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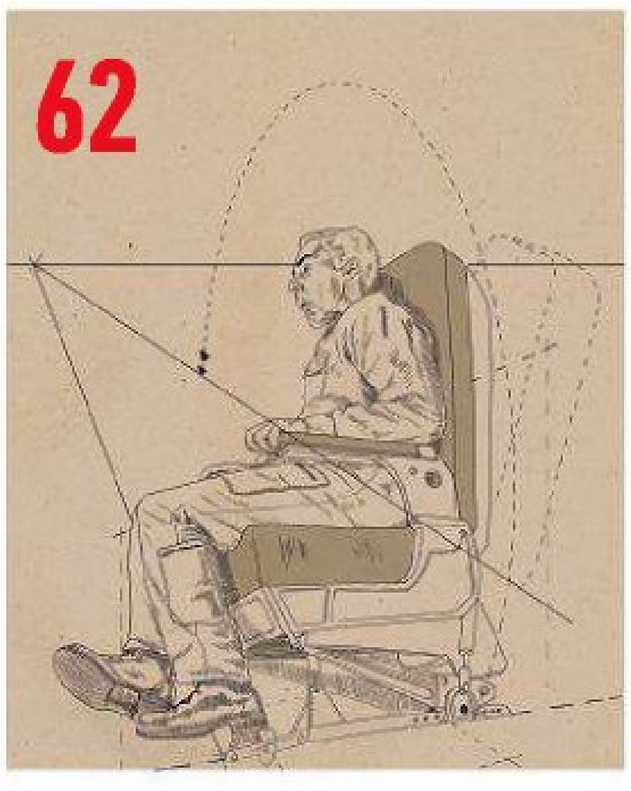

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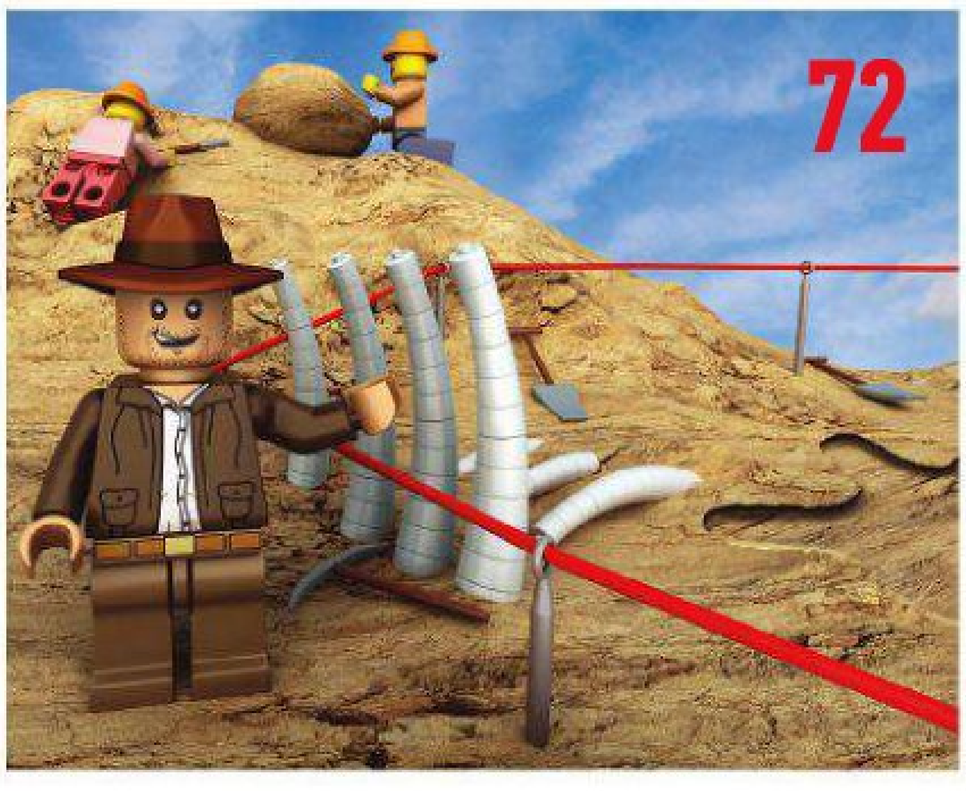

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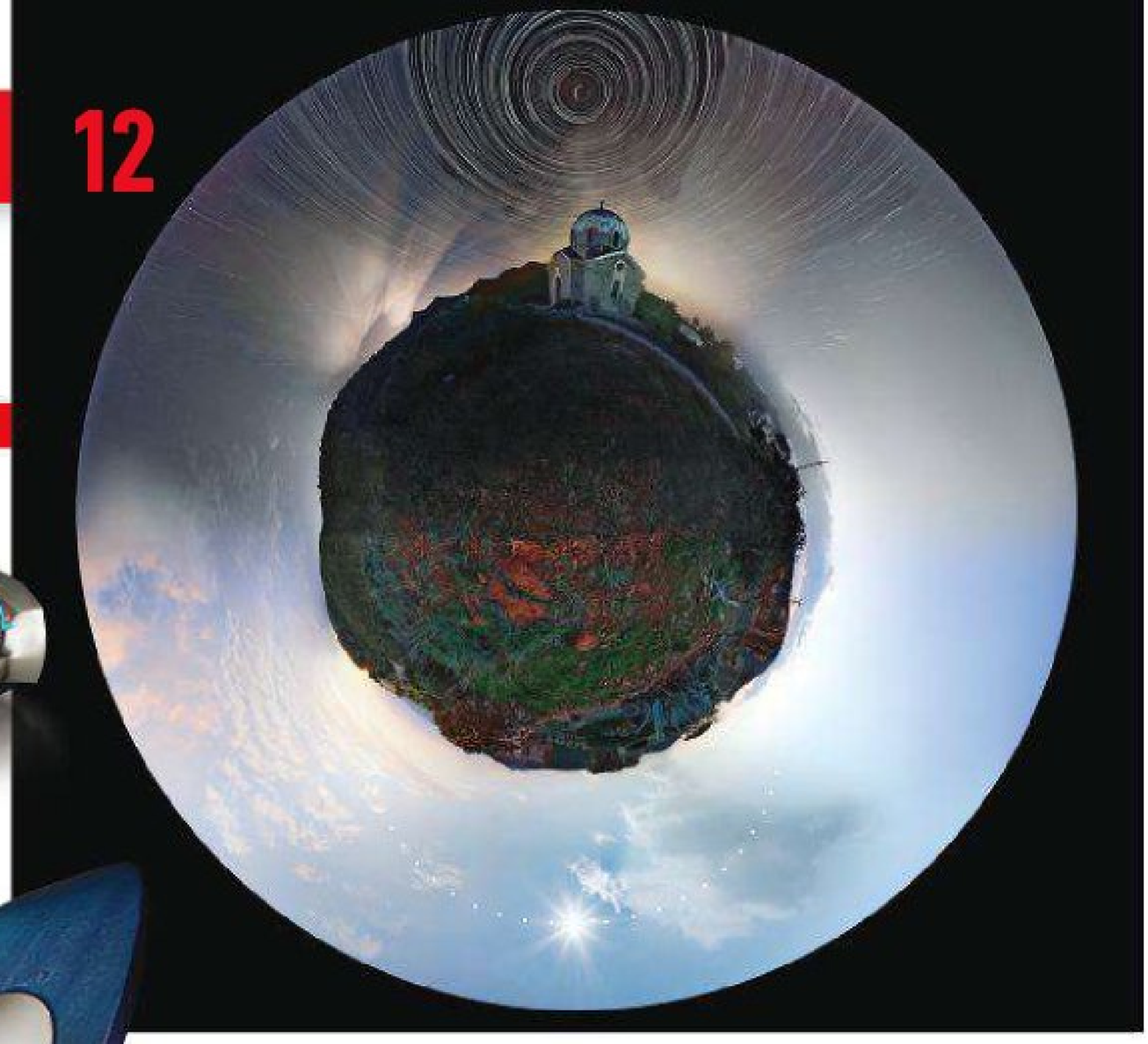

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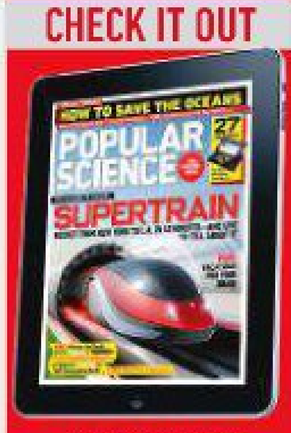

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STARING AT THE SUN

There are still profound holes in our knowledge of our local star. Read about the quest to understand the sun at ***popsci.com/thesun***.

SAVE THE OCEANS, ON GOOGLE EARTH

Experience this issue's story about saving the oceans [page 46] on Google Earth, with awesome interactive data visualizations, at ***popsci.com/savetheseas***.

GOT QUESTIONS?
E-mail fyi@popsci.com or tweet @popscifyiguy.

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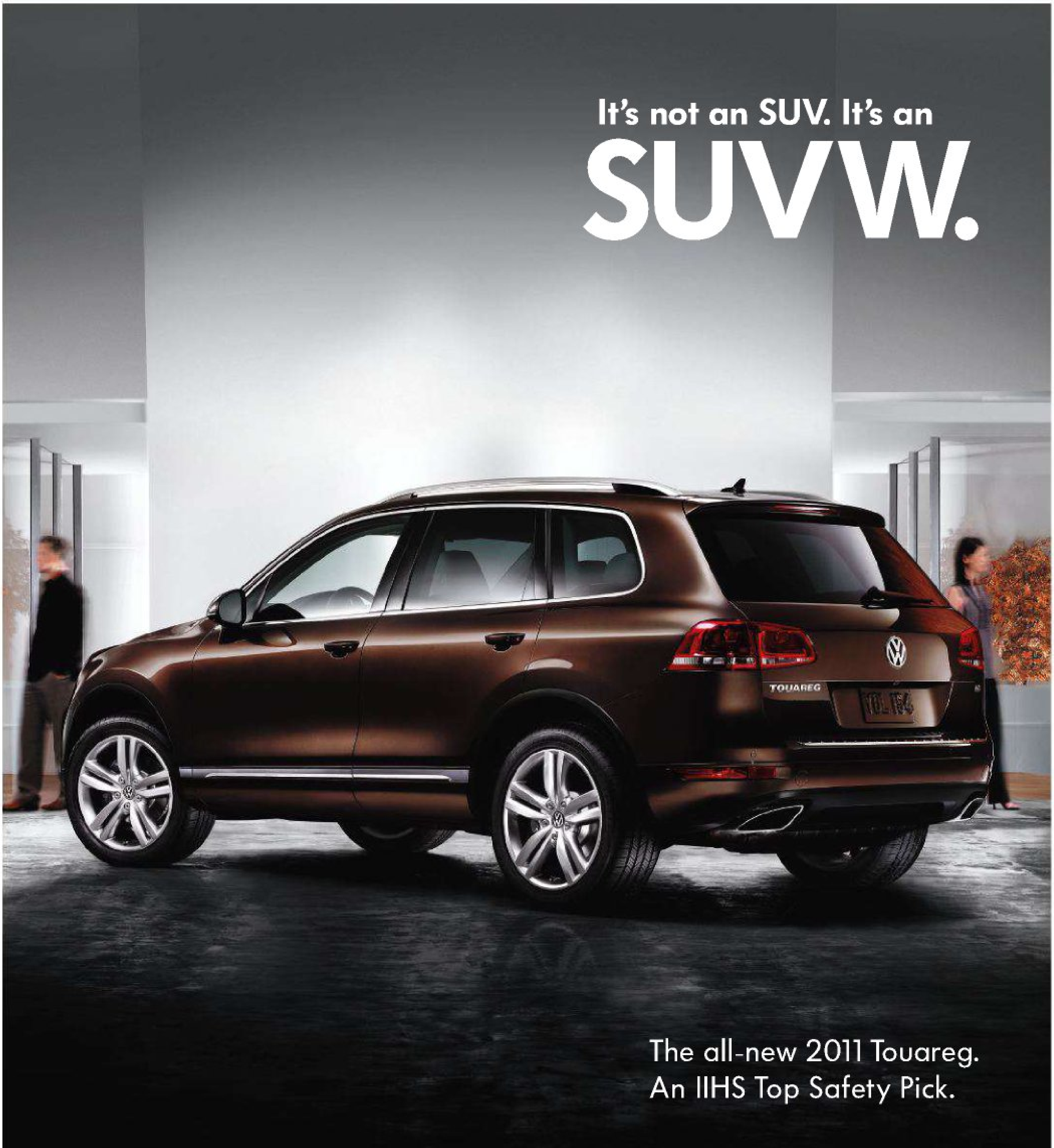

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FROM THE EDITOR

SAVE OUR SEAS

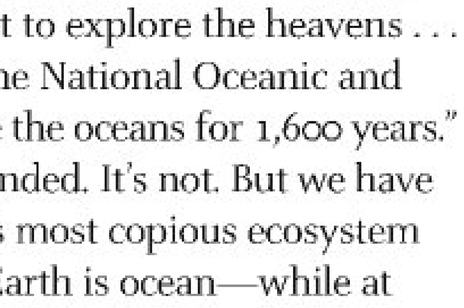
TWO YEARS AGO, I sat with roughly 1,500 fellow attendees of the annual TED Conference and listened as one of the world's greatest explorers explained why we must stop plundering the oceans and start protecting them—immediately. "Business as usual means that in 50 years, there may be no coral reefs and no commercial fishing, because the fish will simply be gone," the explorer said. "Imagine the ocean without fish. Imagine what that means to our life-support system."

There's a decent chance you've heard of Sylvia Earle, the author of that talk, but it's quite possible you haven't, because in this culture oceanographers aren't astronauts; even a great scientist who's led at least 50 expeditions and spent more than 6,000 hours underwater is never going to have the name recognition of a Buzz Aldrin. And that priority gap is reflected pretty sharply in funding, too. As another marginally famous ocean explorer, Bob Ballard, commented in an earlier TED talk, "NASA's annual budget to explore the heavens . . . would fund the National Oceanic and Atmospheric Administration's budget to explore the oceans for 1,600 years."

"WE HAVE TO DO EVERYTHING POSSIBLE, AND WE HAVE TO DO IT NOW."

Which is not to suggest that NASA is overfunded. It's not. But we have chronically neglected to understand our planet's most copious ecosystem—more than 99 percent of the living space on Earth is ocean—while at the same time exploiting and poisoning it. Our special report in this issue, "Seven Ways to Save the Seas" [page 46], lays out how bad things really are: radically reduced fish stocks, a third of the world's coral destroyed, 405 "dead zones," acidity on the rise, and plastic garbage everywhere. And in true PopSci style, we detail some solutions that can be (and in some cases are being) implemented. But as an individual, it's easy to feel inadequate in the face of a crisis this huge. As Earle herself told us, "Asking which way is best to save the oceans is like asking which way is best to save your heart. The answer is we have to do everything possible, and we have to do it now."

So what should you do? Anything and everything. Start with getting informed, and see where that takes you. Once you've digested our report, I strongly recommend you take in Earle's talk at *ted.com* for your next dose of insight and inspiration, and support her quest to protect large swaths of ocean at *mission-blue.org*.



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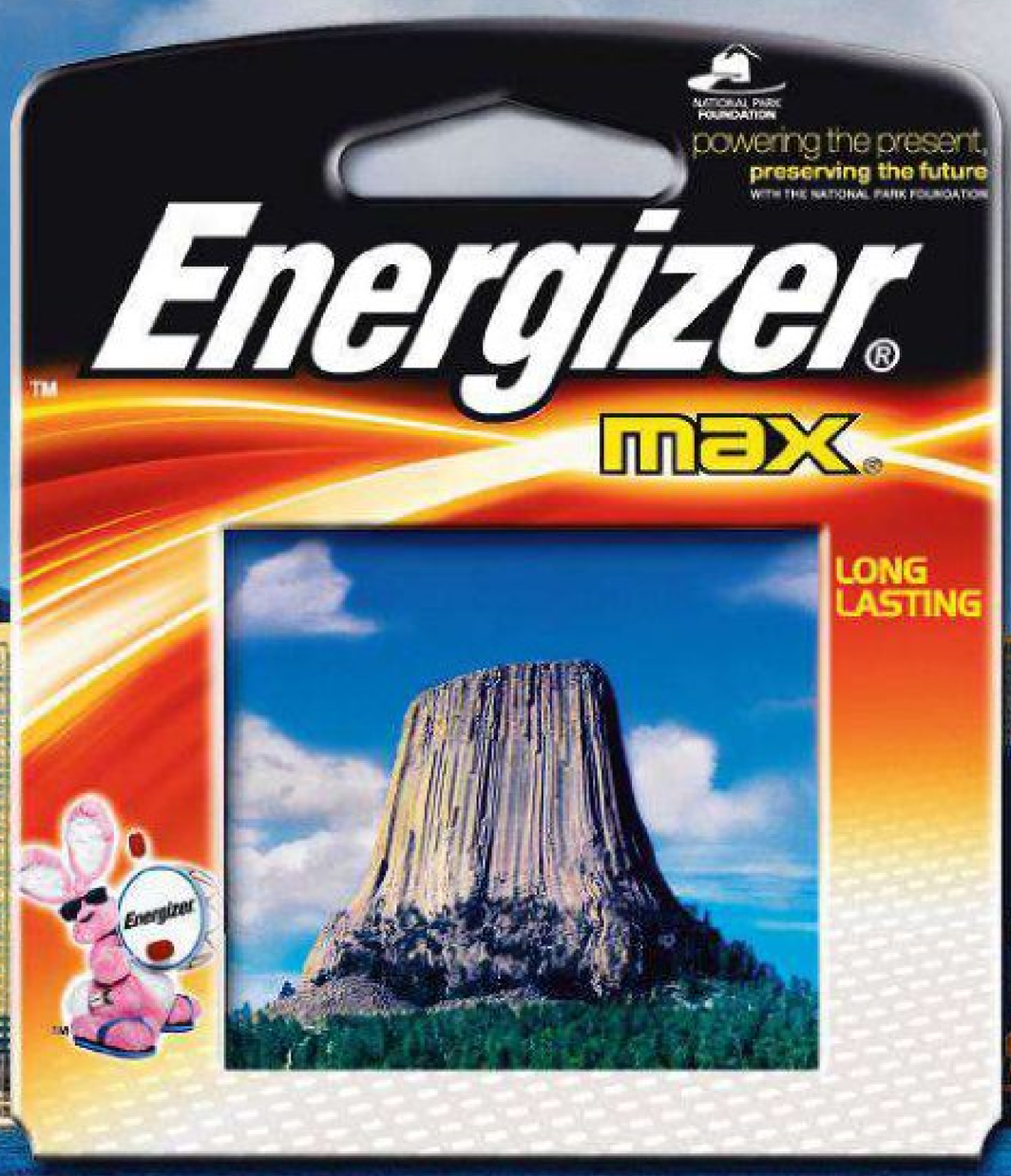

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THE INBOX

AFTER EARTH

It's hard to talk about relocating humankind to space without sounding a little insane, so we expected a volatile response to our March cover story. We got it. Some told us that planning for life among the stars is folly. Others appreciated the boldness of the researchers who dare to publicly debate the finer points of starship design. Here's a sampling.

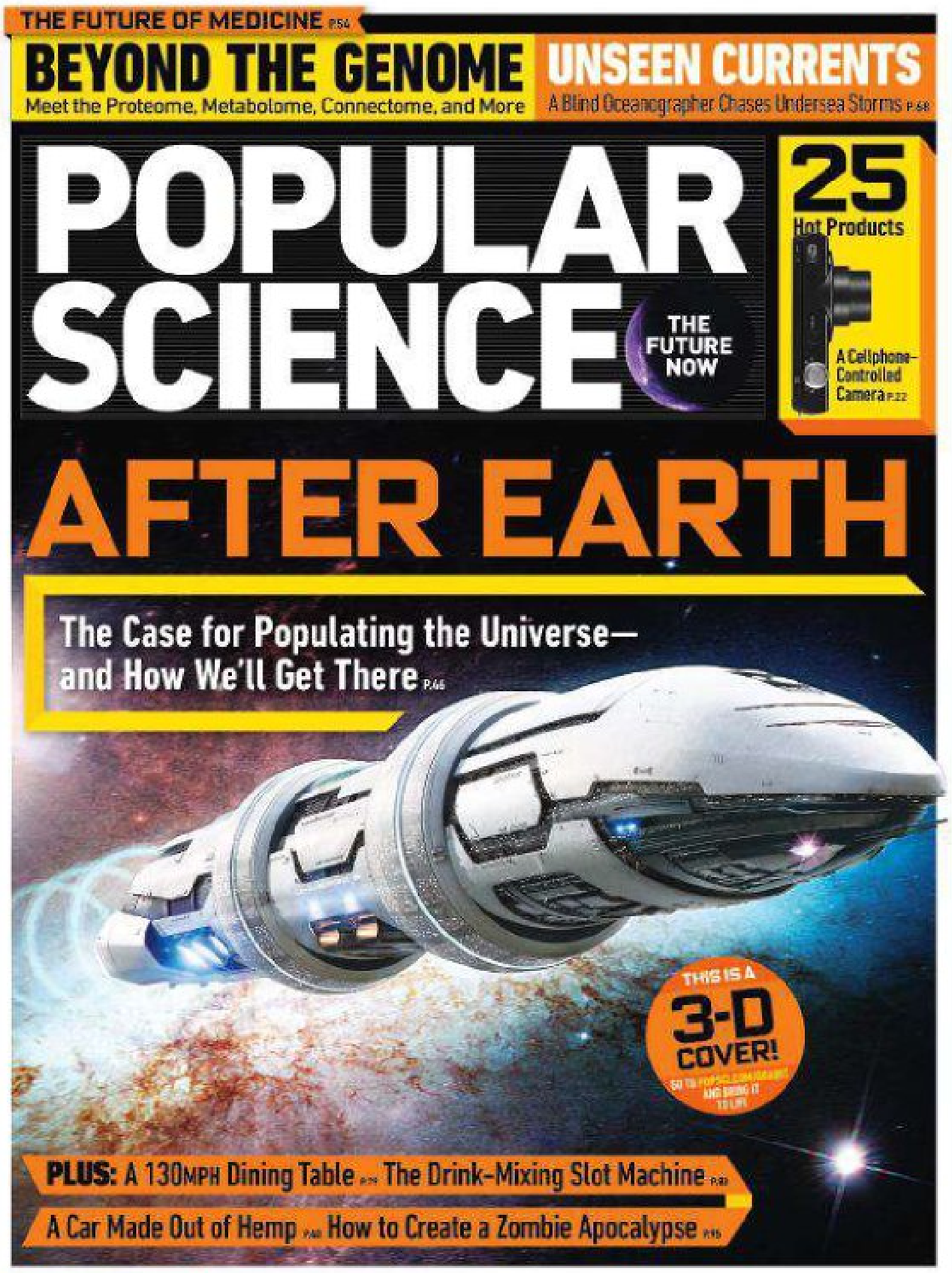
Space Debate

Being a "reengineered sentient machine" on a carefully selected space rock sounds like great fun. Meanwhile, here on Earth we have war, intolerance, murder, theft and hunger. What if the same amount of brainpower and money were directed at solving these problems? I know it sounds impossible and expensive. But so does everything else in this article.
Ellie Bloomfield
Glendale, Calif.

"After Earth" was categorized as Uncommon Knowledge. A more accurate description would have been Science Fiction. The best place for humans is on this planet. If we can't solve our problems here, what's the chance we're going to find a new home elsewhere and not destroy it, too?
Greg Schaffer
Cupertino, Calif.

I just finished reading "After Earth" for the second time. It's a very good piece. Many people have clearly put a lot of thought into colonizing space, but considering the state of humanity—countries bankrupt, people starving—where are the trillions going to come from? These questions need to be answered long before any of those regarding technology. I think we will run out of water, food, oil and energy long before this happens. I really hope I am wrong.
Ken Boyle
Paradise, Calif.

Art-wise, "After Earth" was among POPULAR SCIENCE's best. The illustrations left me feeling hopeful about the future. You're lucky to have [illustrator] Michael Zimmerman on the payroll.
Gigi Garcie
via e-mail



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HONORS AND AWARDS

In March, POPSCI's Gray Matter columnist, Theodore Gray, received the American Chemical Society's James T. Grady–James H. Stack Award, the purpose of which is "to recognize, encourage, and stimulate outstanding reporting directly to the public, which materially increases the public's knowledge and understanding of chemistry, chemical engineering, and related fields." The ACS cited his monthly column as one of the reasons for the award. Congratulations, Theo!

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MEGAPIXELS

THE MUST-SEE PHOTOS OF THE MONTH

TIME LAPSE

A photographer shoots and assembles an entire day of skies

Amateur photographer Chris Kotsiopoulos created this continuous image of the sky over Sounio, Greece, a town near his home. Late last December, he recorded the sun's path across the sky during the day and an 11-hour star trail at night. With his DSLR camera on a tripod, Kotsiopoulos snapped a photo every 15 minutes while the sun was in the sky. An astrosolar filter softened the sun's glow, but he removed it for a more dramatic image when the sun was near its highest point. For the night image, he took 500 consecutive 90-second exposures. To make the little planet, Kotsiopoulos took 25 horizon shots during a 360-degree pan of the landscape. He stitched the image together using Photoshop, Startrails and PTGui image software, but Kotsiopoulos relied on some low-tech help, too: An alarm clock kept him awake for the nighttime part of the shoot. BY CAITLIN KEARNEY

PHOTOGRAPH BY CHRIS KOTSIOPOULOS

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POO LAGOON These "Poo-Gloos," which normally rest on the bottom of a wastewater pond, await installation. Bacteria living in the domes break down contaminants into compounds such as carbon dioxide. Aerators within them keep oxygen flowing to the microbes.

COURTESY WASTEWATER COMPLIANCE SYSTEMS

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CLEANUP CREW

Plastic enclosures provide a cheap, bacteria-based sewage solution

Roughly 7,000 rural communities in the U.S. deal with sewage the old-fashioned way: by dumping it into an open holding pond and letting sunlight and bacteria do the rest. Not only do these ponds smell bad, but it takes the bacteria a long time to render the sewage nonhazardous, a situation that could pose a contamination risk to waterways. Wastewater-treatment plants, the most common solution, cost upward of $2 million to build, according to Kraig Johnson, the chief technology officer of Salt Lake City–based Wastewater Compliance Systems. Johnson, who researched biological solutions for sewage treatment at the University of Utah, is pilot-testing a simple and cheap solution: BioDomes, which house bacteria that break down contaminants in sewage and which could be installed for as little as $200,000. So far, 200 BioDomes (colloquially known as Poo-Gloos) are cleaning up sewage in six states, including Alabama and Nevada, and early data suggests that they might be as efficient as mechanical wastewater-treatment plants.

BY CAITLIN KEARNEY

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BE INSPIRED, GET INVOLVED.

WHAT DOES ENVIRONMENTAL RESPONSIBILITY MEAN TO YOU?

The Eco Tour is a dramatic example of what can be done with the energy saved by turning off just one household item when not in use. Follow career journalist and electric vehicle tinkerer Pierce Hoover and his 12-year-old son, Nash, as they cross the country on the power generated by a single GE lightbulb. The vehicle's available energy supply is 2,400 watts per day — the equivalent of a 100-watt bulb left on all day. The three-month tour will take them across the heart of the U.S. along the transamerica bike route. Pierce and Nash will cover from 60 to 100 miles per day, stopping to spread the message along the way.
First stop, Washington, DC.

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WHAT'S NEW

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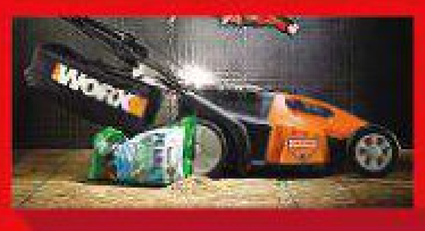

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Powerful tools to tame your yard

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Nissan's electric sports car

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iPhone-controlled robotic toys

BEACH BURNER

A jet-propelled surfboard helps battle the breakers

Surfers want to ride waves, not tire out while paddling to them. That's where the WaveJet comes in. Two battery-powered jets tucked into the shortboard's three-inch shell provide 20 pounds of thrust to propel riders at 12 mph—three times the average paddling speed.

Unlike a Jet Ski's circular exhaust nozzles, the oblong ones on the WaveJet save space and add power. By forcing water through smaller, flatter openings, the jets produce a higher-pressure stream. Riders turn the jets on and off with a bracelet remote control that also acts as a kill switch if they wipe out. Because the battery-and-jet module sits just ahead of the fins, where a standing surfer's weight rests, the 15 pounds it adds only minimally affects the board's balance and performance.

Although the WaveJet's power could realistically help pro surfers shred harder, its true purpose is to make water sports less frustrating for amateurs. The board's propulsion system is currently built into 11 surfboard models, including paddle- and lifeguard boards, and will soon be installed in bodyboards, kayaks and kiteboards as well.—MARK ANDERS

HANDY MAN The bodies of WaveJet boards are designed by Steve Walden, an originator of the modern longboard.

WAVEJET SHORTBOARD
DIMENSIONS: 7.1 ft. x 21 in. x 3.125 in.
WEIGHT: 32 lbs.
RUN TIME: 39 min.
PRICE: $4,500 (est.)
MORE INFO: *wavejet.com*

JEFF HARRIS/ARTMIX

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WHAT'S NEW

Stayin' Alive

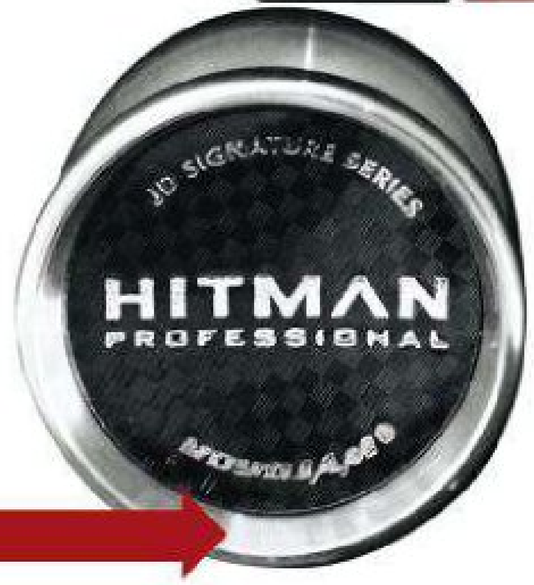
Improve your odds in the wild with the SOL Origin survival kit. The palm-sized, 6.4-ounce set consists of 17 one-handed tools (including a knife, whistle, compass, signaling mirror, sparking device and tinder), all housed in a waterproof case. **SOL Origin Essential Tool $60; *surviveoutdoorslonger.com***

Leg Up

Unlike most pogos, the BoGo has a flexible fiberglass bow on its front. Working with a coiled metal spring in the base, the bow helps capture more energy when compressed, and allows riders to bounce two thirds higher with no extra effort. **Razor BoGo $60; *razor.com***

Spin Master

The Hitman Pro aluminum yo-yo maintains near-perfect balance and stability. The trick is that its axle inserts completely into the casing, so the rod won't get stuck on internal edges, cause friction, and make the yo-yo wobble out of control. **Hitman Pro Yo-Yo $50; *yoyojam.com***



Speed Racer

Rather than getting bogged down copying files to an external drive, new MacBook Pros tear through the task 20 times as fast as other laptops—and can feed a high-def movie to a monitor at the same time. They're the first notebooks to use Intel's high-speed Thunderbolt port, which merges a data and display connection into one wire. **Apple MacBook Pro with Thunderbolt From $1,200; *apple.com***

Insight

The MenasZoom is the first dome magnifier with multiple powers. Twisting the top changes the distance between its two lenses—much like a camera's zoom lens—and adjusts magnification among five settings, from 2.2x to 3.4x. **Eschenbach MenasZoom $190; *eschenbach.com***

Smart Car

Open your car doors even when you've locked your keys inside. OnStar's new smart mirror can retrofit into more than 50 million cars on the road today and uses a cell connection to link your vehicle's computer with a centralized server. **OnStar mirror $300 (plus installation and subscription fees); *onstar.com***

Stored4gs.com

Tiny Tunes

At just 2.8 inches wide, Razer's portable speakers can fill a room with audio from a cellphone, iPod or laptop. Each speaker's 1.2-inch driver fires upward, so sound waves bounce off the top wall and spread a full 360 degrees out of the circular grill. **Razer Ferox $60; *razerzone.com***

Laser Tag

Blow opponents away—with lasers! In KHET, a chess-like board game, players arrange mirrored pieces to create a path for an eye-safe laser beam that kills the other player's pieces. Last man standing wins. **The Laser Game: KHET 2.0 $40; *khet.com***

Drive On

Rockwell's drill is the first 12-volt compact tool to double as a heavy-duty driver. For big, load-bearing screws, an anvil weight provides up to 800 inch-pounds of extra torque. **Rockwell 3Rill $180; *rockwelltools.com***

Corner Painter

Paint without scuffing the ceiling or going back to the bucket. The RapidRoller is the first roller with both a head that locks in three positions and a handle that sucks paint from the pail. **Black & Decker RapidRoller From $35; *blackanddecker.com***

THE goods

A dozen great ideas in gear

Dual View

The Kyocera Echo is the first phone with two 3.5-inch touchscreens, so it can display two apps at once. Now if you're lost, you can pull up a map while texting a friend to let her know you'll be late for dinner. **Kyocera Echo $200 (with two-year contract); *kyocera.com***

Line of Sight

Read your PC's screen the same way you would a cookbook on the kitchen counter. Instead of staying rigidly upright, HP's 23-inch touchscreen reclines backward up to 60 degrees, making it comfortable to see while standing. **HP TouchSmart 610 Consumer PC $900; *hp.com***

CONTRIBUTORS: Max Fischer, Corinne Iozzio, Susannah F. Locke

StoreMags.com

FINE PRUNING

Garden aids that help tame your yard with less time and effort

Getting your lawn in shape after the spring thaw can mean many uncomfortable hours of lifting, bending, stretching and sweating. These tools cut down on all that back-breaking labor, leaving you more time to relax and smell the roses.

