detach when you want to swap them out. These engineers rejected mechanical latches, which would have detracted from the phone's aesthetics and added more moving parts.

At the first Ara Developers Conference in April 2014, Google announced that it would use electropermanent magnets to connect the endoskeleton and modules. Modules will be held in place magnetically while in use. To remove one, you'll use an app to send a brief surge of electric current through the magnets that hold it, altering their magnetization enough to free the module from the frame.

PROJECT ARA COULD also change how we get rid of our smartphones. The modular design of the platform would make it easy for Ara users to swap, share, and resell components, extending their usefulness and keeping them out of landfills. A cracked screen on an Ara phone would be annoying, but it could be fixed easily by swapping in a single part. Team members estimate that the endoskeleton will have a life span of five years or more. That's much longer than phones currently last in many parts of the world. According to the latest available data, phones get replaced every 22 months in the United States and every 27 months in South Korea.

The agnostic nature of Ara's UniPro foundation means modules could have uses outside the endoskeleton. Imagine popping an MP3-player module out of your phone and inserting it into your car dashboard or home entertainment system. Toshiba has proposed an activity-monitoring module for Ara phones that could also operate in a wristband.

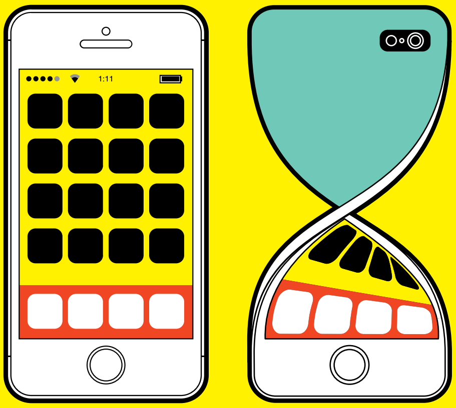
Although Ara is designed for everyone, any grand rethinking of the smartphone is bound to encounter some obstacles. For example, while some users will want to make their phones unique, others may find that level of customization daunting. And Google's record on product launches is not spotless. "Google does many experiments," says mobile-industry analyst Ken Dulaney. "Not all succeed."

Eremenko admits that getting Project Ara off the ground will be a tricky proposition. When the phone launches later this year, the company will have to build a user base and a developer ecosystem simultaneously. Google thinks it can do that by building a market where niche products can thrive.

One developer, for example, is working on a battery with three times the energy density of standard smartphone batteries. It's currently good for only 50 or so charging cycles, though. Ordinarily, Eremenko says, such innovators would be surviving on venture capital while they try to improve the technology. By turning to Ara, this company can sell a high-capacity battery with a limited life span–probably not a go-to power source, but one that some users might be interested in.

That's the potential power of a modular phone: Because the pieces can be ordered à la carte, hardware doesn't have to appeal to the masses to succeed. Instead, modules by independent developers and big companies alike can serve just a small community well. Eremenko and his team think there are many products like this looking for a home. With Project Ara, Google is aiming to bring them all into the fold.

—IAN CHANT



FAST FORWARD

Not Your Father's Smartphone

Future smartphones will get smaller and lighter—but not by that much

BY 2020 **SINCE APPLE'S IPHONE** was introduced in 2007, smartphone design has meant a rectangular box with a glass touch screen. Sizes and specifications vary, but the core aesthetic remains to this day. With wearable devices like the Apple Watch and Google Glass hitting the market, could we be on the verge of big changes to the shape of smartphones? Not anytime soon, say industry analysts.

In the next five years, smartphone components will likely get more efficient and streamlined, but the shape of the finished product will remain largely the same.

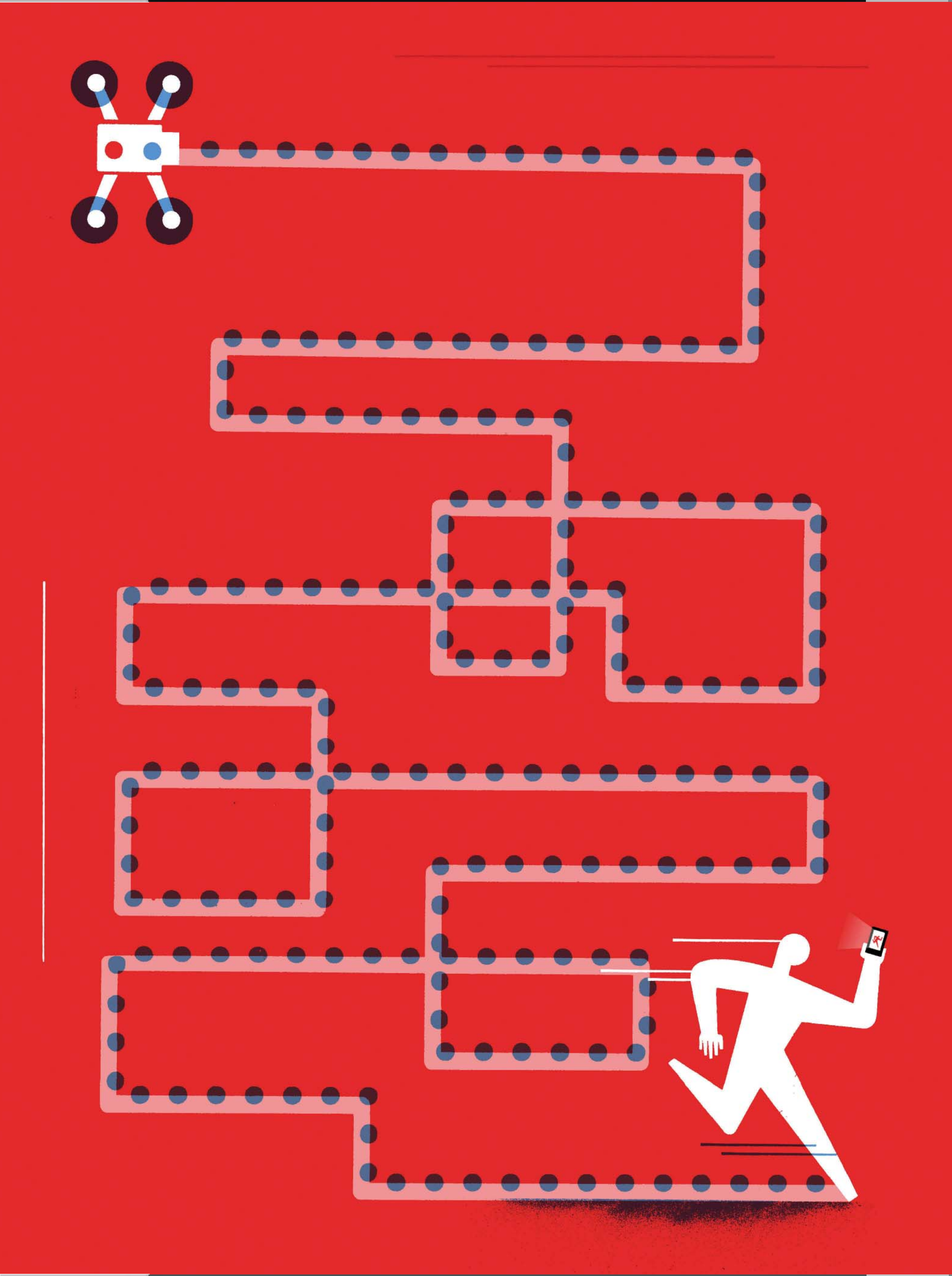
One reason is that every phone needs a power supply, and batteries take up lots of space. While they will continue to get smaller, finding room for a good battery will remain a design constraint.

