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POPULAR SCIENCE*

May/
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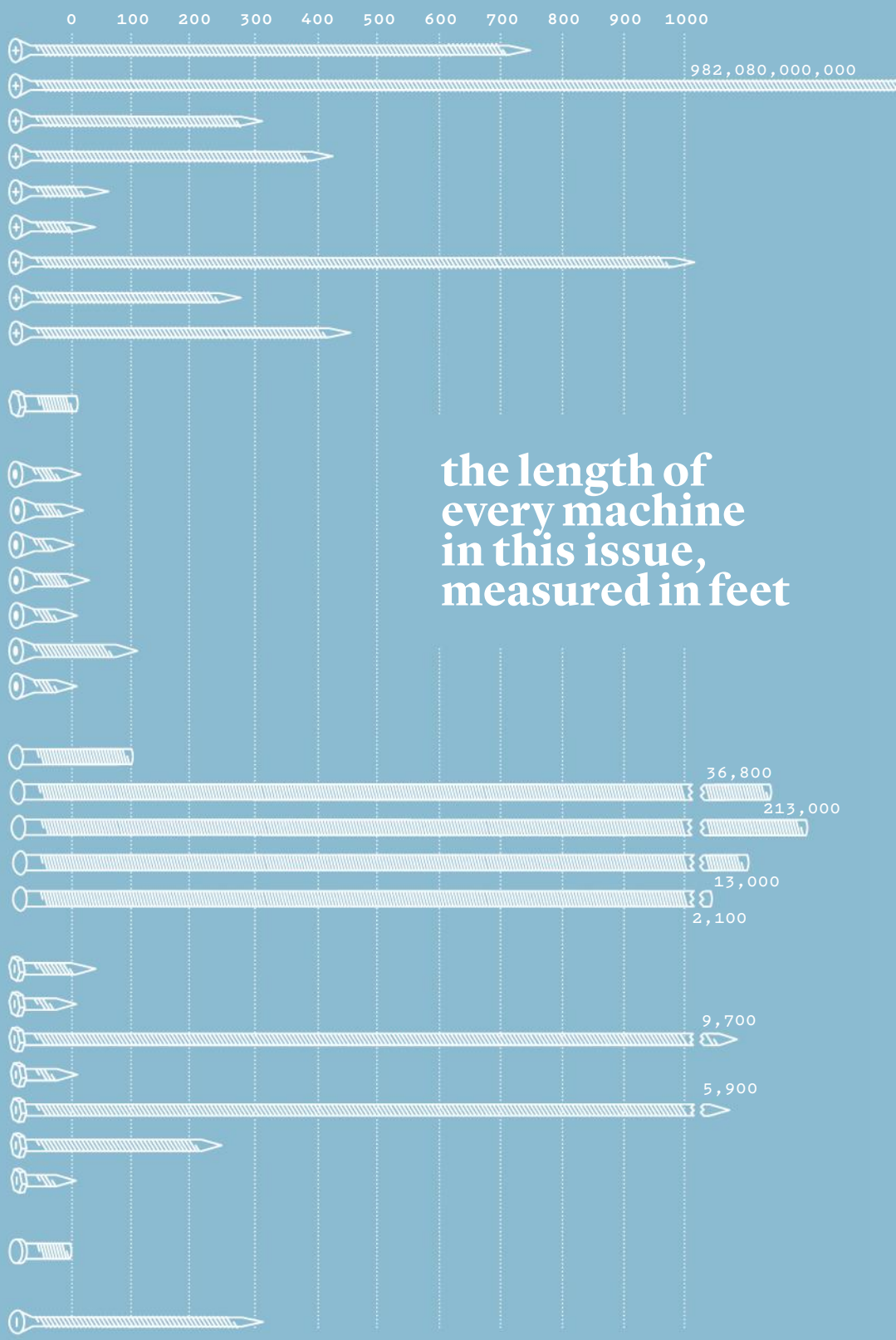

the length of every machine in this issue, measured in feet

FOR OUR COVER: THANKS TO HOLTCAT FOR THE HEAVY LIFT

cover photograph by The Voorhes / infographic by Sara Chodosh

TONS OF FUN

FOR ME, IT STARTED WITH trains. As a kid in Manhattan, the typical objects of childhood fixation were often scarce. I couldn't climb trees or skip stones—but I had 400 tons of urban-rail righteousness thundering beneath my apartment. I'd spend hours in the subway: riding lines to their ends, exploring abandoned stations, and racing through tunnels (sorry, Mom). My friend Nicky even figured out how to jimmy the doors to empty conductor compartments so we could hijack the PA system. (Not sorry.)

To this day, there are few sensations that center me like the repetitive rock of a rail car. I still ride the subway every day, and if I'm traveling anywhere near a train line, you'll find me on it seconds after my bag hits the hotel floor.

At stations around the world, I find silent solidarity with strangers, all of us wearing that same look of awe. Because TRAINS! I see it at airports, at work sites, at ports. Trains are a symptom, but machines are the disease. And if that makes me sick, then I never want to be healthy.

What is it about big machines that speaks so loudly into our heart microphones? Maybe it's their eye-filling size. Or maybe it's the brilliance of their complexity: tons upon tons, every piece abiding a delicate choreography. Whatever the reason, fascination with mechanical masterwork is a common trait—unusually common, I'd hazard, among *PopSci* readers.

That's why we dedicated this entire issue to these giant wonders. You like to look at them; we like to show you them. You like to read about them; we like to write about them. What a match!

So turn the page and you'll find as many behemoths as we could fit (plus some that didn't). We've got rockets and boats and computers and chain saws and...well, it's enough to make you break out a plus-size bowl of ice cream and settle in. Which is exactly the idea.

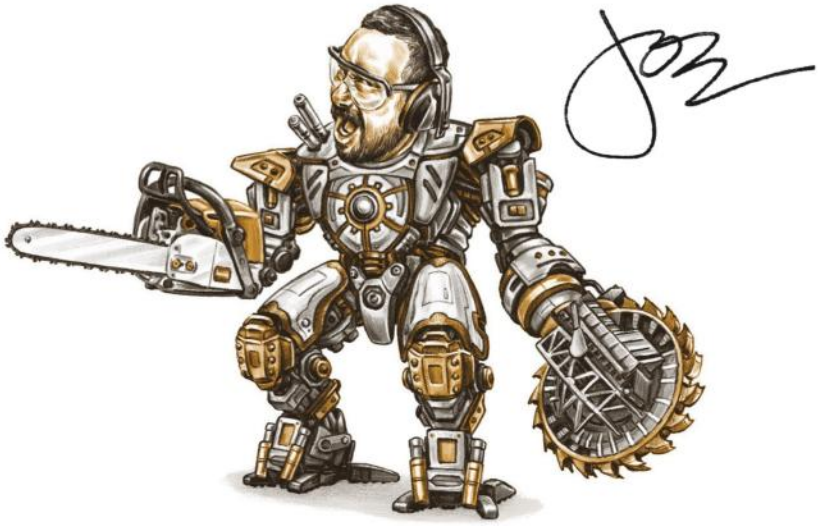

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illustration by Tim Tomkinson

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4

conveyor belts receive overburden (soil and rock) or lignite from the buckets, and carry the material at more than 11 mph. Each belt is 10.5 feet wide, big enough to ferry a Smart car with ease.

8,600

square feet of tread carry the Bagger's 13,000 tons of weight at a stately 0.4 mph.

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mining monster

TALLER THAN THE STATUE OF LIBERTY AND HEAVIER THAN THE EIFFEL TOWER, THIS German mining machine is one of the largest land vehicles on Earth. In HBO's futuristic *Westworld*, a bucket-wheel excavator like this claws out an entire city. In reality, these diggers work in open-pit mines. The excavator pictured here, called Bagger 288, uses its revolving wheel of buckets as a shovel to continually shift 8.5 million cubic feet of dirt a day. Once it reaches a seam of brown coal, or lignite, it can harvest 265,000 tons of fuel a day. And the crew this behemoth requires? A mere three to four people.