—MAX FISCHER

Grass Seed

Imagine mowing only once a month and rarely having to water. Pearl's blend of Dakota fescue, perennial rye and Kentucky bluegrass grows deeply (to capture more nutrients) and slowly (to extend time between mows). **Pearl's Premium Grass Seed (Sunny)** $36 (five pounds); *pearlspremium.com*

Multitool

Fiskars's scissors come fully equipped for small garden jobs, such as clipping flowers or quick hedge-trimming touch-ups. The snippers have a removable titanium-coated blade, a notch to snip twine and a serrated edge to chew through thicker brush. **Fiskars Cuts+More scissors** $20; *fiskars.com*

Pruning Saw

With extra-sharp and deep teeth, this mini reciprocating saw cuts through branches of up to three inches thick. The trick to its clean, one-handed cuts is a retractable, spring-loaded arm that pushes stems into the blade. **Black & Decker PSL12 Piranha Pruning Saw** $80; *blackanddecker.com*

Hedge Trimmer

An extendable 5.5-foot shaft, a head that rotates 135 degrees, and 12 volts of power give Craftsman's hedge trimmer an edge when pruning hard-to-reach areas, such as the tops of tall shrubs and other inaccessible spots. **Craftsman NEXTEC Articulating and Rotational Hedge Trimmer** $100; *craftsman.com*

Lawn Mower

Unlike typical electric mowers, this Worx doesn't flinch when it hits weeds or overgrown grass. The battery-powered mower can crank up the torque, increasing the relative strength of its spinning blades, so it won't get stuck in the rough. **WorxECO Pacesetter Mower WG 789** $780; *worxyardtools.com*

JEFF HARRIS/ARTMIX

▶ **GROUNDS CREW** The average American spends at least 40 hours a year working in the yard.

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THE TESLA KILLER

With the Esflow, Nissan shakes up the electric-sports-car scene

When Nissan introduced its Leaf last year, it became the first major automaker to enter the modern pure-electric-vehicle market, which was previously populated almost entirely by tiny carmakers such as the Palo Alto, California, company Tesla Motors. Renault-Nissan CEO Carlos Ghosn said that his company would invest more than $5 billion in electric cars through 2013, and that it would soon become the world's largest electric-vehicle maker. Then in March, Nissan made its most direct assault on the little guys—it unveiled an electric sports car.

For now, the Nissan Esflow is a concept, but Nissan is considering full production. It's not a stretch: The Esflow is based on the same batteries and motors that power the Leaf. The rear-drive Esflow carries a 975-pound, 36-kilowatt-hour lithium-ion battery pack, compared with the 24 kilowatt-hours found in the Leaf. To partially offset that extra weight, the concept uses a feathery carbon-composite body affixed to an aluminum chassis. Rear-mounted cameras replace side-view mirrors, reducing drag. Fixed seats sculpted into the bulkhead eliminate seat frames and the motors that adjust them. Likewise, the accelerator, brake pedals and shifter are electronic, eliminating the mechanical steering column and pedal assemblies.

120 mph
top speed

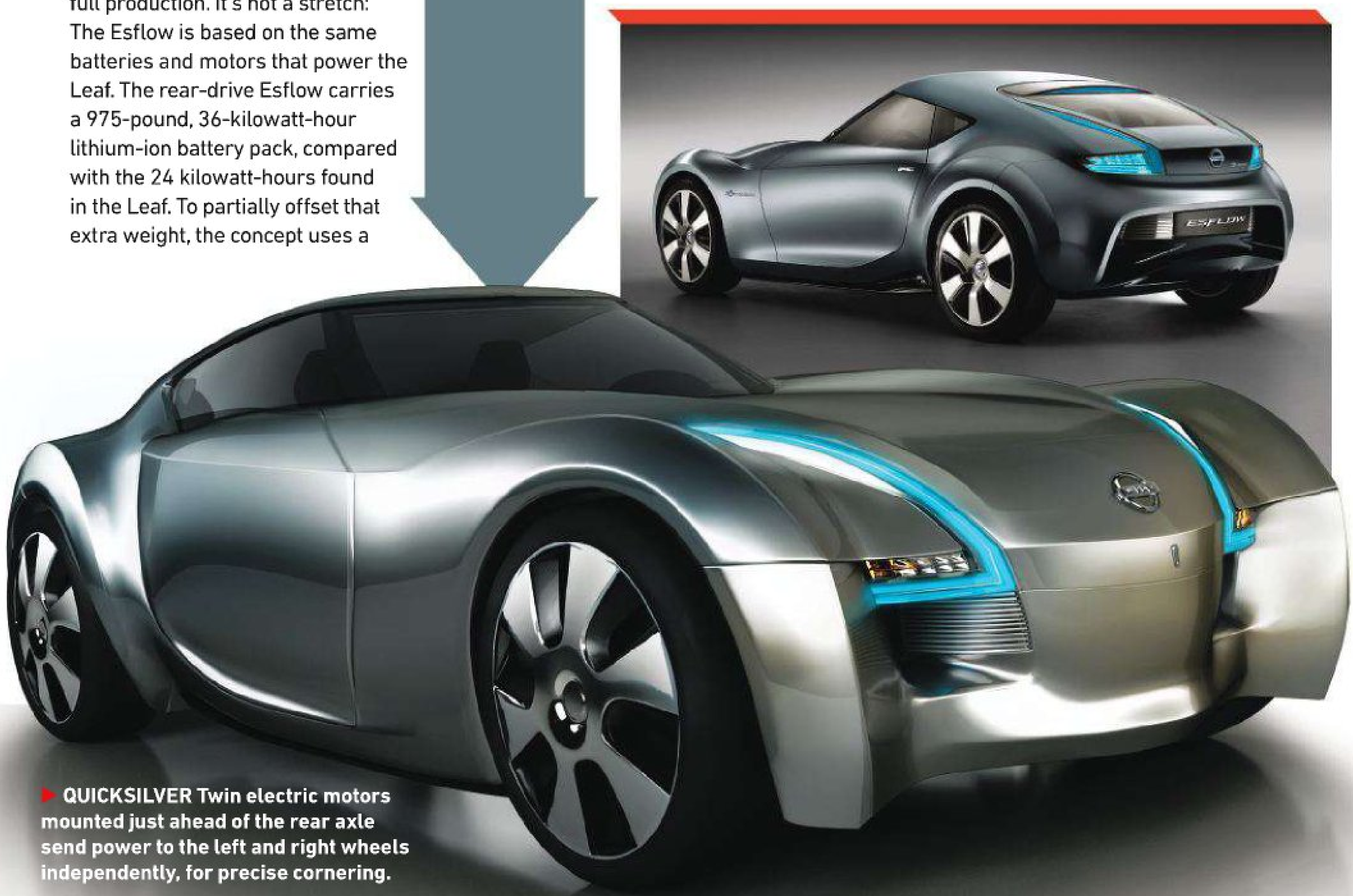
150 mi.
driving range

36 kWh
battery capacity

?
Production date

Bob Yakushi, the director of product safety and environment for Nissan North America, says the Esflow should travel up to 150 miles on a charge. (The Leaf gets about 100 miles.) Propelled by two rear-mounted 107-horsepower motors, the Esflow scoots from 0 to 60 mph in less than five seconds, with a top speed of roughly 120 mph.

Tesla's $109,000 Roadster has been on the market now for three years, but the Esflow illustrates the challenges that lie ahead as global automakers get into the high-end electric market. Nissan has the resources to undercut Tesla on price, along with a trusted name and dealer and service networks that no start-up can match. Just a few years ago, pundits predicted that Tesla would revolutionize the car business. What it may have done instead is to wake sleeping giants.—LAWRENCE ULRICH



▶ QUICKSILVER Twin electric motors mounted just ahead of the rear axle send power to the left and right wheels independently, for precise cornering.

ILLUSTRATION: DANNY SCHUMPERT AND JASON BLINEY; PHOTOGRAPH: COURTESY NISSAN

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BREATHE EASY

New jacket fabrics vent sweat without letting water or cold air sneak in

For 35 years, Gore-Tex has dominated the market for waterproof, breathable fabrics, but this spring it has some competition. Textile maker Polartec has developed its own waterproof, breathable fabric that threatens to trump Gore-Tex's latest. We put both through the wringer to see which stands out.—BERNE BROUDY

THE TECH

Rab Stretch Neo Jacket with Polartec NeoShell

Under a microscope, NeoShell's permeable layer looks like spiderwebs spun from a polyurethane thread. The webs form tiny channels large enough that humid air can escape but small enough that water droplets (even those with the force of a 10-foot waterfall) can't get in. A polyester lining and durable outer-face fabric sandwich the layer and are fused to it with pinhead-size dots of adhesive, which keeps channels clear and air flowing. **$365; *us.rab.uk.com***

Millet Trilogy Limited GTX with Gore-Tex Active Shell

Thinner and lighter than its predecessor, Gore-Tex's Active Shell fabric features a porous membrane that looks like cotton candy up close. The fabric bonds directly with a moisture-wicking lining, eliminating a heavy layer of adhesive and trimming a few ounces off the jacket. An outer-face fabric attaches with microscopic glue dots; this way, the pores (about nine billion of them per square inch) don't get gummed up. **$400; *milletusa.com***

THE TEST

For one month this winter, four testers wore both jackets while skiing front- and backcountry in the mountains of Vermont, Colorado and Utah. Conditions ranged from snow squalls to bright sunshine, and temperatures varied from close to freezing to as low as –30°F.

THE RESULTS

All four testers felt consistently more comfortable in the 17-ounce Polartec shell, despite the Gore-Tex's jacket being three ounces heavier. Testers had to physically air out the Gore-Tex jacket by unzipping its armpit vents, whereas sweat evaporated quickly out of the ventless Polartec. **WINNER: Polartec NeoShell**

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APPETITE FOR DATA

Welcome to your automated grocery store

Home cooks have plenty of gadgets to help them whip up a smoothie or soufflé, but now touchscreens, facial tracking and object-recognition technologies are taking the labor out of a much more mundane chore: food shopping.—REBECCA BOYLE

NOW: TAP FOR A SNACK

After 30 years of incremental changes, vending machines are getting a serious facelift. Instead of the usual machine with a window, Samsung created the Diji Touch vendor, featuring a 46-inch LCD touch panel. Shoppers can tap a snack icon and pull up nutrition information before making their final purchase. Last fall, Samsung deployed 20 machines in the Northeast and plans to add about 150 more this year. **Samsung uVending** *samsunglfd.com*

SOON: DINNER DECIDER

It's 8 p.m. You're famished and standing in the middle of the supermarket. Where do you turn? Soon the answer could be an Intel, HP and Kraft kiosk that decodes your cravings for you. The station scans shoppers' faces to judge their age and sex and then pairs that assessment with time of day and holidays to suggest recipes and shopping lists. For example, a customer identified as being in his mid-20s, at 11:00 on a Tuesday night, might get a suggestion for mac and cheese. Kraft plans to start testing the kiosks in grocery stores by the end of this year. **Kraft Meal Planning Solution and Intel Connected Store**
intel.com

LATER: SMART SCAN

Self-checkout counters can be swift—if you're not buying produce. In the next few years, shoppers could use Toshiba's object-recognition system, which identifies fruits and vegetables, rather than typing tedious codes. With a camera, the system determines a food's shape, color and apparent texture, even through plastic bags, and picks the likeliest identity and alternatives (say, similar red apples). Shoppers correct any mistakes, making the system smarter. It already discerns 34 foods with 90 percent accuracy. **Toshiba Object Recognition with Implemented Learning Capability**
toshiba.com

ILLUSTRATIONS: PAUL WOOTTON; PHOTOGRAPHS, FROM TOP: COURTESY KRAFT FOODS; COURTESY INTEL

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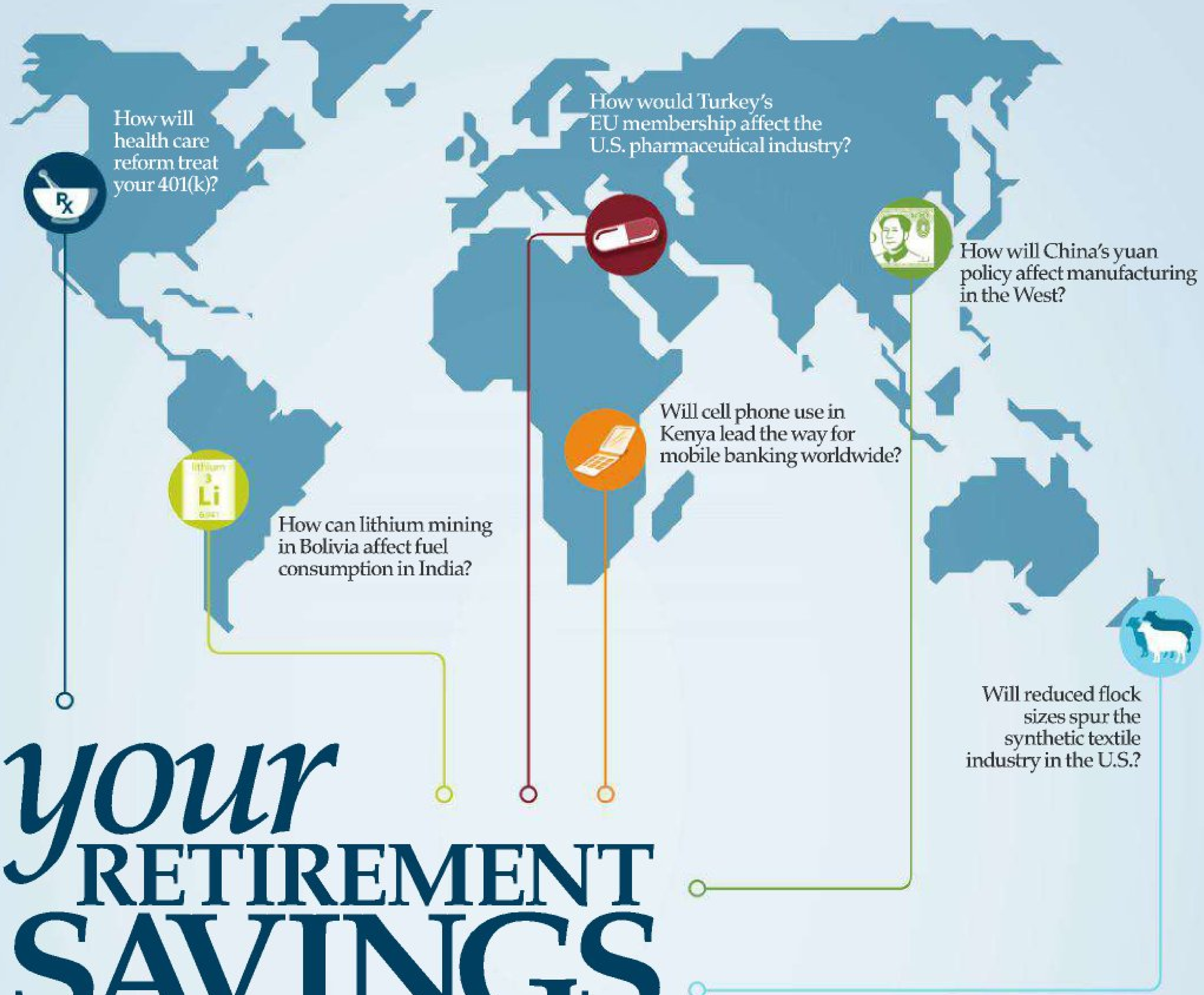

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PHONE DRONES

Radio-controlled toys trade joysticks for smartphones

THE TREND

Toys controlled by smartphones, leading to enhanced maneuverability and augmented-reality games

WHY NOW

Some 45 million Americans have a ready-made, near-universal remote control in their pockets. We already use smartphones to turn up home stereos, scroll through iTunes playlists, and pause Apple TVs. The devices' built-in radios, such as Wi-Fi and Bluetooth, can also control toys.

HOW YOU'LL BENEFIT

Smartphone touchscreens and motion-sensing accelerometers provide greater motion control than their button and joystick controller counterparts. You'll also be less likely to lose the remote and won't need to scrounge around for new batteries.—CAITLIN KEARNEY

Taking Flight

The WiFli Helicopter makes flying easy. The controller app has directional commands and a virtual throttle, letting it take off with a finger swipe. In a crash, its hinged propellers fold instead of breaking. **Interactive Toy Concepts WiFli Helicopter** $80 (est.); *interactivetoy.com*

Having a Ball

About the size of a baseball, Sphero rolls according to the tilt of your phone, using its own internal gyroscope for propulsion. Because Sphero reports its location back to its connected phone over Bluetooth, it can engage in multiplayer games. In an augmented-reality game called Sumo, for example, two players try to knock each other out of a ring shown on the phones. Sphero's open-source platform lets anyone design apps. **Orbotix Sphero** $100 (est.); *gosphero.com*

Seeing Infrared

Tankbots operate on four frequencies so that four people—and their 'bots—can play together. Each Rubik's Cube–size tank comes with a dongle that attaches to a smartphone, turning the handset into an infrared remote. In autopilot mode, the toy uses infrared sensors to avoid obstacles. **Desk Pets Tankbot** $20; *mydeskpets.com*

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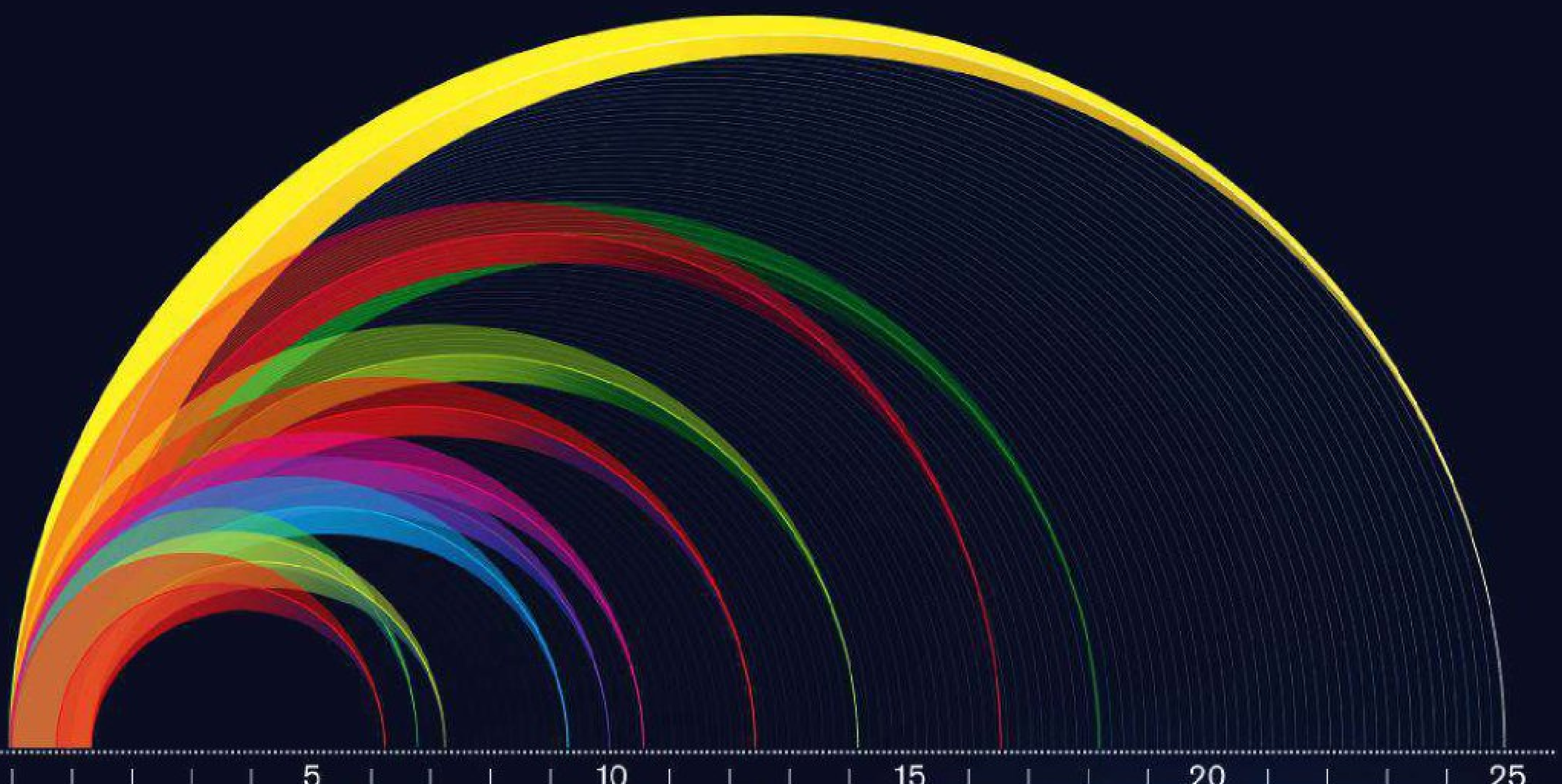

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HEADLINES

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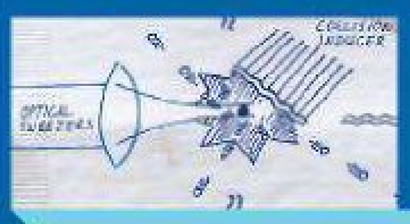


36 Trapping atoms with laser beams

38 Eradicating a deadly virus

44 Driving blind at Daytona

INFRASTRUCTURE

THE MILLION-DOLLAR MILLISECOND

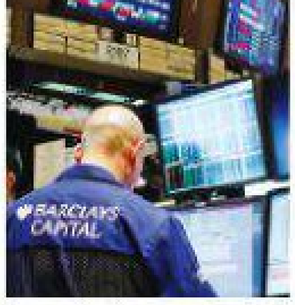
A new transatlantic cable will speed up information exchange—for a price

Traders used to all buy and sell stocks in the same crowded room. Everyone received information at the same time, and the first guy to shout or signal got the sale. Today, using algorithms that exploit slightly different prices changing at slightly different speeds, and computers connected to exclusive fiber-optic lines that can buy and sell stocks within fractions of a second, high-frequency traders are able to buy low and sell slightly higher in virtually the same instant. "A couple of milliseconds can roll out to a $20-million difference in [a trader's] account at the end of the month," says Nigel Bayliff, the CEO of Huawei Marine Networks, one of the companies laying down superfast fiber-optic lines.

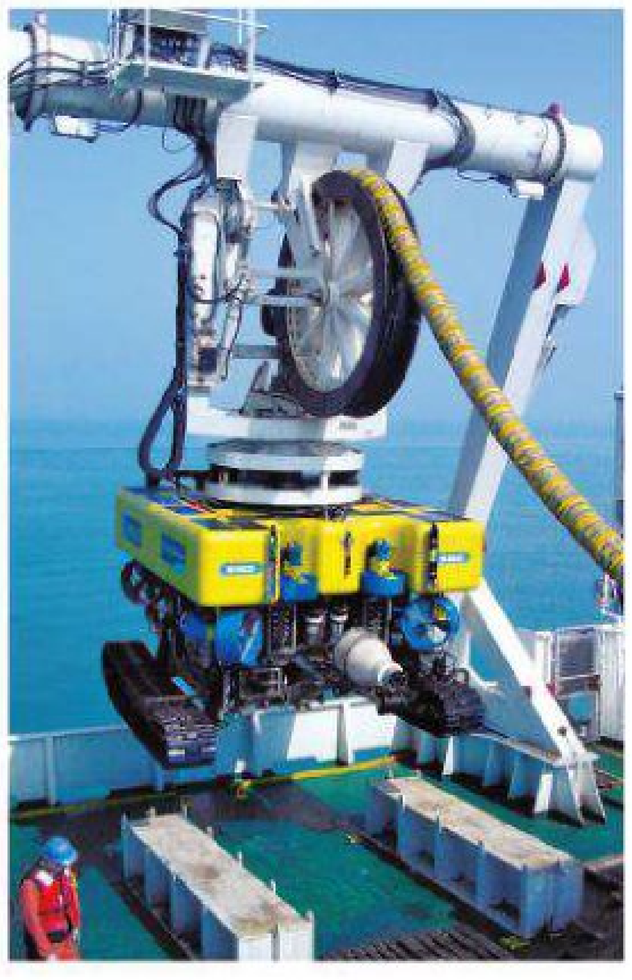
Companies like Bayliff's are looking for ways to shave time, and the easiest method is to build a more direct route. Last year, Mississippi-based Spread Networks opened a shorter connection between New York and Chicago that saved about three milliseconds and was estimated to have cost $300 million to develop. Huawei is working with another company, Hibernia Atlantic, to lay the first transatlantic fiber-optic submarine cable in a decade, a $400-million-plus project that will save traders five milliseconds.

To do this, Hibernia is laying nearly 3,000 miles of cable across the Grand Banks off Canada and the North Atlantic, a shorter route that most companies have avoided because it traverses relatively shallow waters. Undersea-cable companies prefer to work at greater depths; they can just drop naked cable down to the ocean floor. At

(CONTINUED ON PAGE 351



SPEED SELLS
Fiber-optic cables [above right] allow stocks to be bought and sold in an instant. A company is building an exclusive, faster undersea cable using ROVs [right] and armoring about 1,200 miles of cable in the Atlantic Ocean, connecting the New York Stock Exchange [above] to London.



CLOCKWISE FROM TOP: ISTOCK; COURTESY GLOBAL MARINE ENERGY; JOSHUA LOTT/REUTERS

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AIRSHIPS RISE (AGAIN)

The next generation of dirigibles takes flight

A whirring comes across the sky. From 20,000 feet above the Mexican border or Afghanistan's Korengal Valley, a vehicle as long as the Chrysler building is tall drifts into the stratosphere. It looms like a cloud and stays put for 21 days, scanning for body heat below. These blimps are lighter than air, fuel-efficient and quiet—which is why they could become the military's go-to vehicles for surveillance and transport.

—BARRY HARBAUGH

SKY HQ

Last summer, the U.S. military awarded Northrop Grumman a $517-million contract for a Long Endurance Multi-Intelligence Vehicle (LEMV). The 300-foot-long aircraft gets about 40 percent of its lift from its hull's aerodynamic shape. It can stay aloft for three weeks at a time running surveillance. Northrop says the LEMV will be ready for action by the beginning of next year.

Pop Proof

The pressure within the LEMV's **helium envelope** is low enough that if it is somehow shot or punctured, the ship will neither explode nor tumble from the sky.

Unmanned

The military plans to deploy the LEMV without anyone on board. Autonomous sky trains, made up of a series of ships tied together, are a possibility (although current flight regulations require a pilot to steer ships through commercial airspace).

Efficient

The ship's four diesel engines cost $15,000 to fuel on a three-week mission—one tenth the consumption of a helicopter and one quarter that of an airplane used on similar missions.

FISH OUT OF WATER

Unveiled in 2009 by the EMPA, the Swiss federal laboratories for materials science and technology, this balloon has electric actuators attached on either side of its body. When voltage is applied, polymers in this 26-foot-long helium-filled balloon's skin expand and constrict like a fish, propelling the craft silently. Christa Jordi, the lead scientist on the project, says the trout balloon could be used in such sound-sensitive situations as spy missions, animal observation and stadium events. The Flaming Lips need one. . . .

Shock Propulsion

Dielectric elastomer actuators act as artificial muscles, compressing and expanding when charged with electricity.

Bone Structure

A thin and rigid **carbon-fiber-reinforced epoxy skeleton** runs lengthwise through the "fish" and, like a spine, bends without any hinged joints.

Clear Skin

The helium-tight membrane is made of **Heptax**, a plastic that's also used to seal food products.

KEVIN HAND

(CONTINUED FROM PAGE 33)

less than a mile deep, though, they must bury armored cable to protect it from ship anchors, fishing trawls, dredging gear, and attacks from sharks, which are drawn to the line's electricity.

For all the money Hibernia and its clients will make from a 60-millisecond trip across the Atlantic, the installation will be slow. Crews on two ships, the *Sovereign* and the *Cable Innovator*, will deploy 24-ton ploughs to cut a trench up to six feet into the seabed, into which they will lay the cable. The top speed is about one mile an hour. Each ship is outfitted with a dynamic positioning system that keeps it in place while laying cable, regardless of currents or winds. If something gets in the way, such as another submarine cable, the

THE CABLE MUST BE PROTECTED FROM SHIP ANCHORS, FISHING TRAWLS AND SHARKS.

crews will use a remotely operated vehicle equipped with a pair of high-pressure water "swords" to break apart sediment. The ROV then uses a mechanical arm to bury the new cable underneath the obstacle and into the temporarily softened earth. "The seabed always throws up something unexpected," says Stuart Wilson, the manager of cable-route engineering for Global Marine Systems, the company installing the Hibernia line.

Hibernia says its cable will go live next year, connecting it to Hibernia's Global Financial Network, which has fiber optics running 15,000 miles between financial centers from Chicago to Frankfurt. But the New York-to-London line could be the company's biggest draw, providing a competitive advantage of just five milliseconds—about the amount of time it takes a bee to flap its wings.

—MATT DELLINGER

HEAVY LIFTER

Hybrid Air Vehicles, which teamed with Northrop on its design for the LEMV, is working on a set of three larger-capacity hybrid airships that can carry up to 200 tons and will be the biggest airborne carriers in the world, the smallest of which is larger than a 747. The HAV 606 [shown here], is 607 feet long and has a helium envelope of 16 million cubic feet, twice the size of the *Hindenburg*. Hybrid Air plans to sell the ships, which take 24 months to build, for mining and oil exploration.

Well-Balanced

When fully loaded, the HAV is no longer lighter than air (the weight of the load is greater than helium's lift) and its **airfoil design**, wide and aerodynamic, becomes crucial for staying aloft.

Dock Anywhere

Landing skirts, which allow the craft to touch down, are retractable and amphibious, so the LEMV can land on ground or water. The crew activates a vacuum anchor when the craft lands, which does away with the need for a mooring tower.

Roomy Interior

A **payload container** can carry the weight of up to 85 humvees.

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BIG VS. LITTLE

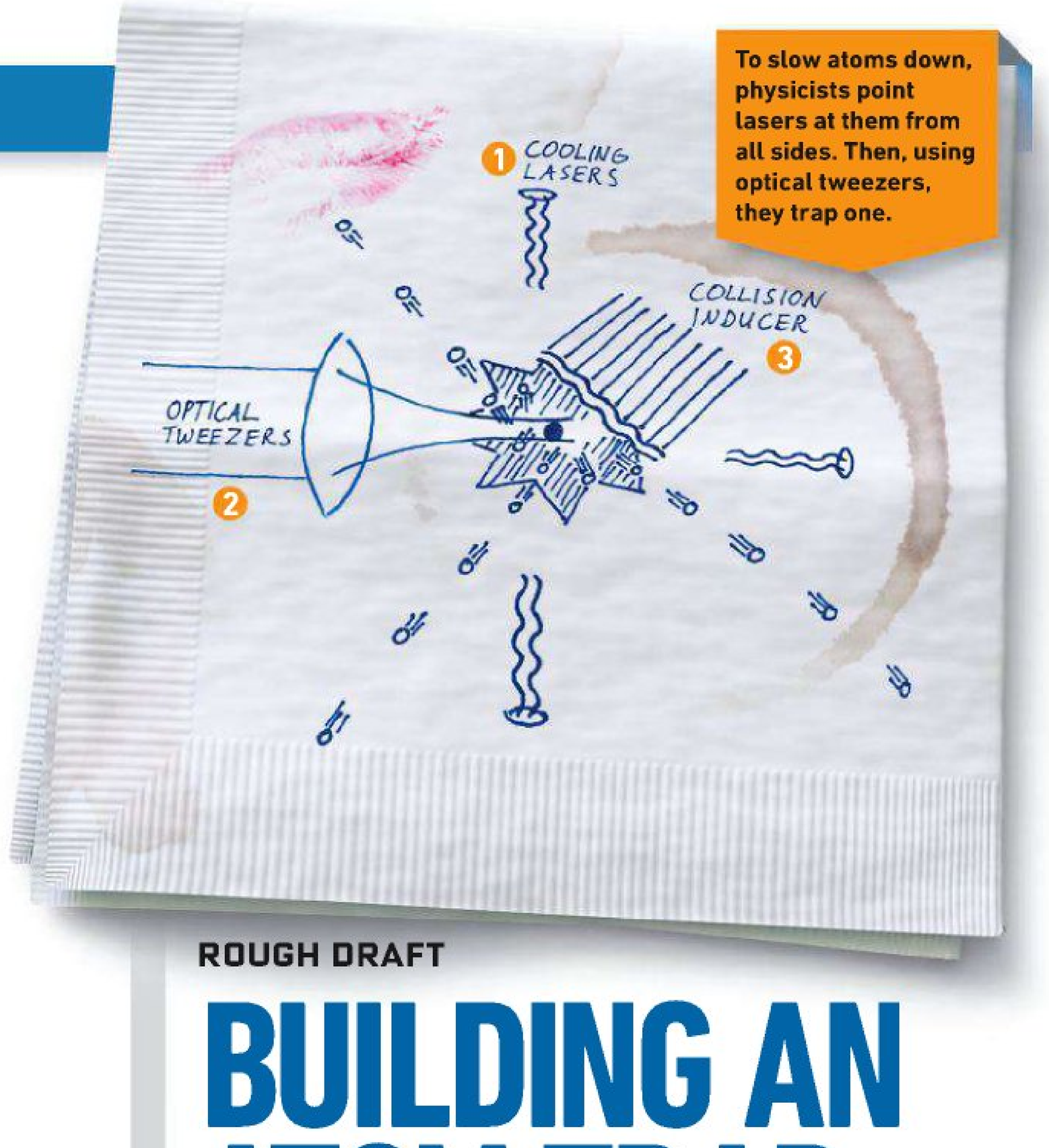
10,000

The weight, in pounds, **that a 10-centimeter-long, one-centimeter-wide metal-alloy rod can hold (the equivalent of an adult male Asian elephant).** The new material was developed by scientists at Lawrence Berkeley National Laboratory and the California Institute of Technology, who tried 109 alloys before finally settling on the right mix of palladium ($400 worth), phosphorus, silicon, germanium and silver, melted together at 2,700°F.—NATHAN EDDY

STAYING SHARP

The sea urchin secret

Sea urchins hide from predators by chewing into rock, so their teeth need to be very sharp and stay sharp, which they do. No one knew how until Pupa Gilbert, a physicist at the University of Wisconsin, put several of the echinoderms under an x-ray. She found that the teeth contain irregular bands of brittle organic material that function like perforated paper. The pressure from rock chomping continually chips the tooth at these bands, revealing new, razor-sharp calcite beneath. Gilbert was contacted by a a knife manufacturer interested in funding her research (she declined).—RYAN BRADLEY



To slow atoms down, physicists point lasers at them from all sides. Then, using optical tweezers, they trap one.