Another challenge will be finding enough real estate for a keyboard. Even the virtual ones demand physical space, and that limits how radically tech companies can rethink smartphone design. Voice controls are standard in new smartphones, but they're not reliable or convenient enough to be the only means of input.

BY 2025 **A DECADE FROM** now, things could be a lot different, though. By coating plastic sheets in a layer of light-emitting chemicals, manufacturers are already creating flexible screens that could eventually transform the smartphone. Current models like the LG G Flex and Samsung Galaxy Round have proved that curves and flexibility can be built into phones.

In the next decade, plastic could replace glass in most smartphone screens, opening the door to thinner, lighter devices with more durable displays. Analysts say that by 2025, plastic screens could mean phones that bend for better viewing angles or deform into different shapes. Because components like flexible keyboards and batteries already exist, such screens could mean the introduction of a phone that you could wrap around your wrist. *—I.C.*

ILLUSTRATION BY **MCKIBILLO**



Flying Selfie Bots

Sports enthusiasts are clamoring for aerial robots that can record their best moves

IN LAST YEAR'S JANUARY tech issue, I focused on the disturbing threat to privacy that unmanned aircraft seemed to pose. Who, after all, would want to be stalked by a small, camera-toting drone that was recording their every move?

Seems I got that one wrong. Plenty of people–sports enthusiasts in particular–are ravenous for selfies taken by aerial robots. And start-ups everywhere are now scrambling to develop this technology for them.

One of those companies is Squadrone System, whose genesis began in 2013, when some hopeful entrepreneurs in Grenoble, France, began thinking about making a camera-equipped drone that could all by itself capture aerial videos of you while you were skiing or snowboarding.

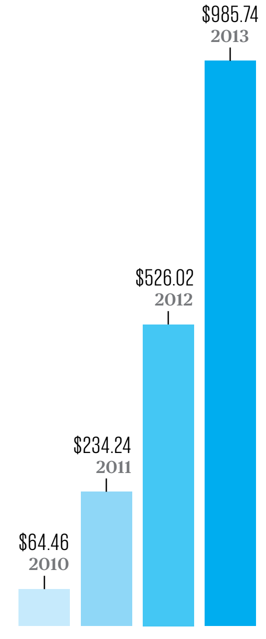
The idea was a natural for Grenoble, a city situated at the foot of the French Alps. And while the team proposing this idea had no experience building or flying drones of any kind, it included snowboarders and skiers–and programmers, who had a track record developing software for civil aviation.

The group later broadened its plans and decided to create a self-following drone that would work for most any action sport. In February 2014, the entrepreneurs formally established their company, settling on a design for a fast-moving six-bladed multicopter they called the Hexo+.

In June, they ran a Kickstarter campaign, setting their initial funding goal at US $50,000. They met that within an hour. Within three days, they had surpassed $500,000, mostly from U.S. backers. As if that weren't enough affirmation, a competing self-following video drone being developed in Latvia–the AirDog–appeared on Kickstarter the next day, and within 48 hours it was nearing its $200,000 goal. Almost simultaneously, California-based 3D Robotics, an established manufacturer of small drones, publicly announced the availability of the "Follow Me" mode in its flight-planning software, aimed at those who wanted to use small multicopters to take videos of themselves.

By the end of July, the Hexo+ and AirDog drones had each attracted more than $1.3 million from Kickstarter backers. Without a doubt, the selfie-taking video drone was an idea whose time had come.

"THE CONCEPT HAS been around for a long time," says Chris



GOPRO ANNUAL REVENUE (US $, MILLIONS)

Video-drone makers are hoping for GoPro-like growth.

DATA SOURCE: BUSINESS INSIDER

Anderson, CEO and cofounder of 3D Robotics, which first demonstrated self-following capabilities in its multicopters in late 2013. And he points out that MikroKopter, a German company, had programmed one of its video drones to automatically keep a moving subject on camera several years earlier.

But the idea didn't gain traction until a year or so ago, propelled by the plummeting prices and widespread adoption of small autopiloted multicopters, compact high-definition video cameras like the ubiquitous GoPro, and inexpensive camera gimbals that keep the shot steady even as the platform pitches and rolls in the air.

Getting all these components to automatically work together smoothly and reliably is no small undertaking, particularly if you want to keep your robot simple enough for Joe Consumer to operate straight out of the box. "We have a zero-screwdriver policy," says Antoine Level, Squadrone System's cofounder and CEO.

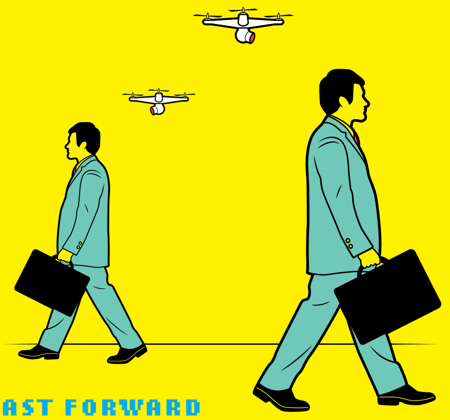
When I visited him in Grenoble in late September, he and his colleagues took me to a grassy field on the outskirts of the city to demonstrate a prototype. The drone they brought along, though, was not the sleek, six-bladed model the company will be sending to its Kickstarter backers later this year–the actual Hexo+ design was at that point still some months away from being finalized. Instead, they flew quadcopters from 3D Robotics, programmed with Squadrone System's software, which is largely a reworking of the community-developed open-source code that 3D Robotics employs.