CHARTED

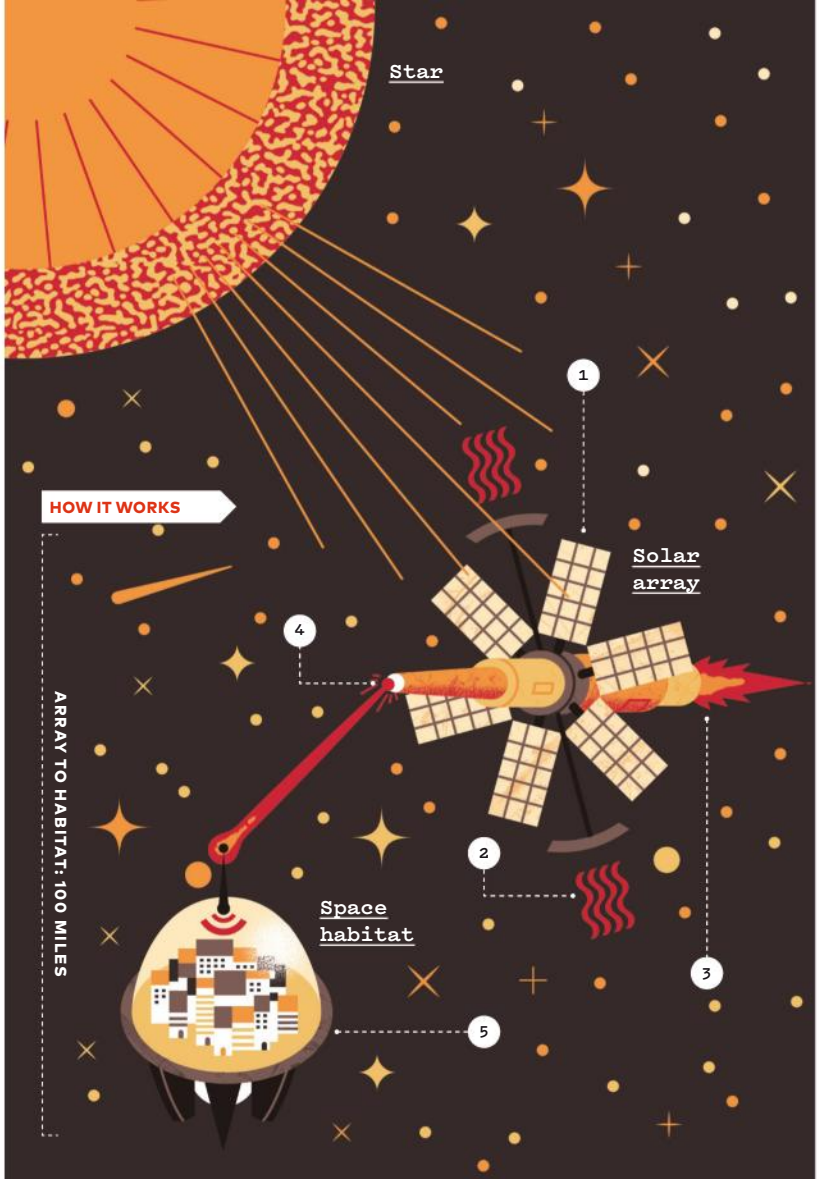
by Kelsey Atherton

STAR POWER

anatomy of a Dyson sphere

BY 3100 A.D., EARTH'S SKYROCKETING population might require so much energy—to run our virtual-reality consoles, jetpacks, and Hyperloops—that our power plants won't be able to keep up. Physicist Freeman Dyson proposed a solution to just that sort of crisis in 1960: a machine that encircles a star in a shell of solar collectors to harness its energy output. In our solar system, such a sphere could surround the sun at 93 million miles to collect 400 septillion watts per second, trillions of times more energy than the world uses now. The catch is that there are no materials strong enough to craft a solid mega-structure that big. We could, however, deploy tens of thousands of solar panels—a Dyson swarm—to harvest that same energy. Here's how one might work.

THE DYSON SPHERE



1/ Solar Power
Arrays of solar panels orbiting the sun convert its light into electricity. Raw materials for the panels come from dismantling asteroids or entire planets—no problem for a technologically advanced, energy-gluttonous species.

2/ Staying Cool
The sun is hot. To avoid melting, radiators emit excess heat off the back of the array. Dyson believed searching for heat signatures around distant stars could help us locate alien civilizations—assuming, of course, that they employ this technology.

3/ Going Steady
As photons hit the solar collectors, they nudge them backward little by little. Thrusters on the panels will occasionally fire to keep the arrays in position—and to avoid colliding with other members of the swarm.

4/ Delivery System
Lasers or microwave beams will send power where it's most needed—to robotic mining operations, space stations, or human settlements. Precision is key; the total energy gathered by the swarm could sustain a laser capable of vaporizing a planet.

5/ Life in Space
Beaming energy over shorter distances—like to a nearby space habitat—is most efficient. Which is a good thing because we'll need somewhere to live after we deplete our planet's resources to build our Dyson swarm.

by Sarah Fecht / illustration by Andrea Manzati

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CHARTED

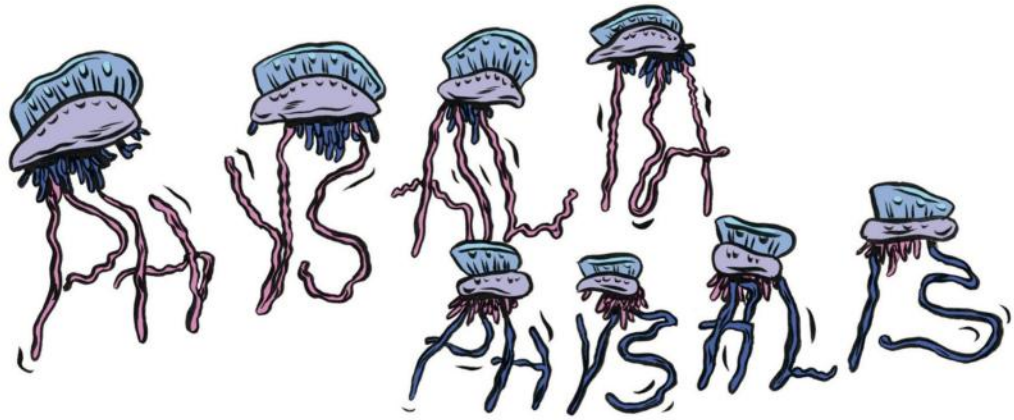
THEY LIVE

biomachines of the ocean

INSTEAD OF PULLEYS AND SPRINGS, LIVING CREATURES RELY ON CELLULAR machinery to do the work of life. Perhaps none function as unconventionally as ocean-dwelling siphonophores. Born as single embryos, these animals grow not by elongating their limbs but by budding entirely new beings called zooids. These cloned bodies complete specialized tasks: Some help the siphonophore move, others find food, or reproduce—yet a single nervous system orchestrates their motion. Here's how three of these chandelier-like invertebrates thrive as multitudes.

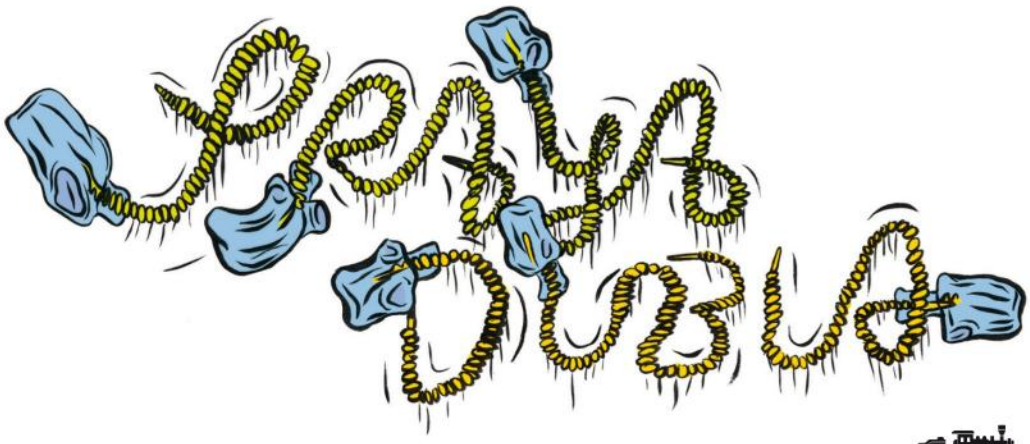
Bathyphysa conifera

When BP oil workers spotted this entity during an ROV patrol of the ocean floor in 2015, they joked that it resembled the Internet-famous "Flying Spaghetti Monster"—a cartoon meme mass of spaghetti and meatballs with a pair of protrusive eyes. The resemblance is uncanny indeed. *B. conifera*'s stem branches off into feeding nodes and stinging tentacles. Unlike some of its neighbors that must remain near the ocean floor, *B. conifera* can propel itself up and down by contracting and relaxing its body—thereby moving wherever it pleases. As spaghetti should.



Physalia physalis

Freshly stung swimmers often mistake *Physalia physalis*—aka the Portuguese man o' war—for a jellyfish. It's not. It's a siphonophore. The big, bulbous section—a gaseous sac known as its float—makes up the largest portion of this creature's body and keeps it bobbing at the ocean's surface. Other teammates drift into the deep sea like ornamental indigo streamers. But don't mistake them for decoration. They are feeding tentacles. Armed with barbed, venom-filled cells, they stun and kill small crustaceans and fish. They also don't feel so great when they touch human flesh.



Praya dubia

Maxing out at 130 feet, *P. dubia* holds the record for world's longest ocean animal. Its notable talent is jetting through the deep, dark ocean, a half-mile down, via blue bioluminescent zooids called nectophores. They propel the colony forward by contracting in a coordinated, timed fashion. Other offshoots that are designed to stun, eat, and reproduce lag behind the attached nectophore in a long train. The constant movement keeps this siphonophore's ever-budding figure aligned, positioning its feeding polyps to capture microscopic morsels.

by Rachel Feltman / illustration by Kelsey Dake

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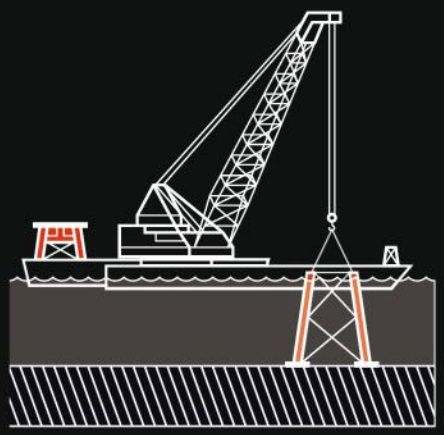
EASY, BREEZY BEAUTIFUL