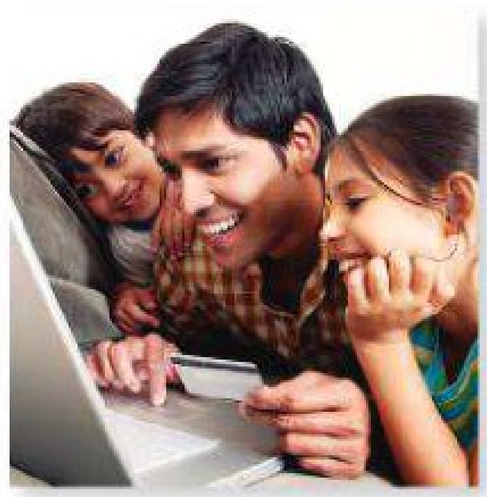
ILLUSTRATION: *COHERENTIMAGES.COM*; PHOTOGRAPH: PUPA GILBERT/UNIVERSITY OF WISCONSIN

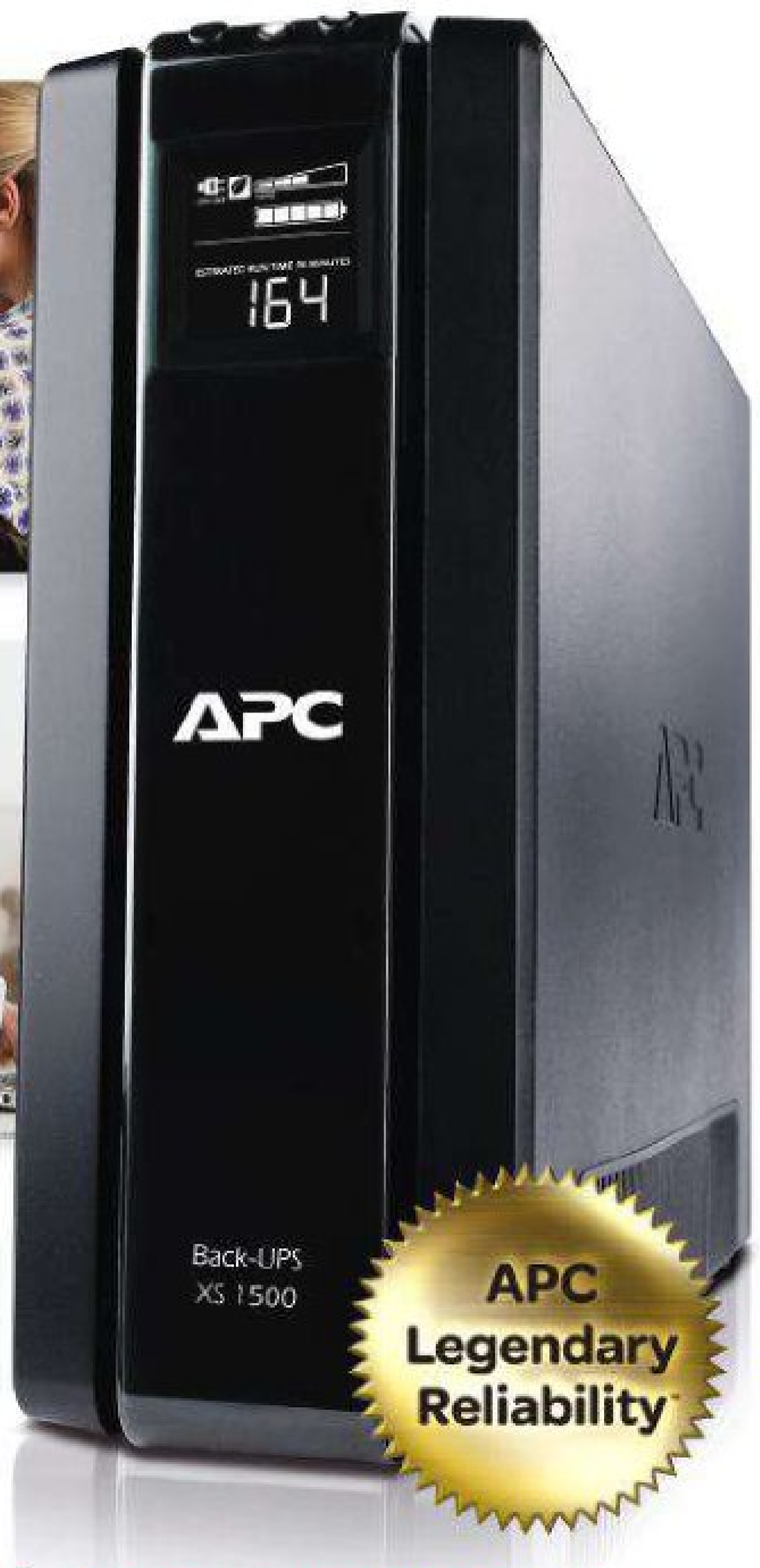
ROUGH DRAFT

BUILDING AN ATOM TRAP

"We created a method to control individual atoms, to get them exactly where we want them, when we want them: an atom trap. Atoms are very fast, so we use powerful cooling lasers to slow them down [1]. The lasers are on a table floating on air cushions, in a room without windows so we can't harm people on the street. We need laser beams coming from all directions so there's a force on the atom opposite its motion regardless of which direction it's moving. It's like a bicyclist's nightmare: Whichever way you go, the wind is against you. Because an atom is so small, light can bring it from moving at the speed of sound to complete rest over about half a meter [about 1.6 feet]. That's a bigger deceleration than a supersonic jet flying into a concrete wall. Then we turn on the optical tweezers [2]—a tightly focused laser that creates a strong electric field, which pulls the electrons in the atoms in one direction and the nucleus in the opposite direction—attracting the atom to the high-intensity region of the beam. We then use another laser to induce collisions and make the atoms repel each other out of the trap [3]. You consistently end up with just one atom left. Scientists only became confident that atoms exist 100 years ago. Now we let everyone who visits the lab trap their own atom and print the picture if they want to."—MIKKEL ANDERSEN, *a physicist at the University of Otago in New Zealand, as told to Flora Lichtman*

What's at risk if bad power damages your home network?





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HEADLINES HEALTH

THE DEATH OF A DISEASE

First we eradicated smallpox—rinderpest is next

The plague begins with a fever, weepy eyes and a drippy muzzle. Dysentery and diarrhea follow, and then death by dehydration. Rinderpest sweeps through a herd quickly, and can kill half its animals in a matter of weeks. The loss of thousands or even tens of thousands of cattle can devastate a community. An outbreak in 1889 killed enough of Ethiopia's livestock that the ensuing famine caused a third of the country to starve to death. But this summer, the Food and Agriculture Organization of the United Nations plans to formally announce rinderpest's eradication, making it the second scourge, after smallpox, to be intentionally wiped off the face of the Earth.

Rinderpest arrived alongside the domestication of cattle, in the Indus River valley about 10,000 years ago. It traveled west out of Asia with the Huns and Mongols. With the growth of the railroad, rinderpest spread so quickly that Europe was nearly cow-free in the 1870s.

PET MED

In 1761 Claude Bourgelat founded the first veterinary school in Lyon, France, as a response to rinderpest.

Epidemics continued among Africa's cattle and wildlife—including buffalo, antelopes and giraffes—well into the 20th century. Then, in 1950, an English veterinary pathologist named Walter Plowright started working in labs in Kenya and Nigeria. Soon he was growing rinderpest, and by the 1960s he had a weakened strain that gave lifelong immunity without side effects. Plowright had made a safe, inexpensive vaccine, and about 100 million doses were delivered throughout Africa from 1962 to 1969. But still the disease returned.

In the 1980s, Nigeria's new oil wealth created a demand for beef that brought cattle carrying rinderpest from as far as Somalia, and a pandemic soon swept across the continent. Another vaccination campaign followed. The African Union and the United Nations trained health workers and respected villagers, who inoculated livestock, tested animals, and watched for signs of infection—a rigorous education program absent from previous eradication efforts.

By sequencing the virus's genetic material, scientists discovered that there were several strains, which helped them track the disease to remote areas of East Africa (smallpox's last refuge, too) and focus their vaccination and surveillance.

The Food and Agricultural Organization says that rinderpest was last spotted in the wild in Kenya in October 2001. Following a decade of testing, the FAO believes that no infected animals remain on Earth. After a seven-decade fight, rinderpest lives on in laboratory freezers—and nowhere else.

—SUSANNAH F. LOCKE

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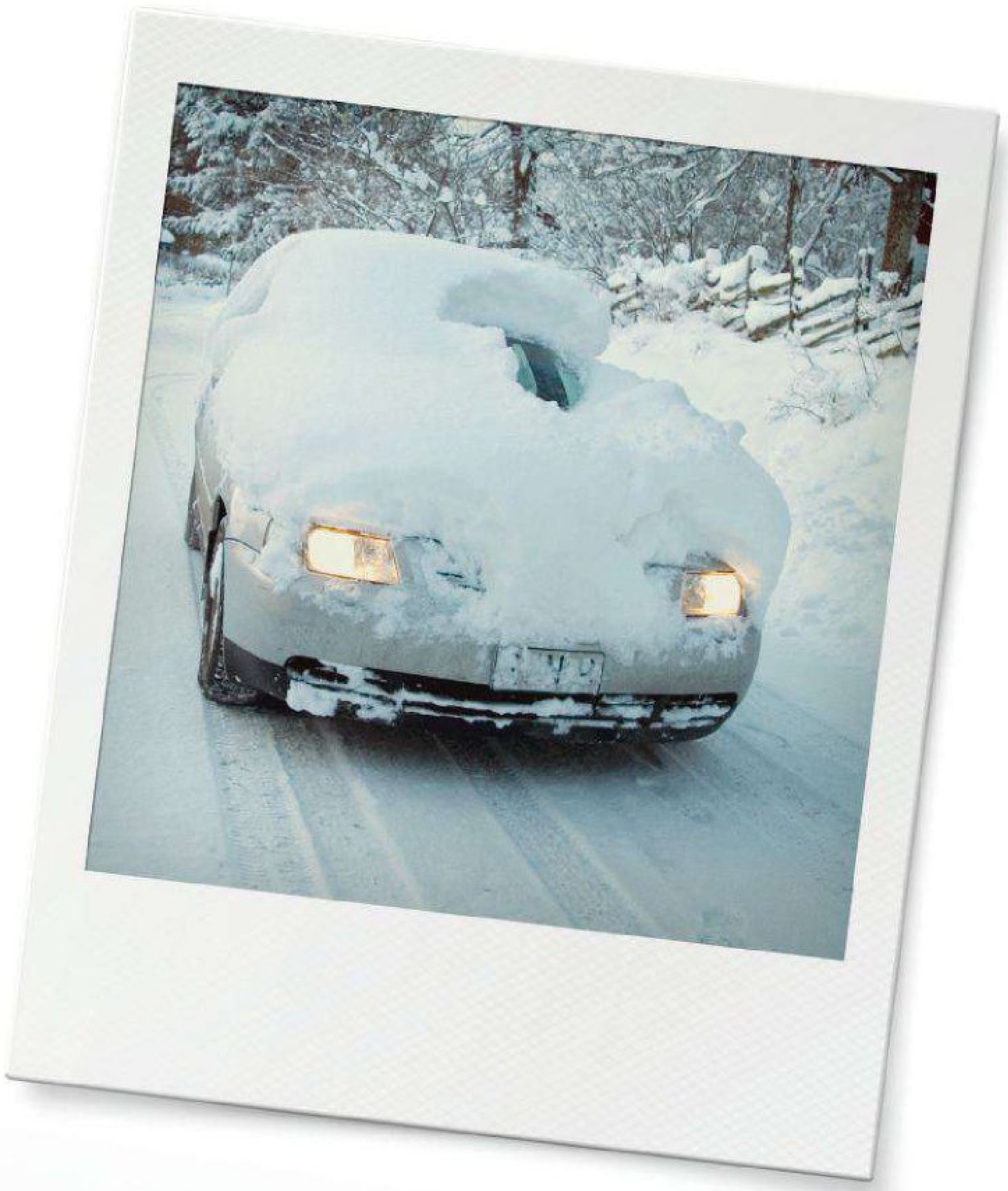
SO WHY ARE YOU PAYING LIKE HIM?



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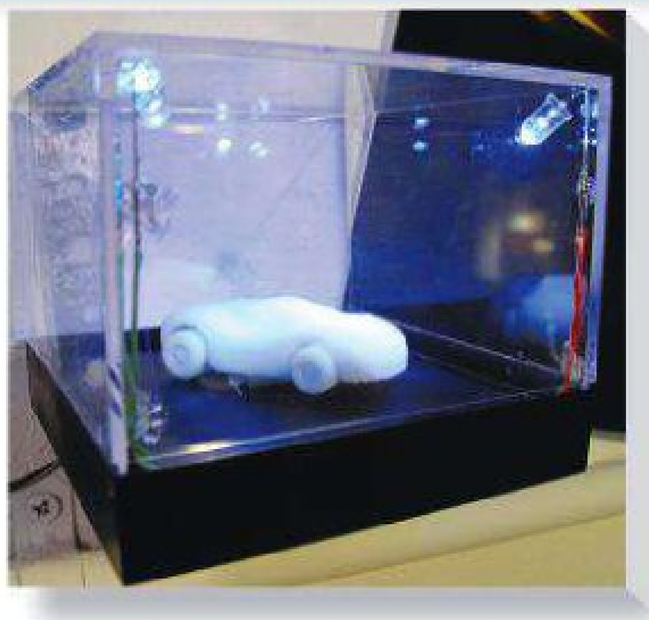
MEET UP, MAKE STUFF

Hackers return to their roots



Nearly 150 hacker spaces have opened in the U.S. in the past three years. Rather than havens of illicit computing, these communal workshops are places for members, in exchange for monthly dues, to get together and share equipment too big and dangerous for a home or garage (oscilloscopes, welding rigs, laser-cutters) and collaborate on projects too audacious to undergo alone (thought-controlled helicopters, helium balloons with autonomous robot pilots). In this way, the movement is a bit of a throwback—the first people to call themselves hackers were members of MIT's Model Railroad Club in the 1950s who were infamous for their manipulation of the school's lock and telephone systems.

Hijacking systems to make them work differently is what hackers do, and hacker-space members are no exception. A New York group called NYC Resistor created a 3-D printer they named MakerBot, which is open-source and can "print" its own parts. San Francisco's Noisebridge group built an anklet with a direction-sensing microchip and an array of pager motors. After a few hours, the wearer has an innate sense of magnetic north. Inventions birthed by the movement have been so prolific and of such high quality that they've been featured in this magazine before, most notably (and recently) a beer-dispensing slot machine.—BENJAMIN PHELAN

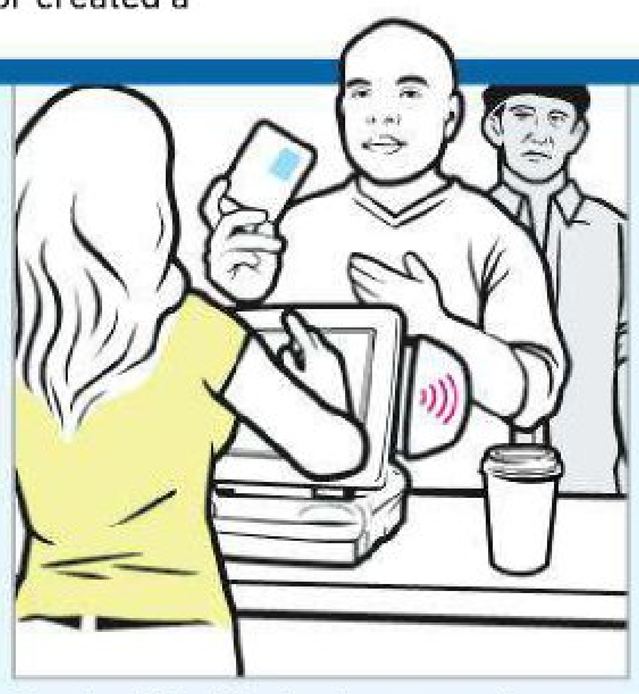
MANY HANDS The hacker-space movement is global—with a "Brain Machine" for meditation on display in Tokyo [top right], a 3-D RepRap printer from Vienna, Austria [top left], and labs in New York [insets above] and San Francisco [bottom right].

ILLUSTRATIONS: TODD DETWILER; PHOTOGRAPHS: SCOTT BEALE/LAUGHING SQUID AND MITCH ALTMAN

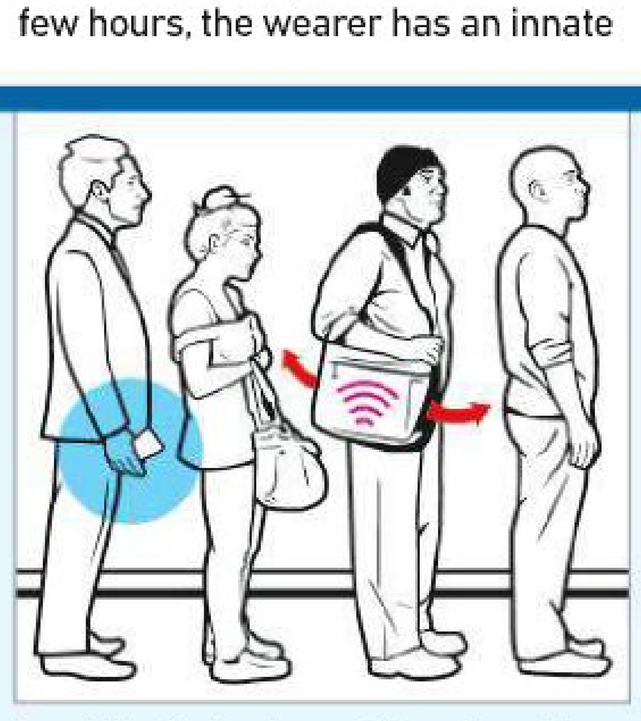
LOW TECH

FOILED!

The cheapest way to stop electronic pickpockets



More than 140 million Americans now make purchases by holding a radio-frequency-identification-embedded credit or debit card within inches of a reader.



A would-be thief can buy an RFID reader on eBay for $70, throw it into an innocuous-looking laptop bag, walk into a crowded area, and start stealing credit-card numbers and expiration dates.

The solution? Having multiple RFID cards produces conflicting transmissions that confuse the scanner. Or you can shield your wallet with aluminum foil.—KATHLEEN MASSARA

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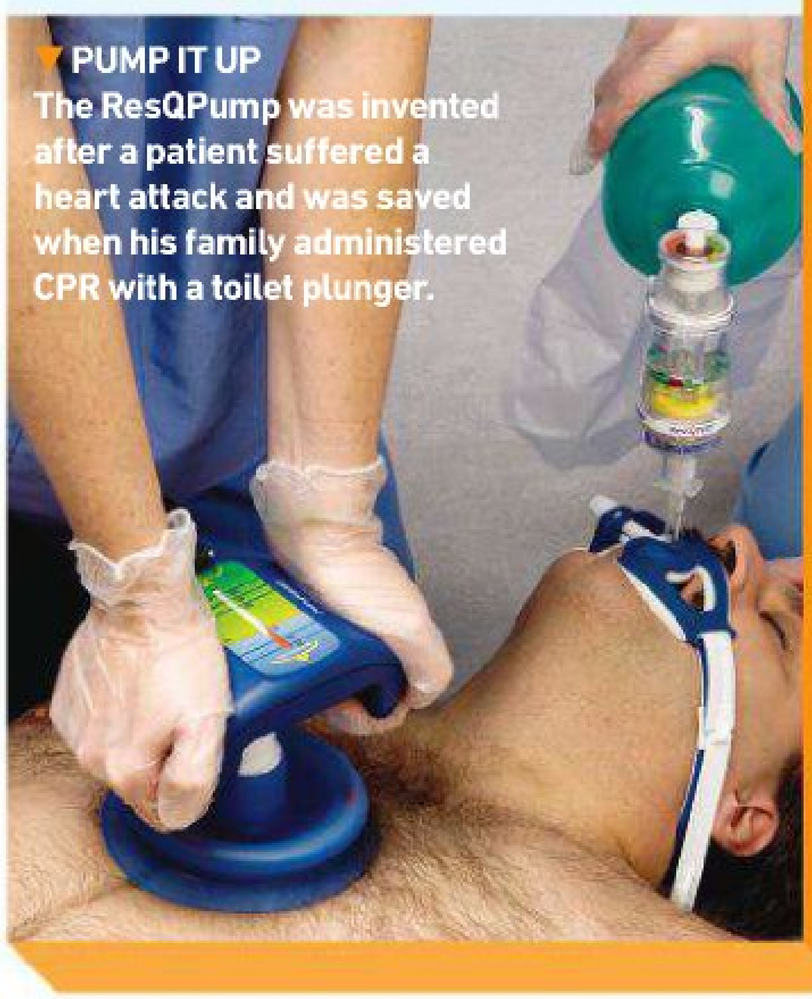
HEALTH

HEART PLUNGER

More than 325,000 Americans die every year from sudden cardiac arrest, but two simple CPR devices could reduce that number by 10,000. According to a study published in *The Lancet* this winter, the ResQPump, which is used for chest compressions, and the ResQPOD, which prevents too much air from entering the lungs during CPR, could increase certain cardiac-arrest victims' chances of survival by 50 percent. The ResQPump works like a toilet plunger, but while decompressing it can draw air back into the lungs. The ResQPOD, cleared by the FDA in 2003, regulates airflow by creating suction in the chest, which draws blood up into the brain. Both tools are made by Advanced Circulatory Systems in Minnesota. The study, led by Tom Aufderheide, a professor of emergency medicine at the Medical College of Wisconsin, had EMTs and doctors using the tools in combination in seven U.S. locations. Together the pump and "pod" increased patient survival from 6 percent to 9.

—CAITLIN KEARNEY



PUMP IT UP
The ResQPump was invented after a patient suffered a heart attack and was saved when his family administered CPR with a toilet plunger.

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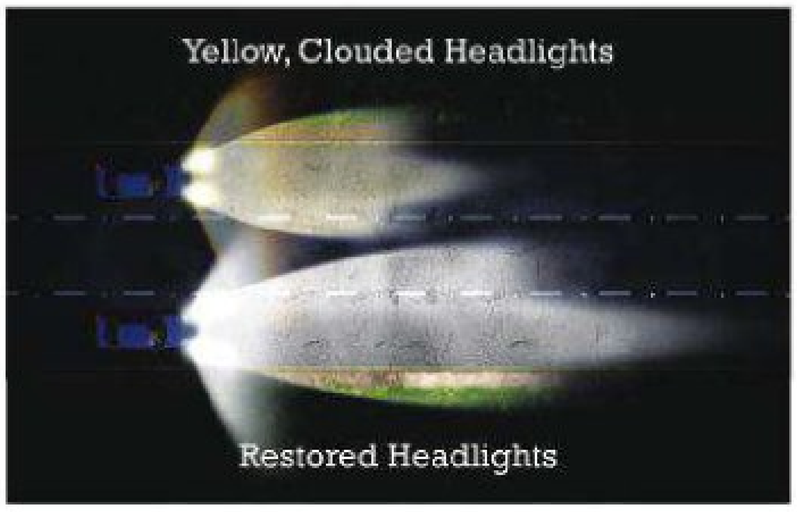

Not only is this an unsightly problem, but lower light output also reduces your ability to see at night, creating a serious safety concern.

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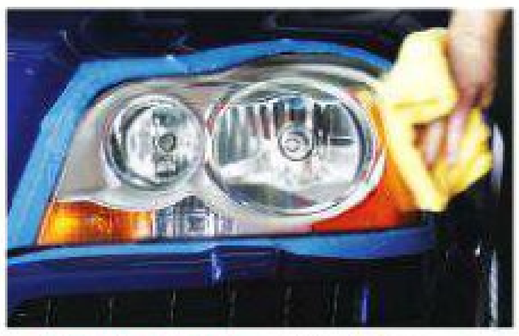

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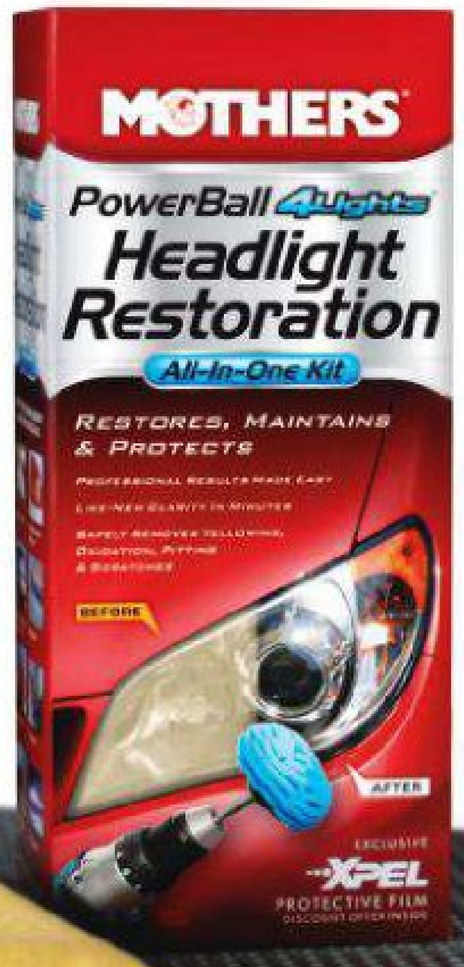


Q&A

DRIVING BLIND

In January, Mark Anthony Riccobono, who is blind, drove a modified Ford Escape hybrid on the Daytona International Speedway, turning to avoid obstacles. He navigated using feedback from the car's laser sensors and cameras, installed by a team of researchers from Virginia Tech and the company Torc Technologies. POPSCI spoke by phone to Riccobono, the executive director of the National Federation of the Blind's Jernigan Institute, which researches new technology for the blind.—JULIET LAPIDOS

How did you know when to turn?

The car's laser range-finding sensors sent data to a computer, which in turn sent me directional information. I was wearing gloves with motors in the knuckle. When I needed to make a sharp left, the motor on the left pinky vibrated. For a more gradual turn, the index finger, and so forth.

Did you have a sense of how fast you were going?

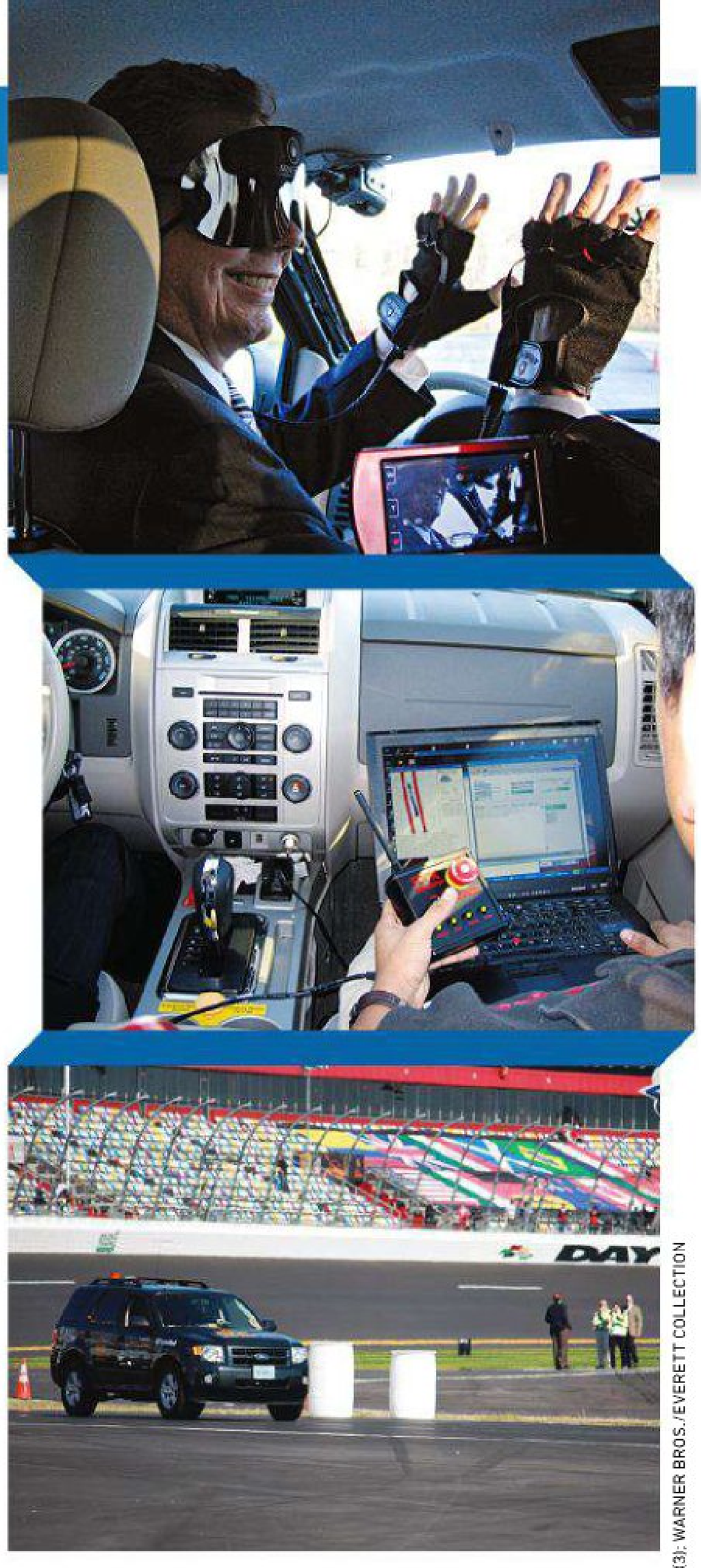
My top speed was 25 or 26 miles per hour, and I had a general feel for what the vehicle was doing. A strip on my seat gave me a more exact impression, kind of like looking at a speedometer. The strip also contained motors—it was like a massage chair. If I felt vibrations around my knees, I knew I needed to speed up. As I accelerated toward what the car considered a proper speed, the vibrations moved up my leg, toward my back.

What would you do to make cars even better in the future?

The car I drove has just two interfaces [the gloves and the driver's-seat strip]; I can imagine adding an auditory component that would provide advance information about oncoming turns or traffic. Like a GPS system: "Approaching a left turn in 500 feet."

And someday, blind drivers could get enough data to make decisions for themselves, rather than following the car's directions. But the Department of Motor Vehicles probably isn't going to change its vision requirements anytime soon. In the meantime, are there other applications for this technology?

Right now driving is purely visual, which is limiting, when you think about it. The work we're doing could encourage non-visual innovation. Everyone has a blind spot. Maybe there's an auditory solution to that problem. And if it's raining hard or there's a blizzard, drivers can't see the road clearly. The interfaces we've developed could help make driving easier and safer.



Mark Anthony Riccobono, who is blind, drove 1.5 miles along the Daytona International Speedway [bottom] without the aid of a sighted person. The car's laser sensors and cameras fed data to an onboard computer [middle], which sent steering cues to vibrating gloves [top].

FROM TOP: COURTESY NATIONAL FEDERATION OF THE BLIND/VIRGINIA TECH (3); WARNER BROS./EVERETT COLLECTION

INSURMOUNTABILITY INDEX
ARTIFICIAL INTELLIGENCE

INSURMOUNTABLE? Winning at war
Computers have long been a part of warfare—they cracked the German code during World War II. But in the future, will they be the generals?

HARDER: Winning on *Jeopardy* Watson, another IBM computer, trounced past champions earlier this year with programs that grasp the nuances of human language.

HARD: Winning at chess In 1997, using 256 parallel processors, IBM's Deep Blue beat Garry Kasparov, then the reigning world chess champion.

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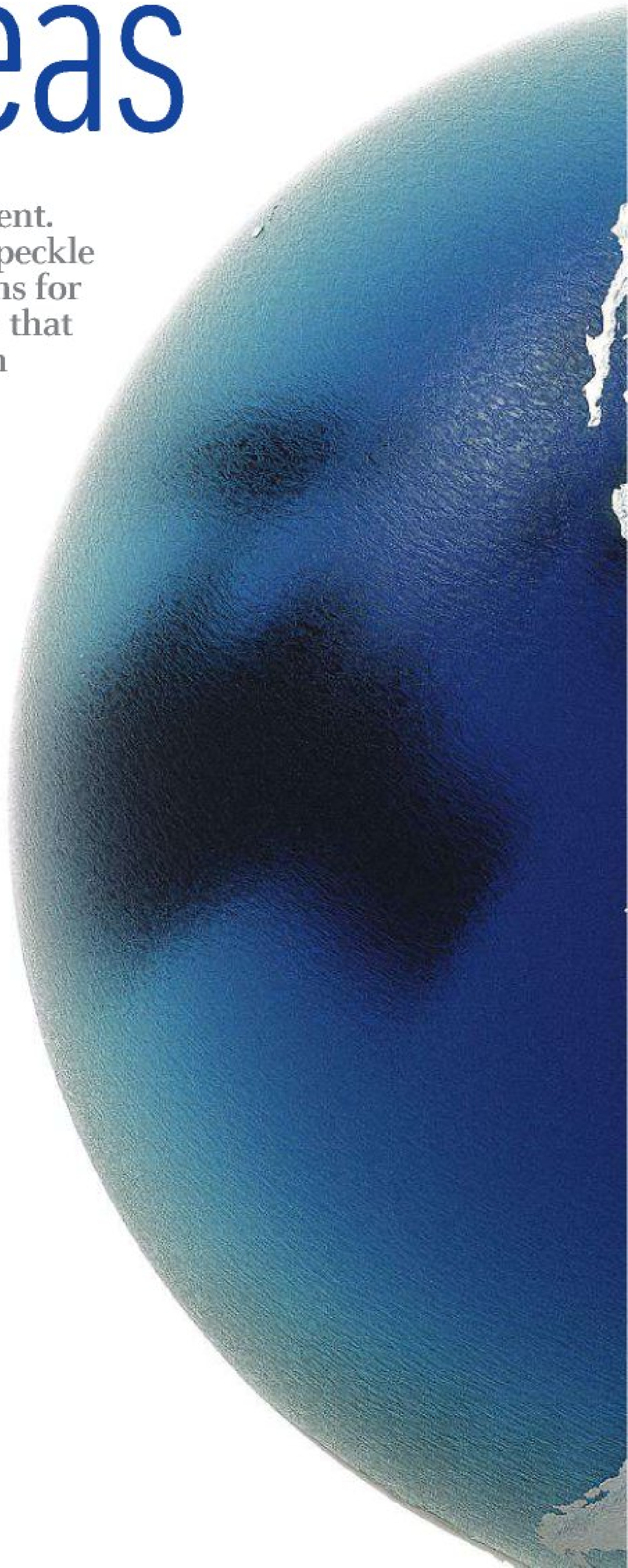
THE BIG FIX

Seven Ways to Save the Seas

The oceans are in trouble. Fish stocks are down 90 percent. Coral has died off by a third. Hundreds of dead zones speckle the globe. Yet amid these grim realities, there are reasons for hope—commonsense solutions and ambitious schemes that could rescue the oceans, and humanity along with them

ILLUSTRATIONS BY GRAHAM MURDOCH



Stop Filling Them with Poison

Marine pollution takes many forms, from the millions of gallons of oil that run off our highways each year to the Great Pacific Garbage Patch, a massive gyre of floating plastic trash. But the most devastating pollutants are the nitrogen and phosphorus found in our fertilizer and sewage. When too much of either washes downstream, coastal waters become choked with heavily fertilized algae, which then dies and decomposes, consuming the oxygen in the water and asphyxiating animal life. This process, called eutrophication, has created at least 405 "dead zones" worldwide.