Etienne Zwiebel of the Hexo+ team used a smartphone coupled with a radio dongle to communicate with the drone, which took off on push-button command and then hovered nearby. Next he showed me how to set things up on the phone so that the buzzing copter would follow me at a preset distance, height, and bearing.

After he handed me his phone, I set off on a run, doing my best to dodge the little drone while feeling a bit like Cary Grant in *North by Northwest* as he tried to outrun a crop duster. Unlike Grant, though, I had no difficulty shaking my aerial pursuer, which didn't seem all that accurate in its video strafing runs. All I had to do to evade it was to stop suddenly or dart off in an unexpected direction.

As Zwiebel and Level explained, the software is designed to anticipate where the target is headed. But as my informal tests showed, it's easy to confound it if you act like a squirrel. The software's "360 Selfie" feature also had some rough edges. When placed in this mode, the drone flies, as the name suggests, in a circle around its video target. But it did that merely by flying in rapid sequence through a series of waypoints. And as it reached each of these intermediate points, the craft would pitch backward briefly, as if trying to heave to in midair.

The drone's motorized camera gimbal counteracted the unwanted



FAST FORWARD

The Future of Personal Drones

Expect a lot more buzzing

BY 2020 **SELF-FOLLOWING VIDEO DRONES** will surely get smaller, cheaper, and easier to use over the next five years, and as a consequence they will be more and more common—that's easy enough to predict. It's also safe to assume that over the next few years their ability to frame the shot will improve and that their owners will be able to program in complex instructions: "I'll set it to start 100 meters up and back, then swoop down from the rear, zooming past me on my bike just 5 meters overhead, then record a 15-second pan of the surrounding scenery before hovering 3 meters off to my right at shoulder level. . . ."

BY 2025 **THE WORLD OF** personal drones a decade from now is much harder to forecast. So rather than trying to predict what is most likely, let me suggest the future for them I see as most desirable.

A decade from now, the regulatory roadblocks preventing businesses in the United States from using small, low-altitude drones will surely have been eased. So the now-critical distinction between personal and commercial use will become less important. But that doesn't mean the air around our heads will be full of drones following kids to the bus stop and carrying advertising banners.

Ideally, the FAA will recognize that air rights close to the ground belong to landowners. That is, drone operators would have to seek permission to fly their machines low over other people's property. That would at once address privacy concerns while allowing farmers to use these machines to survey their own crops, for example. *—D.S.*

ILLUSTRATION BY MCKIBILLO

IEEE SPECTRUM Previous Page | Contents | Zoom in | Zoom out | Front Cover | Search Issue | Next Page Qmags THE WORLD'S NEWSSTAND®

pitching, but getting rid of this strange wobble and keeping the drone better targeted both need more work, as Zwiebel acknowledged. "It's one of the challenges," he says, "to have something that is really smooth and to tune the anticipation algorithms for one sport or another."

Even if the drone's algorithms are substantially improved, the limited precision of satellite navigation makes it hard to keep the craft and camera positioned perfectly. 3D Robotics, for one, hopes that real-time video processing will help, which is why it has been working to outfit its drones with microcomputers powerful enough to process live video.

According to Anderson, there are about 10 start-ups developing self-following drones right now, all from a common base: the 3D Robotics' flight controllers and software. So the technology will most likely make rapid strides in the coming year. At the very least, there will be increasing availability–and diversity. "Everybody is adding value in their own way," says Anderson.

The Hexo+, for example, is designed to go fast: 70 kilometers per hour. The AirDog, with its waterproof, wrist-mounted "leash," is tailored for water sports. Makers of the backpackable PlexiDrone are targeting customers who are on the go. And those same people might later be trading in their luggable PlexiDrones for a tiny *wearable* self-following drone now in development, the Nixie.

HELICO AEROSPACE INDUSTRIES

FOLLOW ME ANYWHERE: Camera-equipped drones, like the AirDog shown here, can readily follow a target moving through rough terrain.

TAKING VIDEO SELFIES hadn't even been on the list of promising applications for small drones bandied about over the past few years. Now it's at the top. How did that happen?

Part of the answer has to do with the regulatory hurdles these machines face, particularly in the United States, where the Federal Aviation Administration generally forbids commercial uses. Posting YouTube videos of yourself typically doesn't qualify as a business activity, so drone makers can cater to such whims without running afoul of U.S. regulations.

Or maybe not.

In June of last year, in the midst of the Hexo+ and AirDog Kickstarter campaigns, the FAA released its interpretation of its rules for model aircraft. That interpretation asserts that flying related to a business doesn't qualify under the hobby exemption for model aircraft. In addition, the FAA says, the operator needs to hold the aerial contraption in view at all times for it to qualify as an unregulated model. It's hard to see how anyone can do that while performing a Haakon flip or hanging ten.

The FAA is facing legal challenges to its position here, but for the moment those are the rules. Does that then mean that self-following drones are not, in fact, legal in the United States? "You'll have to ask the FAA," says Anderson.

Even if the FAA technically doesn't allow the use of self-following drones under the hobby exemption, so long as it doesn't stop companies from selling them, these gadgets are bound to be hot items this year: Drone's-eye-view shots are just too popular in television and film for sports enthusiasts not to want to record their own.

Indeed, these close-in aerial perspectives will no doubt become even more common as time goes by. In September of last year, the FAA granted six movie- and television-production companies permission to use small drones for their work in the United States. So if there aren't enough dizzying drone shots on view at the first drone film festival, which will take place in New York City in February, look for what is sure to be a deluge at the second one.

–DAVID SCHNEIDER

Thus Spoke the Autobahn

Europe's smart highway will talk to cars over a route spanning three countries, with more to follow

SEEING TAILLIGHTS flash up ahead, you slam on the brakes, thus sending the signal you've just received to the car behind, with a lag. That car relays the same information with a lag of its own, creating a monstrous traffic jam kilometers down the line.

That's the sorry state of car-to-car communication today. Drivers must be totally alert; yet even so, they can't help triggering perverse results. This problem will start to end this decade, as cars begin to communicate with one another in a way that allows each to see through the eyes of those that have gone before. The roads will be safer, traffic jams fewer, and cars more autonomous.

But because the early adopters won't have other cars to talk to, many traffic specialists want to focus first on giving voice to the roads. In this scenario, smart roads—that is, intelligent transportation systems, or ITS—will provide a payoff from the start. Later, as talking cars proliferate, the vehicle itself will become the center of the conversation.