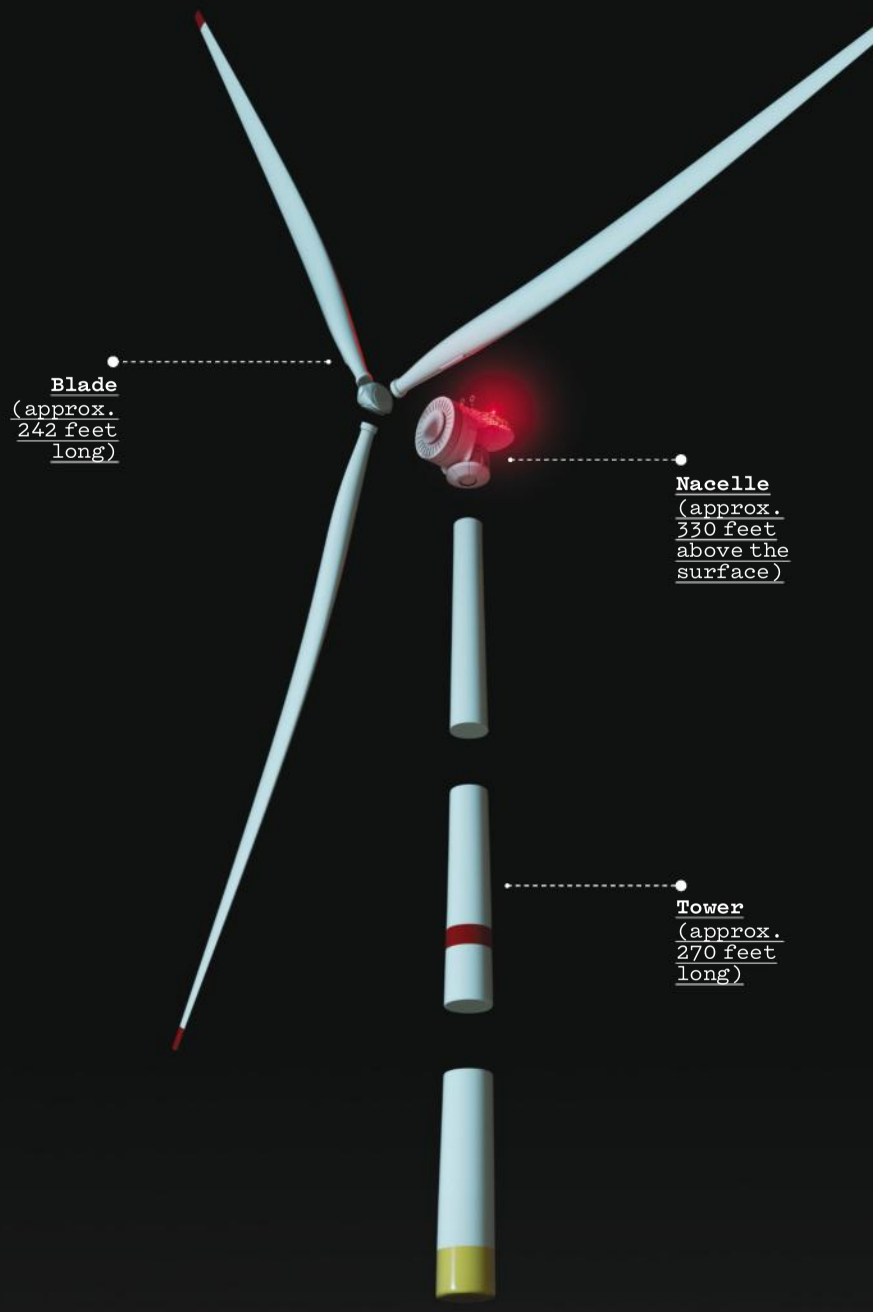
how to build a giant windmill—at sea

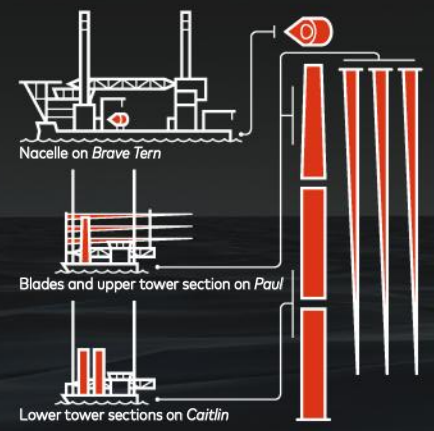
OUR SMALLEST STATE (RHODE ISLAND) NOW HARBORS A BIG RECORD: the nation's first air-powered offshore energy facility. The five-turbine, 30-megawatt Block Island Wind Farm, which opened in December, can power up to 17,000 homes. Such turbines have spun across the country for years, mostly in wide-open and gusty places like Texas, Oklahoma, and Kansas, generating around 4.4 percent of our national energy. Ocean breezes are stronger and more consistent, which means the plants net more electricity. Here's how these monstrous machines get assembled at sea.



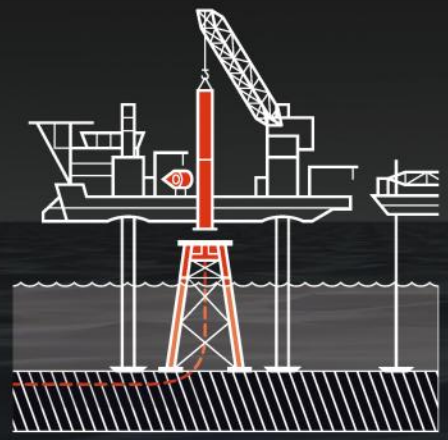
1/ Foundation Formation
Fabricators in Louisiana cut 400-ton steel foundations to varying lengths. That way the turbines all reach the same height when placed upon the uneven seafloor. A barge brings these pieces to the site, where a crane lifts and lowers them to the seabed. A pile driver affixes it all to the ocean floor.

2/ Premium Cable
First, a water jet plows a trench 6 feet below the seabed. Then a machine called Big Max lays the 7-inch-thick cable (weighing 4.9 million pounds and able to transmit 34,500 volts), connecting the foundations to Block Island, 3.8 miles away, and to the mainland 17 miles away.





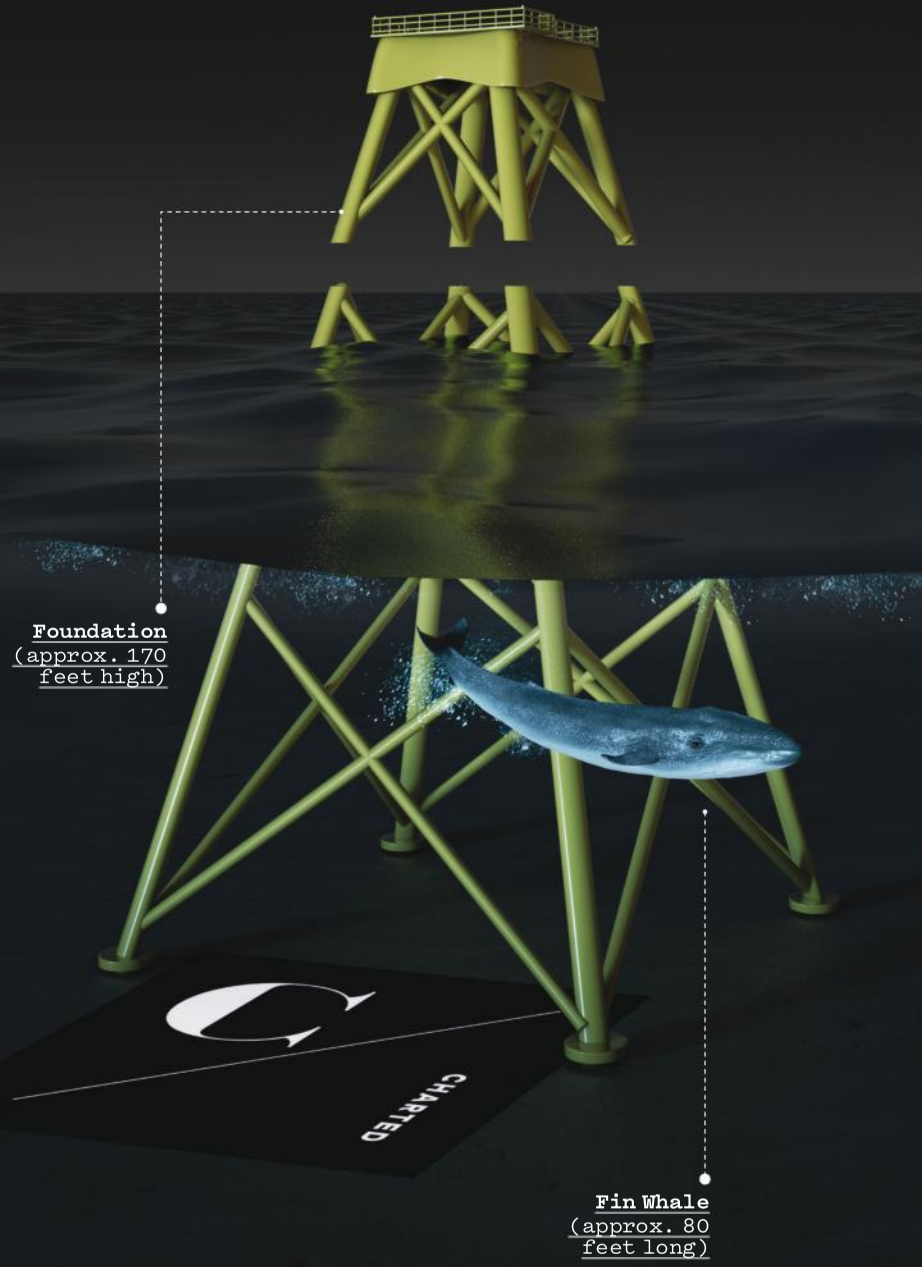
3/ Special Delivery
Three ships haul and install the main hardware: The 433-foot-long *Brave Tern* carries nacelles (housing all generating equipment), the 140-foot-long *Paul* hauls three blades and one of three 95-foot segments that make up the tower, and the 137-foot-long *Caitlin* carries the other two.



4/ Standing Ship
Brave Tern looks and moves like a boat, but once it reaches the site, it lowers four legs and shoots up as high as 230 feet. A crane operator then lifts each segment of the tower (a total of 440 tons) and places one atop the other. Together, they reach 270 feet—just 35 feet shy of Lady Liberty's torch.

5/ Nacelles in the Wind
The crane operator hoists the school-bus-size nacelle atop the tower, where workers guide it into place. The top of this 400-ton pod functions as a platform for workers to access the engine inside it. On days when the sea is too choppy for boats to travel, it could be used as a helicopter pad for delivering workers by air.

6/ Blades of Glory
Each of the three fiberglass blades are nearly the length of a Boeing 747 and—though hollow—weigh 29 tons apiece. A yoke on *Brave Tern*'s crane cables swings each sliver from *Paul* to the nacelle, where workers guide it onto bolts. A blade can withstand the ocean's heavy winds for 20 years.