Human sewage is the top source of eutrophication in the developing world, but in the U.S., Europe and China, animal waste and fertilizer are the main culprits. Every year in the U.S. alone, some 10 billion chickens, 80 million cows and 149 million pigs produce 500 million tons of manure, much of which is sprayed on fields. Farmers also add another 55 million tons of synthetic fertilizer to their cropland, much of which washes back into the watershed. The result: The largest dead zone on Earth spreads from the mouth of the Mississippi. In the summer, when Midwestern agricultural runoff reaches its peak, it can grow to be the size of New Jersey.

Eutrophication is reversible. In the 1980s, for instance, the Black Sea contained the planet's largest dead zone. But when the Soviet Union disintegrated, farmers there could no longer gain access to synthetic fertilizer; by 1996 the dead zone had disappeared entirely.

Similar results can be achieved without societal collapse. Improved wastewater treatment and more restrictions on livestock-manure management will help. But the greatest gains can be had simply by abandoning plowing. Over the past two and a half decades, farmers have adopted "no-till" methods on 36 percent of U.S. cropland. They leave the stubble and root structure of last year's crops in place, plant new seeds using modern seed drills, and deposit fertilizer beneath the surface using fertilizer injectors. In doing so, they reduce phosphorus runoff by about 40 percent, atmospheric nitrogen release by about half, and overall erosion by up to 98 percent—and achieve equal yields using just half the energy. "Still," says David R. Montgomery, the author of *Dirt: The Erosion of Civilizations*, "only about 5 percent of the world's farmland is worked with no-till methods. What happens on the rest may well shape the course of civilization."—ROWAN JACOBSEN

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TOO MUCH GROWTH Synthetic fertilizer draining from farmland has helped create at least 405 near-lifeless patches of ocean worldwide. Fertilizer and sewage generate the growth of algae [below, green], which, when it eventually dies, asphyxiates surrounding marine life.

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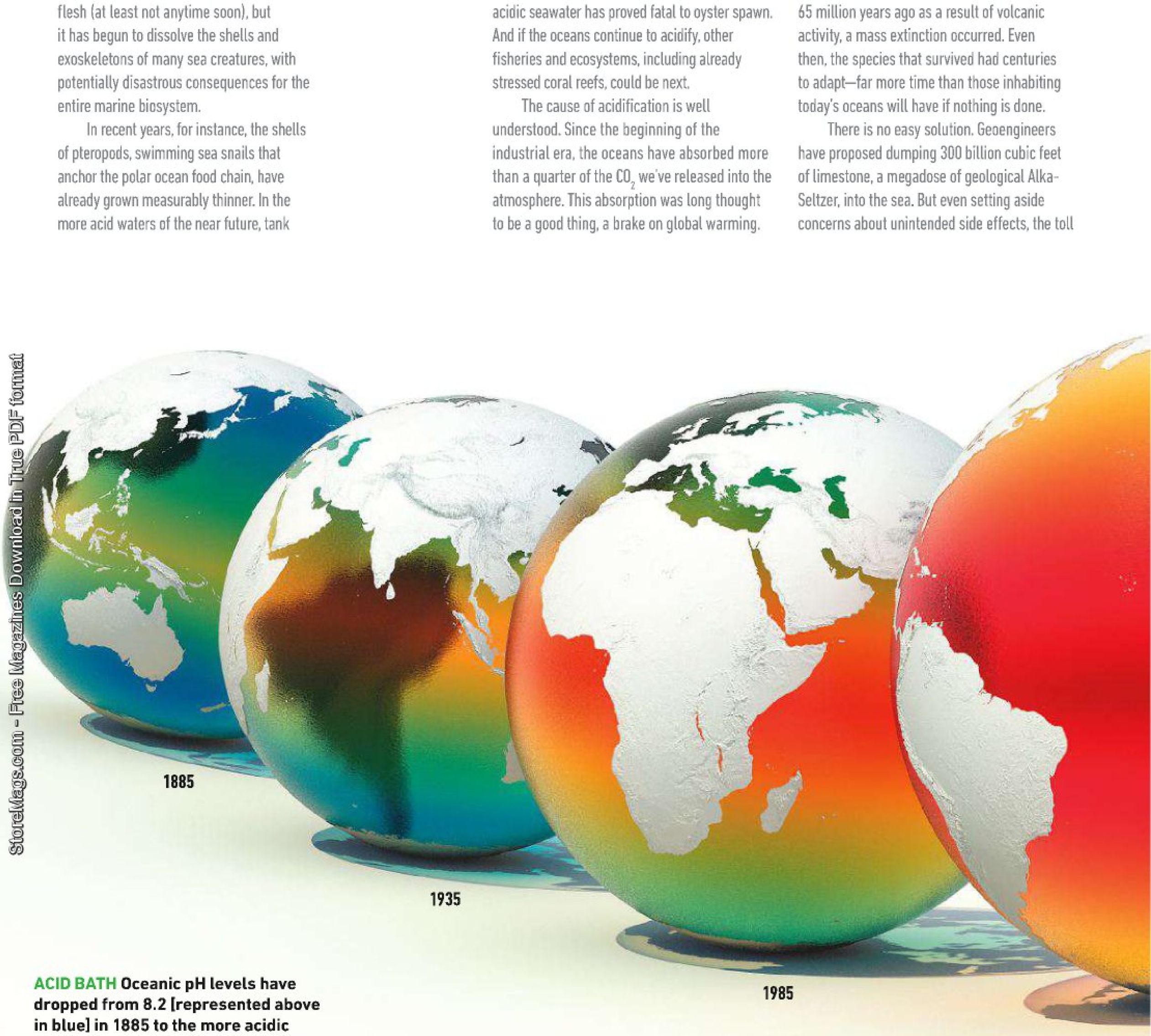
Put a Price on Carbon

In the past two centuries, at a pace unprecedented in the geological record, the chemistry of the oceans has changed. Seawater has become approximately 30 percent more acidic. It won't burn human flesh (at least not anytime soon), but it has begun to dissolve the shells and exoskeletons of many sea creatures, with potentially disastrous consequences for the entire marine biosystem.

In recent years, for instance, the shells of pteropods, swimming sea snails that anchor the polar ocean food chain, have already grown measurably thinner. In the more acid waters of the near future, tank experiments show, their shells will begin to disappear, scrolling up at the edges like melting candle rims. In the Pacific Northwest, meanwhile, acidic seawater has proved fatal to oyster spawn. And if the oceans continue to acidify, other fisheries and ecosystems, including already stressed coral reefs, could be next.

The cause of acidification is well understood. Since the beginning of the industrial era, the oceans have absorbed more than a quarter of the CO_2 we've released into the atmosphere. This absorption was long thought to be a good thing, a brake on global warming. But that brake comes at a high price. When CO_2 mixes with seawater, it forms carbonic acid. The last time the oceans acidified so dramatically, 65 million years ago as a result of volcanic activity, a mass extinction occurred. Even then, the species that survived had centuries to adapt—far more time than those inhabiting today's oceans will have if nothing is done.

There is no easy solution. Geoengineers have proposed dumping 300 billion cubic feet of limestone, a megadose of geological Alka-Seltzer, into the sea. But even setting aside concerns about unintended side effects, the toll



ACID BATH Oceanic pH levels have dropped from 8.2 [represented above in blue] in 1885 to the more acidic level of 8.0 [orange] in 1985. By 2085, that number could reach 7.8 [red].

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in dollars and emissions to produce that much alkaline antidote is prohibitive, and the benefits would be temporary. The best and perhaps only cure? Reduce CO_2 production. The problem is, in part thanks to subsidies in the U.S. tax code, the dirty burning of fossil fuels remains cheaper than cleaner alternatives, a "savings" that does not account for the cost of environmental damage caused by carbon pollution.

How to reckon the real price? "A carbon tax is the preferred method," says Hauke Kite-Powell, a researcher at Woods Hole Oceanographic Institution in Massachusetts. By one estimate, a tax of just $12.50 per *ton* of CO_2 would reduce emissions by 30 percent, keeping some 214 million tons of pollution out of the ocean. That wouldn't bring acidification to a halt, but it would buy the oceans—and us—some badly needed time.—DONOVAN HOHN

A TAX OF JUST $12.50 PER TON OF CO_2 WOULD REDUCE CARBON EMISSIONS BY 30 PERCENT, KEEPING SOME 214 MILLION TONS OF POLLUTION OUT OF THE OCEAN.

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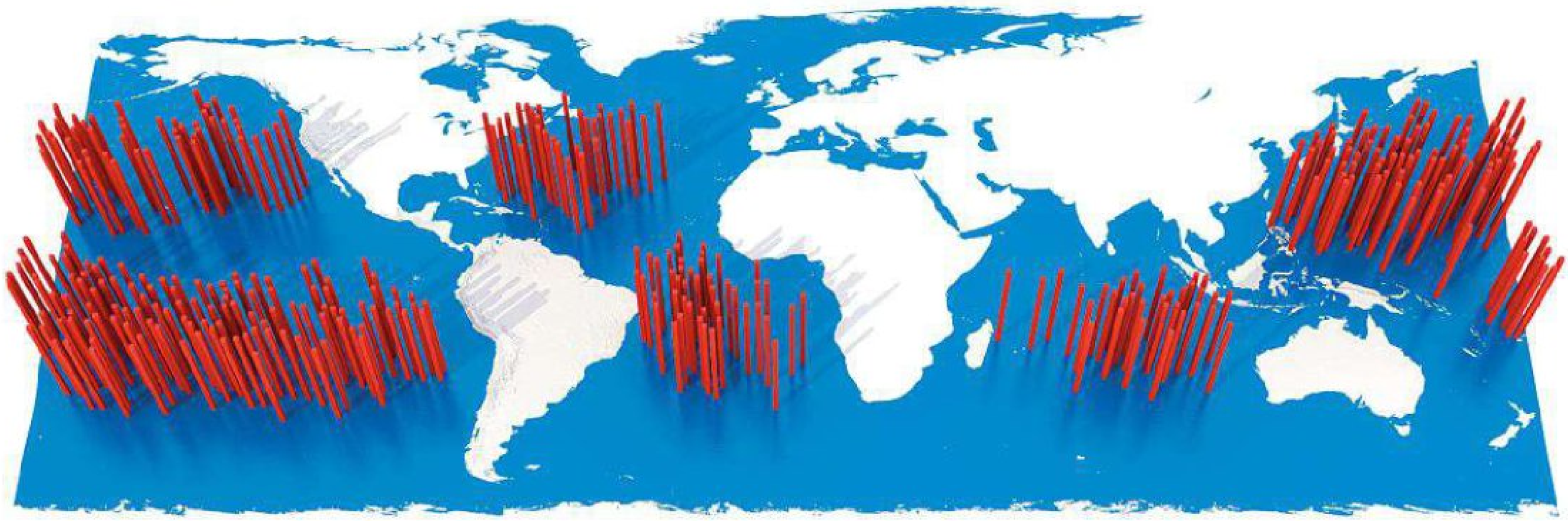


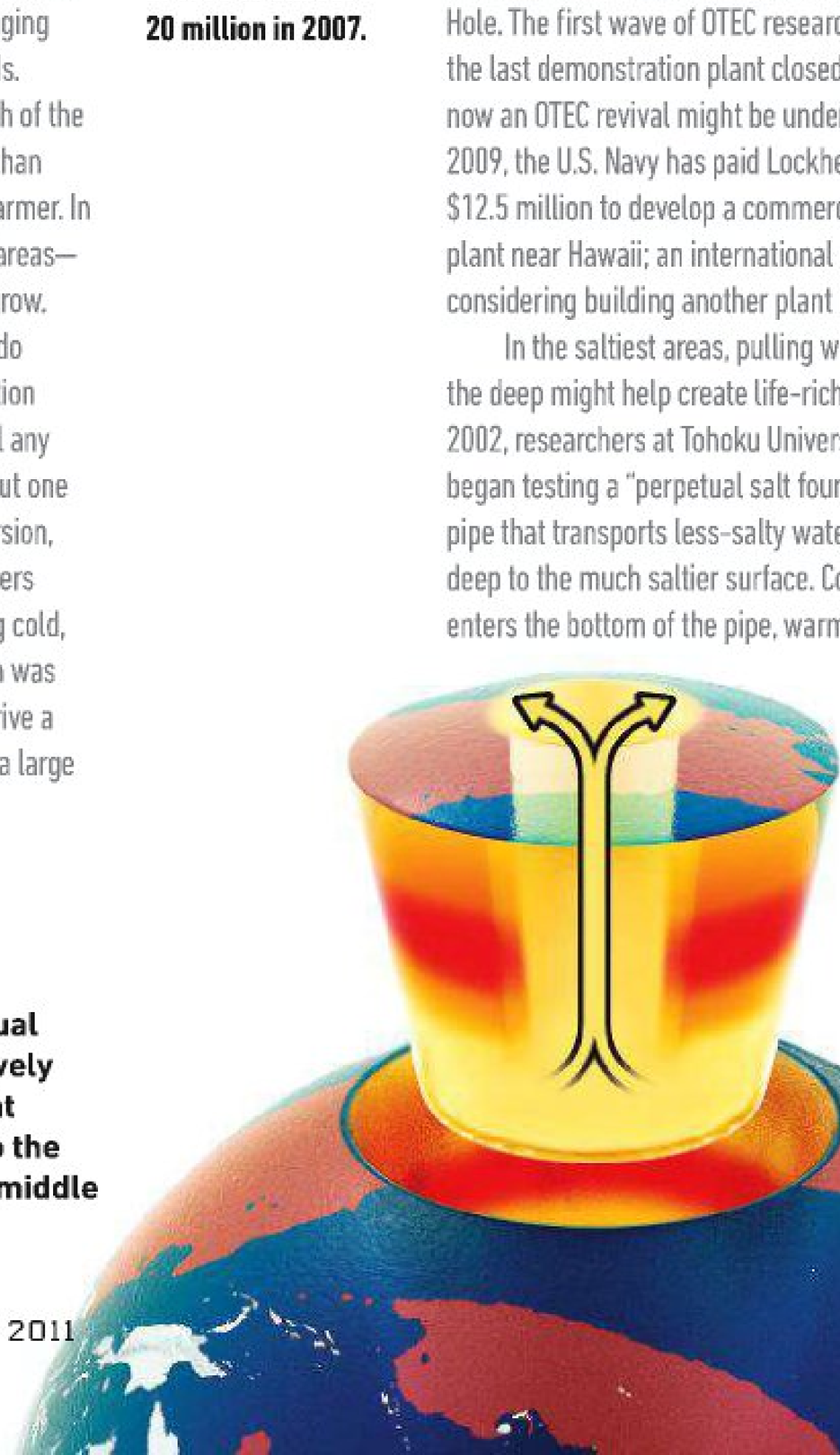
Repair the Water Cycle

As the atmosphere warms, the water cycle—the process by which seawater evaporates, rains down, and then evaporates again—will intensify. Everywhere, the ocean surface will become, on average, saltier. The extra evaporated water vapor will rain down disproportionately in areas such as the tropics and Scandinavia, bringing stronger storms and more frequent floods. Meanwhile, the areas just north and south of the tropics, which already tend to be saltier than other regions, will become saltier and warmer. In the very saltiest areas, existing "desert" areas—those too salty to host most life—could grow.

So far, scientists have been able to do about as much to reverse the intensification of the water cycle as they have to control any other aspect of the weather: not much. But one technique, Ocean Thermal Energy Conversion, or OTEC, might help. In the 1970s, engineers began using platform-based rigs to bring cold, deep water to the warm surface; the idea was that the temperature difference would drive a heat engine, generating energy. Used on a large scale, OTEC could have the healthy side effect of lower the surrounding surface temperatures, and that would be a very good thing. "If we lower the seasonal surface temperature, then we should expect the water cycle to become less intense," says Ray Schmitt, an oceanographer at Woods Hole. The first wave of OTEC research died when the last demonstration plant closed in 1998, but now an OTEC revival might be under way. Since 2009, the U.S. Navy has paid Lockheed Martin $12.5 million to develop a commercial OTEC plant near Hawaii; an international consortium is considering building another plant in Tahiti.

In the saltiest areas, pulling water from the deep might help create life-rich oases. In 2002, researchers at Tohoku University in Japan began testing a "perpetual salt fountain," a thin pipe that transports less-salty water from the deep to the much saltier surface. Cold water enters the bottom of the pipe, warms, and then rises—but as it warms, it remains relatively fresh and rich in nutrients that stimulate the growth of chlorophyll and phytoplankton. For their project, the Japanese researchers have deployed a floating, GPS-equipped, 984-foot PVC pipe in the Mariana Trench area in the Pacific Ocean, and the early results are promising. "Just outside the pipe, the concentration of chlorophyll was enormous," says Shigenao Maruyama, the head of the research team. "About 100 times larger than in the surrounding sea area." Like OTEC, the salt fountain would be only a stopgap measure—a way to treat the symptoms of global warming rather than a solution to the underlying problem. But Maruyama is optimistic about the salt fountain's potential to repair damage on a local scale, and the experiments are scheduled to continue next year with a new salt fountain in the open ocean.—ABE STREEP

▲ **LOW LIFES** **Ocean "desert" areas, pinpointed on the map above, grew from 17 million square miles in 1998 to almost 20 million in 2007.**



THE SALT FOUNTAIN RAISED CHLOROPHYLL LEVELS A HUNDREDFOLD.

▶ **RUNNING WATER** **A "perpetual salt fountain" could pull relatively fresh, nutrient-rich water [light yellow] from the deep ocean to the surface, creating oases in the middle of marine deserts.**

Curb Species Invasions

Fifty years ago, if you pulled a mooring rope from the waters off Cape Cod, it would have emerged covered with mussels, barnacles and algae. Today the lines would be coated with slimy invertebrates called tunicates, one of some 4,000 known invasive aquatic species worldwide. Spread by global trade, invasive species as diverse as tunicates in the Northeast, lionfish in the Southeast, and mangrove trees in Hawaii are competing with native species for resources, attacking indigenous organisms, and restructuring habitats.

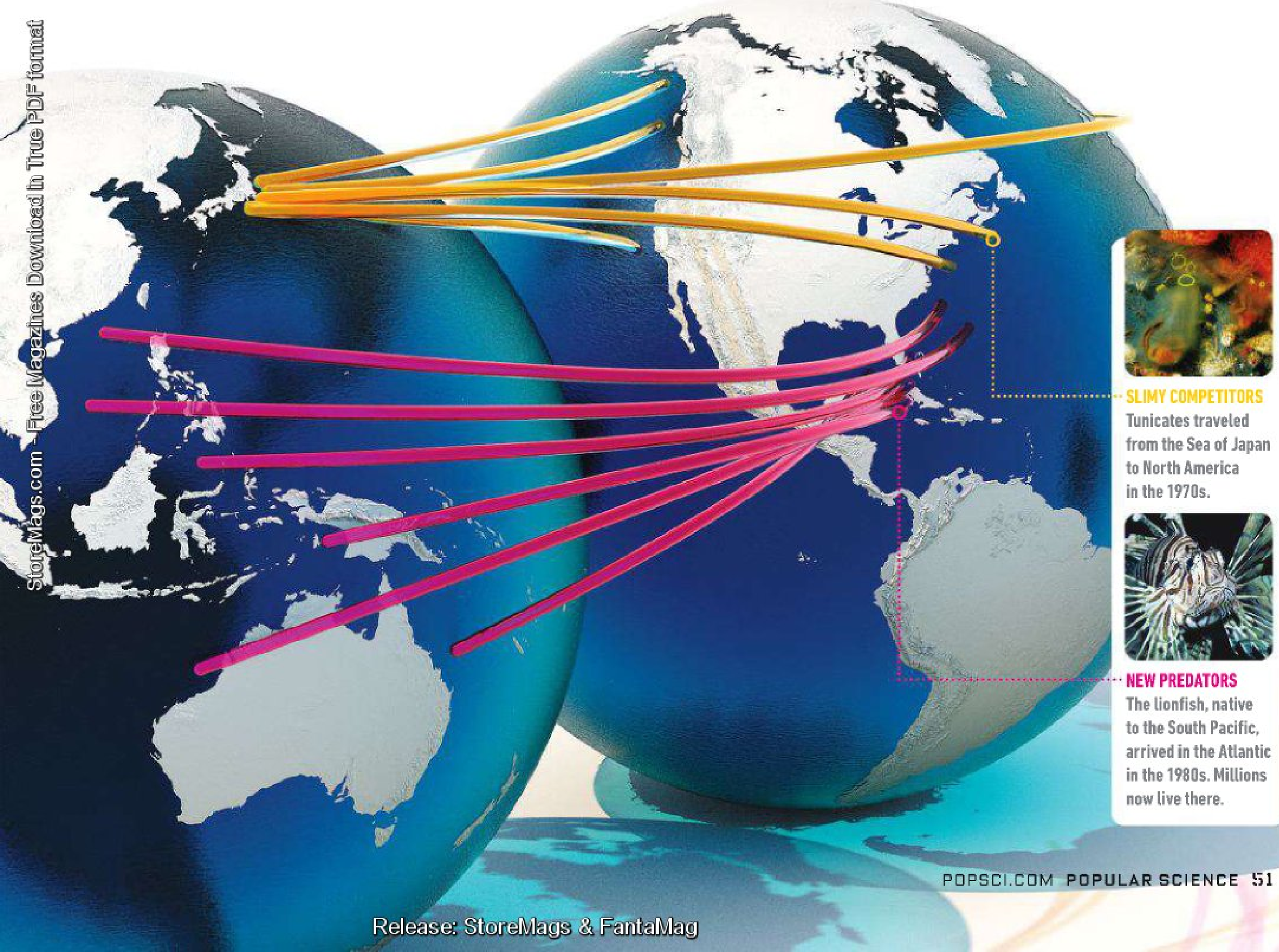
FROM TOP: DANN BLACKWOOD/USGS/WOODS HOLE; KEVIN SCHAFER/GETTY IMAGES

THE BEST HOPE IS TO CONTROL THEIR NUMBERS—EVEN BY EATING THEM.

Tunicates provide a vivid example of how an invasive species can devastate its environment. At least one species came to New England in the 1970s, possibly on a Japanese shipping vessel, says Mary Carman, a researcher at Woods Hole. Some tunicate species have invaded Cape Cod eelgrass beds, pushing out the bay scallop, a major source of income for local fisherman. Attempts to eradicate tunicates with scrubs and bleach dips have met with little success; even a tiny remaining snippet may rebloom into an entire colony. "Their resilience and plasticity are amazing," Carman says.

"In general, we view invasions as toothpaste out of the tube," says ecologist James Carlton of Williams College. "You can't stuff it back in." Even in the rare case of early detection, removal is challenging. In 2000, a diver spotted an invasive seaweed that had recently been dumped in a San Diego County lagoon; it took six years and $7 million to remove.

The best way to reduce invasive species is to prevent them from arriving in the first place. Most appear in the ballast water of the approximately 100,000 commercial vessels that sail to the U.S. every year. The EPA and the Coast Guard are now writing ballast-water regulations, which would set tolerance levels for organisms in ballast water. Meanwhile, dozens of companies are developing techniques for meeting those standards, including computerized filtration and ultraviolet irradiation. But for established invaders, the best hope is to control their numbers—even by eating them. In 2009 the National Oceanic and Atmospheric Administration launched a program to stimulate an appetite among fishermen, chefs and diners for lionfish.—BROOKE BOREL



SLIMY COMPETITORS
Tunicates traveled from the Sea of Japan to North America in the 1970s.

NEW PREDATORS
The lionfish, native to the South Pacific, arrived in the Atlantic in the 1980s. Millions now live there.

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Rescue Coral Reefs

In the past 20 years, nearly a third of the world's coral has been destroyed. Around 90 percent of the reefs off the coasts of Sri Lanka, Tanzania, Kenya, the Maldives and the Seychelles are at risk. If ocean temperatures rise by another 7°F in the next three decades, as is predicted, 95 percent of the Great Barrier Reef will disappear. The primary cause of the die-off is coral bleaching. As temperatures rise, marine bacteria flourish and attack the algae that live symbiotically within every individual coral polyp. The algae photosynthesize sunlight into energy (in the form of sugars) for their hosts and give coral its color. When the algae dies, what's left is a ghostly white.

Some corals in the Red Sea and the Persian Gulf have avoided this fate, although no one knows exactly why. Eugene Rosenberg, a microbiologist at Tel Aviv University, has proposed that the presence of a different form of bacteria is what has made the difference. "Coral has thousands of bacterial species living within it, just as humans do," he says. "These bacteria can help coral adapt to environmental changes."

GHOST CORAL
Bleached staghorn coral in Indonesia's Banda Sea, the site of extensive recent reef damage.

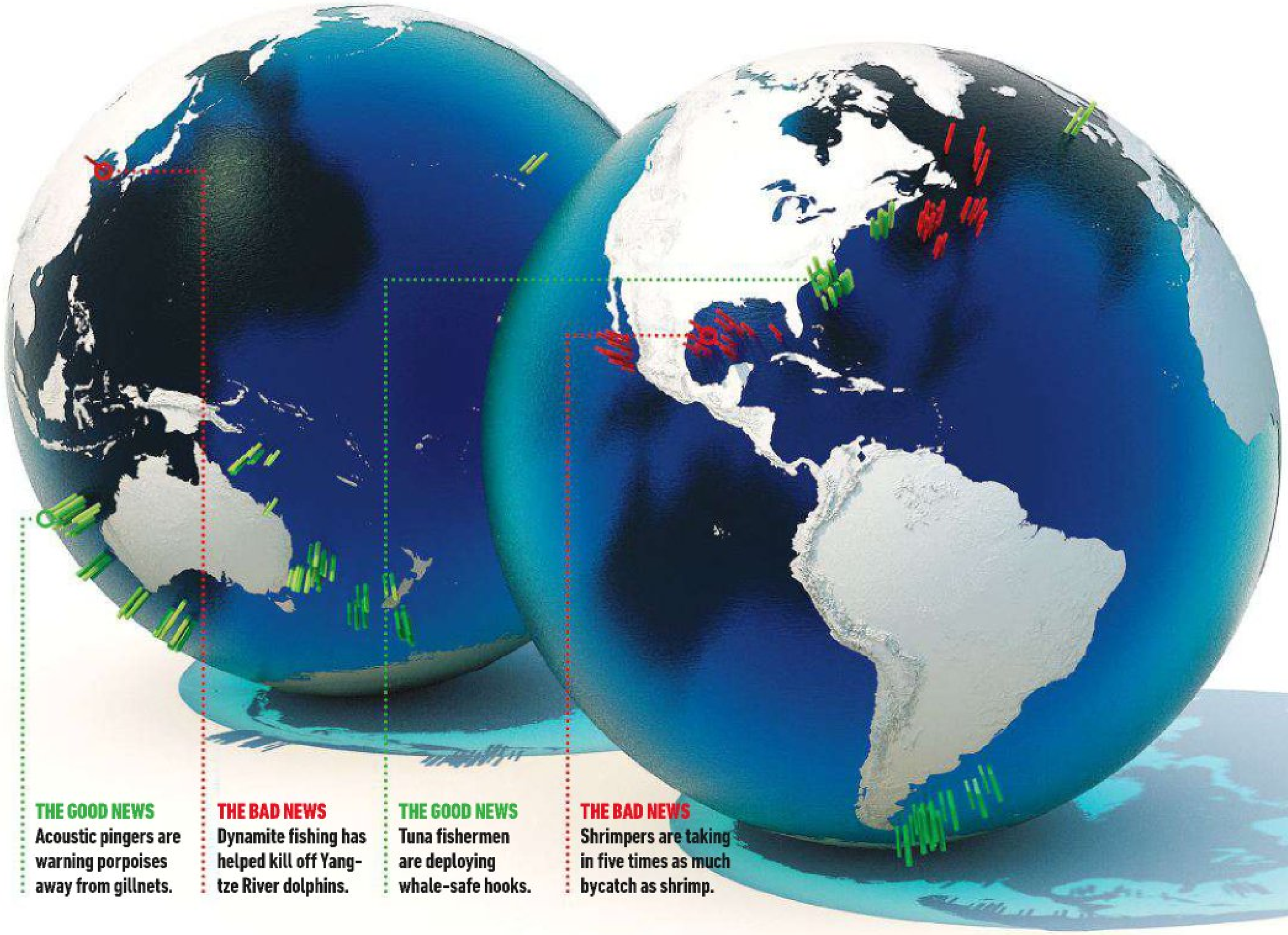
▼ THE DAMAGE
Ninety percent of Australian and Indonesian reefs [below, red] are threatened by bleaching.

When water temperatures rise to 77° in the Red Sea, for instance, a nonresident species of bacteria called *Vibrio coralliilyticus* attacks the algae of some corals. But that same temperature spike may also trigger some of the corals' bacteria to defend the algae, which could explain why certain corals aren't susceptible to bleaching even at high temperatures.

Now Rosenberg and his colleagues are investigating how to boost all corals' natural defenses. One tactic involves unleashing bacteriophages—bacteria-attacking viruses—on *V. coralliilyticus*. In recent lab experiments, the phages quickly destroyed the bleaching bacteria and remained on the coral for two months, staving off further attacks. This summer, in parts of the Great Barrier Reef and the Red Sea's Eilat Reef where some spotty bleaching has occurred, Rosenberg will field-test "phage therapy." He will surround diseased coral with healthy corals, and in one sample he will introduce a phage. If things unfold as they did in the lab, the phage will attach itself to *V. coralliilyticus*. When the attacking bacteria reach the nutritionally rich mucus layer of the healthy corals, the phage will multiply 100 times over and overwhelm its host. Rosenberg predicts that his phage-less control samples will become bleached in a week or two.

If he gets positive results, the next logical step will be a much larger-scale application. Rosenberg says that with a little more than 13 gallons of liquid, mixed at a concentration of four million phages per gallon, he could treat roughly 30 miles of coral. The application would require a boat or a plane. "We're talking about covering a lot of reef," he says.—PAUL KVINTA

GETTY IMAGES/STEPHEN FRINK



Fish Smarter

Last year, fish consumption reached a global annual average of 37.5 pounds per person. Meanwhile, cod and bluefin-tuna populations have collapsed, and animals ranging from whales to turtles have been added to the Endangered Species Act. Our voracious appetite isn't the only problem. Fishermen catch a lot of things unintentionally, in what Tim Werner, director of the New England Aquarium's Marine Conservation Engineering program, calls the "collateral damage" of commercial fishing: bycatch. Bycatch ensnares coral, sponges, starfish, sharks, whales, turtles and even birds. It is "one of the more immediate threats that marine diversity faces," Werner says. It has led to the assumed extinction of the Yangtze River dolphin, has nearly wiped out the Gulf of California's vaquita porpoise (fewer than 200 remain), and threatens the survival of the North American right whale (400 remain) and the short-tailed albatross. A United Nations report estimates bycatch at 7.5 million tons a year, or 5 percent of the total commercial-fishing haul. Because most available data is self-reported, Werner says that the U.N.'s numbers "woefully underestimate" the problem. A more representative statistic, he says, comes from Gulf of Mexico shrimp fisheries, some of which dredge up to five pounds of bycatch for every pound of shrimp.

COURTESY DAN FOSTER

TURTLE FILTER
"Turtle-excluding devices" reduce the number of turtles caught in trawl nets by 97 percent, while only minimally reducing the shrimp catch.

The good news is that compared with the more intractable problem of overfishing, technological solutions to reduce bycatch abound. Shrimp companies, for example, have begun using "turtle-excluding devices," metal grates at the front of a trawl net that let the shrimp in and keep the turtles out. Fishermen who use long subsurface "gillnets" have begun to deter porpoises by equipping these nets with battery-powered acoustic "pingers." In the best cases, pingers have reduced casualties from 25 porpoises per net to one. At Florida Atlantic University, associate professor Stephen Kajiura is trying to protect sharks by affixing rare-earth elements to the lines that fishermen use to catch tuna. The metals react with seawater to create an electromagnetic field that repels sharks (as well as skates and rays).

The most effective solutions will be those that are cheap and easy to implement. Jeffry Fasick, an assistant professor at Kean University, is studying the vision of the North Atlantic right whale in an effort to develop brightly colored ropes that the animals can see and avoid. The quintessential cheap-and-easy fix, however, may be the "weak hook," thinner hooks that bend under the weight of animals (bluefins, sharks, whales) larger than the yellowfin tuna they're designed to catch. In a field test, NOAA found that weak hooks reduced bycatch of endangered bluefin tuna by 56 percent—results significant enough that the agency may soon mandate weak hooks in bluefin-tuna territory.—JOSH DEAN

COMPARED WITH THE MORE INTRACTABLE PROBLEM OF OVERFISHING, TECHNOLOGICAL SOLUTIONS TO BYCATCH ABOUND.

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Increase Our Knowledge

All we really know is that we know very little. We don't know how temperatures are changing in the midwater zone: Satellite sensors penetrate less than seven feet below the surface. We don't know the terrain: Our charts cover less than 10 percent of the seafloor. And we don't know what lives there: The scientists who completed the first Census of Marine Life, an international research initiative, last year documented some 190,000 species—but know next to nothing about as many as a million more.

So it can be easy to feel lost at sea. A group of scientists at the University of California at Berkeley, for instance, claimed that a previously unknown, petroleum-munching microbe accounted for the surprise disappearance of a 22-mile-long oil plume after the Deepwater Horizon disaster in the Gulf of Mexico last year. But others argued that the plume hadn't disappeared at all, or that we simply didn't know enough to know if it had. "The true unknown is the interdependencies, the absolutely complex linkages," says Larry Mayer, the chairman of a National Academy of Sciences committee studying the gulf's ecosystems after the spill. "When you start asking questions about the impact of midwater oil on deepwater biota, or how that cascades into the atmosphere, or how that affects clams and mussels—things like that, nobody really knows."