BY FAR THE MOST ambitious smart-road project is to begin next year in Europe. It's called the Cooperative ITS Corridor, and on day one it's supposed to shepherd cars from Rotterdam through Munich, Frankfurt, and on to Vienna without a single interruption in the initial, basic service: warning drivers of upcoming roadwork and other obstacles. And because the Corridor will be the first to harmonize smart-road standards among different countries, its choices are meant to be a template for us all.

"There are tests everywhere, but this is not a test; this is the first real deployment over three countries in the world," says Frans op de Beek, a senior traffic advisor for the Dutch Ministry of Infrastructure and the Environment. He and his minister helped start the tripartite discussions with their counterparts in Germany and Austria that ended in their signing a formal agreement in June 2013.

Many countries have said they'll eventually hook their local smart-road projects to the Corridor. France, Poland, and the Czech Republic will likely be among the first. The true leader is Japan, whose outstanding smart-road systems already tell drivers about traffic conditions and speed limits by collecting and disseminating data through radio and infrared transceivers.

"They have a big advantage: They are an island," notes Marko Jandrisits, an official in the Austrian transport ministry. "They have harmonized. They don't have to care about partners; they can do all the regulations easily."

The United States lags behind just about everyone, in part because its Highway Trust Fund is practically broke, unable to pay for pothole repairs let alone the automation of the asphalt. That's why the U.S. Department of Transportation has

5.8 GHz
JAPAN ONLY

5.9 GHz
UNITED STATES, EUROPE

SHORT-RANGE CAR-TO-ROAD FREQUENCIES

DATA SOURCE: INTELLIGENT TRANSPORTATION SOCIETY OF AMERICA preferred to fund small research projects (notably a test bed for intelligent roads and cars in Ann Arbor, Mich.) and to mandate a purely vehicle-to-vehicle communications standard. That strategy shifts the cost to the auto companies and their customers.

Yet even Europeans are sensitive about cost. No official interviewed for this article was prepared to cite figures, nor would any of them say that user fees were even being considered as a means to finance the expansion of the Corridor into a pan-European system. That expansion will include additional roadways, new features, and improvements in the core services.

EVEN SIMPLE ROADWORK warnings aren't all that simple to handle internationally. "One of the projects is to mount warning units on roadwork vehicles to broadcast information about an obstruction up ahead–it would go behind a grass cutter, for example," says Gwen van Vugt, director of the mobility center of Tass International, a for-profit research company in the Netherlands. "Where do you need to mount the antenna so that you will not block communication?"

Tass answers such questions on its test bed, an 8-kilometer stretch of road in Helmond that is studded with sensors far more capable than the Corridor will have. "We measure the exact position of vehicles within 1-meter accuracy, 10 times per second, then compare this ground truth with the actual system being tested," Van Vugt says. "There are cameras every 100 meters and Wi-Fi antennas every 500 meters–about twice as dense as what you'd have on a normal motorway. And we put Wi-Fi stations about on the same poles as the antennas and camera systems."

One thing he's learned is that you need just a small number of talking cars to improve the flow of traffic.

Take the problem caused by a car that suddenly brakes in front, forcing you to brake a few seconds later, and so on down the line of cars behind you. The resulting shock wave, as it's called, may even gain in amplitude and finally form a standing wave. The result is a long-lived traffic jam at some random spot, a phantom-wave phenomenon worthy of the quantum world, though it's made of massive cars and trucks.

ROAD, TAKE ME HOME: **The Cooperative ITS Corridor will converse with your car from Rotterdam through Germany and on to Vienna.**

"You can stop it," Van Vugt says, "by telling people a kilometer or more behind me to reduce their speed, for example dropping from 120 kilometers per hour to 110. It completely dampens the shock wave–we've proven it with 100 vehicles, in Helmond."

That particular service, he says, is more important to road managers in the Netherlands than to their counterparts in Germany. But though national priorities may differ, base stations will always work across borders.

Officials from Germany's smart-road program, who responded to questions by e-mail, provided few details on how their approach might differ from that of their partners. But according to several sources in both the Netherlands and Austria, the Germans are perhaps even more intent on jump-starting purely vehicle-to-vehicle communications–perhaps because, among the three countries, only Germany has an auto industry.

THE DUTCH ARE THE prime movers in the Corridor project, and they already provide a lot of infrastructure-to-car information on dashboard GPS navigators, such as TomTom. That's no surprise: Holland lives and dies by infrastructure like dikes and waterworks. Indeed, according to Op de Beek, the Infrastructure Ministry may one day apply Corridor standards to the canals.

A few years after the rollout, he says, other kinds of road information will be brought from the roadside to the dashboard. "We want to get rid of many of the 'This way to Amsterdam' signs," Op de Beek says. "You need just the last one; there's no need to forewarn drivers!"

It's also part of the reason why smart-road experiments back in the 1990s never led anywhere. Those roads were larded with magnets, which cars were able to sense.

"But it never went past the proof of concept," says Richard Wallace, at the Center for Automotive Research, in Ann Arbor. "We didn't have the right technology to do it in a true deployment; since then, we've come a long way."

The techie parts of the Corridor include sensors, short- and long-distance transmitters, and in-car equipment that presents information to the driver as sounds or images. Local transmitters will use IEEE 802.11p, a band designated for vehicles. "It has its own standards, very analogous to Wi-Fi," Wallace says. "Very high speed, low latency, short distance–

UPDATE

Snooping Eyes in the Skies

Small drones remain on privacy advocates' radar

***IEEE SPECTRUM* CAN** pat itself on the back for predicting that concerns over drones and privacy ["Open Season on Drones?," January 2014] would continue to simmer in the United States throughout 2014. "I don't like the fact that someone I don't know…can pick up, if they're a private citizen, one of these drones and fly it over my property," said Supreme Court Justice Sonia Sotomayor at Oklahoma City University's law school in September. "That type of technology has to stimulate us to think about what is it that we cherish in privacy and how far we want to protect it and from whom."

Shortly afterward, California lawmakers enacted a bill to help thwart paparazzi who use camera-carrying drones. They also fretted about other forms of intrusive robotic gadgetry yet to be devised. An analysis of the bill from the California Senate's Rules Committee reads in part: "These advancements will open new avenues of innovation and productivity for our society, but will also have the potential to erode our sense of privacy."

And as this issue went to press, the White House was preparing an executive order requiring federal agencies to report on their use of drones and the surveillance data they collect.

Despite all this, ever more folks sought camera-carrying drones to record themselves [see "Flying Selfie Bots," in this issue]. ■

ILLUSTRATION BY Greg Mably

maybe 300 meters, maybe longer on an absolutely flat plane."

Quickness is key: When you're moving at 200 kilometers per hour, you haven't got a lot of time to transmit data. This glorified Wi-Fi will mainly carry real-time data that bear on safety.