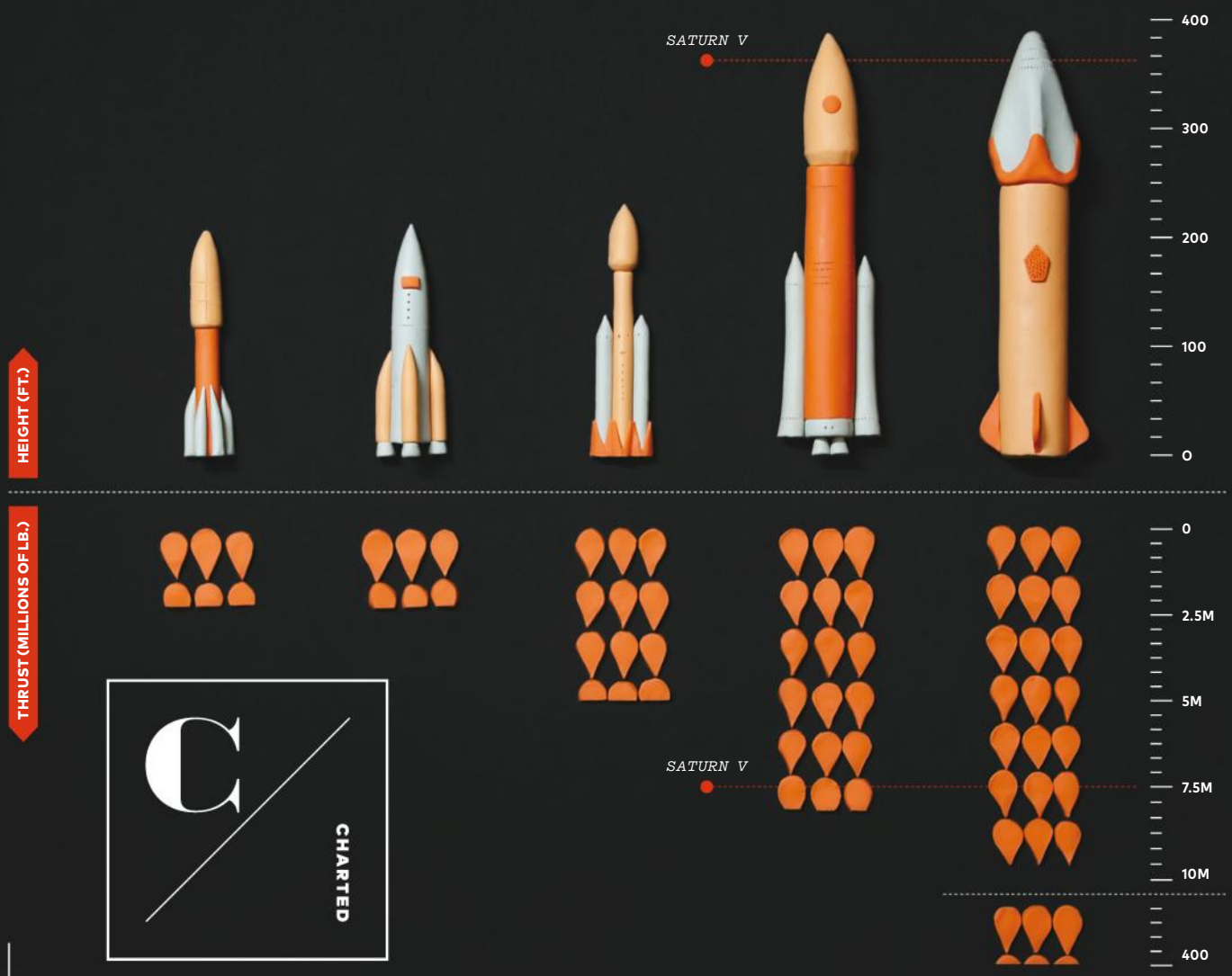


by Kendra Pierre-Louis / illustration by Sinelab

POWER TRIP

the titans of Mars-bound travel

LIKE EVERYTHING ELSE IN THE 1960S, NASA'S *SATURN V* ROCKET SET A mark for extreme. At 363 feet tall, with 7.5 million pounds of liftoff thrust, it lifted six moon-bound missions into space. Retired in 1973, it remains the tallest, heaviest, and most powerful rocket our species has ever built. With moon missions on hold, we haven't needed anything close to its capacity. Until now. As governments and private companies race to send astronauts to Mars, bigger is once again better—and necessary. Whose heavy-lifter is the biggest and baddest? Here's how they stack up.



ULA

Atlas V

In 2011, United Launch Alliance's *Atlas V* lifted off with the largest thing that's ever landed on Mars—NASA's 1-ton *Curiosity* rover. In 2020, it'll carry *Curiosity*'s cousin. Having safely launched to Earth orbit and beyond 71 times, *Atlas V* is ultrareliable.

MAX. MARS PAYLOAD: 11,000 POUNDS

COST TO LAUNCH: $163 MILLION

CHINA

Long March 5

China has been slow to the space race, but it is catching up fast. Its most powerful rocket to date, *Long March 5*, will deliver a Chinese space station —plus astronaut inhabitants—into Earth orbit, and send the nation's first rover to Mars by 2020.

MAX. MARS PAYLOAD: 10,300 POUNDS

COST TO LAUNCH: UNKNOWN

SPACEX

Falcon Heavy

Falcon Heavy, debuting this year, can lift twice as much weight as any current rocket. It may launch a Mars capsule as soon as 2020, followed by crewed missions six years later. If that's the case, SpaceX might beat NASA to putting bootprints in red dust.

MAX. MARS PAYLOAD: 30,000 POUNDS

COST TO LAUNCH: $90 MILLION

NASA

Space Launch System

The first rocket to surpass *Saturn V*'s strength is slated for takeoff next year. SLS will carry astronauts into lunar orbit a few years later, then bring NASA's first crews to Mars in the 2030s. Or 2040s. It's rocket science, so who knows.

MAX. MARS PAYLOAD: 90,000 POUNDS

COST TO LAUNCH: $500 MILLION

SPACEX

Interplanetary Transport System

If built, the ITS will be the largest rocket the world has ever seen, capable of carrying 100 settlers to the red planet. This colonization mega-ship could launch in 2024, or so SpaceX hopes—it will need funding first.

MAX. MARS PAYLOAD: 992,000 POUNDS

COST TO LAUNCH: $62 MILLION

by Mark Kaufman / illustration by Andrea Manzati

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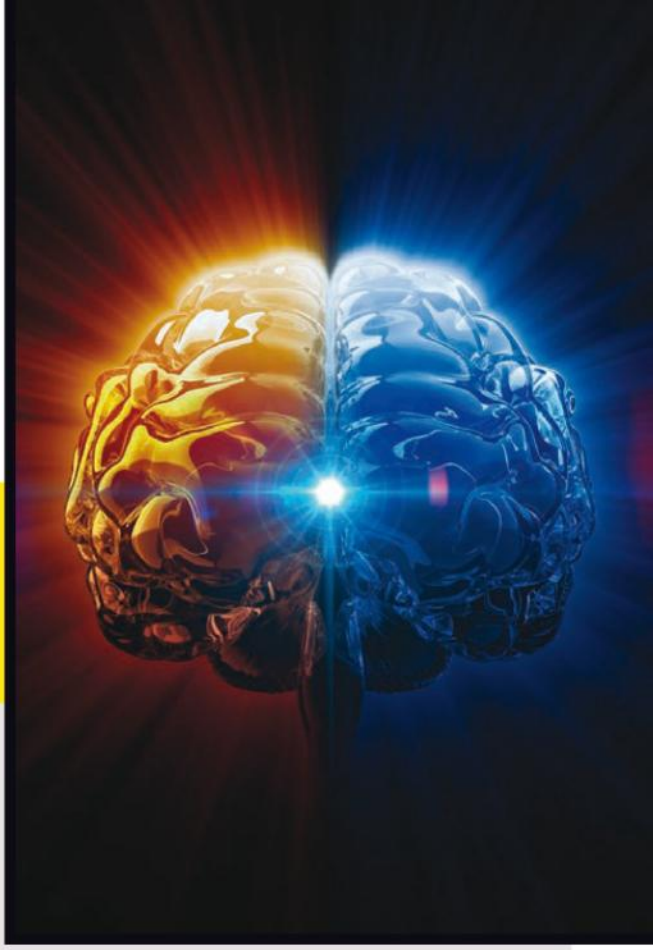

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BREAK IT DOWN

diesel sea beast

SHIPPING UP TO 15,550 20-FOOT-LONG CONTAINERS ACROSS the world's waves is hard work. So hard that *Emma Maersk*, a quarter-mile-long cargo ship, needs serious muscle: the Wärtsilä 14RT-flex96C, among the largest diesel engines on the planet. Because they cost a lot to run and belch filthy emissions, shipping outfits plan to phase out all 24 of the engines now in use, or switch them to cleaner-burning, pricier fuels. By around 2020, new emissions regulations will restrict them on the water. For now, one beast generates enough horsepower to propel *Emma* and tons of consumer merch—one container holds 6,000 pairs of sneakers, 10,000 iPads, or 48,000 bananas—from Suffolk to Shenzhen at 28 miles per hour. That's about 60 percent faster than competitors.

1,660
Fuel use, in gallons per hour
Although it's a relatively efficient engine, the 14-cylinder RT-flex96C can still consume nearly 12 million gallons of diesel in a year. And since fuel can account for roughly 70 percent of a cargo ship's operating budget, this one is a money burner.

284
Fuel heat, in Fahrenheit
Engineers must warm the engine's tarlike heavy fuel oil—the dregs of the refining process—before use. Newer engines can use cleaner fuel, such as more-refined diesel or liquid natural gas, at lower temperatures.