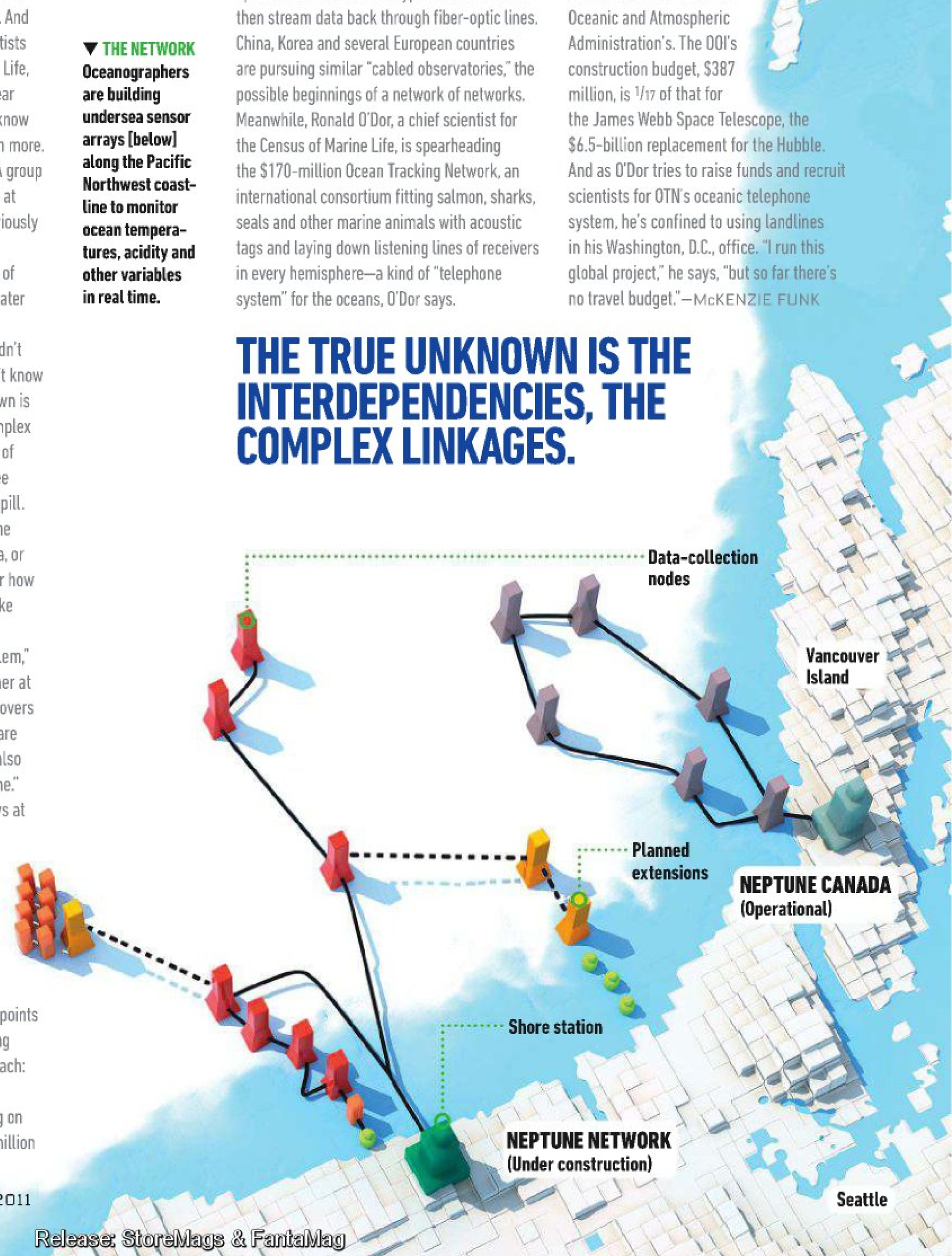
"The scale of the oceans is the problem," says Giora Proskurowski, an oceanographer at the University of Washington. Saltwater covers 71 percent of the planet, 139 million square miles. "But it's not just surface area; it's also depth. And it's that they're dynamic in time." Research vessels motor for five or 10 days at $25,000 a day just to reach the middle of an ocean. In deep water, generating a full salinity and temperature profile can mean parking in the same spot for more than four hours, unspooling and then retracting 10,000 feet of wire.

Shipboard sampling is necessarily piecemeal—single points in space, single points in time. Now, though, scientists are pushing for a radically more comprehensive approach: continuous data collection. Proskurowski, Mayer and hundreds of others are working on the National Science Foundation's $760-million Ocean Observatories Initiative (OOI), which will wire the Pacific and Atlantic with a network of data and power cables. The network will send 200 kilowatts out to sea to power remotely operated vehicles and 49 types of sensors and then stream data back through fiber-optic lines. China, Korea and several European countries are pursuing similar "cabled observatories," the possible beginnings of a network of networks. Meanwhile, Ronald O'Dor, a chief scientist for the Census of Marine Life, is spearheading the $170-million Ocean Tracking Network, an international consortium fitting salmon, sharks, seals and other marine animals with acoustic tags and laying down listening lines of receivers in every hemisphere—a kind of "telephone system" for the oceans, O'Dor says.

Which brings us to another way we can save the seas: money. NASA's exploration budget is 900 times that of the National Oceanic and Atmospheric Administration's. The OOI's construction budget, $387 million, is 1/17 of that for the James Webb Space Telescope, the $6.5-billion replacement for the Hubble. And as O'Dor tries to raise funds and recruit scientists for OTN's oceanic telephone system, he's confined to using landlines in his Washington, D.C., office. "I run this global project," he says, "but so far there's no travel budget."—McKENZIE FUNK

▼ THE NETWORK
Oceanographers are building undersea sensor arrays [below] along the Pacific Northwest coastline to monitor ocean temperatures, acidity and other variables in real time.

THE TRUE UNKNOWN IS THE INTERDEPENDENCIES, THE COMPLEX LINKAGES.



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SIXTIETH ANNIVERSARY

Focal length: 270mm (equivalent to 419mm) Exposure: F/6.3 1/640 sec ISO320 WB: Auto Handheld

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[1] For high-zoom-ratio DSLR camera lenses with 15x magnification, as of December 2010. (Source: Tamron)
* Sony digital SLR camera bodies rely on the camera's image stabilization function. For that reason, the VC (Vibration Compensation) image stabilization function is omitted from lenses manufactured with Sony DSLR mount.
* This lens is designed for use only with APS-C sensor digital SLR cameras.

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What Would You Do?

We asked 12 of the world's foremost ocean experts—from scientists to policymakers to a sea captain—how they would begin to save the seas

The Food and Agriculture Organization of the United Nations reports that by 2048, most commercial fisheries will have collapsed. If fishing collapses, so do we. **I know it sounds sort of dramatic, but commercial fishing has the potential to destroy civilization as we know it. To stop the cycle, I'd shut it all down.** But that's not going to happen.

As an alternative, I'd first close the Mediterranean, which is basically fished out already, then I'd shut down the Gulf of Mexico and the Southern Ocean.

Paul Watson, captain of the *Steve Irwin*, founder of the Sea Shepherd Conservation Society and subject of the television series *Whale Wars*

We owe two of every three breaths we take to plankton, which cycle carbon dioxide back into oxygen, but ocean acidification is killing those organisms on a massive scale. We need to get off fossil fuels as soon as possible. **Our organization started by installing 120 solar panels on our roof.** The electric companies now give us money back.

Louie Psihoyos, director of *The Cove* and executive director of the Ocean Preservation Society

Refuse single-use plastic bottles and bags. Most of the floating debris that pollutes our oceans is made up of plastic, and it is sometimes mistaken for food by marine animals. So **the next time someone hands you a single-use plastic bottle or bag, just say "no thanks."**

Jim Moriarty, CEO of the Surfrider Foundation

More than a billion people rely on fish for protein. In meeting this demand, we have destroyed global stocks of commercially valued fish, reducing many populations by two thirds or more over the past century. We are now eating our way further down the food chain and fishing in deeper waters, disrupting food webs and destroying fragile ocean habitats. Properly executed, **aquaculture can help stop this cycle by providing a sustainable alternative source of fish**. Together with responsible and effective management of wild fisheries, it would go a long way toward stabilizing global food security, averting collapse of marine ecosystems, and allowing natural fish stocks to recover.

Susan Avery, president and director of the Woods Hole Oceanographic Institution

The shipping industry is cooperating closely with governments on a host of initiatives, including identifying the best feasible ballast-water-treatment technology for installation on ships; using low-sulfur fuel in emission-control areas; assessing how emission-scrubbing technologies could be applied to allow cleaner burning of marine fuels; **improved ship design and other measures to reduce CO_2 emissions; applying new hull coatings to improve efficiency,** reduce emissions, and reduce hull fouling; establishing no-discharge zones in environmentally sensitive areas; and reducing the risk of whale strikes.

Anne Marie Kappel, vice president of the World Shipping Council

Asking which way is best to save the oceans is like asking which way is best to save your heart. The answer is we have to do everything possible, and we have to do it now. Destructive fishing practices should stop. The ocean is the cornerstone of Earth's life-support system, and **we should take care of it as if our lives depend on it.** Because they do.

Sylvia Earle, oceanographer, founder of the Sylvia Earle Alliance

To save the ocean, we need to understand it, and to understand it we need data. At Scripps, we are in a race to deploy enough sophisticated, satellite-connected robots so we can effectively monitor our changing oceans, understand the processes at work, and incorporate that understanding and soon-to-be terabytes' worth of data so that reliable predictions can be made.

Tony Haymet, director of Scripps Institution of Oceanography

We need to invest in clean energy technologies that will help reverse the ocean acidification now taking place. Increasing levels of pollution in the atmosphere are forcing our oceans to absorb levels of carbon dioxide beyond what is healthy for fish, plants and other wildlife dependent on the oceans.

U.S. senator Ben Cardin of Maryland, chairman of the Wildlife and Water Subcommittee of the Environment and Public Works Committee

Rather than a traditional fisheries perspective, which was a single-species concern, we need to **continue shifting toward ecosystem-based management**, incorporating not just a fishing community but many concerns, including tourism and oil and gas development. When you're managing how humans affect the ocean, you need to consider all of the different constituent groups of who uses the ocean.

Doug DeMaster, acting chief scientist of fisheries at the National Oceanic and Atmospheric Administration

For too long, we've been eating too far up the food chain. We need to eat more across it, by **consuming items like mackerel, sardines and squid**. Instead we're consuming the top predators: the swordfish, the tuna.

Gef Flimlin, board member of the U.S. Aquaculture Society

We can solve the biggest threat to the oceans—overfishing—by **eliminating harmful fisheries subsidies**. Governments are paying to maintain a global fishing fleet that is up to two and a half times larger than what our oceans can sustain.

Ted Danson, actor, founding board member of Oceana and author of *Oceana: Our Endangered Oceans and What We Can Do to Save Them*

If I could do one thing, it would be to **stop using the ocean as a universal sewer**. Every year, we create thousands of new chemicals that reach the oceans, accumulate in the fish there, and eventually find their way back to our dinner plates. Yet we have neglected to find out what the consequences might be.

Jean-Michel Cousteau, president of the Ocean Futures Society

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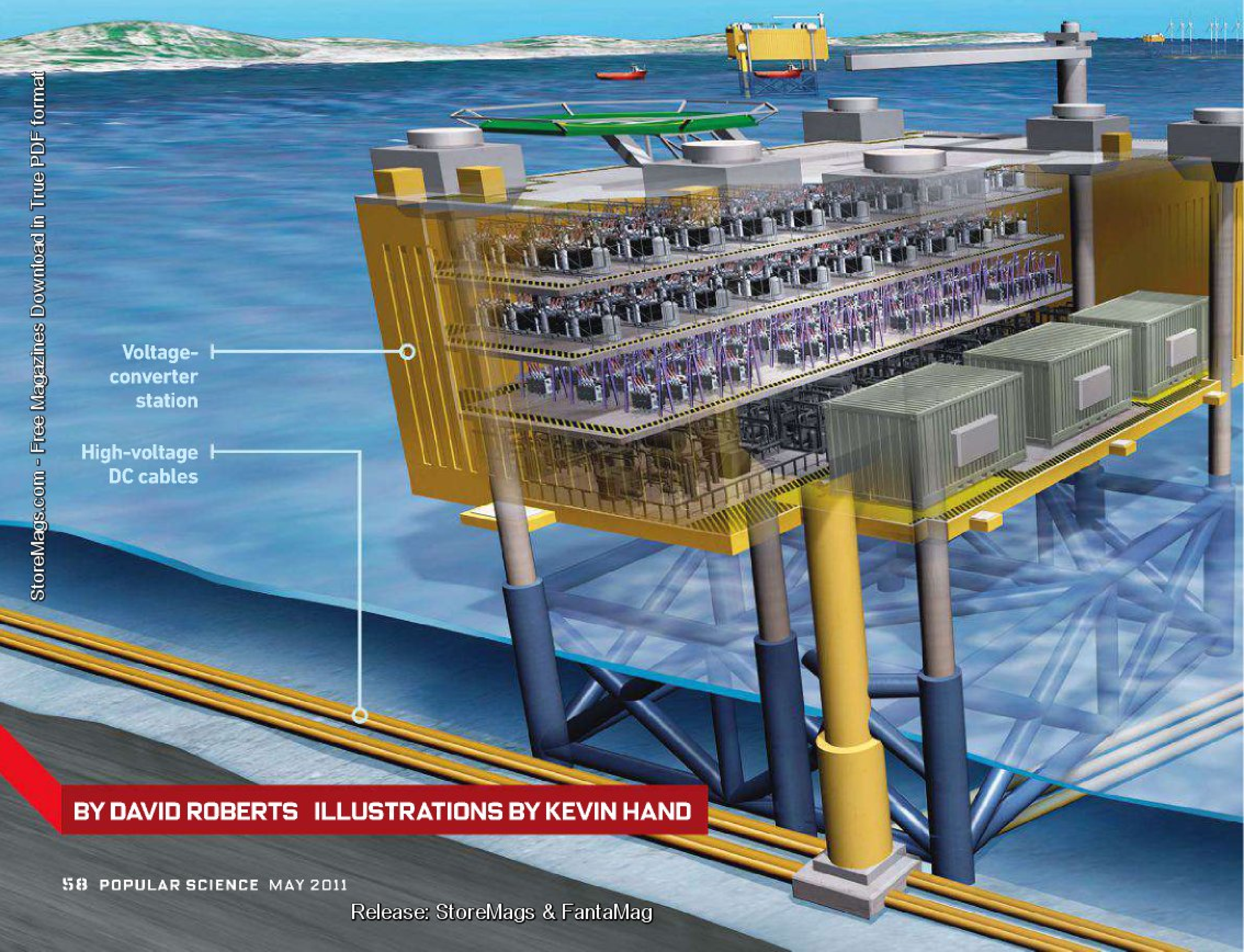
CONCEPTS & PROTOTYPES

SHORE LINE

How an undersea power network off the East Coast could make offshore wind power cheaper than coal

DURING THE LAST ice age, glaciers a mile high pushed several dozen cubic miles of rock, sand and debris into the ocean off North America's mid-Atlantic coast, creating a broad shelf that extends up to 40 miles offshore. This long, flat stretch of seabed and the shallow, windy waters that cover it make the ideal spot for dozens of offshore wind farms—and if all goes well, the network that would link those turbines together and back to the coast will soon be in place.

Offshore wind power has significant advantages over the onshore variety. Uninterrupted by changes in terrain, the wind at sea blows steadier and stronger. Installing turbines far enough from shore that they're invisible except on



BY DAVID ROBERTS ILLUSTRATIONS BY KEVIN HAND

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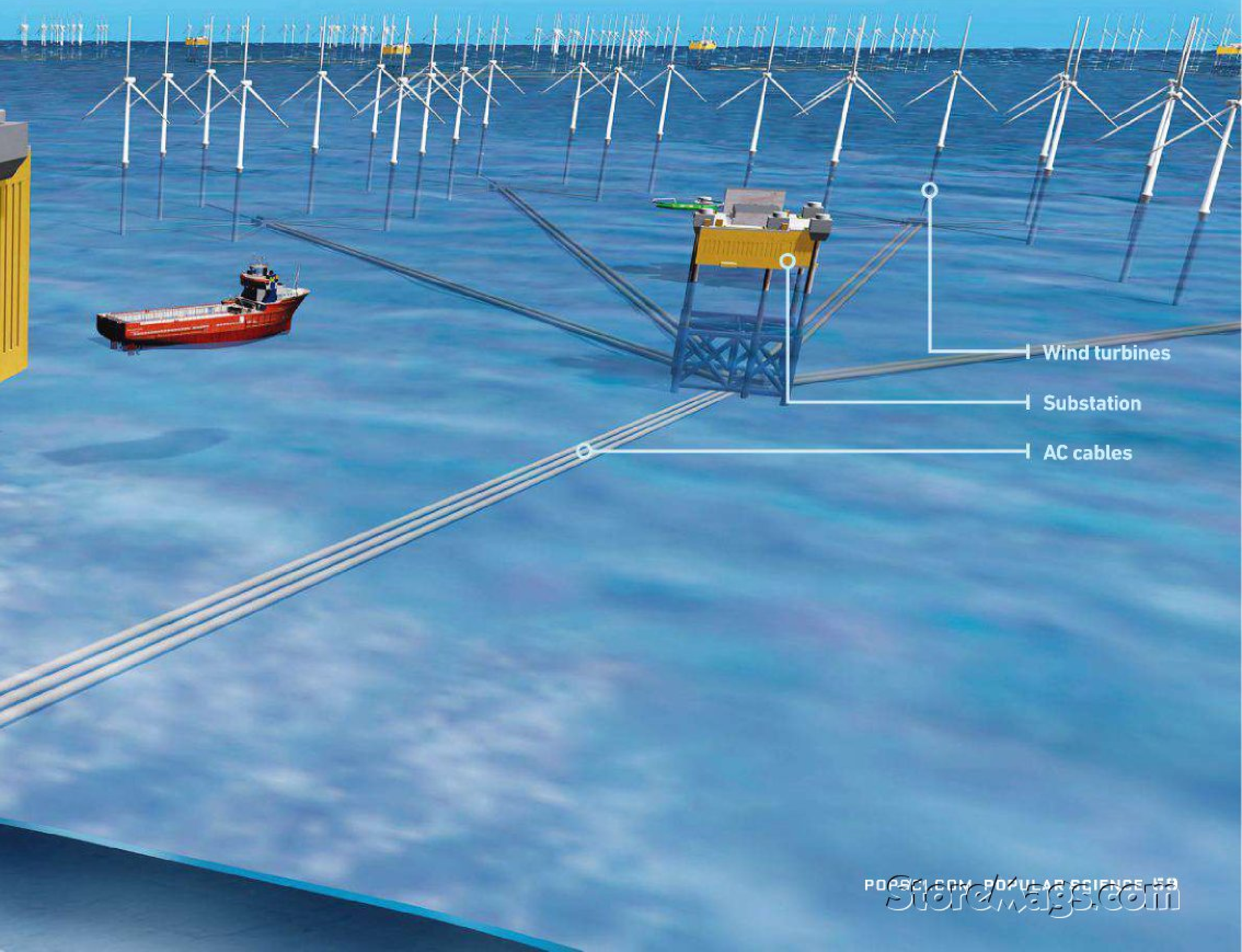
the very clearest days lessens the possibility of not-in-my-backyard resistance. The challenge is getting the electricity back to land, to the people who will use it.

The Maryland-based transmission-line company Trans-Elect proposes to do just that with a $5-billion undersea power grid that would stretch some 350 miles from northern New Jersey to southern Virginia. The Atlantic Wind Connection (AWC) would provide multiple transmission hubs for future wind farms, making the waters off the mid-Atlantic coast an attractive and economical place for developers to set up turbines. The AWC's lines could transmit as much as six gigawatts of low-carbon power from turbines back to the coast—the equivalent capacity of 10 average coal-fired power plants. So far, the project has attracted backing from Google, the clean-energy investment firm Good Energies, and the Japanese trading company Marubeni. Trans-Elect says it plans to begin construction on phase I—a $1.8 billion, 150-mile span from Delaware Bay to Atlantic City—in 2013, and that section could be operational by 2016.

To appreciate the novelty and potential of the Atlantic Wind Connection, it helps to understand the building blocks of an offshore wind system. At its simplest, offshore wind transmission involves connecting a group of wind turbines to an AC transmission cable, which will carry the electricity they generate back to land. (Nearly every wind turbine on the market today generates AC power, the standard for the terrestrial grid.) But AC cables are generally efficient only over short distances, particularly when they're used underground or underwater [see "AC vs. DC" on the next page]. Wind farms connected to land by AC cables would therefore be forced to cluster around a limited number of spots where the cables could

▼ ON THE GRID The Atlantic Wind Connection would link wind farms over hundreds of miles using undersea cables and voltage-conversion stations.



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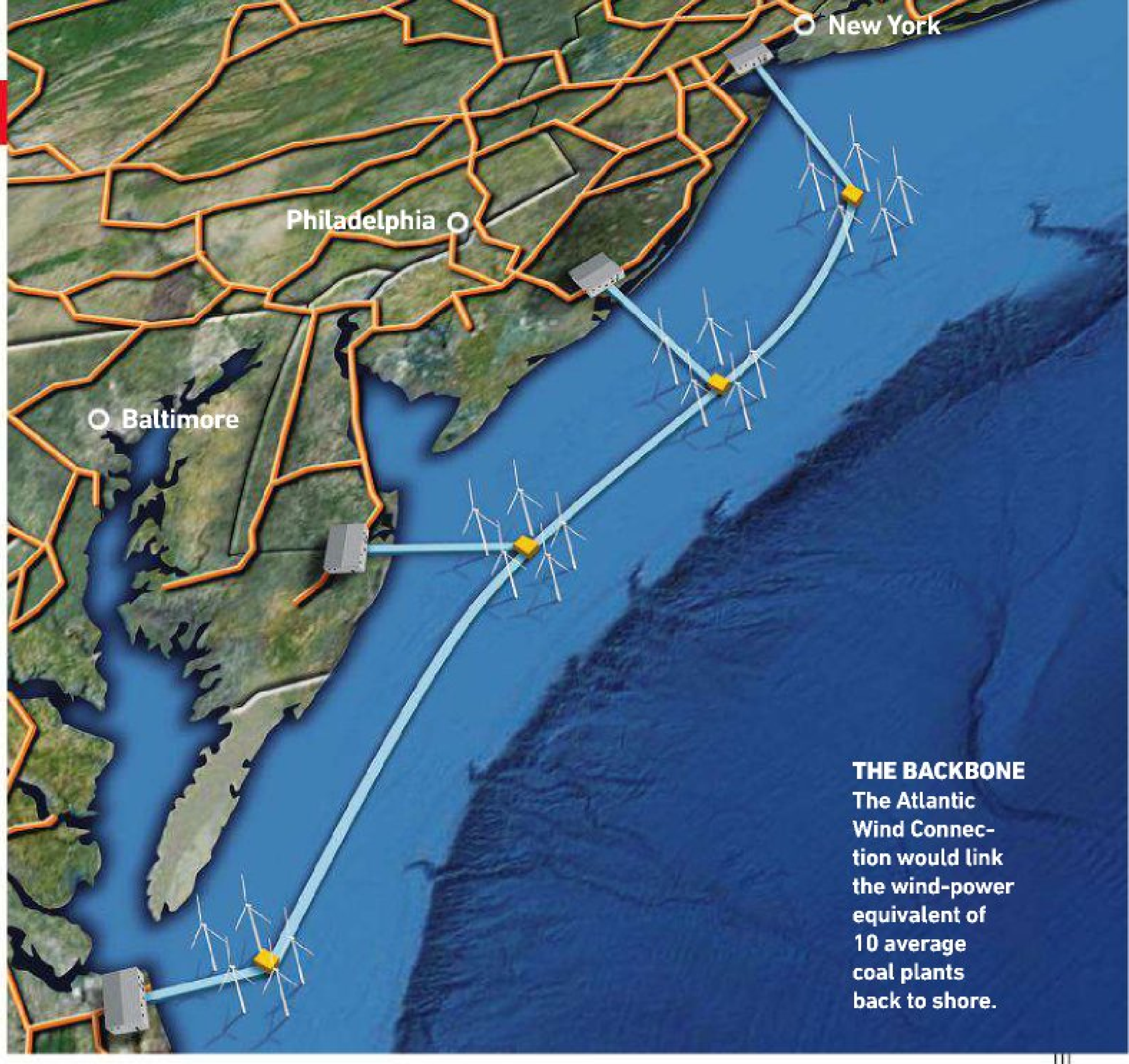
access the terrestrial grid. Those spots, however, might not necessarily be the best places to park a wind farm. Placing turbines in the windiest possible places might involve transmitting power greater distances than AC lines are capable of—and that requires high-voltage DC cables, along with a series of voltage converters to transform the AC power coming out of the windmills to DC and then, once ashore, back again.

What makes the AWC both so ambitious and so innovative is that it is designed to link multiple DC systems together into a full, multidirectional undersea grid. The system will be capable of channeling power as needed among multiple wind farms and consumers on shore, a project of unprecedented scale and complexity.

The nodes of this network will be voltage converters that sit on offshore platforms in huge, weatherproof boxes. Each one will be connected to other wind farms and converter stations. Power will flow among them, as well as to the land-based stations that feed into the terrestrial grid. Each voltage converter will be able to respond instantly to changes in power flow in the terrestrial grid—to ratchet power up and down based on supply and demand back on land. As a result, even before the AWC is connected to a single wind farm, it will help stabilize the mid-Atlantic's aging, overtaxed grid, preventing brownouts and blackouts.

Relieving strain on the existing grid would just be the beginning. The AWC would draw wind-farm developers to the region by allowing them to hook new turbines into an existing transmission backbone, cutting the cost of laying their own cables and building the infrastructure to connect those cables to the terrestrial grid. Developers will also be free to place turbines where the wind is. "It's not just about transmission access," says Markian Melnyk, who developed the initial AWC concept. "It's also about providing access to the best sites for wind."



THE BACKBONE The Atlantic Wind Connection would link the wind-power equivalent of 10 average coal plants back to shore.

The Atlantic Wind Connection could provide an entirely new model for connecting seaborne energy with land users.

But the AWC's greatest advantage would be its sheer scale. It would tie together wind farms distributed over hundreds of miles of coastline, and because the wind will usually be blowing *somewhere*, its breadth would compensate for the unpredictability of wind at any individual site. Together, the steadier flow of power, combined with the money that wind-farm developers will save by feeding electricity into an existing network, could make wind power cheaper than electricity generated by natural gas or, in some cases, even coal.

Obviously, there is a long way to go. Multiple regulatory authorities will have to sign off before the AWC becomes reality. But the large-scale, holistic approach to offshore wind power that it represents is already echoed by at least two undersea power-transmission proposals being considered in Europe. And if the AWC succeeds in delivering predictable, low-cost, low-carbon power to the mid-Atlantic, expect the number of imitative projects to grow.

AC VS. DC

Undersea power cables require metal shielding to protect them from fishing nets and marine life. But metal shielding doesn't work so well for the alternating-current (AC) lines used almost universally in the terrestrial grid, because the electric field surrounding an AC line changes direction 120 times a second, enough to heat up a metal shield like a toaster coil. Over long distances, this interaction saps enough energy to make buried AC lines impractical—hence the use of direct current (DC), in which the electrons move in one direction, at a constant speed, producing an electric field that interacts only minimally with the shielding.

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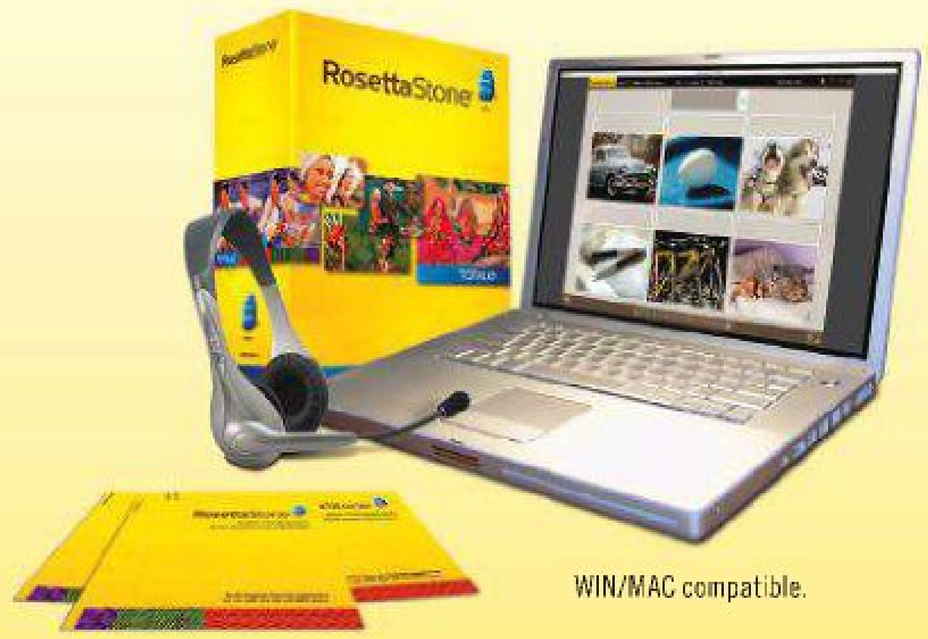

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LINEAR ACCELERATION

At its most extreme, fast travel can be uncomfortable or even deadly. To prevent injury and keep passengers happy over the long haul, engineers must consider many factors. The first: how quickly they can bring people up to speed. Humans have survived 46 Gs of linear acceleration, but some begin to feel uncomfortable at 0.15 G, and commercial pilots try to keep their takeoffs below 1 G. That gain in comfort, though, means getting there a little less quickly.

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Bodies in Motion

The limits of travel are defined not by what vehicles can do, but by what vehicles can do to us. So how much can we take?

BY JACOB WARD • ILLUSTRATIONS BY OLLIE BLAND

BLANDDESIGNS.CO.UK

Release: StoreMags & FantaMag

ON THE MORNING of October 25, 1999, captain Michael Kling and his first officer, Stephanie Bellegarrigue, piloted a Learjet Model 35 out of Orlando and set a heading for Dallas, where their passengers—the professional golfer Payne Stewart, Stewart's agents Robert Fraley and Van Ardan, and golf-course architect Bruce Borland—were planning to build a new course. The Learjet, a plane often used for such trips, was a marvel of engineering: It could climb 4,340 feet in a minute and cruise at up to 530 mph. In 1976 a similar Lear, the Model 36, set a round-the-world speed record.

As the crew headed north, they received instructions from a Jacksonville controller, first to climb to 26,000 feet, then 39,000. "Three nine zero bravo alpha," the first officer acknowledged. It was her last transmission. A few minutes later, the Learjet leveled out and the controller issued another routine instruction. No one radioed back. The controller tried to reach the crew five more times in the next four and a half minutes.

When a flight crew is unresponsive, the FAA asks that the nearest military jet make a visual assessment—in this case, it was an F-16 pilot on a test run out of nearby Eglin Air Force Base. Coming even with the Learjet, the test pilot reported that both of the plane's engines were running. By all indications, the Learjet was in perfect working order. But the test pilot also reported a disturbing detail: The Learjet's windows were opaque, as if covered from the inside with condensation or ice.

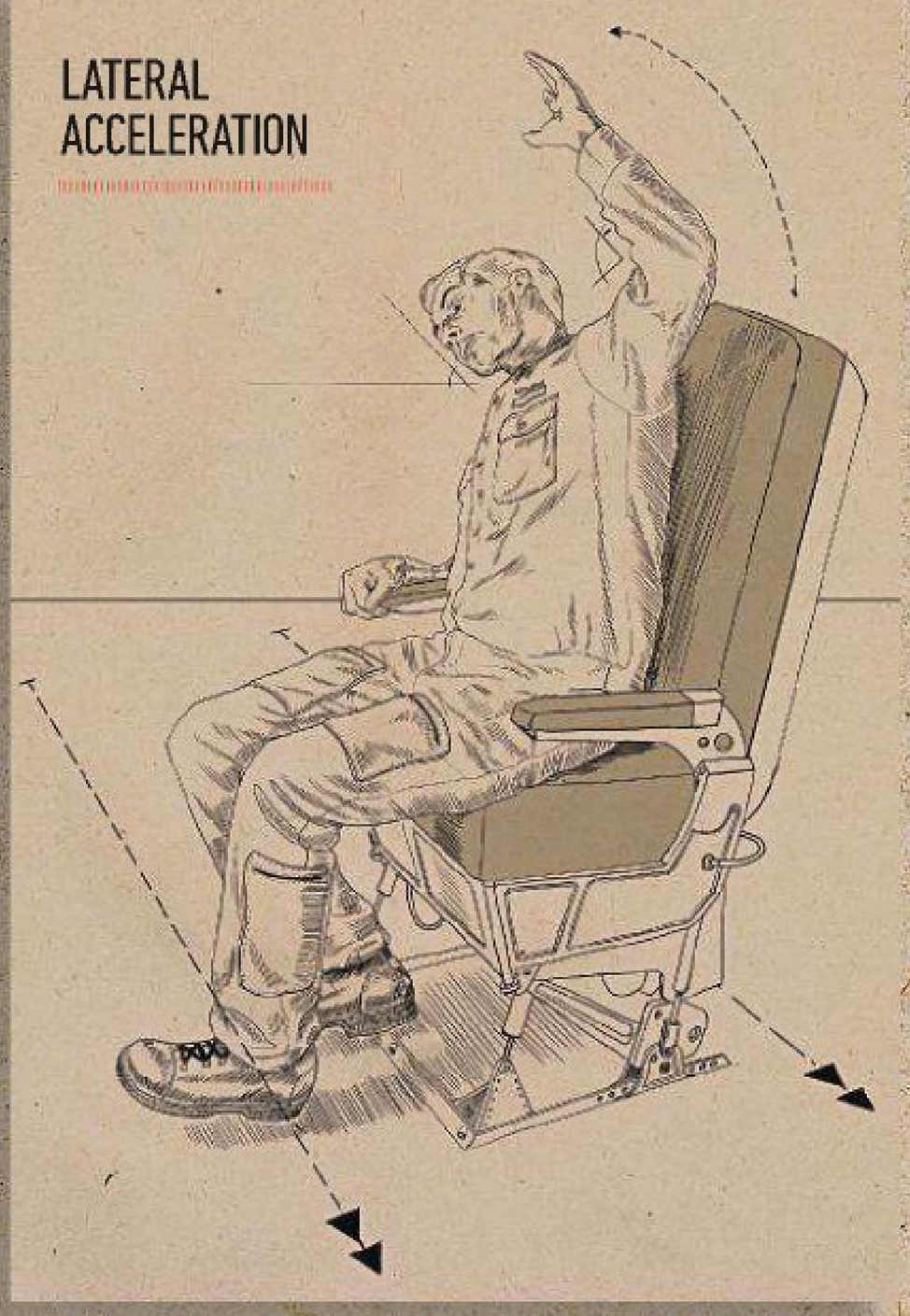
It was becoming clear that in the minutes after Bellegarrigue's last transmission, the cabin had lost pressure and all its oxygen began to escape. Within as little as eight seconds, the crew and their passengers most likely began to experience hypoxia—lack of oxygen in the bloodstream—that impaired their most basic motor and cognitive functions. They may not have even been aware that there was a problem, but within a few minutes of the breach, they were probably dead.

Yet the plane continued on, because a plane does not need its occupants to be comfortable in order to operate. It does not even need them to be breathing.

Humans are flimsy. Our bones snap after a fall of only a few feet. Our flesh ignites at the operating temperature of the average wood-burning stove. The highest human settlements are no more than 19,520 feet up, and none of us can stay alive long past 26,000.