"The LTE bandwidth could be used to collect probe data [on car speed and position] for traffic management," he adds. "You could have a separate cellular subscription, or you marry the phone you have already to the car."

The one component that must still be agreed on is the coordinating station for large chunks of roadway–a central ITS station. "Each traffic-management center will have one," says Anto Komarica, an engineer at Vienna's Kapsch TrafficCom, which supplies road-telematics equipment. "You could have one for an entire country, like Austria; in Germany you could have one for each state."

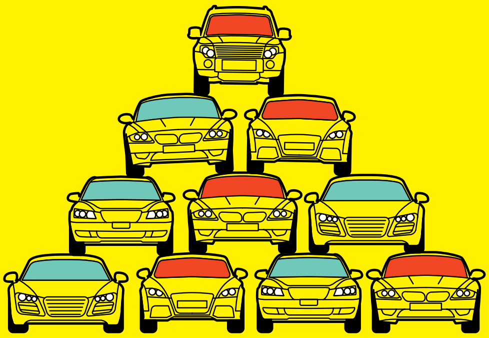
That's a regulatory issue. For engineers, though, there's only one real problem: how to safeguard communications. Today's cars are dripping with communications channels, each of which offers a way into critical systems like engine controls, antilock brakes, and even the actuators that lock the doors and lower the windows. That's a lot of targets, and smart roads threaten to hook them together and make them vulnerable to attackers, just as the Internet has done with the world's desktop computers.

THE SOLUTION TO these concerns for the Corridor, as well as for the Internet of Things in general, will no doubt involve some clever forms of cryptography.

"Security will use public-key encryption, and the concepts for it now are state of the art, especially in Germany, where there is a huge effort," Komarica says. "The question is, Do we need it on a European level, and who is operating it? The current concept foresees that there could be different [public keys] for different routes or in each member state, or even for every car manufacturer."

Unhappily, regulators must set standards now and discover their errors later, when it will be hard to change things. That early-adopter penalty may explain why the European community is willing to allow three of its members to serve as guinea pigs in 2015. Even if the project achieves all of its objectives, the Corridor's standards may not form the final template but only a first draft.

–PHILIP E. ROSS



FAST FORWARD

Cars Will Talk, Then Collaborate

Vehicles will just share data at first. Later they will cooperate more actively

BY 2020 **WITHIN A FEW YEARS**, the Cooperative ITS Corridor will expand to include other European countries. Instead of relying on signage, drivers will begin to get local information on things like speed limits and upcoming exits beamed directly into their cars.

New cars will be capable of communicating both with other vehicles and the roadway infrastructure, and older ones may have to be retrofitted. The pattern will unfold around the world: According to a recent study by McKinsey & Company, global sales of car communications equipment will rise nearly fivefold by 2020, to €170 billion.

Cars will query cars, and the road will query them all, gaining "probe data" with which central stations can control the flow of traffic. For instance, by changing the speed limit so that a line of cars will slow down together, road managers can ease a traffic problem without causing a backward-propagating shock wave.

In other parts of the world, like the United States, the necessary road infrastructure still won't be in place. But even so, groups of vehicles may stand in for it by assembling themselves ad hoc into moving networks.

BY 2025 **BEGINNING IN A DECADE** or so, the Corridor and its ilk will bypass the driver and go straight to the car's brain. It will issue both advice and commands, creating the illusion that cars are pretty much driving themselves.

Because cars will keep to their lanes, lanes will be narrower; because cars will avoid frontal collisions, lead distances will shrink. The carrying capacity of the roads will rise. Cars will swarm like bees, but each one will also act like a horse.

"We'll have two modes, loose reins and tight reins," said design guru Don Norman, speaking in July at a smart-car symposium. "Loose reins: The horse is in control and takes you home. Tight reins are to force the horse to do things that are uncomfortable—but not dangerous."

The edges of the road will fade into the built-up world. A pedestrian walking down the street toward the curb will be noted by the sidewalk, which will speak to the road, which will warn the car. You'll never know why your car is gently braking. Nor will you really need to know. —*P.E.R.*

ILLUSTRATION BY MCKIBILLO

A ROBOT IN THE FAMILY

CONTINUED FROM PAGE 29

Suddenly, the doors opened and everyone went silent. Masayoshi Son entered, took a seat, and stared at the Pepper prototype. The first demo was simple enough: The engineers turned the robot on, and it did a little dance. Almost immediately, Son was "like a kid," beaming at the robot, an Aldebaran engineer told me.

WHAT FOLLOWED WAS an intense two years for the French company. Engineers worked day and night, with no breaks for weekends or holidays. The work culminated in the demo of all demos: the highly produced, Apple-esque launch, where Son would introduce Pepper to the world. Aldebaran and SoftBank rehearsed the event several times a day for an entire month, using stand-ins for Son and Maisonnier.

The emotion engine, which Son highlighted in the event, uses the robot's vision system to detect smiles, frowns, and surprise, and it uses speech recognition to sense the tone of voice and to detect certain words indicative of strong feelings, like "love" and "hate." The engine then computes a numeric score that quantifies the person's overall emotion as positive or negative. Aldebaran admits the system is not very sophisticated, but the company promises that it will improve.

Not everyone is convinced that people will want a Pepper at home—at least not until the robot can do some actual chores. The robot will have "a very difficult time getting off the ground as a viable consumer product," a robotics observer told *PCWorld*. Others have accused SoftBank of hyping Pepper's capabilities. The technology website The Verge found the robot's emotion-recognition skills disappointing, saying that "Pepper has a heart of COBOL."

SoftBank counters that it is pricing the robot very aggressively, which should help drive demand. Indeed, Son says he's willing to lose money selling the robots until the company can ramp up volume and reduce costs. Still, it's unclear whether consumers will be convinced of Pepper's usefulness, especially outside Japan. SoftBank has yet to articulate its plans for international sales.

Maisonnier says Pepper will become more capable over time, as developers create new applications for it. Users will then be able to download and install these new functionalities, just as they add new apps to their smartphones. "The most important thing is to have a huge community of people trying, experimenting," he says. "This community will create the applications that will make the next wave of people want to have the robot."

Last September, SoftBank and Aldebaran held a developers conference in Tokyo, where they revealed details about Pepper and a set of software-development tools. A thousand attendees showed up, 600 of whom preordered a robot.