7,000
Hours in operation per year
Your car engine might last a few thousand running hours in its lifetime. The 14RT-flex96C can chug up to 175,000 hours. Thanks to their rugged construction, engines like this one can run continuously for as long as 25 years.

102
Revolutions per minute
A consumer four-stroke engine might top out at 3,500 rpm, firing every other revolution. This runs a two-stroke operation, moving more slowly but firing every cycle. It produces more power while moving the pistons less frequently.

by Mary Beth Griggs / illustration by Kelsey Dake

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LIFE AQUATIC

port of sprawl

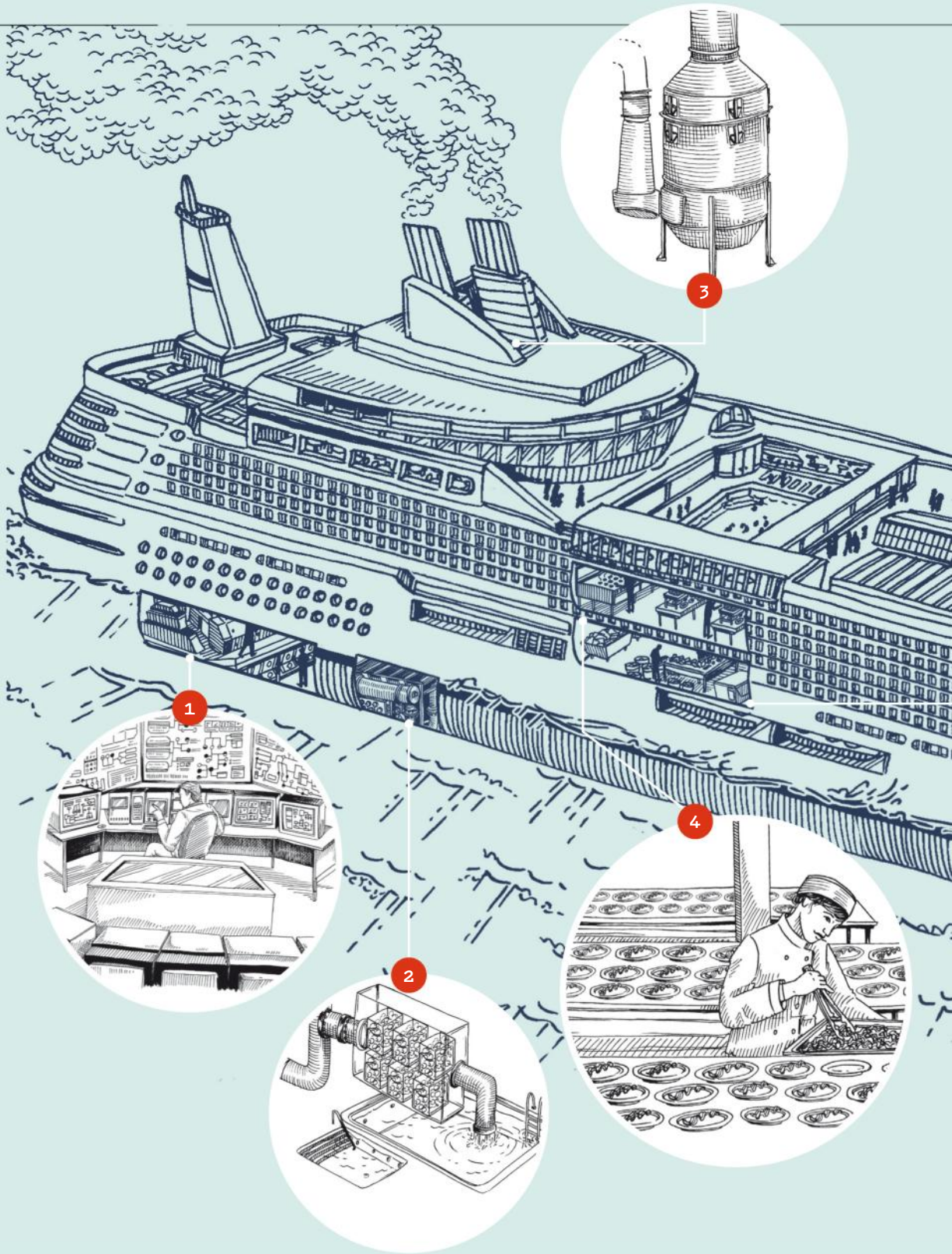
CRUISE SHIPS ARE ENTIRE CITIES SET TO SEA—THE LARGEST ONES CAN CARRY thousands of people. To function far from shore, floating burgs like these rely on washing machines that swallow hundreds of pounds of sheets, water-filtration systems that serve both fresh- and saltwater swimming pools, and an army of aerobic bacteria to eat tanks of poop. This is the often-hidden machinery working behind the scenes on an average mega-liner.

1/Control Room
Two floors below the "hotel," or passenger decks, sit the engines, air-conditioning compressors, and diesel-power generators, which engineers can adjust directly or remotely, from a control room. Certain ships display these controls on massive touchscreen tables.

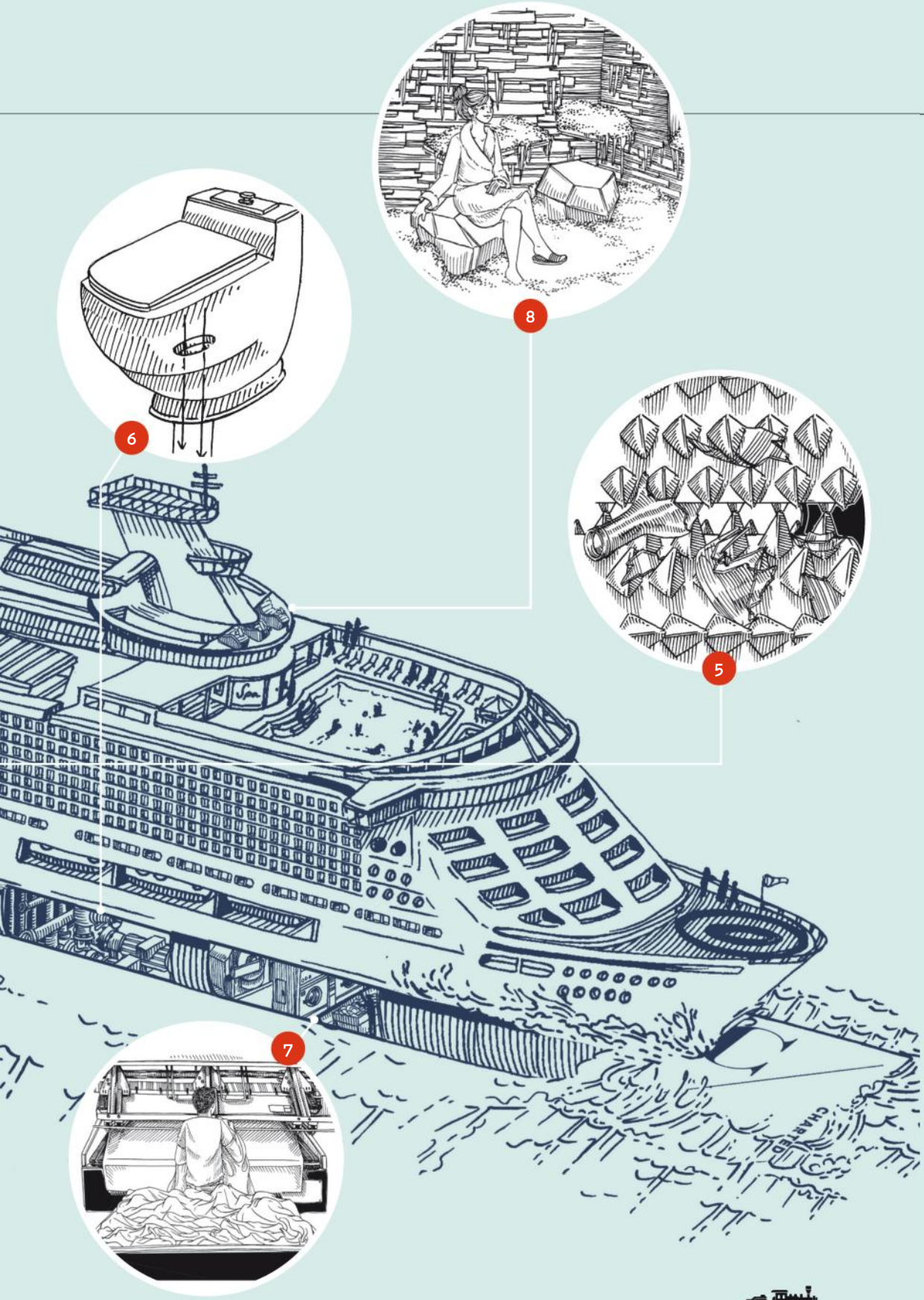
2/Water
To clean seawater, ships often rely on two main methods. Reverse-osmosis membranes filter out salt, and evaporators use heat from the engine to boil off the fresh H_2O. Once liquid goes through one of these processes, it can safely fill onboard swimming pools.

3/Exhaust
Exhaust scrubbers are the most innovative machinery on ships today. Before venting, exhaust enters a cylindrical tank. A solution of caustic soda or seawater sprays from all angles to trap toxic sulfur oxides. Then, the solution falls 150 feet into a storage tank.