Machines, meanwhile, can take a lot. The wings of a Boeing 777, for instance, can bend as much as 24 feet from their resting position, and any turbulence powerful enough to bend them that far will damage the passengers long before it damages the airplane. In 1997, United Airlines Flight 826, en route from Tokyo to Honolulu, encountered a sudden gust of "clear air turbulence" that crushed passengers into their seats and flung them at the ceiling. The turbulence killed one passenger and injured 70 others. But the pilot was able to return the plane itself safely to Tokyo.

This is the fundamental limit of all forms of travel. "You can create a system to do whatever you need it to do," says Michael Planey, a former U.S. Air Force engineer and now a consultant for commercial airlines. "But can you keep a person conscious and alive inside it? That's the challenge."



▲ **Going forward too fast is dangerous enough, but a sudden sideways knock can be deadly. Most airplanes' overhead bins can withstand up to 14 Gs of lateral acceleration, but humans confronted by the same force must either envelop themselves in racecar-style seats or risk having their organs torn loose.**

HOW WE'LL MOVE from place to place in the future will be determined by what passengers can withstand. How fast can the body accelerate? How long can it sit in one place? How many can we pack into a vehicle? Right now we have only a rough sense of these corporeal limits.

Much of what we know is drawn anecdotally from the violent, often accidental experiences of airmen and astronauts. In 1966 a test pilot named Bill Weaver managed to eject when his SR-71 Blackbird broke apart at Mach 3.18. His systems officer was killed, but at 78,000 feet Weaver survived more than 2,000 mph of air resistance, revealing that a human can in fact withstand incredible shock at a very high altitude, at least when protected by a pressurized suit. In 1960, Air Force captain Joseph Kittinger established as-yet-unbroken records for the highest parachute jump

JERK

Also known as "jolt" and "lurch," jerk refers to rapid changes in acceleration, as when a driver repeatedly jams on a car's brakes or an air passenger bounces up and down on a turbulent flight. Jerk is one of the most unpleasant and potentially dangerous forces for passengers. The sudden change can spill a cup of coffee or cause whiplash.

"YOU CAN CREATE A SYSTEM TO DO WHATEVER YOU NEED IT TO DO. BUT CAN YOU KEEP A PERSON CONSCIOUS AND ALIVE INSIDE IT?"

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(102,800 feet) and the fastest human free-fall through the atmosphere (614 mph). And between 1947 and 1954, Air Force colonel John Stapp, part of the Aero Medical Laboratory of the Wright Air Development Center, subjected himself to repeated tests on a rocket sled that zipped across what is now Edwards Air Force Base. During one run on his "human decelerator," Stapp went from 630 mph to a complete halt in just a few hundred feet, experiencing 46 Gs of deceleration.

But standardized data about human tolerances is hard to come by. J.D. Polk, NASA's chief of space medicine, knows a great deal about the strain of space travel—his astronauts have endured hours of waiting at the launch pad and lived for months in a weightless environment—but even he can't quite name the breaking point of a human being. That's because engineers can't test humans the way they can other components of a spaceship. In designing a space shuttle, "you can stress a part until it breaks," Polk says. "The human body is the only system in engineering that you can't take to failure."

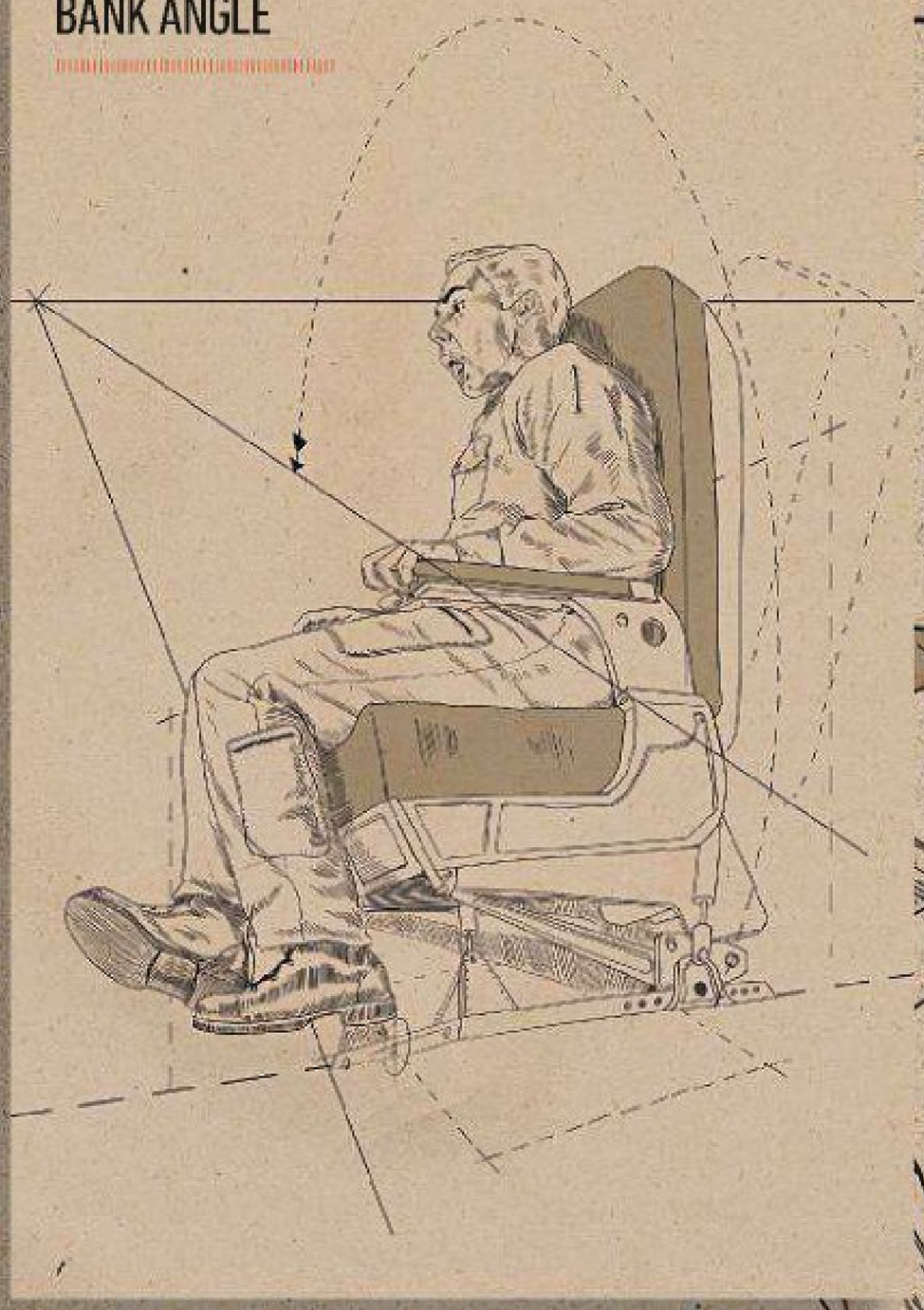
Military and NASA researchers don't really investigate human comfort, at least not in the way that a commercial traveler might hope. They aren't attempting to engineer conditions that will convince the traveler to fly a particular airline or buy a particular car. That distinction was highlighted during the Iraq war, when Baghdad International Airport became one of the few places in the world where civilians regularly encountered the discomfort of military efficiency. Rather than the usual long, low approach to the runway, commercial pilots instead had to drop from as high as 35,000 feet in a hard spiral "corkscrew descent," the better to avoid rockets and small-arms fire. It's a standard military approach path. But for a civilian, it's terrifying. "It's pretty amazing what airplanes can do," says Tom A. Peter, a freelance reporter who has flown into Baghdad several times. "I've never been in a plane crash, but I have to imagine that a corkscrew landing is about as close as you can come without actually wrecking a plane."

NASA engineer Dustin Gohmert, who designed seat systems for the crew module of the *Orion* spacecraft, explains the military-civilian distinction in straightforward terms. "Comfort itself is difficult to quantify," he says. "We look primarily at the safety of the crew."

CAPACITY

Airlines want to pack the maximum amount of people into the minimum amount of space, and it is safety, not comfort, that determines those limits. As a Boeing spokesman told the BBC last year when a European airline proposed a stand-up only route, "Stringent regulatory requirements—including seats capable of withstanding a force of 16 Gs—pretty much preclude such an arrangement."

BANK ANGLE



▲ **Proper banking makes turns more comfortable and efficient, but passengers become uneasy if the angle is too steep. Autopilot systems avoid angles greater than 30 degrees, but the authors of a 1994 study found that most high-speed-rail travelers will tolerate as much as 37 degrees of banking.**

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“COMFORT IS DIFFICULT TO QUANTIFY. WE LOOK PRIMARILY AT SAFETY.”

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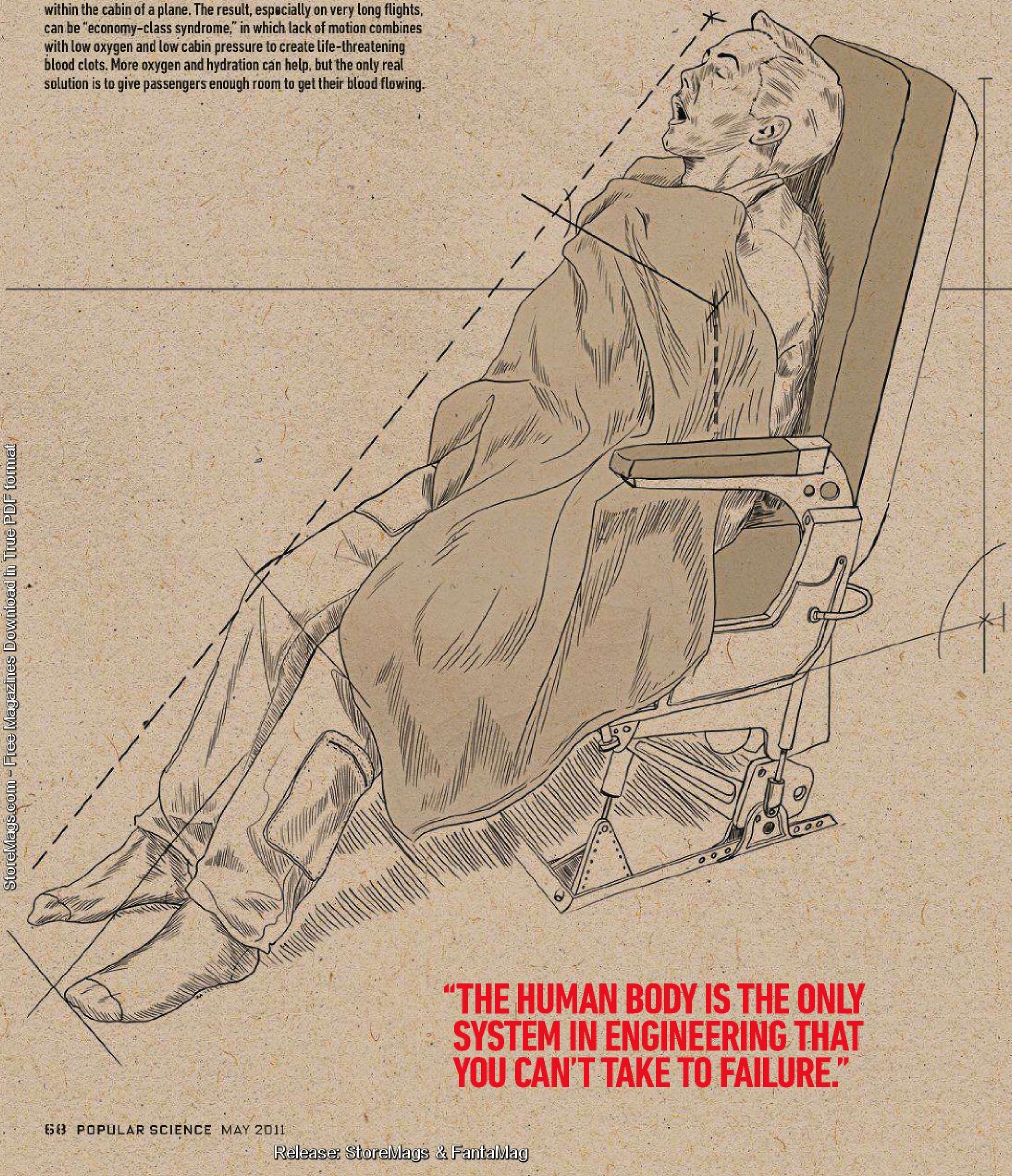
ENDURANCE

Even as they travel great distances, most passengers rarely move within the cabin of a plane. The result, especially on very long flights, can be "economy-class syndrome," in which lack of motion combines with low oxygen and low cabin pressure to create life-threatening blood clots. More oxygen and hydration can help, but the only real solution is to give passengers enough room to get their blood flowing.



"THE HUMAN BODY IS THE ONLY SYSTEM IN ENGINEERING THAT YOU CAN'T TAKE TO FAILURE."

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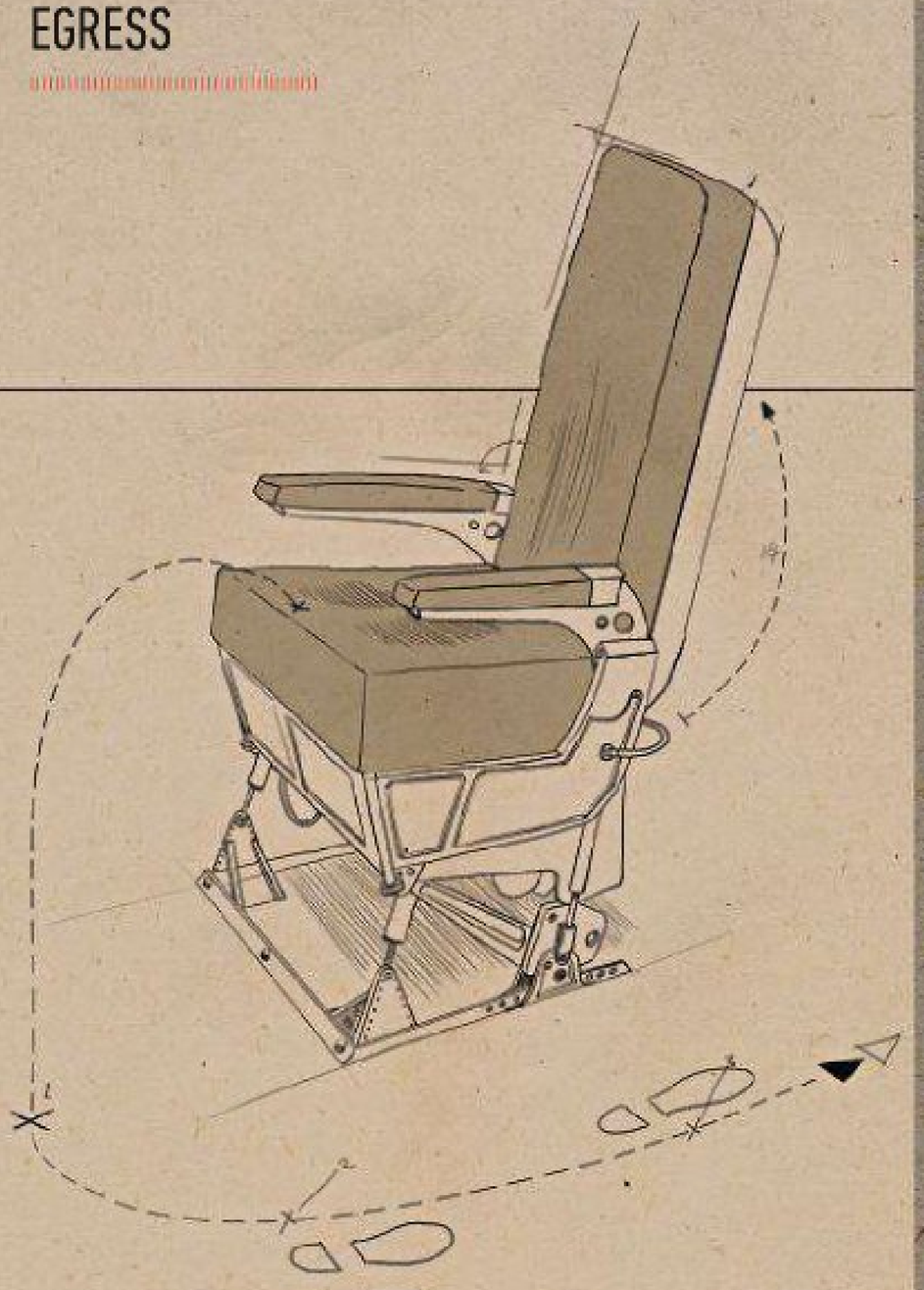
The standards are very high for NASA vehicles. Because a spacecraft can crash hours or days from help, "we have to make it such that the crew can self-rescue," Gohmert says. And sometimes that means doing away with conventional amenities. In the *Orion* capsule plan, for instance, Gohmert's team dispensed with seat cushions altogether. Cushions may separate the body from the hard seat underneath by just a few millimeters, but in a sudden deceleration, the body can close even that small distance with enough force to cause injury. The *Orion* seats fit each astronaut fairly closely, and the weight distribution makes for a more or less tolerable experience. But comfort isn't the goal. The seats keeps the astronauts alive.

Of course, NASA also gets to be picky about *who* comes on board, a degree of selectivity that further limits what the agency can teach us about our own comfort. The Federal Aviation Administration requires commercial airlines to safely accommodate nearly the entire spectrum of humanity, from a 5th-percentile woman (about 5 feet tall) to a 95th-percentile man (over 6'3"). Not so at NASA. To make sure each astronaut fits the operating environment of the spacecraft, the agency assesses not just height and weight, but every measurement of every extremity. If you don't fit, you can't fly. "We do three-dimensional body scans of the astronauts as part of the screening," Gohmert says. "If your femur is too long, it might disqualify you." Air Force pilots must also properly fit their plane—legs longer than the engineered standard could break when the pilot ejects in an emergency.

EGRESS



CIVILIAN PASSENGERS, no matter how tall or wide, expect gentle treatment. As a result, engineers must set extremely conservative tolerances. Rail system designers, for instance, consider the acceptable limit of linear and lateral acceleration (the force exerted on passengers by starting, stopping, and rocking from side to side) to be no more than 0.15 G—roughly what you'd feel on the moon. That limit allows passengers to dispense with seatbelts and walk around freely inside.

But design constraints also act as speed constraints. In 1990, engineers for a federal program called the National Maglev Initiative began to investigate the domestic potential for high-speed magnetic-levitation (maglev) trains—the fastest, a Shanghai airport shuttle, reaches 268 miles an hour. Daniel Patrick Moynihan, then the chair of the Senate subcommittee responsible for the U.S. highway system, had suggested that maglev trains be placed along the median of U.S. highways, so in July 1992, to better understand what it would be like to travel an interstate at maglev speeds, four engineers set out from National Airport in a private jet. "We did 180 mph and began banking as if we were obeying the turns you'd have to make on the New York State Thruway," recalls Laurence Blow, now a maglev consultant. As the pilot cranked the plane back and forth, simulating the thruway, the engineers began to heave and retch. "It wasn't the speed or acceleration that made us all sick," Blow says. "It was the banking."

Motion sickness is one of the few areas where civilian desires overlap with military requirements; no commander wants his soldiers or astronauts puking when they need to fight or fly. A lot of data has been generated. In 1995, for example, British naval doctors subjected participants to repeated vertical and horizontal motions while the participants were either seated upright or lying on their backs, and determined that the subjects found horizontal movement while prone to be the most tolerable, and seated horizontal movement to be least tolerable. And a 2006 study established that low-frequency movement (a camel's gait) is more nauseating than high-frequency movement (a horse's gait).

The accepted notion, proposed by the English physician J.A. Irwin in 1881 and largely confirmed by NASA in 1970, is that we get sick when our visual input contradicts our vestibular, inner-ear input—when what we see (an unmoving bulkhead) is in conflict with what we feel (sudden acceleration). This is why passengers get sick before drivers or pilots do. "It's the lack of sightlines that are the problem in the backseat," says Gary Strumolo, the manager of vehicle design and infotronics at Ford Motor Company. This helps to explain, he says, why even those people who are highly susceptible to motion sickness can often avoid it by driving.

The same goes for air travel. "Pilots on the controls have a foreknowledge of the aircraft motion," says Catherine Webb, a psychologist who studies motion sickness at the U.S. Army Aeromedical Research Laboratory at Fort Rucker, Ala-

(CONTINUED ON PAGE 93)

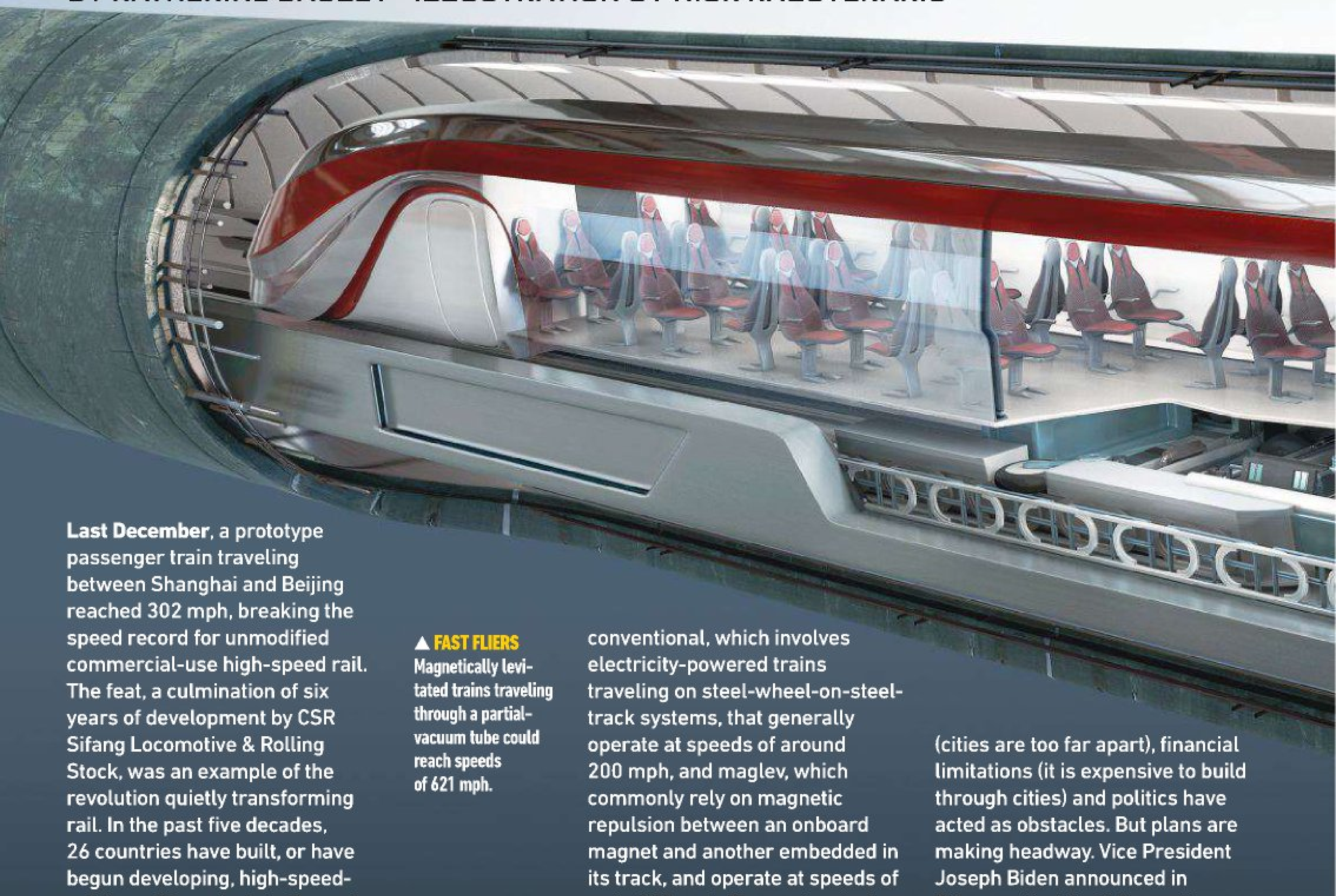
▲ **On average, passengers can file aboard a Boeing 757 in about 22 minutes, and they can find their way to the exit in about 10 minutes. But that's probably the outer limit for commercial travel. More doors would mean a weaker structure—and the expense of a bigger staff to keep an eye on things.**

THE FUTURE OF TRAVEL

FASTER THAN A SPEEDING BULLET

China's supertrains set new speed records while the U.S. plays catch-up

BY KATHERINE BAGLEY ILLUSTRATION BY NICK KALOTERAKIS



Last December, a prototype passenger train traveling between Shanghai and Beijing reached 302 mph, breaking the speed record for unmodified commercial-use high-speed rail. The feat, a culmination of six years of development by CSR Sifang Locomotive & Rolling Stock, was an example of the revolution quietly transforming rail. In the past five decades, 26 countries have built, or have begun developing, high-speed-rail lines. These include France's TGV to the Seoul-to-Pusan line in South Korea. Even the U.S., which has lagged behind other nations, has acknowledged the need for high-speed rail to improve the nation's infrastructure, strengthen the economy, and enhance international competitiveness.

High-speed-rail travel generally falls into two categories:

▲ **FAST FLIERS** Magnetically levitated trains traveling through a partial-vacuum tube could reach speeds of 621 mph.

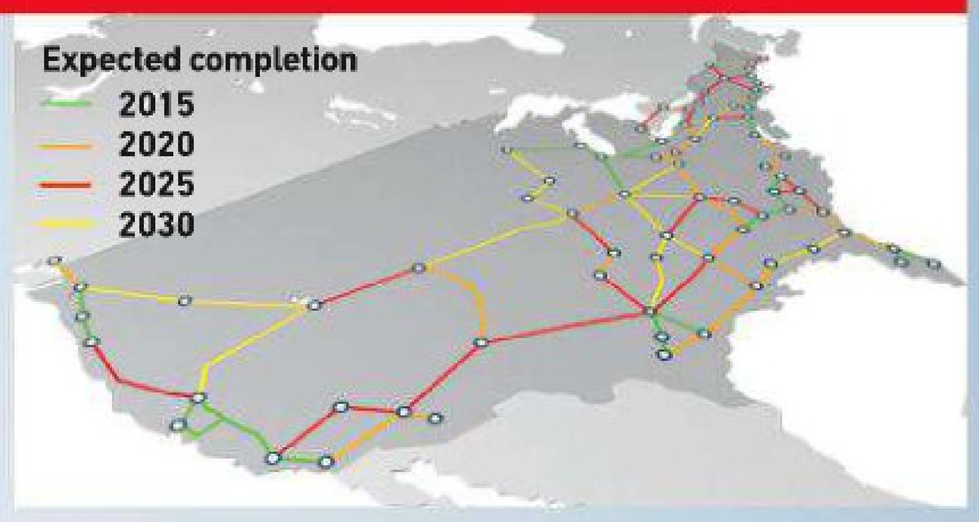
conventional, which involves electricity-powered trains traveling on steel-wheel-on-steel-track systems, that generally operate at speeds of around 200 mph, and maglev, which commonly rely on magnetic repulsion between an onboard magnet and another embedded in its track, and operate at speeds of up to 270 mph. The vast majority of development has gone into conventional systems. In an effort to mitigate the growing congestion caused by its rapidly growing population, China's rail authority says it will add 9,941 miles of track by 2020, more than tripling the size of its current network.

In the U.S., innovation has been slow. Geographic factors (cities are too far apart), financial limitations (it is expensive to build through cities) and politics have acted as obstacles. But plans are making headway. Vice President Joseph Biden announced in February that the U.S. would invest $53 billion in high-speed rail over the next six years.

For all the progress in conventional high-speed rail, some of the most exciting research is being done on maglev systems. In 2004, citing concerns about high costs, Chinese officials scrapped plans to build a maglev line between Shanghai and

Planned High-Speed-Rail Projects in the U.S.

Major corridors	Funding*	Total miles	Top speed
California	$3 billion	1,955 miles	220 mph
Northeast Corridor	$683 million	727 miles	110 mph
Charlotte–Raleigh–Richmond–Washington, D.C.	$688 million	480 miles	110 mph
Eugene–Portland–Seattle–Vancouver	$637 million	467 miles	150 mph
Kansas City–St. Louis–Chicago	$1.17 billion	570 miles	110 mph



TO AND FRO The trade group US High Speed Rail Association envisions a 17,000-mile network of track. The proposed 220mph trains could cut travel times in half.

Beijing, so for now, maglev trains cover only short distances. The fastest maglev train currently operating reaches 268 mph on the 7.5-minute, 19-mile trip between Shanghai's Pudong airport and the city center. Engineers at China's Southwest Jiaotong University, however, are at work on the next generation: evacuated-tube maglevs that could smash all previous speed records.

PAUL WOOTTON

Vactrains: How Fast Is Superfast?

In 1972, Robert Salter, a physicist with the RAND Corporation, posited a "very high speed" train that would travel along magnetic rails "much as a surfboard rides the ocean's waves." Unlike a surfer, though, this train would be sealed in a vacuum, and therefore would not only face no rolling resistance from the rails but also no wind resistance from the atmosphere. No one has yet built one, but last year engineers at Southwest Jiaotong University in China announced plans to build a 500-foot-long prototype for a 600mph vactrain system. And Daryl Oster, founder of the Florida-based company et3, says his proposed maglev could travel at up to 4,000 mph and could zip between New York and Los Angeles in 41 minutes.

*Numbers are estimates from the U.S. Department of Transportation Federal Railroad Administration

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MIND TRIPS

Amusement parks are so bland. This summer, take a brainier vacation—visit a particle accelerator, sail the Pacific aboard a marine research vessel, or watch simulations of epic natural disasters

BY AMANDA SCHUPAK ILLUSTRATIONS BY STUDIO LIDDELL

DIG FOR DINOSAURS

SOUTH DAKOTA SCHOOL OF MINES & TECHNOLOGY, VARIOUS LOCATIONS

The tectonic forces that raised the Rocky Mountains also buried and preserved many dinosaurs. This makes the American West a playground for today's fossil-hunters. The Field Paleo program at the South Dakota School of Mines & Technology's Museum of Geology runs several digs and welcomes visitors to participate in trips of four to 11 days. Options include hunting for Ice Age fossils in Oregon, stegosauruses in Wyoming, and marine reptiles along the Missouri River in South Dakota. Working with paleontologists, you'll learn dinosaur classification and anatomy, and map and preserve your findings.

TRIP TIP: If you want to look for fossils in other areas, head to *pasthorizons.com* for more digs around the world.

INFO: Trips run May to July; $600–$1,500; *museum.sdsmt.edu/field-paleo*

WATCH DISASTERS HAPPEN (SAFELY)

LAWRENCE LIVERMORE NATIONAL LABORATORY, LIVERMORE, CALIF.

At Lawrence Livermore's National Atmospheric Release Advisory Center, scientists use sophisticated computer-modeling techniques to predict and plan for nuclear, chemical or biological catastrophes. Visitors will view big-screen animated simulations of worst-case scenarios, including volcanic eruptions and the meltdowns at Chernobyl and Three Mile Island. They can also take a bus tour of nearby Site 300, where LLNL researchers conduct non-nuclear explosives tests (although they won't blow anything up for you—we asked).

TRIP TIP: At the National Ignition Facility, you'll see technicians at the controls of the world's largest and highest-energy laser and get the lowdown on the quest for hydrogen fusion.

INFO: Free; ages 18 and up; for reservations, call the Public Affairs Office at 925-422-4599; *llnl.gov/about/tours.html*

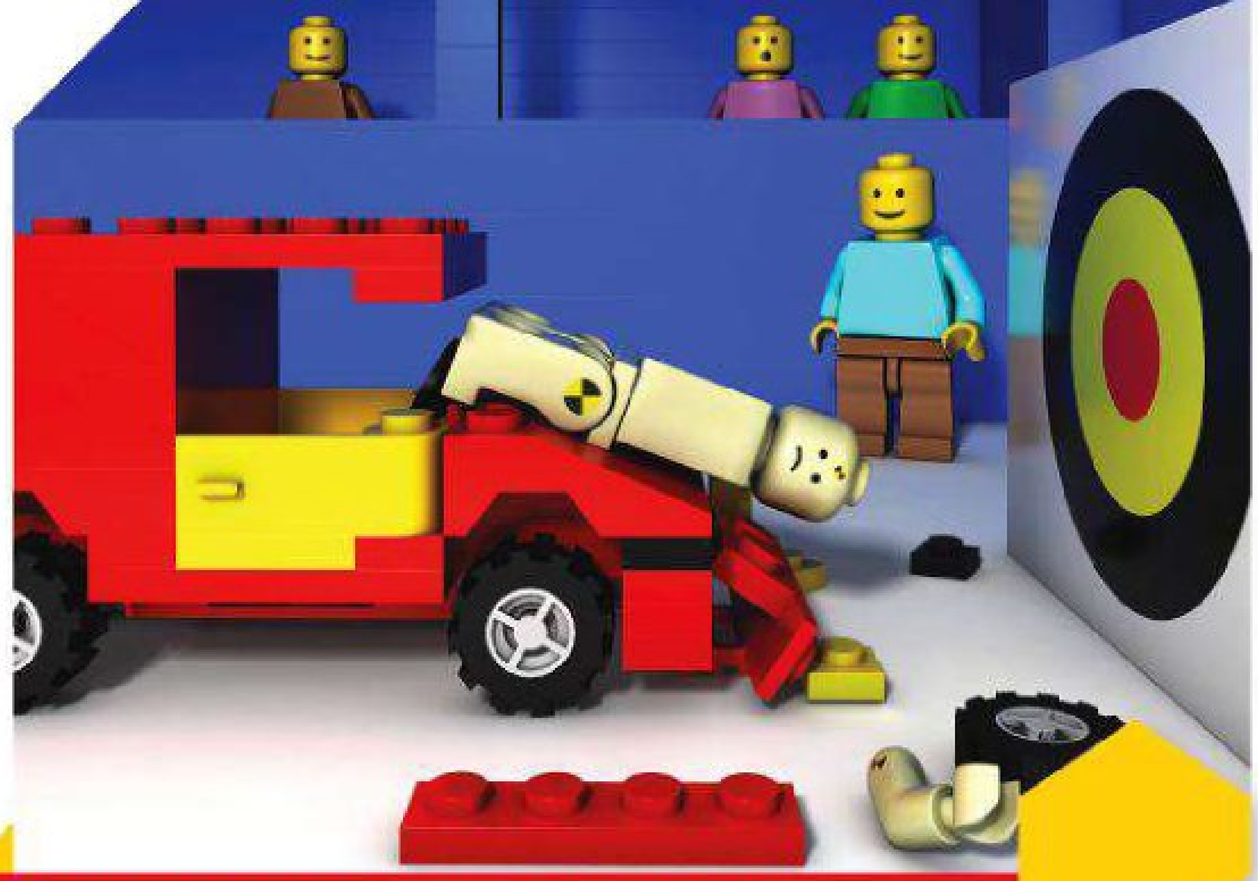
HEAD INTO THE LAB

BROOKHAVEN NATIONAL LABORATORY, UPTON, N.Y.