Maisonnier believes Pepper's debut is the beginning of a revolution whose effects will eventually be of the same magnitude as those of the PC, the Internet, and mobile phones. "People want robots, and they're frustrated because there are no robots," he says. "We're going to give people the robots they've been waiting for." —ERICO GUIZZO

THE XPRIZE'S LUNAR DEADLINE DRIFTS

CONTINUED FROM PAGE 33

which will be assembled in a facility managed by Israel Aerospace Industries. The team recently signed a contract for the construction of a $1 million onboard transceiver, which will be built by Space Micro, a San Diego-based hardware firm.

But SpaceIL is still struggling to find a ride. While Astrobotic plans to purchase an entire rocket for its mission, SpaceIL aims to go with the cheaper approach of piggybacking on an existing launch. Saat estimates that this should run about $10 million to $15 million.

Finding a shared berth has proved challenging. Piggybacking payloads is routine nowadays, but rocket companies and their customers are generally squeamish about a cargo that's carrying a load of extra propellant, because it might endanger the primary payload. As Saat puts it: "For us to come with a spacecraft that's 80 percent rocket fuel and stick it to the side? They're not always as excited as we are about that."

"There's no commercial market today for sending secondary payloads to deep space—or primary payloads, for that matter," says Andrew Barton, director of technical operations for the Google Lunar XPrize. "This is definitely charting new waters for the industry." And that's a good thing: "That's one of the intents of the prize," he notes.

Team Phoenicia, a former competitor based in California, has jumped in to see what it can do to help the launch market. After dropping its prize bid in 2013, the team reinvented itself as a launch broker and is now gathering customers together for a ride to space on an as-yet-unannounced rocket. The Lunar Lion team has reserved one of about 20 slots available for larger spacecraft, Team Phoenicia CEO William Baird says.

Incentive prizes have been used before to spur activity in aerospace, and extensions are nothing new. Charles Lindbergh won the $25,000 Orteig Prize with the first nonstop New York-Paris flight in 1927, after the prize went unclaimed and the competition was extended by five years.

Still, extensions can be counterproductive, notes Jonathan McDowell, an astrophysicist and space historian at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass. When we interviewed him before this latest lunar prize extension, he said that another deadline change could make it hard to take future incentive-prize deadlines seriously. Better, he says, to divert the unclaimed prize money to a new competition.

As 2015 progresses, we'll see how far teams move along. But we'll have to wait a while more before it's clear whether any teams will make the revised deadline.

Regardless of what's to come, McDowell says the competition has already done a lot to stimulate new activity and excitement about space. "I think it was always a pretty long shot," he says, "[but] I don't think it will have been a waste."
—RACHEL COURTLAND

BIG SOLAR'S BIG SURGE

CONTINUED FROM PAGE 41

ENVIRONMENTAL CONCERNS ASIDE, solar PV continues to benefit from a virtuous cycle in which new installations beget cost reductions that drive further adoption. In the process, the price of solar-generated electricity has plummeted. While PG&E is obligated by its 2008 agreement to pay about US $0.20/kWh for Topaz's electricity, recent PV projects are earning just $0.05/kWh to $0.06/kWh. The price drop reflects both mass production and technology upgrades, the latter of which is visible at Topaz. When First Solar installed the first panels there in 2012, each was rated to produce 77.5 watts of direct current. The last panels to be installed, by contrast, are rated for 97.5 W DC–a 26 percent increase in output–thereby cutting the per-megawatt cost of installing new capacity.

Such advances in PV technology have turned utility-scale solar into a mainstream option for utilities looking to meet midday power demand. According to the financial firm Lazard, new grid-scale solar plants now deliver at $0.072/ kWh to $0.086/kWh when subsidies are excluded. That stacks up well against electricity from even the most efficient natural-gas-fired plants, which costs $0.061/kWh to $0.127/kWh (with the higher end including the cost of CO_2 capture). Between June 2013 and July 2014, U.S. utilities announced plans to buy 3,000 MW of utility-scale solar power without or ahead of state mandates, according to the Solar Energy Industries Association, a Washington, D.C.-based trade group. Bolinger says that utility-scale solar is also advancing in South America and Asia.

And while solar-generated electricity does come with some variability–from passing clouds, rain, and such–plants such as Topaz may actually be in a position to help balance the grid, says First Solar vice president and interconnection expert Mahesh Morjaria. For one thing, the plants' control systems and power electronics are designed to maintain output during any faults on a transmission line and can be programmed to support the line voltage as required or requested by grid operators. And unlike wind power, solar output tends to look much the same from day to day, especially in sunny places like the U.S. Southwest. "The solar panels have very predictable curves for when they'll be ramping up and down," says Millar of CAISO.

Millar adds, though, that as solar deployments continue, things will get more complicated. CAISO modeling of conditions in 2020 suggests that some areas will suffer from excess midday generation on low-demand days or be starved for electricity in the late afternoon as the sun sets. To continue to balance demand and supply as solar grows, CAISO is already pushing for investment in fast-acting resources, including conventional power plants, battery storage, and demand-response programs (which give customers incentives to curtail their electricity consumption at peak hours).

The modeling looked to the future, says Millar, but "the reality is actually showing up now." –PETER FAIRLEY

香港中文大學(深圳)
The Chinese University of Hong Kong, Shenzhen

THE CHINESE UNIVERSITY OF HONG KONG, SHENZHEN
Professor /Associate Professor/Assistant Professor
– The School of Science and Engineering

Located in Longgang District of Shenzhen, CUHK(SZ) is a research-intensive university established through a Mainland–Hong Kong collaboration, with campus and infrastructure provided by the Shenzhen Government. It will develop its academic programmes in phases. The faculty will be recruited internationally, as will some of the students. The language of instruction will be English and Chinese, and the students will receive degrees of The Chinese University of Hong Kong. The School of Science and Engineering at CUHK(SZ) will begin to admit undergraduate and graduate students from 2015. The School's mission is to develop innovative and forward-thinking science and technology leaders, and to become a top science and engineering school nationally and internationally.

Faculty positions are available in all related fields, including Computer Science and Engineering, Electronic and Information Engineering, New Energy Science and Engineering, Statistical and Data Sciences, and Financial Engineering. Applications in areas: Mathematics, Physics, Chemistry, Biomedical Science and Engineering, Design and Manufacturing Systems, Industrial Engineering and Operations Research, Material Science and Engineering, Environmental Science and Engineering, etc., will also be considered.

Junior applicants are expected to have a PhD degree and high potentials in teaching and research. Candidates for Associate and Full Professor positions should have demonstrated academic leadership and strong commitment to the highest international standards of excellence. Salary will be comparable to international standards, commensurate with experience and accomplishments. The University will provide comprehensive fringe benefits, including housing and medical care, for qualified candidates.