4/Food
A single ship can go through 23,000 pounds of flour and 42,000 pineapples (mostly for fruity cocktails) in a year. Ballroom-size freezers store ingredients until mealtime, when waiters deliver grub to 1,000-seat dining rooms via escalators.



by Amy Schellenbaum / illustration by Lucy Engelman

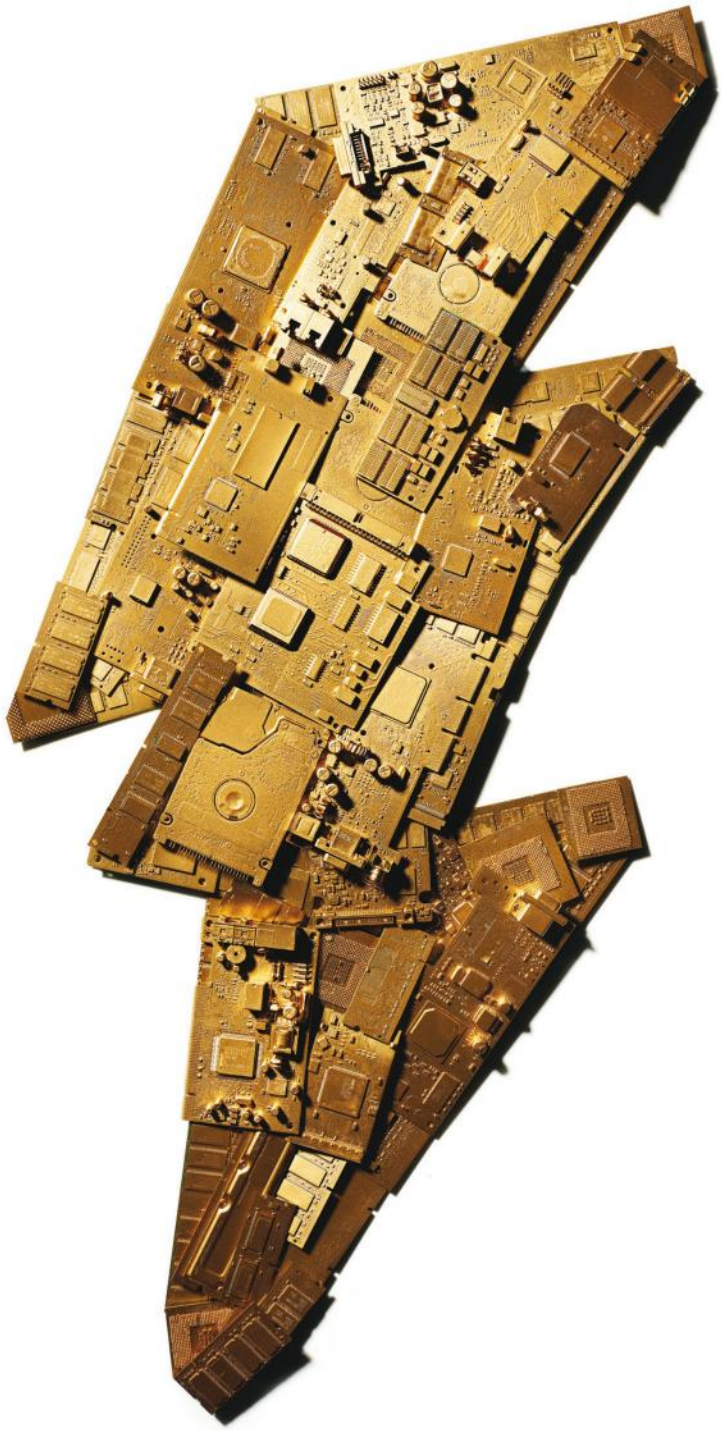


5/Garbage
In the waste-recycling plant, a 50-cubic-foot glass crusher gnashes bottles into pea-size pellets, hydraulics squeeze cardboard and aluminum into blocks, and incinerators burn nonrecyclable refuse. Some ships pulp food waste and tip it overboard as instant fish food.

6/Poop, etc.
Vacuum suction lines zip toilets' contents to marine sanitation farms, which siphon out the water, treat it until it's drinkable, then pump it into the ocean. Helpful aerobic bacteria digest the remaining sludge in storage tanks until it's all offloaded ashore, about once a month.

7/ Laundry
Large-capacity washing machines—which can hold hundreds of pounds of fabric—churn away while elaborate machines iron and press. There's even a 27-foot-wide device solely for stretching and folding sheets into crisp rectangles.

8/The Fun Stuff
More entertaining machines hustle on the upper decks. Cold compressed air and tiny water nozzles can fill spa rooms with snow. Some ships also have wave machines for onboard surfing or 23-foot-tall chambers that blast 100-mile-per-hour winds to simulate a skydive.



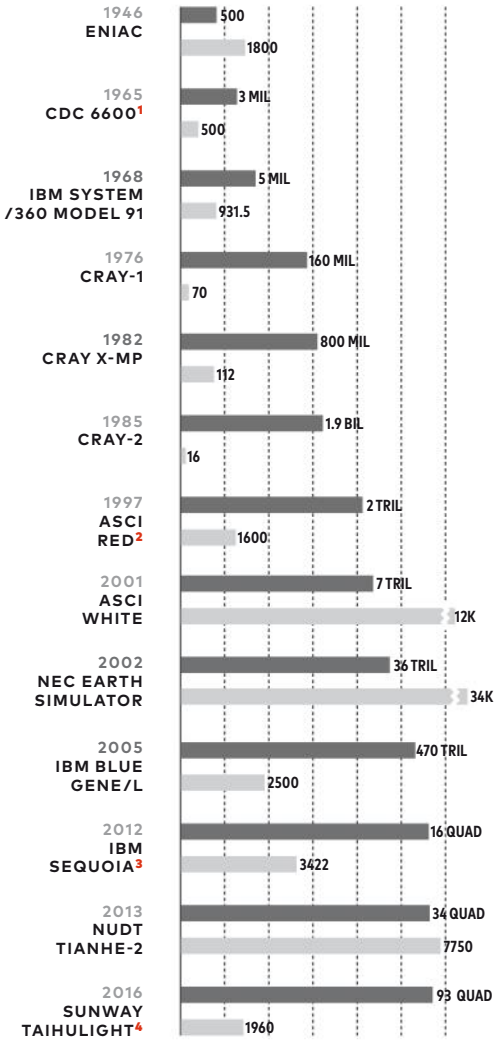
SUPERSIZE ME

the bigger they are, the harder they compute

ENGINEERS MEASURED EARLY COMPUTING DEVICES IN KILO-GIRLS, a unit roughly equal to the calculating ability of a thousand women. By the time the first supercomputer arrived in 1965, we needed a larger unit. Thus, FLOPS, or floating point operations (a type of calculation) per second. In 1946, ENIAC, the first (non-super) computer, processed about 500 FLOPS. Today's supers crunch petaFLOPS—or 1,000 trillion. Shrinking transistor size lets more electronics fit in the same space, but processing so much data requires a complex design, intricate cooling systems, and openings for humans to access hardware. That's why supercomputers stay supersize.

BY THE NUMBERS

Supercomputers, then and now



● = **Processing power** (in FLOPS; bar size uses logarithmic scale, where an increase in one unit represents 10 times as many FLOPS)

● = **Approximate size** (in square feet)

1/ CDC 6600
Rapidly sifted through 3 million of CERN's experimental research images per year

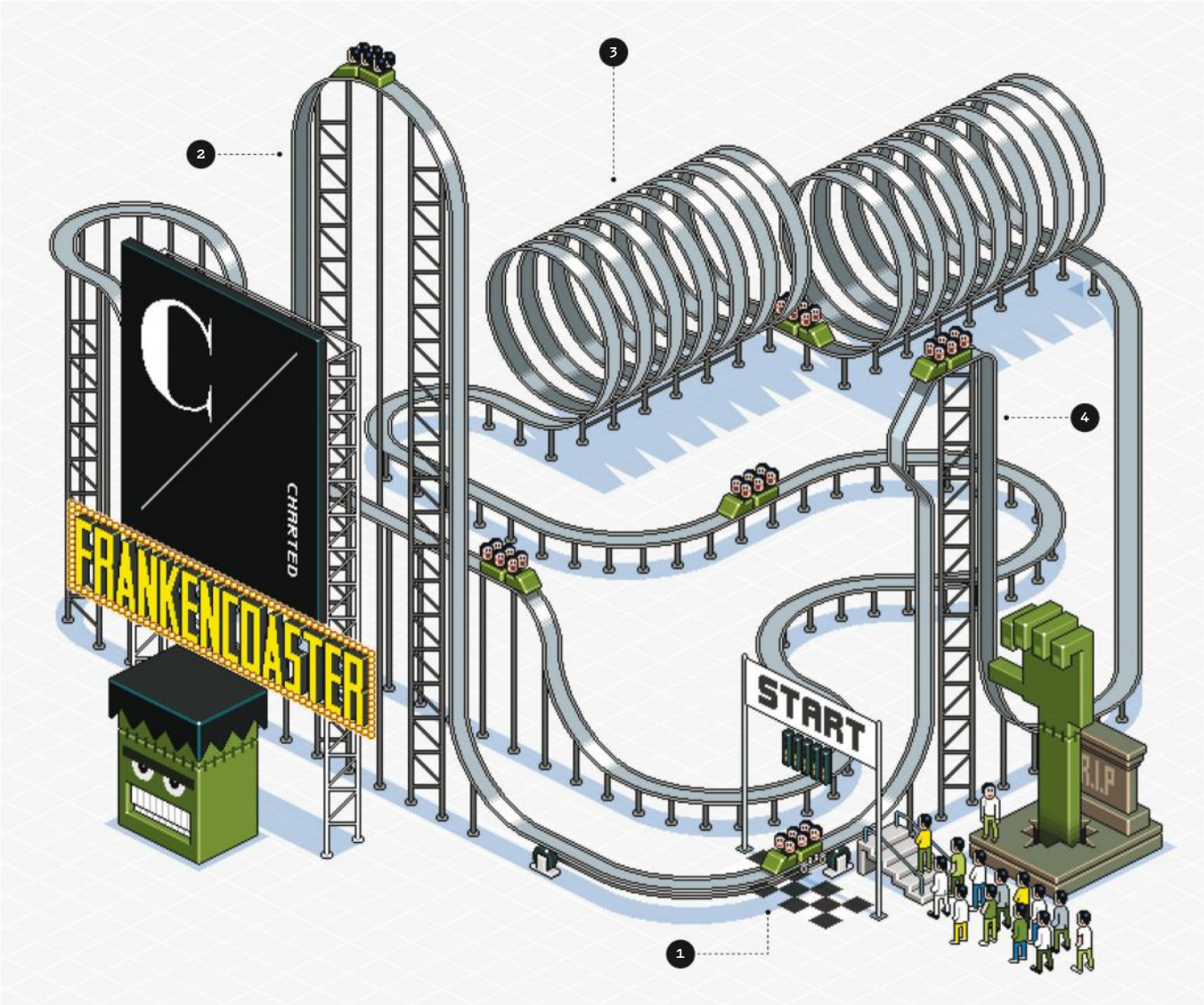
2/ ASCI Red
Modeled the U.S.'s nuclear weapons' capabilities, avoiding underground testing