Researchers from some of the dozens of labs at Brookhaven, a U.S. Department of Energy facility, will guide you through the latest developments in medical, energy, environmental and national-security research. Tours run on summer Sundays starting July 17 at the Center for Functional Nanomaterials, where scientists will demonstrate their work with electron microscopes and plasma etchers. Or check out the National Synchrotron Light Source (NSLS), used for revealing proteins and other microscopic structures, and the nearly complete NSLS-II. At 10,000 times the strength of its predecessor, the x-ray will be one of the brightest lights in the world, enabling researchers to see ever-smaller entities in great detail. In August you can enter the 2.5-mile tunnel housing the Relativistic Heavy Ion Collider to get a look at its 1,740 superconducting magnets and two condo-size collision detectors, and follow storm trackers in the National Weather Service control room.

TRIP TIP: Don't miss the solar-powered bio-bus mobile lab, where you can get hands-on with sophisticated microscopes on loan from Columbia University.

INFO: Free; Sundays, July 17–August 14, 10 a.m.–3 p.m. (first come, first served); *www.bnl.gov/community/summer_sunday.asp*



WITNESS A CAR CRASH

KETTERING UNIVERSITY CRASH SAFETY CENTER, FLINT, MICH.

At Kettering's crash-test facility, visitors get to watch something being mercilessly smashed. Here, students and technicians test the strength and durability of automobile seats, seatbelts, airbags and other components. Using a deceleration sled that takes just 100 milliseconds to stop subjects moving at up to 40 miles an hour, researchers create 70 Gs of deceleration—100 times the jolt of braking in traffic. In addition to testing commercial autos, Kettering conducts occupant-safety tests for military transport vehicles and investigates things like how safe it is for a pop star to drive around with a baby in her lap. A workshop for kids allows them to create safety systems for eggs on a mini sled.

TRIP TIP: Be sure to meet Kettering's family of crash-test dummies. Peek at the steel-and-rubber innards of dismembered dummies and, when they're not being hurled into a wall, have your picture taken with them.

INFO: E-mail Sheryl Janca at sjanca@kettering.edu or go to *ketteringcrashsafety.com*.

DESCEND INTO DARKNESS

KANSAS UNDERGROUND SALT MUSEUM, HUTCHINSON, KANSAS

A two-minute elevator ride brings visitors 650 feet belowground into the winding mines of one of the country's largest salt deposits. At the Kansas Underground Salt Museum, 150 miles of tunnels connect 980 acres of mines, which provide 500,000 tons of road salt every year. On your way through, you'll meander beneath 17-foot walls of sparkling crystalline salt and learn about the science and history of the mine, which opened in 1923. You'll see how water droplets collect salt dust that builds to form hollow stalactites, or "salt straws," which can grow to five feet before falling from the ceiling. Salt being a natural preservative, the tour includes relics such as the world's oldest-known living organisms—250-million-year-old bacteria—and unusual items miners of yore have left behind.

TRIP TIP: Adjacent to the museum is a bonus feature: Underground Vaults and Storage, a two-million-square-foot archive that depends on the stable climate to protect seven million boxes filled with documents from around the globe, and the original reels of almost every movie ever made.

INFO: Admission is $7.35–$18.25; reservations encouraged; *undergroundmuseum.org*

STUDY THE SEA

PANGAEA EXPLORATION, VARIOUS DESTINATIONS WORLDWIDE

Explore uninhabited Pacific islands, swim with manta rays, and add to our knowledge of marine ecosystems. For intrepid civilians who want to man rigs and mine data alongside a crew of scientists, Pangaea Exploration sells passage on the *Sea Dragon*, a 72-foot sailboat used for international research expeditions. The organization offers as many as a dozen trips every year, most of them focused on conservation or remote island surveys. In May, for instance, the crew of the *Sea Dragon* will perform an environmental survey of the Northern Cook Islands, then assess ecosystem damage in the Northern Line Islands. Spots are also still available—at $10,000 a pop—for the 20-day July 7 voyage to collect and analyze the plastic debris that is polluting the North Pacific between Hawaii and Vancouver.

TRIP TIP: Batten down. These aren't luxury cruises—accommodations are spare, and participants must be in good health and able to lift a third of their body weight so that they can handle such crew tasks as manning lines and pulling in the sampling trawl.

INFO: *panexplore.com*

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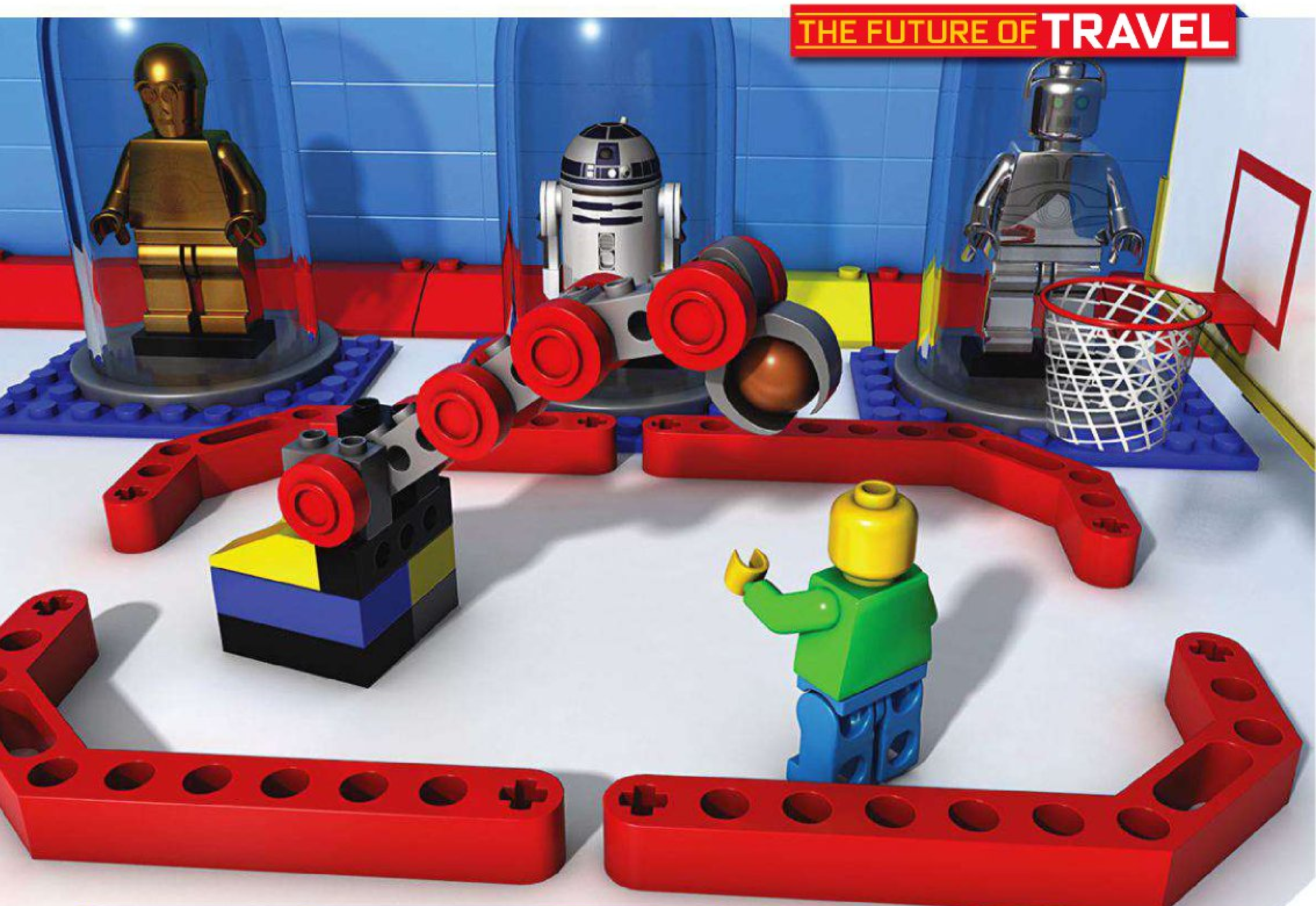

PLAY WITH ROBOTS

ROBOWORLD AT THE CARNEGIE SCIENCE CENTER, PITTSBURGH, PA.

Roboworld is filled with robots programmed to destroy you—at party games. With a paddle for a hand, Air Hockeybot 1000 uses an overhead camera to see the puck, while a 32-bit CPU factors in speed, direction, spin and friction to predict where it will go next. StarKick Foosbot operates on a foosball table rigged with infrared lights that let it track the ball. And then there's Hoops. Originally part of an automotive assembly line, the robo-arm welder-turned-baller shoots free throws with 98 percent accuracy. Challenge him only if you don't mind being schooled by an automaton. While you're there, see Cye—sort of a hybrid of a Roomba and a bulldozer—work through an obstacle course, and watch AARON create original paintings.

TRIP TIP: Also on view are full-size models of inductees into the Robot Hall of Fame, including R2-D2 and C-3PO, several Mars Rovers and T-800, the original Terminator.

INFO: Admission is $17.95 for adults and $9.95 for children; *carnegiesciencecenter.org*

LEARN ABOUT THE BOMB

OAK RIDGE NATIONAL LABORATORY, OAK RIDGE, TENN.

Oak Ridge, the Department of Energy's largest laboratory facility, was built in 1943 as part of the top-secret Manhattan Project. Driving tours of the 58-square-mile compound stop at Y-12 and K-25, two of the original uranium-enrichment plants established during World War II, and the graphite reactor where Enrico Fermi accomplished the first sustained nuclear reaction. Visitors will also swing by the Spallation Neutron Source, which produces the most intense pulsed neutron beams of any facility in the world and is used to study everything from superconductivity to the structure of virus particles.

TRIP TIP: The nearby American Museum of Science and Energy features a cross-sectional model of a nuclear reactor, as well as models of nuclear weapons developed at Y-12.

INFO: Free tours Monday–Friday at noon, June 1–September 3; *ornl.gov/ornlhome/visiting.shtml*

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TIPS, TRICKS, HACKS AND DO-IT-YOURSELF PROJECTS

80
Build the ultimate high-tech doghouse

82
An 11,000-pound solar coffee roaster

86
Search and archive your old tweets

YOU BUILT *WHAT*?!

THE DRIVER'S SEAT

A college student roars around campus on a motorized easy chair

Chris McIntosh's first recliner was not your standard La-Z-Boy—it was electric-powered and capable of going 15 mph. After finishing it a year and a half ago, he used it to pull a doughnut on his high school's front lawn, circle the gym during a pep rally, and rule the street near his home in Orinda, California. Now a freshman at the University of Southern California, McIntosh spent his youth building ad-hoc vehicles (he once made a mini hovercraft out of a leaf blower), so when the chair's paltry electric motor burned out, he decided it was time for a monster makeover. "I wanted to go *fast*," he says.

To upgrade the recliner, he removed the electric motor he had installed, the motor's controller, a pair of batteries, and other parts. He bought a nine-horsepower, four-stroke dirt-bike engine, which fit perfectly in the space beneath the seat, and welded on a fixed rear axle so the engine could power both rear wheels instead of just one, as the electric motor had. Bike engines need to be kick-started, but the recliner's lever snapped when he tried to use it. He welded on a motorcycle kick-start lever instead.

Then there was the danger of the vehicle catching on fire. The dirt-bike engine's exhaust pipe got so hot that it sometimes glowed

[CONTINUED ON NEXT PAGE]

EASY RIDER
Chris McIntosh first got the idea for his rideable recliner when, in ninth grade, he saw a motorized sofa chair at a robotics competition.

CODY PICKENS

SITTING PRETTY
McIntosh found the recliner on Craigslist, and his mother reupholstered it so it would match the colors of his high school.

(CONTINUED FROM PRECEDING PAGE)

red and threatened to set the upholstery (and McIntosh) ablaze. To avert disaster, he rerouted the pipe, mounting it farther from the underside of the chair, and then covered it with a heat-shielding, fireproof wrap. His parents were pleased.

Still, the first test drive was frightening: McIntosh immediately popped an accidental 45-degree wheelie. He added 30 pounds of weights near his feet to keep the front down, along with a roll bar and harness for safety. The newly completed gas-powered version now goes 40 mph and, just as important, he says, "it sounds like a Harley."—GREGORY MONE

HOW IT WORKS

TIME: 18 MONTHS
COST: $1,000

CONTROLS

The dirt bike had a foot shifter, but McIntosh converted it completely. He attached an electric-scooter throttle to the steering wheel and wired that to a speed controller from an electric wheelchair, which governs an electric motor that changes the gears. Now if he flicks the lever on the converted throttle, the chair upshifts; if he flicks it while holding down a nearby red button, it downshifts. This quick-shifting system, he says, "is especially useful for popping wheelies."

STREET ILLEGAL

McIntosh figured the chair wouldn't be street-legal, so he designed it to fit in the back of his hatchback. He slides off the backrest, leans a ramp against the back of his car, and pushes the heavy frame up and in. He typically uses it in parking lots, but he does occasionally take it around local streets and is thinking of bringing it to USC's homecoming parade this fall.

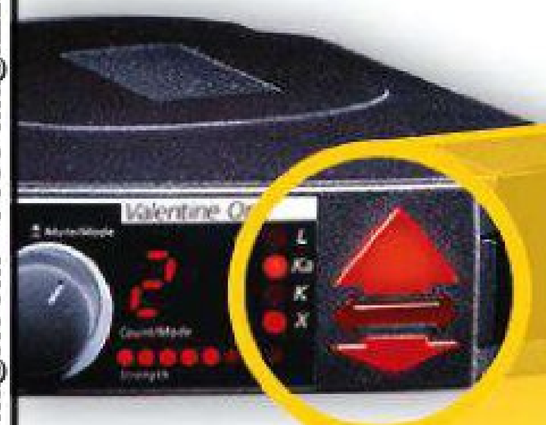
HANDLING AND COMFORT

The chair has no suspension at all. "The ride gets a bit bumpy," McIntosh says. "But then again, there's plenty of padding." Initially he had trouble turning because all the chair's mass was toward the back, but adding weights near his feet gave the front wheels more traction. He says he has now mastered climbing hills and turning at stop signs, although he's planning to add a rearview mirror to reduce the large blind spot behind the backrest.

THE H2WHOA CREDO: DIY CAN BE DANGEROUS.
We review all our projects before publishing them, but ultimately your safety is your responsibility. Always wear protective gear, take proper safety precautions, and follow all laws and regulations.

CODY PICKENS

"In fighter combat, this feature is the difference between life and death."
– us.gizmodo.com



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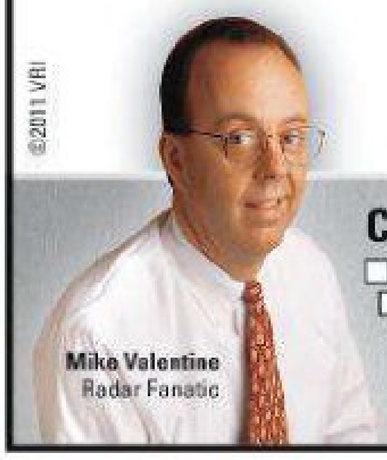

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5 WAYS TO IMPROVE YOUR FACEBOOK PAGE

1 CHANGE THE LOOK

Enough with the blue and white. The FaceTweak plugin for Firefox (*facetweak.com*) allows greater creative control of your social surfing. Pick from 20 new backgrounds, then lock the menus at the top of the window, highlight birthdays, and zoom photos by mousing over them.

2 MAKE A CLEAN BREAK

Hiding your ex will keep her out of your newsfeed, but friend suggestions and new photos will still crop up. Eternal Sunshine for Chrome (*chrome.google.com/extensions*) conceals stream and profile updates, albums and more, without the social awkwardness of people finding out you unfriended them.

3 ELEVATE YOUR STATUS

If you're stumped for a status update, the Generatus generator (*generatus.com*) will come up with one for you (example: "Sarah is wondering how to set a laser printer to stun"). Or type your status into *toolsgeek.com/upsidedown.php*, to turn it into upside-down text.

4 MAKE IT OFFICIAL

Professionals need something a bit slicker than the default fan page. Business owners can build a Facebook landing page on *pagemodo.com* with customizable templates that incorporate photos and videos and offer a wide selection of colors and fonts.

5 CUT THE FAT

Toss all the clutter for a stripped-down page. Download the Greasemonkey add-on for Firefox, or GreaseKit for Safari, then copy the script at *userscripts.org/scripts/show/11992* and select the ads, invites and other types of information that you'd rather not see. The code is open to tinkering as Facebook changes.—AMANDA SCHUPAK

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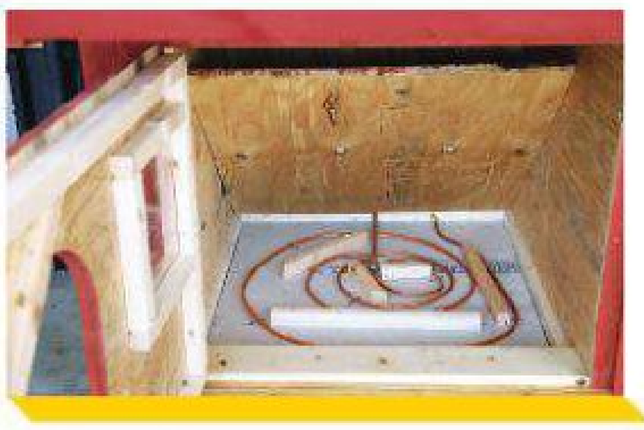
ANIMAL HOUSE

Man's best friend gets a high-tech home, complete with a solar heating system, LED lights and a Wi-Fi security camera

Pearl, my beloved labradoodle, dutifully watched me build myself a new house for the past three years. So when I was almost finished, I decided to build her a place of her own. A standard model just wouldn't do, though, so I went a little overboard. After creating the design with CAD software, I added a solar hot-water radiant-heating system and made a green roof that retains rainwater, creates oxygen, and improves insulation. Then I decked it out with a few other touches, including some colored LED lights to brighten things up and a Web-enabled wireless video camera that lets me keep an eye on Pearl from my computer or phone. That's plenty of features for her, but the doghouse has one extra benefit for me: The battery that powers it also powers all the low-voltage exterior lights on my property.—JOHN CARNETT

CANINE CASTLE
The house is not designed for a dog to live in 24 hours a day, as much as Pearl seems to wish it were. The design could also be used for a kids' clubhouse.

◀ IT'S ELECTRIC
A box houses the solar controller, voltage reducer, and switches.



▶ DOWN BELOW
Fluid-filled copper pipes under the floor radiate heat upward.

A HIGH-TECH DOGHOUSE

TIME: 70 HOURS COST: $1,500
EASY □□■□□ HARD

For more details and photos, go to *popsci.com/doghouse.*

Frame
I chose a size that would be comfortable for a medium-sized dog. I started with a frame made from two-by-fours and added structurally insulated panels to the sides and exterior-grade wood for the porch.

Solar collection
The wall with the solar panel has a window and faces south. The opposite side has no windows, so it retains heat.

Electrical
Charged by the solar panel, the gel battery is mounted inside the house. A solar charge controller, switches and other parts are inside a waterproof panel mounted on the exterior for easy adjustment.

Roof
To waterproof the plywood, I covered the roof with a polyethylene film and coated it with a liquid rubber called EPDM.

Heating
When the photovoltaic panels are exposed to sunlight, a pump circulates glycol fluid through evacuated tubes to a series of copper pipes underneath the floor. The pipes heat a concrete backing board below them, which in turn disperses heat through the hardwood floor into the house.

Cooling
The entire house is insulated. During warm weather, air can flow from vents in the rear through the front door when it's left open.

Lighting
The porch ceiling contains a waterproof 12-volt LED light. The two interior lights go on automatically when it gets dark outside.

Security
A motion- and heat-activated Wi-Fi security camera is mounted inside the front wall so I can see when Pearl is inside the doghouse. The camera I used is only for interior use; for an added home-security measure, a model that's rated for exterior mounting and that pans around would work as well.

ILLUSTRATION: GREG MAXSON; PHOTOGRAPHS: JOHN B. CARNETT

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Storedmags.com

MORNING JOE

A five-and-a-half-ton solar array—to make better coffee

In 2004, artist Dave Hartkop was looking for a way to move out of his parents' house. Pairing his interest in alternative energy with his brother Mike's passion for coffee, he decided to start an online coffee business, and designed a huge solar-powered roasting system to supply it. Now the brothers are on their fourth, and by far largest, version of the roaster. Dubbed Helios 4, it's made up of more than 600 mirrors and has a 35-foot-by-35-foot footprint.

Hartkop chose solar power because it was the only renewable resource that could produce high-enough temperatures for roasting at a feasible cost. But he faced a major obstacle: Wind gusts in the Pueblo, Colorado, area where he lives regularly reach 90 mph. So he hired contractors to fabricate a truss from two I-beams to stabilize the solar array, bringing the structure's weight to about 11,000 pounds. The array is mounted on two concentric circular tracks and turned by a solar-cell-powered motor to keep the mirrors pointed at the sun. During the roasting process, an operator adjusts the array's heading and angle every two to three minutes by following a pinhole-camera feed of the sun on a closed-circuit video system. The mirrors concentrate the sun's rays onto a receiver box that heats air to as high as 900°F. Solar-cell-powered fans duct the air into the roaster chamber.

Hartkop is now working on a lighter system to be mounted on the roof of the brothers' warehouse. But the Helios 4 won't go to the landfill—he plans to sell it to a local recycler who will use it to make path stones from plastics.—ANDREW ROSENBLUM

TIME: 10 MONTHS
COST: $65,000

ON REFLECTION

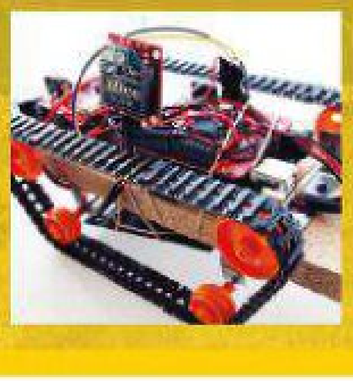
As the mirrors turn, a motor powers a winch system that raises or lowers the array like an easel. The roasting process takes up to 25 minutes for 15 pounds of coffee.

TWO MORE SUN-DRENCHED PROJECTS

Solar Tank

TIME: 10 HOURS **COST: $150**

The body of New York engineer Chris Rojas's iPhone-controlled tank features a microcontroller, an antenna module for receiving commands (software he wrote translates input from the iPhone into commands the tank understands), and a solar charger and batteries. Eight hours in the sun yields an hour of driving time.



Boom Bike

TIME: 120 HOURS **COST: $6,630**

British artist Dan Fox built a mobile stereo on top of a tricycle for parades and other events. The Boom Bike's two six-volt solar panels power a sound system made up of 13 speakers. The lithium-iron-phosphate battery powers the stereo for more than five hours when it's fully charged, which takes about 20 hours in direct sun.

CLOCKWISE FROM TOP: LINDSAY HARTKOP (2); DAN FOX; CHRIS ROJAS

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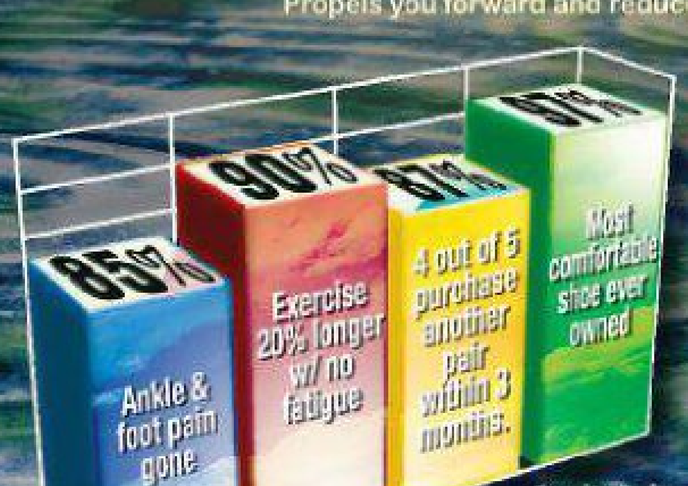

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10" SLIDING COMPOUND MITER SAW

CHICAGO ELECTRIC POWER TOOLS

LOT NO. 98199

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SAW BLADE INCLUDED

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CHICAGO WELDING

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CHICAGO ELECTRIC POWER TOOLS

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70701750

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DIGITAL INSPECTION CAMERA WITH 2.4" COLOR LCD MONITOR

CEN-TECH

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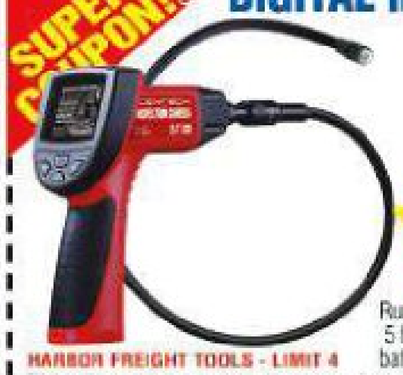

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$79.99

Runs approximately 5 hours on four AA batteries (included).

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6" DIGITAL CALIPER

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With an estimated 175 million Twitter users, it's no wonder it's so hard to track down old tweets—yours or anyone else's. Twitter stores them forever, but because of capacity limitations, its search engine takes you back just a week or two. Your only other option is to manually scroll through the individual tweets on a page, which is inefficient and does you no good beyond the 3,200-tweet limit.

If you need to search back further, start with TweetScan (*tweetscan.com*), which keeps an index to 2007; though incomplete, it's often the best bet. If that doesn't work, you may still be able to retrieve what you need using a search engine. Try Googling with a query like this: twitter.com/ username keyword (swap in the username of the person who tweeted and a keyword from the tweet).

For easier access to your tweets in the future, back them up. Among the services available, TweetBackUp (*tweetbackup.com*) is free and has active support on Twitter itself (@TweetBackUp). Once you've signed in (it uses your Twitter account for authentication), it automatically backs up your tweets, and you can quickly export your last 3,200 tweets into any of four formats, which you can then search. As a bonus, the HTML and CSV formats give you the permanent URL for each tweet.

SARAH MILSTEIN is co-author of *The Twitter Book*.

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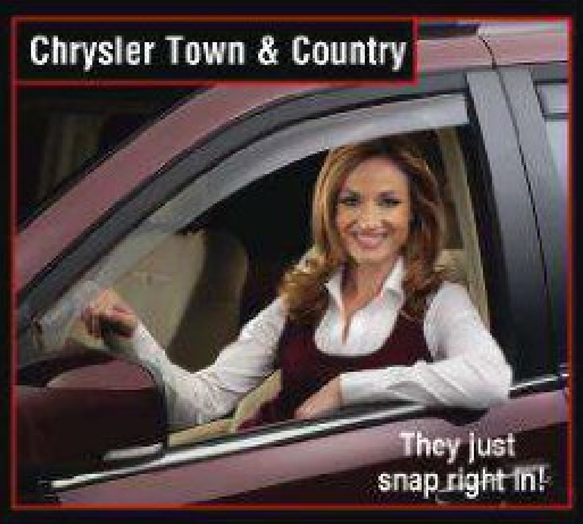

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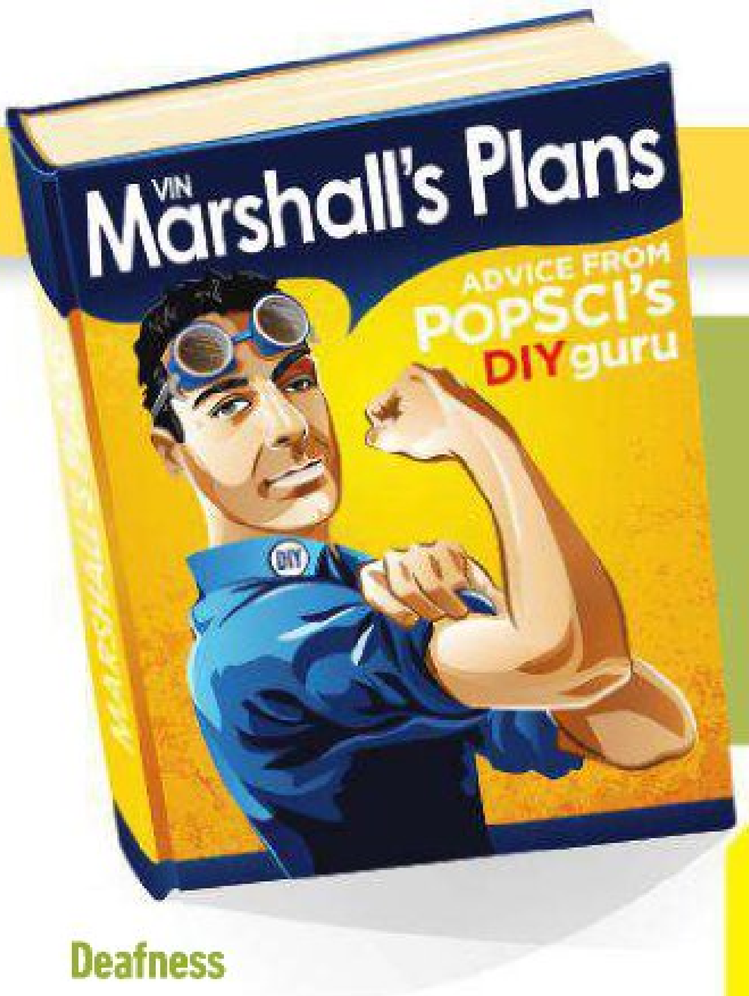

I've accidentally dropped an engine on my foot, set myself on fire, fallen off all sorts of things—and now I'm here to tell you about safety. Four of the biggest risks to DIYers are ones that often don't get taken seriously, but they all can be mitigated with some easy-to-find gear.—VIN MARSHALL

Deafness

Prolonged exposure to sounds above 85 decibels (about as loud as traffic on a busy highway) can cause permanent hearing damage. There are several good options to protect yourself, including earplugs that you squish up, earmuff-style headphones and, my favorite, the earplugs on a plastic band, which are reusable, can be taken on and off easily, and stay out of the way of a welding helmet or hard hat.
I recommend: Howard Leight hearing bands

Crushed Feet

Years ago, a hoist holding the 700-pound engine and transmission from my Triumph TR3 collapsed and dropped the entire assembly on my foot. Luckily, the oil pan deformed and I got to keep my toes (if in a slightly modified configuration). Since then, I've worn safety-toe boots. The relevant U.S. standard specifies that a safety toe must withstand a 75-foot-pound impact and 2,500 pounds of pressure.
I recommend: Red Wing safety-toe work boots

Damaged Lungs

By the time you smell something, you've probably already killed off a few cells in your lungs. Even if you're only soldering wires, don't just hold your breath and work quickly. Depending on the nature of the fumes, you should open a window, turn on a fan, or install a fume extractor. At the very least, keep a respirator handy.
I recommend: Weller fume extractors

Electrocution

At some point, we've probably all touched an apparently dead circuit that turned out to be quite alive. For a DIYer without the experience of a professional electrician, insulated screwdrivers are an added layer of safety. My electrician buddy points out that you can make your own version by slipping some rubber hose over the shaft of a regular screwdriver.
I recommend: Wiha slotted screwdriver set

JON ARVIZU

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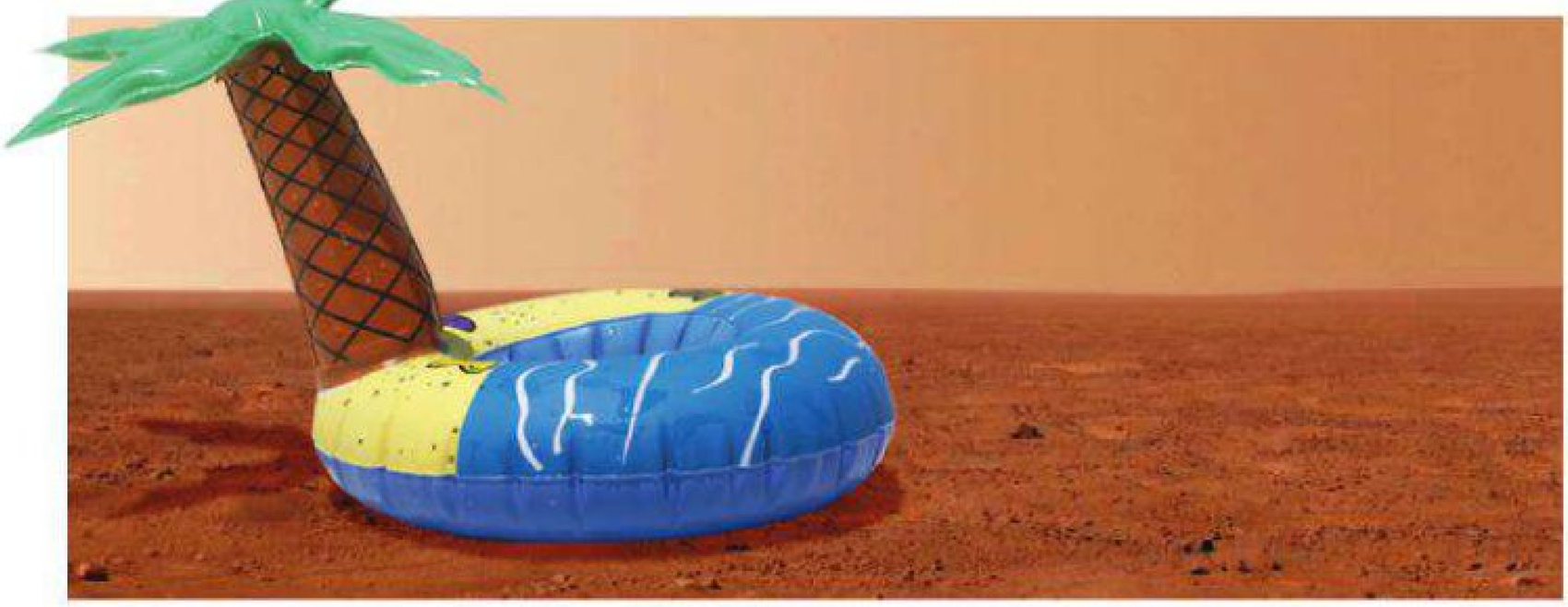

Q CAN WE MAKE MARS HABITABLE BY PUMPING THE ATMOSPHERE FULL OF OXYGEN?