Applications (with CV, and three references) should be emailed to hr-1@cuhk.edu.cn.

Michigan State University Founded 1855

Faculty Position in ECE

Michigan State University Department of Electrical and Computer Engineering **http://www.egr.msu.edu/ece/**

The Department of Electrical and Computer Engineering (ECE) at Michigan State University invites applications for an open rank, tenure-system/tenured faculty position. The department seeks exceptional candidates with established records of excellence in the area of Integrated Circuits and Systems, especially Low Power, Mixed-signal and RF design, and Biomedical applications. The successful candidate will be expected to collaborate with colleagues within the College of Engineering and across other colleges for interdisciplinary projects. Candidates at all ranks will be considered. The appointment starts in August 2015. Candidates should have a Ph.D. in Engineering or a closely related field with evidence of research accomplishments, teaching skills, and ability to work effectively with other researchers.

The ECE Department has 48 tenure system faculty members, including two National Academy of Engineering members, 17 IEEE Fellows, and 13 NSF CAREER awardees. The Department has strong research programs in all major areas of electrical and computer engineering, with annual research expenditure of over $17M. Faculty in the Department are leading several federal and industry-supported centers, including the NSF Science and Technology Center BEACON, and the Fraunhofer Center for Coatings and Laser Applications. The Department has accredited B.S. degree programs in both Electrical Engineering and Computer Engineering. The current enrollment is approximately 260 full-time graduate students and 770 undergraduate students. For additional information about the ECE Department, the College of Engineering or MSU, see: **http://www.egr.msu.edu/ece/**

MSU enjoys a park-like campus with outlying research facilities and natural areas. The campus is adjacent to the city of East Lansing and the capital city of Lansing. The Lansing metropolitan area has a diverse population of approximately 450,000. Local communities have excellent school systems and place a high value on education. Michigan State University is pro-active in exploring opportunities for employment for dual career couples, both inside and outside the University. Information about WorkLife at MSU and the College of Engineering can be found at **http://www.egr.msu.edu/WE**.

Applicants should submit a cover letter, curriculum vitae, the names of at least three references, and statements of research and teaching interests for this position through **http://jobs.msu.edu** and refer to posting #0570 (PDF files are preferred). Applications will be reviewed on a continuing basis until the position is filled. Review of applications will begin on **February 1st, 2015**. Nominations or questions are welcome by contacting the search committee chair through email at

ece-faculty-search@egr.msu.edu.

MSU is an affirmative-action, equal opportunity employer. MSU is committed to achieving excellence through a diverse workforce and inclusive culture that encourages all people to reach their full potential. The university actively encourages applications and/or nominations of women, persons of color, veterans, and persons with disabilities.

上海科技大学
ShanghaiTech University

ShanghaiTech Faculty Search

ShanghaiTech University invites highly qualified candidates to fill multiple tenure-track/tenured faculty positions in the School of Information Science and Technology. Candidates should have exceptional academic records or demonstrate strong potential in cutting-edge research areas of information science and technology. English fluency is required and overseas academic connection or background is highly desired. ShanghaiTech is built as a world-class research university for training future generations of scientists, entrepreneurs, and technological leaders. Besides establishing and maintaining a world-class research profile, faculty candidates are also expected to contribute substantially to graduate and undergraduate education.

Academic Disciplines:
We seek candidates in all cutting-edge areas of information science and technology. Our recruitment focus includes, but is not limited to: computer architecture and technologies, nano-scale electronics, high-speed and RF circuits, intelligent/integrated signal processing systems, computational foundations, big data, data mining, visualization, computer vision, bio-computing, smart energy/power devices/systems, next-generation networking, as well as inter-disciplinary areas involving information science and technology.

Compensation and Benefits:
Salary and startup funds are highly competitive, commensurate with experience and academic accomplishment. We also offer a comprehensive benefit package to employees and eligible dependents, including housing benefits. All regular ShanghaiTech faculty members will be within its new tenure-track system with international practice for performance evaluation and promotion.

Qualifications:
- A detailed research plan and demonstrated record/potentials;
- Ph.D. (Electrical Engineering, Computer Engineering/Science, or related field);
- A minimum relevant research experience of 4 years.

Applications:
Submit (in English, PDF) a cover letter, a 2-page research plan, a CV plus copies of 3 representative publications, and names of three referees to sist@shanghaitech.edu.cn by Feb. 28, 2015. For more information, visit **http://www.shanghaitech.edu.cn**.

UNIVERSITY OF MICHIGAN-DEARBORN

Department Chair Position

The Department of Electrical and Computer Engineering at the University of Michigan-Dearborn (UM Dearborn) invites applications for the Department Chair Position at the rank of Professor, starting **September 1, 2015**. The successful candidate must possess a distinguished record in teaching, research, and departmental administration and must assume leadership for developing academic, research, and outreach initiatives.

Applicants must have an earned doctorate in Electrical, or Computer Engineering with appropriate accomplishments in teaching and research in any area of electrical, and/or computer engineering, and robotics engineering. Preference will be given to candidates with a strong track record in obtaining funded research, as well as excellent communication and administrative skills.

The Department offers BS and MS degrees in Electrical Engineering and Computer Engineering, as well as BS degree in Robotics Engineering. The department participates in interdisciplinary degree programs, including a MS degree in Automotive Systems Engineering, MS in Energy Systems Engineering, and Ph.D programs in Information Systems Engineering and Automotive Systems Engineering. The department has 20 tenured or tenure-track faculty and 370 undergraduate and 200 graduate students.

UM-Dearborn is located in historic Dearborn, MI, the heart of the U. S. automotive industry. UM-Dearborn is an equal opportunity employer and encourages applications from women and minorities.