3/ IBM Sequoia
Used more than 1 million cores to help Stanford engineers study jet engines

4/ Sunway TaihuLight
Reached a record 93 petaFLOPS by trading slower memory for high energy efficiency

PROP STYLING BY SARAH GUIDO-LAAKSO FOR HALLEY RESOURCES

by Sara Chodosh / photograph by Levi Brown



BY DESIGN

monster mashup

MANY OF THE WORLD'S 4,000-or-so roller coasters are of the humdrum county-fair variety. Only an elite few rides reach the monumental heights and speeds of record-smashing supercoasters, which draw millions of thrill-seekers a year—and inspire cut-throat competition that makes it way harder to keep a record than to break one. We rose to the challenge. Our Frankencoaster splices together four real-life record breakers—tallest, fastest, steepest, and most topsy-turvy—into one seriously sick ride. You'd better buckle up.

1

Quick Takeoff

A hydraulic start just like the ones used to launch fighter jets? Oh, yeah. The **Formula Rossa** debuted at Ferrari World in Abu Dhabi in 2010 and—as you'd expect from Ferrari—stole the checkered flag for world's fastest acceleration. Just 4.5 seconds after takeoff, you're hurtling forward at an utterly stomach-lurching 149 miles per hour. Oh, look! There goes lunch.

2

The Big Drop

You're about to plunge from a 45-story building. That's the height of 456-foot-tall **Kingda Ka**, at Six Flags Great Adventure in New Jersey. Opened in 2005, it remains the world's tallest coaster—which means it also takes the crown for world's longest drop. What goes up must come down—fast. Kingda Ka hits a top speed of 128 miles per hour.

3

So Many Twists

Loop-de-frickin'-loop. A record 14 inversions—including two in the shape of a heart, awww—make **The Smiler** a real head-turner at the Alton Towers theme park in Staffordshire, U.K. Famous for its curves, it's also notorious for its delays, stalled cars, and one serious crash. Fortunately, our string of circular loops will never leave you hanging.

4

The *Crazy* Drop

Imagine you reach the top of a coaster and—whoops!—the tracks are gone. That's the horrifying experience on Japan's **Takabisha** steel coaster. The tracks invert backward, seeming to disappear, creating a 121-degree inverted decline. The drop pushes you down and back at the same time, making the ride, which debuted in 2011, even steeper than a straight fall.

by Eleanor Cummins / illustration by Supertotto

THE OLD-SHOW HERO

LIKE A LOT OF KIDS WHO GREW UP IN RICHMOND, VIRGINIA, during the '60s, Guy Spiller loved *The Sailor Bob Show*, a locally produced children's program about an artistic mariner and his posse of puppets. So it was more than a little surreal when, almost five decades later, the semiretired broadcast engineer found himself at home digitizing the show's original reel-to-reel recordings with the help of one of the few machines left on Earth that could play them. "Holding the actual episodes I had seen as a kid, watching and remembering all the songs and segments, it was a pretty amazing experience," Spiller recalls. In an age when we can summon up virtually any video from any era on YouTube, it's tempting to assume that television history has been fully preserved. Tempting, but wrong. Whether it's *Sailor Bob* or hokey restaurant and car-dealership commercials, at least three decades' worth of low-budget pre-digital television remains in real danger of disappearing forever.

> **"I'M SAVING THESE MACHINES; I'M GETTING TO SAVE SHOWS FROM THE GOLDEN ERA OF TV, AND I'M MAKING PEOPLE VERY HAPPY. SO, YEAH, IT'S SATISFYING ON PRETTY MUCH EVERY LEVEL."**

Drive 85 miles north of Spiller's Midlothian, Virginia, home, and you're confronted with this reality head-on. More than 40,000 reels of 2-inch quadruplex—the same tape format *Sailor Bob* was recorded on—line the shelves at the Library of Congress' Packard Campus for Audio-Visual Conservation. Only a fraction of these have been digitized, usually the higher-profile stuff like President Dwight D. Eisenhower's inaugural color-TV broadcast or the newscasts of Martin Luther King Jr.'s assassination.

The Library's archivists have a lot of work to do; smaller fries, like the retired newscaster looking to preserve his reel on a format his grandkids can watch, often get referred to a guy like Spiller, who can rip your 2-inch strip into nearly any digital video format you require. But Spiller also has a backlog. He's one of only a handful of people—including the full-timers at the Library—with both the means and expertise to help usher these vital pieces of Americana into the digital realm. Working out of his home, Spiller digitizes around 100 hourlong reels of 2-inch quadruplex videotape a year.

Step into Spiller's basement studio, and you'll find the primary engines of his art: two 1,800-pound, armoire-size RCA TR-70C videotape recorders. Machines like these basically went extinct three decades ago, says Spiller. He should know. The 67-year-old spent the early part of his career using and repairing them. So far, Spiller has managed to find and rescue eight so-called quads before they ended up in landfills. "I guess I'm kind of like the SPCA for old broadcast and recording equipment," he says.

Introduced in 1956, quads were some of the most complex machines of their era. Invented to play 2-inch quadruplex reels—the first official tape-based format of the broadcast television industry—they allowed for the real-time recording and instant playback of any show. A quad's guts are an amalgamation of vacuum pumps, air compressors, motors, electrolytic capacitors, resistors, and transistors.

"The 'quad' in quadruplex refers to the four video heads they use to divide up the picture," says Spiller. "All four of those channels need to play back as close to perfectly in sync as possible, or you'll start to see visual artifacts," he says.

Before quads, TV stations would essentially record broadcasts by filming TV monitors. (Yep.) If you wanted to rebroadcast something, you'd have to develop that film, so most networks simply wouldn't replay a show in multiple time zones. Quads changed everything. Then easier-to-manage machines made them obsolete.

by Bryan Gardiner / photographs by Marius Bugge

Shoved in a forgotten backroom at the University of Georgia, Spiller's RCA hadn't seen an electric current in 27 years when he found it in 2010. It required around 70 new electrolytic capacitors plus a full week of tinkering to bring it back to life. Watching the technomancer prep and operate the restored machine, it's clear why he's in rare company. Spiller often looks like he's conducting some elaborate electromechanical symphony.

It can take upwards of 15 minutes to clean the tape path: the guide, the rotating rollers, the stationary heads, and the control track head. You do this before every recording. Once you've threaded a tape through this labyrinth, extracting the best picture then requires near-constant knob-twiddling and fussing.

Despite these complexities, it's a process the retired engineer loves, especially in an age of disposable tech. Spiller charges hundreds of dollars to digitize an hour of footage (though it varies a lot depending on the tape), and gets material from all over the country. "I'm saving these machines; I'm getting to save shows from the Golden Era of TV, and I'm making people very happy," he says. "So, yeah, it's satisfying on pretty much every level."

THE RCA TR-70C, Spiller's quadruplex rig, by the numbers

12
Warning lights to prevent mistakes in recording

1,800
Total weight in pounds, not including reels

40
Knobs and dials on the main control panel

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ENGRAVE IT. CUT IT. MARK IT.

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GOODS

LUMBER: JACKED

THOR HAS HIS CRUSHING HAMMER. Vulcan has his crippling anvil. And modern-day mortal tree-fellers have the Stihl MS 880 Magnum. The most powerful chain saw available, the professional-grade tool can slice clean through an 8-foot-thick oak trunk in just two minutes.

The saw's 8.6-horsepower gas engine is more than four times burlier than what weekend limb-trimmers cut with, which gives the MS 880 enough oomph to run a massive 5-plus-foot chain bar. Despite its brawn, Stihl engineers made sure the slicer isn't too heavy for arborists to hold steady: The designers shaved weight off the engine housing by replacing magnesium with a light-but-sturdy plastic, which keeps the entire package to a (relatively) manageable 33.1 pounds. Still, that's not bad for a machine that can slash lumber as wide as a San Francisco trolley. **$2,200**

PROP STYLING BY SARAH GUIDO-LAAKSO FOR HALLEY RESOURCES

by Mark Kaufman / photograph by Levi Brown

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TOYBOX OVERFLOWETH

YOU BOGARTED YOUR NIECE'S ROBOT DINOSAUR for a solid three hours after her birthday party. Admit it. We won't judge you. Today's playthings are some tempting stuff. They're bigger, stronger, and faster than the foot-powered plastic "cars," immobile Lego fortresses, and dead-eyed Teddy Ruxpin dolls that came before. Building sets are so lifelike, go-karts so zippy, and robots so intelligent that even adults will find these outsize toys utterly irresistible. Now kindly hold my beer, kid; there's a Nerf battle that needs my full attention.