A In a roundabout way, yes. But first we must heat that atmosphere, since the surface of Mars is about –58°F. "We know how to warm planets; we're doing it right now," says Robert Zubrin, the president of the nonprofit Mars Society, a group devoted to Martian exploration. To make Mars more Earthlike, or "terraform" it, we just need to increase the greenhouse effect by adding fluorocarbons to the atmosphere, absorbing and trapping the sun's rays. Tetrafluoromethane, or CF_4, is a simple refrigerant that could work without destroying the ozone, as other fluorocarbons do.

As Mars warms, its frozen soil would thaw enough to release carbon dioxide, and more carbon in the atmosphere would further accelerate the greenhouse effect, bringing the average temperature up to 32°. Mars's frozen

BACKGROUND: NASA/JPL-CALTECH/UNIVERSITY OF ARIZONA/TEXAS A&M UNIVERSITY; PALM TREE: JUNOS/GETTY IMAGES

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underground water supply would melt and flow back into ancient riverbeds. And when the water reaches Martian soil, it would break down latent peroxides, releasing oxygen into the atmosphere—not yet enough to sustain human life, but enough to grow plants—which would further increase the supply.

Once the plants took root, we could just wait for oxygen to accumulate. At this point, Mars colonizers, who Zubrin imagines would work out of a research base camp and wear something akin to scuba gear to supplement their oxygen intake, would also grow algae and seaweed in ponds, which could anchor a growing food chain. "You could have fish farms on Mars," he says. "Water would become the first environment that would be habitable by higher animals without any kind of artificial assistance."

After bringing in fish, we could begin introducing land-dwellers to Mars, starting with insects and, as more and more oxygen became available, progressing to warm-blooded creatures. Using this process, Zubrin says, humans could walk around without supplemental oxygen within 1,000 years. But he also predicts that we'll come up with other ways to speed up our settlement of Mars, such as genetically engineered plants that photosynthesize faster. "We can grapple with it and come up with a way to do it using 20th-century technology," he says. "Yet these are solutions that people in the future will consider prophetic but quaint."

—CAITLIN KEARNEY

What's the point of sex?

This may seem obvious. But in evolutionary terms, the benefits of sexual reproduction are not immediately clear. Male rhinoceros beetles grow huge, unwieldy horns half the length

of their body that they use to fight for females. Ribbon-tailed birds of paradise produce outlandish plumage to attract a mate. Darwin was bothered by such traits, since his theory of evolution couldn't completely explain them ("The sight of a feather in a peacock's tail, whenever I gaze at it, makes me feel sick!" he wrote to a friend). Moreover, sex allows an unrelated, possibly inferior partner to insert half a genome into the next generation. So why is sex nearly universal across animals, plants and fungi? Shouldn't natural selection favor animals that forgo draining displays and genetic roulette and simply clone themselves?

Yes and no. Many animals *do* clone themselves; certain sea anemones can bud identical twins from the sides of their bodies. Aphids, bees and ants can reproduce asexually. Virgin births sometimes occur among hammerhead sharks, turkeys, boa constrictors and komodo dragons. But nearly all animals engage in sex at some point in their lives. Biologists say that the benefits of sex come from the genetic rearrangements that occur during meiosis, the special cell division that produces eggs and sperm. During meiosis, combinations of the parents' genes are broken up and reconfigured into novel arrangements in the resulting sperm and egg cells, creating new gene combinations that might be advantageous.

One animal, however, has done just fine without any sex at all. Bdelloid rotifers can be found in most freshwater ponds, measure a few tenths of a millimeter long, contain only about 1,000 cells, and have been chaste for roughly 80 million years. The nearly 400 described species of bdelloids prove that the group is respectably diverse, yet no one has ever seen a male. Bdelloids lay unfertilized eggs that grow to be fully fertile daughters. What's the secret?

Harvard University biology professor Matthew Meselson and his lab have spent the past several years investigating bdelloids' molecular genetics. By exposing bdelloids to extremely high levels of ionizing radiation (a treatment that causes hundreds of physical breaks in DNA strands), one of Meselson's former graduate students, Eugene Gladyshev, showed that bdelloids can completely rebuild their genomes—an unprecedented feat among animals.

Recently, Meselson and Gladyshev made an even more amazing discovery: Bdelloids have foreign DNA from bacteria and fungi in their chromosomes, which is a great way to maintain genetic diversity. As for the rest of us, we're stuck with sex.

—BENJAMIN EWEN-CAMPEN

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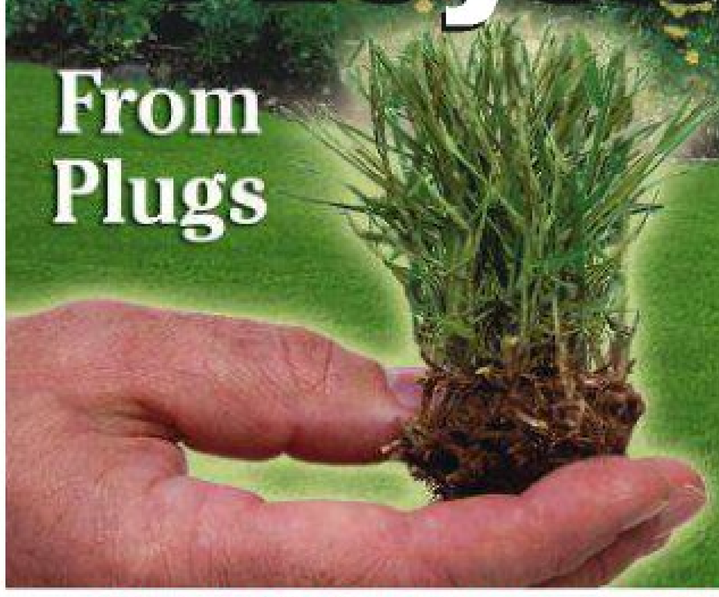

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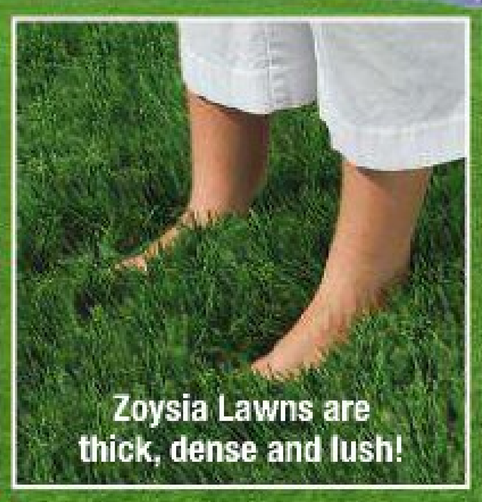

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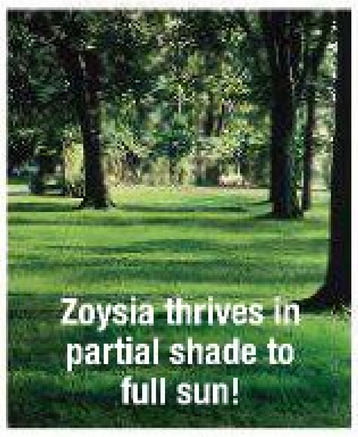

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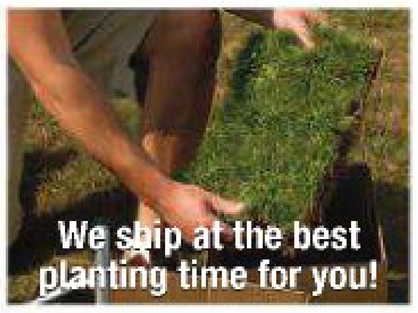

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[CONTINUED FROM PAGE 69]

BODIES IN MOTION

bama. For passengers, she explains, "expectations of aircraft motion often conflict with actual motion, and sickness often results."

The drug dimenhydrinate, sold under the brand name Dramamine, can help, but it also causes drowsiness and can sometimes even act as a hallucinogen. NASA, eager for a substitute, is studying the use of LCD shutter glasses, like those worn at 3-D movies. The vestibular system, when disturbed, may prevent the retina from holding images steady, thereby inducing nausea. Shutter glasses create a strobe effect that breaks the view into discrete images, fixing each one in one place, which helps the brain coordinate the vestibular with the visual.

For now, a good view is the best way to ease motion sickness. But showing passengers the true movement of the plane can also create problems. In turbulence, a passenger seated at the rear of the plane is moving around in very different ways from the people seated up front. "If you have a clear view," Planey says, "you can see the fuselage twisting, which is what it's supposed to do." But the sight tends to alarm passengers, so designers have learned to interrupt the view through the interiors of most modern jets with restrooms and curtains.

WHAT ARE the real limits for commercial transit on Earth? Assume for a moment that vehicles can travel any route at any speed without tearing apart or running out of gas. Onboard, what can our bodies take?

The longest commercial nonstop flight in the world is Newark to Singapore—a 9,535-mile haul that takes just under 19 hours. Imagine the trip on a maglev train. On a smooth, straight, point-to-point track between the two cities, a commercial maglev operator wanting to avoid passenger complaints would still have to obey conservative, 0.15G limits on acceleration and deceleration. Within those

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BODIES IN MOTION

confines, the train would accelerate continuously until, at a halfway point somewhere in the Arctic Circle, it very briefly reached a peak speed of 11,000 mph. Then it would immediately begin a comfortable 0.15G deceleration, for a total trip of just under two hours. If we allowed our theoretical supertrain to follow the more permissive standards of commercial flight, however—1.5 Gs of acceleration, 1 G of deceleration—the journey would be much faster. The train would use the first third of the trip to accelerate to 30,000 mph. Then it would use the remaining two thirds of the trip to (somewhat) gently decelerate. Total time: 46 minutes. All other considerations aside—such as the sonic booms that would deafen the towns along the way—these are the fastest trips any paying, conscious passenger will ever take on this planet.

How close are we to such a trip? In March 2001, Boeing announced its concept for a so-called Sonic Cruiser, capable of flights at just short of the speed of sound—as much as 20 percent faster than the Boeing 747-400, one of the fastest commercial jets in service. The new wide-body plane would, Boeing promised, shave nearly an hour off every 3,000 miles traveled.

But airlines for the most part are finding that it's easier and cheaper to distract passengers from the experience of travel than it is to make the trip faster and shorter. Passengers are happy to spend a bit of time on the plane, it turns out, if they have a sense of control over their surroundings. "Watching the moving-map display, inflight Internet, television—all of that helps," Planey says.

Boeing, for its part, is betting that passengers will choose comfort over speed. The company shelved the Sonic Cruiser program in 2002 to focus on the 787 Dreamliner, due to make its first commercial flights next year. The new plane borrows much of the Sonic Cruiser's structural design; composite materials make up 50 percent of the plane, as compared with 20 percent on the 777.

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(CONTINUED FROM PAGE 94)

BODIES IN MOTION

The flights will be no shorter. But a lighter plane requires less fuel, and, more important, Boeing claims that the composites will make for a more comfortable environment. In a conventional aluminum-fuselage plane, the metal can be corroded by humidity in the cabin, so engineers need to keep the environment extremely dry. On a pressurized 747, passengers are sitting at the equivalent of 8,000 feet of altitude. In the 787, that perceived altitude can instead be 6,000 feet, and the air will be moister and more pleasant, because the composite materials don't corrode as quickly. In a Boeing-sponsored Oklahoma State University study, 500 people took a simulated 20-hour flight in the cabin. Passengers reported feeling less achy and more relaxed in the new perceived altitude. Combined with in-flight entertainment and the right lighting, comfort seems to do away with the need for extra speed. If time seems to pass faster, why bother designing a faster plane?

THAT PILOTLESS Learjet crossed most of the country on its own, and except for the one system needed to keep everyone breathing, the rest of the plane appeared to be functioning flawlessly. The flight couldn't have been more comfortable, perhaps even for the passengers and crew. The progression of hypoxia—disorientation, sedation, unconsciousness—is often imperceptible to the victim. With a drink or a half-finished latte in their hands, the passengers probably remained in their seats throughout the flight.

The experience of travel gives us the illusion that motion comes at no cost. But vehicles are essentially cocoons, and the systems that cradle us inside them have one fundamental purpose: to keep us from feeling how fast and how far we've come.

Jacob Ward is POPULAR SCIENCE'S *West Coast bureau chief.*

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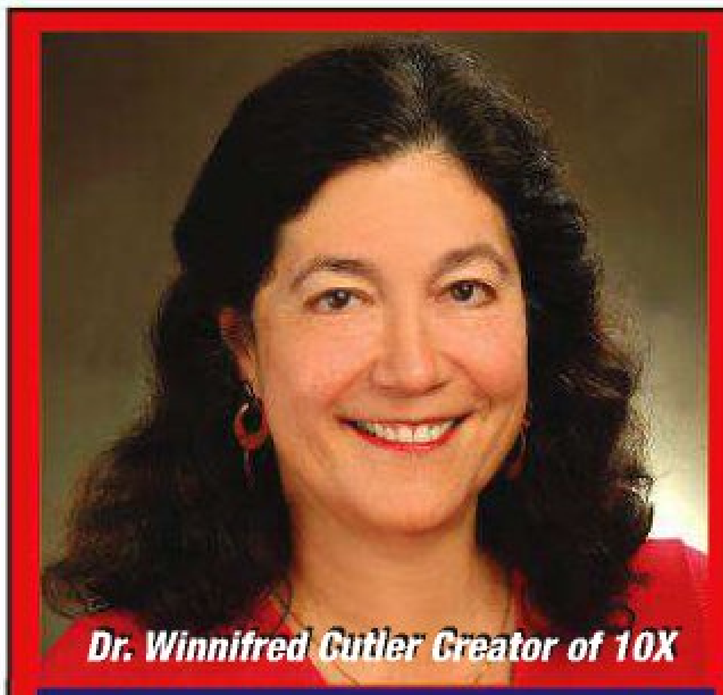

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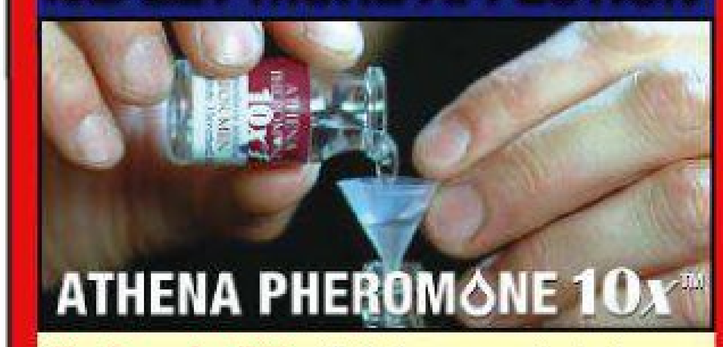

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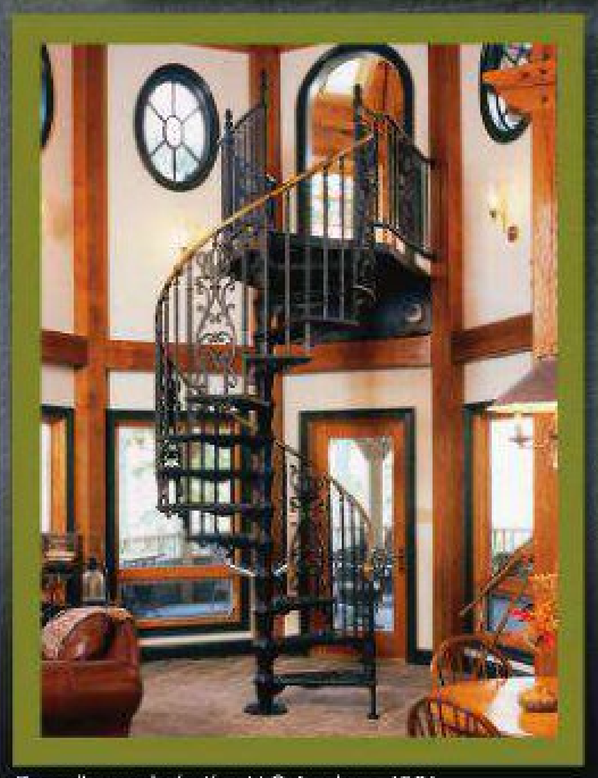

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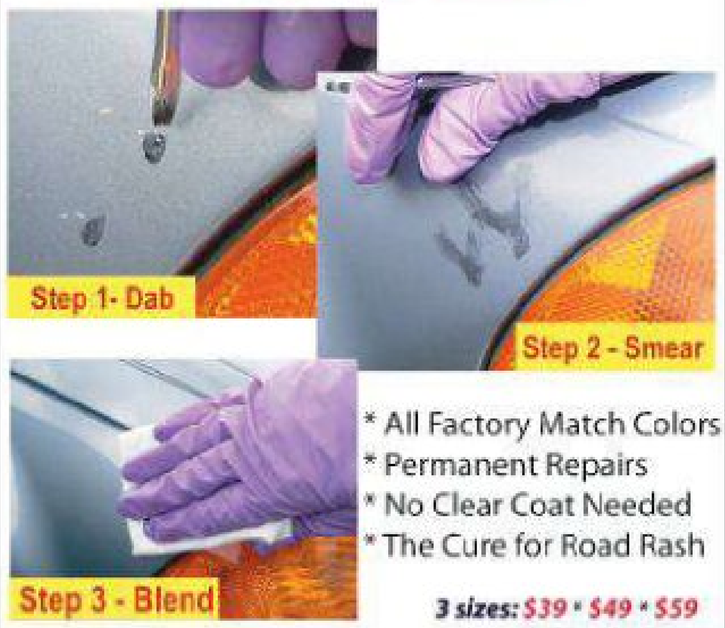

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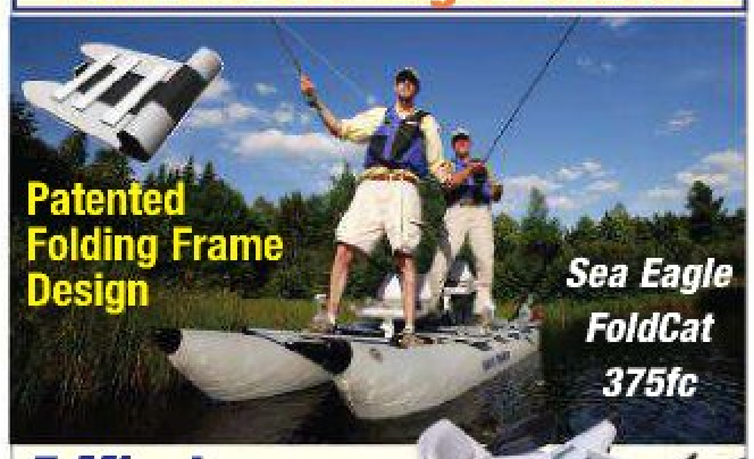

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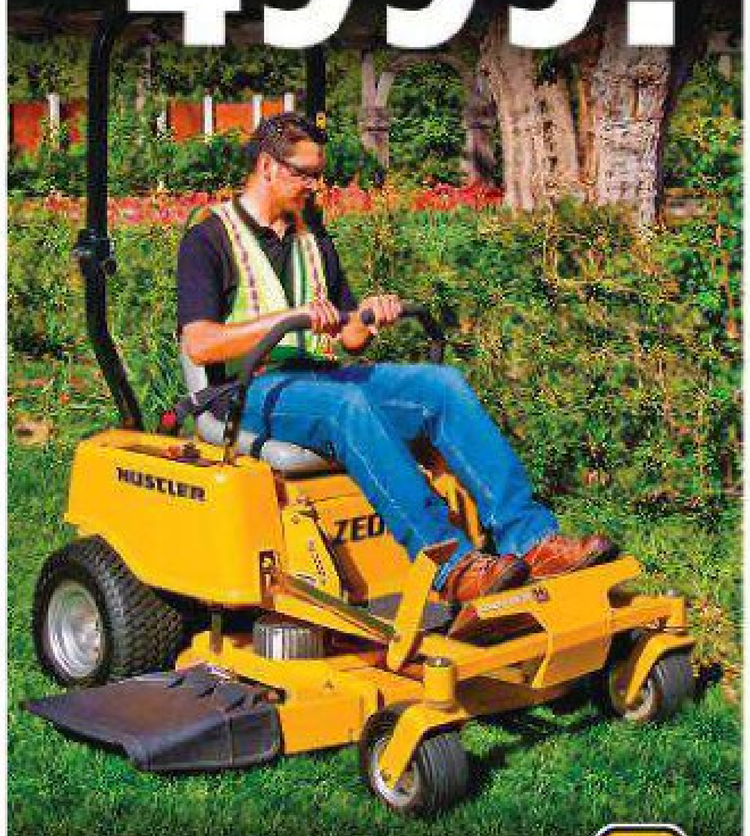

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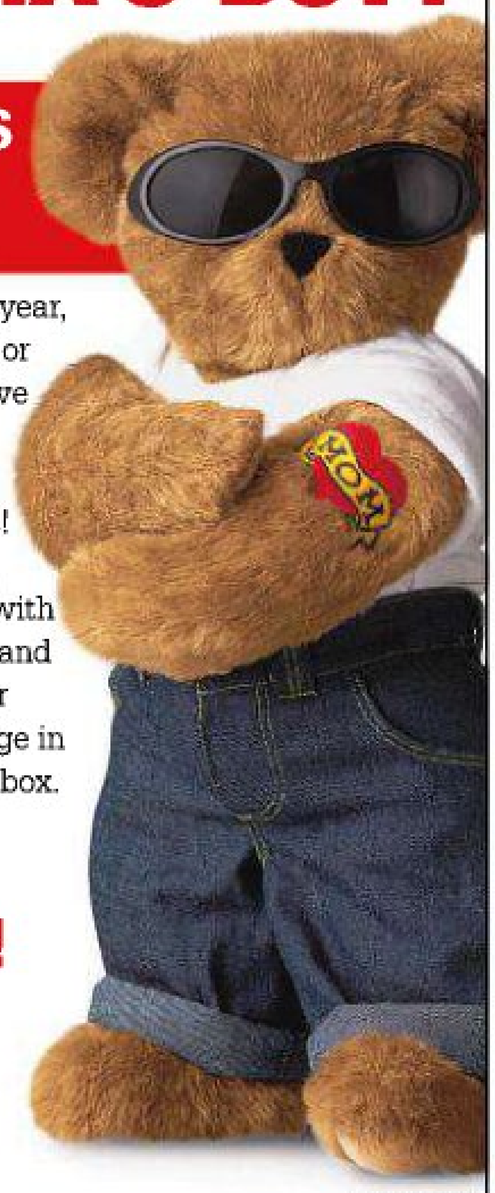

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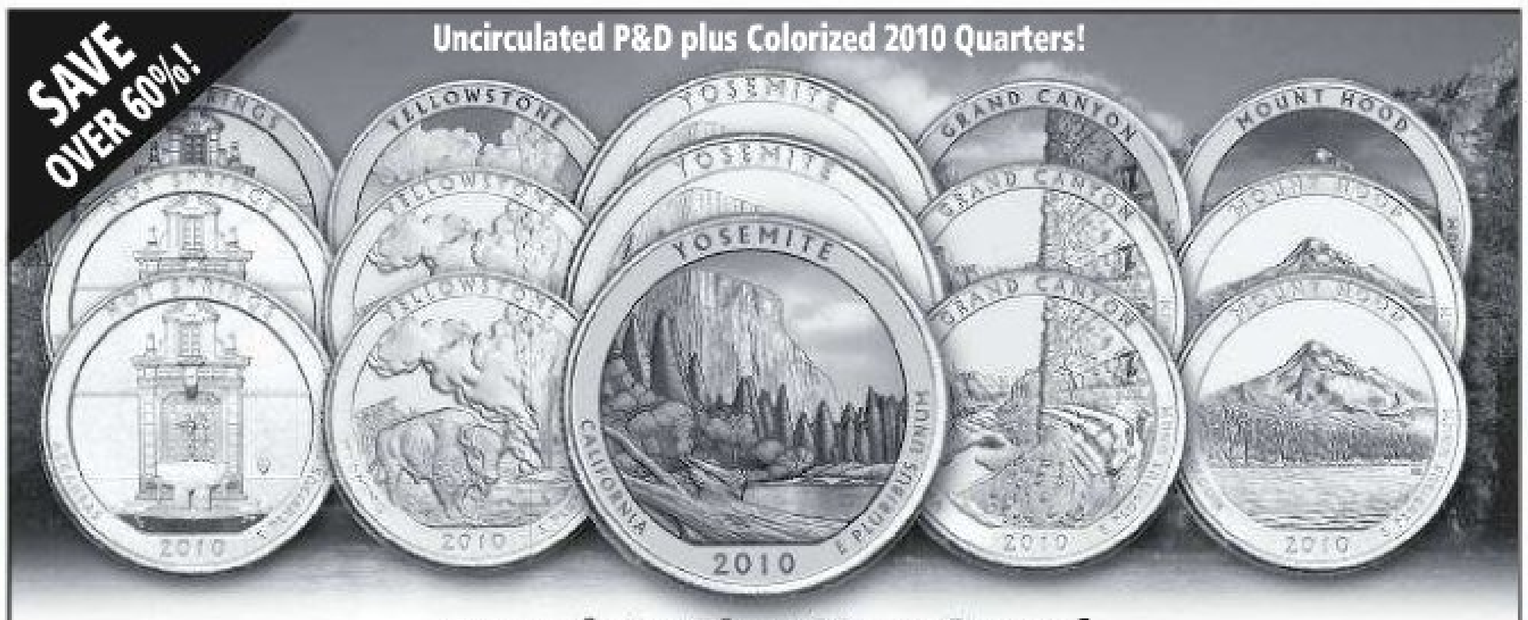

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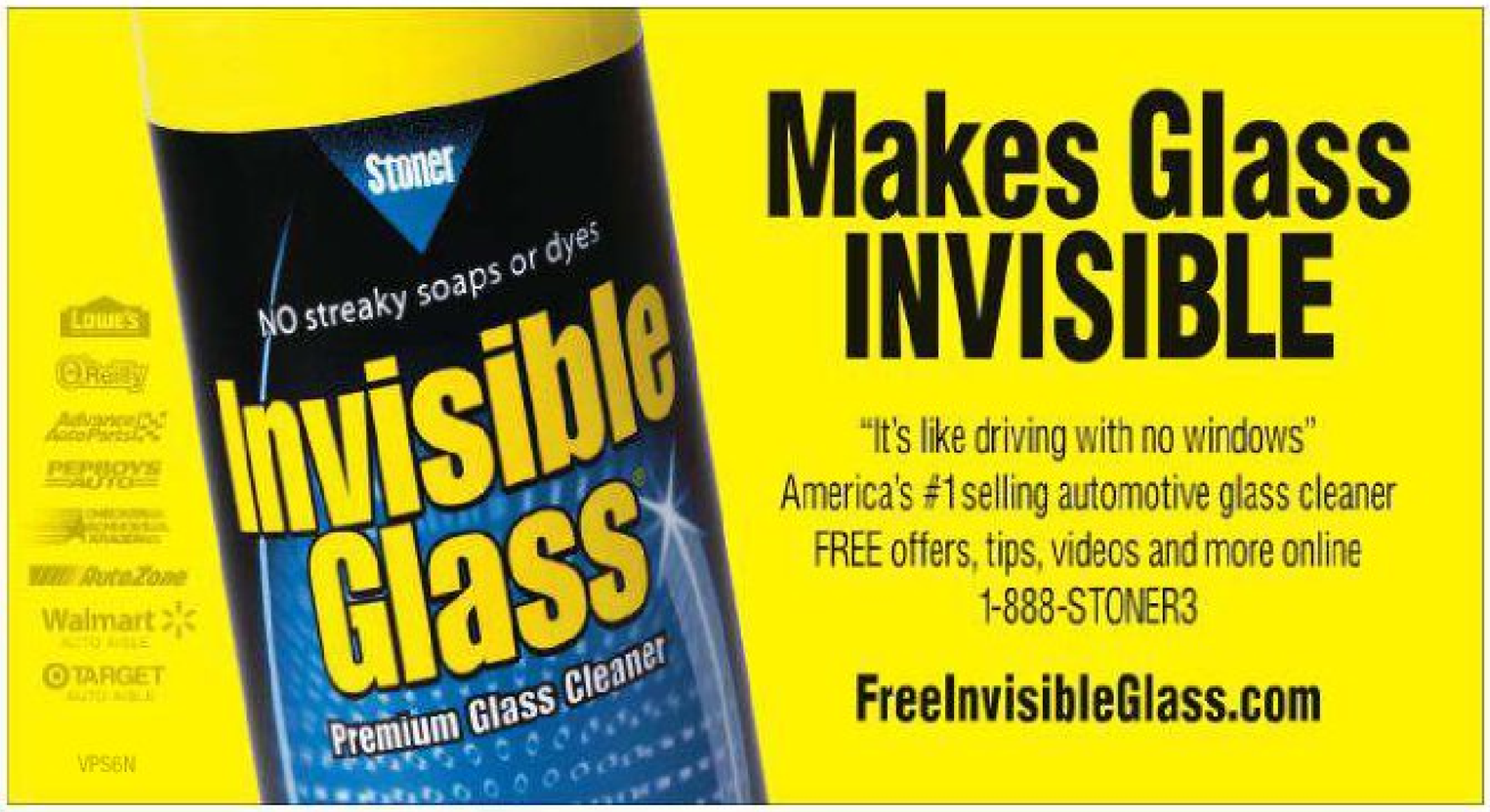

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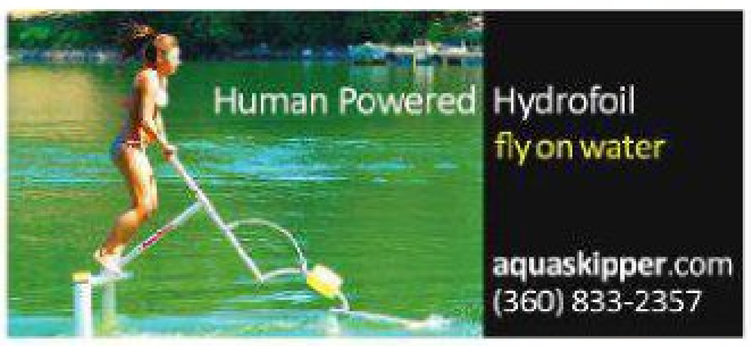

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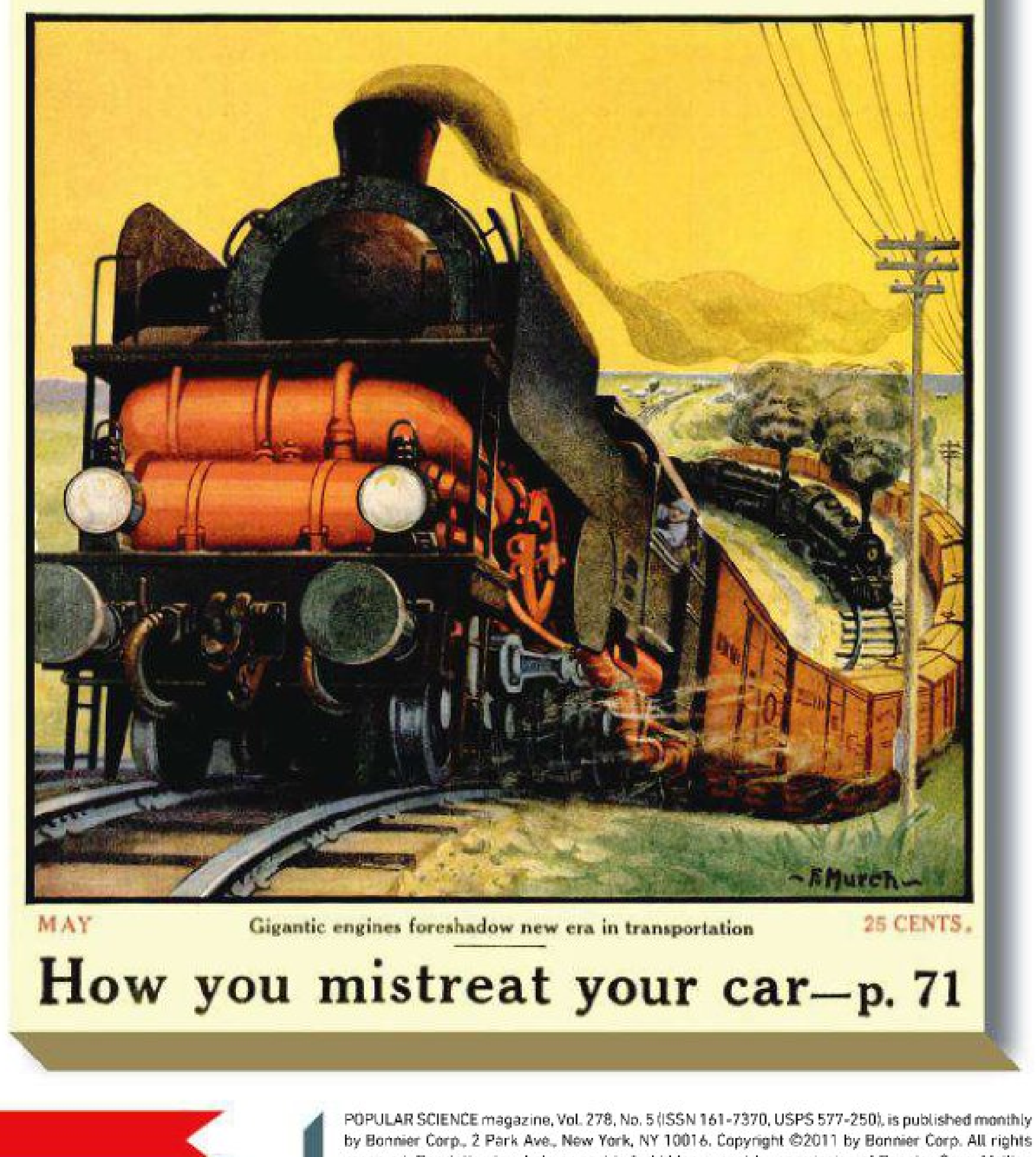
"Coal-burning locomotives long have been recognized as wasteful machines," Popular Science correspondent Hawthorne Daniel wrote in our May 1925 issue. By then, diesel-electric engines—which burned diesel fuel, generating electricity to power electric motors—were becoming advanced enough that Daniel felt confident predicting the demise of coal-fired steam power. As evidence, he cited a 340-ton locomotive from Henry Ford's Detroit, Toledo & Ironton Railroad, which used a diesel engine to generate electricity for sixteen 250-horsepower electric motors. Steam loyalists struggled to compete. The 2,000-horsepower steam-turbine train on the cover shown here, built by the German firm Krupp, may have been steam's last, best hope, but the efficiency of diesel-electric was unbeatable. Now, more than eight decades later, we're on the verge of another revolution in rail. See page 70 for more.—NAOMI MAJOR



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The Flying Train

The world's first commercial magnetic-levitation train floated away from Birmingham, England's airport, hovering 0.6 inches above its quarter-mile track.

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