Please submit complete academic vita including publications, details of funded research, a list of three or more references, and a statement of priorities as a Department Chair. Applications will be reviewed until the position is filled with highest priority given to those received by **February 1, 2015**. Electronic submission is preferred. Submit applications to:

ECEChairSearch@umich.edu
Department of Electrical and Computer Engineering
University of Michigan - Dearborn
4901 Evergreen Rd
Dearborn, MI 48128

SULTAN QABOOS IT CHAIR AT UNIVERSITY OF ENGINEERING & TECHNOLOGY, LAHORE, PAKISTAN

His majesty Sultan Qaboos of Oman has instituted an IT Chair at UET Lahore. Applications are invited for the said Chair. A monthly remuneration of PKR 450,000 will be offered to the selected candidate. Applications/nominations alongwith detailed CV's, list of publications, copies of Bachelors, Master and Doctoral degrees and one-page Statement of Envisaged Research Activities should be submitted by January 19, 2015 to:

Javed Iqbal, Section Officer (IT), Ministry of IT, 4th Floor, ETC Building, Agha Khan Road, F-5/1, Islamabad, Pakistan. P.Code:44000

For details please visit:

http://www.moit.gov.pk/

http://www.uet.edu.pk

BAYLOR UNIVERSITY

Faculty Positions

The Electrical and Computer Engineering Department of Baylor University seeks faculty applicants for three tenured/tenure-track Faculty Positions at all levels. Any area of expertise will be considered but applicants in computer engineering will be given special consideration. Applicants for assistant professor must demonstrate potential for sustained, funded scholarship and excellent teaching; applicants for associate or full professor must present evidence of achievement in research and teaching commensurate with the desired rank. The ECE department offers B.S., M.S., M.E. and Ph.D. degrees and is rapidly expanding its faculty size. Facilities include the Baylor Research and Innovation Collaborative (BRIC), a newly-established research park minutes from the main campus.

Chartered in 1845 by the Republic of Texas, Baylor University is the oldest university in Texas. Baylor has an enrollment of over 15,000 students and is a member of the Big XII Conference. Baylor's mission is to educate men and women for worldwide leadership and service by integrating academic excellence and Christian commitment within a caring community. The department seeks to hire faculty with an active Christian faith; applicants are encouraged to read about Baylor's vision for the integration of faith and learning at **www.baylor.edu/profuturis/**.

Applications received by **January 1, 2015** will be assured full consideration. Applications must include:

1) a letter of interest that identifies the applicant's anticipated rank,

2) a complete CV,

3) a concise statement of teaching and research interests,

4) the names and contact information for at least four professional references.

Additional information is available at www.ecs.baylor.edu. Send materials via email to Dr. Ian Gravagne at Ian_Gravagne@baylor.edu. Please combine all submitted material into a single pdf file.

Baylor University is affiliated with the Baptist General Convention of Texas. As an Affirmative Action/Equal Employment Opportunity employer, Baylor encourages candidates of the Christian faith who are minorities, women, veterans, and persons with disabilities to apply.

Big Data Streaming Analytics in the NOW!

Corvil makes sense of the world's network data by transforming it into streaming analytics so you can run your business in the NOW. It is currently used to monitor billions of transactions per day in the world's leading financial institutions and is trusted to provide real time analytics that power decisions for 9 of the top 10 banks globally. We believe that IT infrastructure is about to undergo a major transformation in the next few years as it looks to take advantage of cloud computing, big data, software defined infrastructure and mobile. We intend to be at the forefront of this space.

Corvil

Headquartered in Dublin, Ireland, Corvil operates in New York, Tokyo, Hong Kong & London. Corvil now plans to bring its real-time streaming analytics platform to much broader markets, including e-commerce, real-time advertising, gaming, media, energy, education and manufacturing. We are growing our product engineering team based in Dublin city centre and are looking to hire:

C++ Software Engineers
3-6 years commercial coding experience working on Multi-threaded applications on Linux. Knowledge of Python, Java, IP Networking and STL are an advantage.

Systems Test Engineers
3+ years experience testing products based on Linux.
Good Python or similar scripting.
Strong Automated test experience.
Chance to work on Selenium, scripting and enterprise products in labs.

So if you are interested in expanding your career in a dynamic and exciting organisation in the Data Analytics space and can live and work in Dublin, Ireland – then log on to www.recruiters/corvil.ie for more information on the roles, living and working in Ireland, package details and more.

THE CHINESE UNIVERSITY OF HONG KONG

Applications are invited for:-

Department of Computer Science and Engineering
Professors / Associate Professors / Assistant Professors
(Ref. 1415/078(370)/2)

The Department invites applications for Professorships / Associate Professorships / Assistant Professorships in computer engineering to pursue new strategic research initiatives, to fill faculty openings within current strengths and to teach in the new curriculum. The Department is looking for a leader and a couple of young and aspiring professors for added momentum to its Computer Engineering Programme, and in particular, talents in the following areas:

- *advanced architectural and 3D chip design for energy efficient computing; and*
- *hardware security for cloud computing.*

Applicants should have (i) a PhD degree; and (ii) a good scholarly record demonstrating potential for teaching and research excellence. The appointees will (a) teach both undergraduate and postgraduate courses; (b) develop a significant independent research programme with external funding; and (c) supervise postgraduate students. Appointments will normally be made on contract basis for two to three years initially commencing August 2015, which, subject to performance and mutual agreement, may lead to longer-term appointment or substantiation later. Applications will be accepted until the posts are filled.

Salary and Fringe Benefits
Salary will be highly competitive, commensurate with qualifications and experience. The University offers a comprehensive fringe benefit package, including medical care, plus a contract-end gratuity for appointments of two years or longer, and housing benefits for eligible appointees. Further information about the University and the general terms of service for appointments is available at http://www.per.cuhk.edu.hk. The terms mentioned herein are for reference only and are subject to revision by the University.

Application Procedure
Please send full resume, copies of academic credentials, publication list with abstracts of selected published papers, details of courses taught and evaluation results (if any), a research plan and a teaching statement, together with names of three to five referees to the Dean of Engineering by e-mail to recruit@erg.cuhk.edu.hk. Applicants should mark clearly the area(s) of their interests. The Personal Information Collection Statement will be provided upon request. Please quote the reference number and mark 'Application – Confidential' on cover.

REWINDING TAPE TECH

IT MIGHT NOT HAVE THE GLAMOUR IT USED TO, BUT TAPE STORAGE IS STILL A FORCE

For *IEEE Spectrum*'s 50th anniversary, the editors spent a lot of time over the past year combing through old issues for notable articles. But we often found ourselves distracted by the advertisements. The ads told a parallel story about the rise and fall of different technologies and how they were sold to engineers. So we are bringing you some of the gems we came across, starting with this March 1964 ad for analog data recorders.

After this point, ads for tape systems increasingly began boasting of their use as digital data storage, and they were a regular presence in *Spectrum*—until ads for disk drives began to crowd in. But tape storage isn't obsolete yet: In fact, there's currently a renaissance for data-tape technology, driven by the needs of today's data centers. In May of last year, Sony announced a new material that could store 185 terabytes on a single tape cartridge, while in January, Google filed for a patent on monitoring vast automated tape libraries.

Companies like Google and Amazon.com are cagey about the details of the inner workings of their data centers, but one thing is clear: Anyone dangling the ashy end of a lit cigarette over any of their storage systems would be rapidly ejected. **—STEPHEN CASS**

PHOTOGRAPH BY Ben Alsop