PROP STYLING BY SARAH GUIDO-LAAKSO FOR HALLEY RESOURCES

1 Top Gun

Childhood isn't childhood if you're not bruising someone's eyeball with a soft dart, amiright? At 2.5 feet, the **Nerf N-Strike Mastodon** is the largest foam-thrower around. In our tests, its motor shot a full magazine of 24 darts up to 65 feet in 8.2 seconds. **$80**

2 Clever Girl

The **RoboRaptor Blue** can't open doors, but it can find its way around the playroom. Infrared sensors in its head let the 3-foot dinosaur wander freely without crashing into anything. Audio sensors trigger roaring reactions to any sudden noises while patrolling. **$100**

3 Diggin' It

At nearly 3 feet long and comprised of 3,929 pieces, the **Technic Bucket Wheel Excavator** is the largest motorized Lego set ever made. Tiny shafts and gears transport plastic loot down functional conveyor belts and into a dump truck waiting below. **$280**

by Sara Chodosh / photograph by Levi Brown

4 Hotter Wheels

Your car is brainy, so why should your kid's ride be dumb? The 4-foot **Actev Arrow Smart-Kart** has proximity sensors that trigger evasive maneuvers if tykes hurtle themselves at obstacles. And though it hits 12 mph, parents can limit range via Wi-Fi and GPS tracking. **From $1,000**

5 Bot Story

Standing 4 feet tall, **Meccanoid XL 2.0** can look kids in the eye while they program it. Moving the bot's limbs teaches it anything from dances to secret handshakes; 10 motors in the joints send motions to a computer, where they're saved—along with 3,000 phrases—for later recall. **$300**

6 Green Giant

When you're bouncing a record-breaking 11.5 feet on a pogo stick, it's good to know you'll have a soft landing. Instead of a spring, the **Vurtego V4 Pro**'s steel and aluminum frame contains highly compressed air, which provides extra force on the jump and plenty of cushioning when you hit the ground. **$420**

7 Eat Dirt

The **Tyco Terra Climber** can tackle the rough terrain of your backyard with ease. Thanks to spiked wheels, a reptilian tail, and arms that rotate a full 360 degrees, the 2-foot-long R/C toy can traverse stairs, rocks, and logs. It can also flip itself over on boring old basement floors. **$100**

SERVER SERVICES

HEADS IN THE CLOUD

RIGHT NOW, IN A DATA CENTER far, far away, gargantuan cloud servers are providing brainpower to devices as minute as fitness trackers. A baseball-size camera, for example, might seem like little more than simple home surveillance; or an adorable green dinosaur might appear to be just a child's plaything. In reality, armies of servers undergird these—and countless other—unassuming gadgets. Here are five of the smartest out there.

1
IoT Attack Dog
Last year, homeowners connected some 4 billion devices to their networks. **Dojo by BullGuard** keeps hackers from exploiting any potential inroads. The 6-inch box monitors traffic, and cuts off any shady activity. Meanwhile, Dojo's server looks for patterns across all its relatives to thwart bigger threats. **$199**

2
All-Seeing Eye
The **Nest Cam Outdoor** is always watching, but it needs help to know what it's looking at. With the Nest Aware service, footage uploads to the company's servers, where computer-vision algorithms distinguish a person from Spot chasing a squirrel. Those smarts reduce false-positive intruder alerts. **$199, plus $10 per month**

3
Personal Trainer
Armed with data from more than 200 million users, Under Armour motivates athletes with what drives them most: competition. The **UA Record app and HealthBox** kit—which includes a heart-rate monitor, fitness tracker, and scale—tap into an IBM-powered virtual coach that stacks up users against other athletes. **$220**

4
Ask Jeeves
Barely larger than a hockey puck, the **Echo Dot** is always ready. The Alexa-powered voice-activated assistant passes commands through Amazon's cloud-based natural language processing to understand and carry out more than 9,000 tasks, including setting alarms, hailing Ubers, and reordering Doritos. **$50**

5
Jurassic Smarts
Imaginary friends, meet the competition. Backed by Watson's encyclopedic memory bank, a custom speech algorithm, and a weekly-updated roster of games, facts, and stories, **CogniToys Dino** is a clever, gregarious (and adorable) chatterbox. It also builds a profile of its human buddy, like if a kid is into pizza or soccer. **$100**

PROP STYLING BY SARAH GUIDO-LAAKSO FOR HALLEY RESOURCES

by Rob Verger / photograph by Levi Brown

EASY, RIDER

HEAVY METAL

IN THE PANTHEON OF THE OPEN ROAD, motorcycles are like adolescent gods: small, yep, but powerful for their size, which makes them very hard to catch. Still, within these teens' ranks you'll find hulks—the biggest, baddest kids on the proverbial schoolyard of Olympus. Either run with the troublemakers or get out of the way.

Terrify Everyone

A 9-foot-long single-seater weighing 800 pounds would look imposing in your rearview mirror, even if it weren't a light-swallowing black that seemed to bend spacetime. But the **Indian Chief Dark Horse** is, and its 1.8-liter engine has enough grunt to tow a small boat. So move. **From $17,499**

Outrun Everything

This 593-pound body exists primarily to house the **Kawasaki Ninja ZX-14**'s massive 1.5-liter four-cylinder engine. At 191 ponies, it cranks out more power than a Honda CR-V. Overkill? Only if you call a sub-10-second quarter-mile and 2.6 seconds to 60 overkill. (So... no.) **From $14,999**

GOODS

Go Everywhere

The GS in **BMW R 1200 GS Adventure** is German for Gelande Straße, or "off-road," where BMW's big baddies have trod since 1980. Though this 580-pound two-wheeler is too heavy to be much of a dirt bike, with its relatively off-piste-friendly suspension, it's as close as you'll get in a bike that's also at home on a highway. **From $18,695**

CLOCKWISE FROM TOP RIGHT: COURTESY BMW; COURTESY KAWASAKI; COURTESY INDIAN MOTORCYCLE

by Joe Brown

GOODS

EARS BEWARE

CAN YOU HEAR IT NOW?

A ROCK CONCERT BLASTS 105 decibels into your ear holes. And, though your neighbors might curse the day you moved in, you can re-create that level of acoustic insanity in your living room, basement, or whatever personal sound cave suits you. WARNING—cranking up the volume can lead to bad sound. But have no fear: If carefully constructed, a high-end audio setup can knock you back in your seat, without losing its fidelity.

1/ Source
Even with bass rumbling, the **Technics SL-1200GR** turntable won't skip. The aluminum platter (aka the playing surface) has a rubber lining, the footings are silicone, and polymer tubes string through the body—all absorbing bad vibes. **$1,700 (est.; cartridge sold separately)**

2/ Preamp
The preamp gets an audio signal ready for the amplifier to crankify. Unlike many big-box-store—even high-end—models, the **Audio Research GSPre** has inputs for modern devices and a circuit, complete with a pair of vacuum tubes, devoted to turntables. **$15,000**

3/ Amplifier
Delivering 450 watts apiece to two speakers, the **McIntosh MC452** is among the loudest stereo amps. Ironically, though, it makes quiet work of pushing massive sound. Inside the 110-pound behemoth, each channel has two amps that cancel out one another's tremors. **$8,000**

4/ Speakers
The midrange driver (the one for guitars and vocals) on the **Bowers & Wilkins 800 D3** rings true at high volumes. A new woven composite stops vibrating faster than its Kevlar predecessor. Meanwhile, a 1-inch tweeter pings highs, and two 10-inch subwoofers go low. **$30,000 (pair)**

22

The reduction, in decibels, provided by sound-filtering earplugs like Vibes ($24). The plugs cut volume equally across all frequencies, so tunes don't sound muddled.

PROP STYLING BY SARAH GUIDO-LAAKSO FOR HALLEY RESOURCES; ARCHETYPE STAND COURTESY SALAMANDER DESIGNS

by Corinne Iozzio / photograph by Levi Brown

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ROLLING ALONG

BED TIME STORY

THERE IS NO VEHICLE MORE AMERICAN THAN THE PICKUP TRUCK. One out of every five automobiles sold in the U.S. is one, and they claim the top three spots on the best-seller list. Since farmers first strapped and hammered wooden crates onto their hacked-apart Model T's in the early 1900s, trucks have—decade by decade—evolved into the enormous, mighty, terrain-tearing monsters that fill our highways, garages, and driveways today. These are the key mile markers along that journey.

1925

Body Double

Before World War I, farmers and tradesmen replaced their cars' rear bodywork with open-topped wood boxes or primitive truck beds. With the **1925 Model T Runabout**, Ford did the work for them: The automaker attached a small (56-by-40 inch) steel bed, adjustable tailgate, and heavy-duty rear-suspension springs onto its famous car's existing substructure.

1929

Main Frame

It didn't take long before car bodies couldn't handle the cargo drivers were hauling or the terrain over which they were rolling. Dodge built the **Merchant Express** atop the first purpose-built truck platform—including a reinforced cab, frame, and body—that could take the abuse. This shift in engineering set up the vehicle class to get stronger and bigger over time.

1932

Warring Powers

Pickup builders have been one-upping each other in terms of engine power since the 1930s, when Ford dropped the first mass-produced V-8 into the **Model BB**. The block's 65 ponies bested all competing 4's and 6's in both price and grunt. The brute strength allowed for the addition of larger beds and beefier frames that could bring more wares to market.

1946

Solid Footing

Though World War II troops were the first to experience four-wheel drive in their Willys (built by Jeep and Ford), Dodge brought the terrain-defying feature home on the **Power Wagon**. By spinning all four wheels at once, the monster could lug huge payloads—on either a 7.5- or 9-foot bed—over tough ground like broken pavement, rocks, and dirt.

1957

People Mover

The more supplies you bring to a jobsite, the more work you can get done—and the more people you need to do it. The **1957 International Harvester Travelette** had the first six-person three-door cab. Harvester followed up with a roomier four-door version in 1961, and eventually let the cab take over the entire vehicle, foreshadowing the rides of future suburbanites.

1973

Doubling Down

Over the decades, burly pickups got easier to drive thanks to additions adapted from cars, including automatic transmissions, independent front suspensions, and power brakes and steering. But they also got better at being trucks: The **1973 Chevy C-Series "Dooley"** was the first to feature dual rear wheels, which allowed it to transport up to 10,000 pounds.

1989-PRESENT

Torque Off

Dodge wasn't the first to drop a diesel engine into a heavy-duty vehicle, but the **1989 Ram** was the salvo that sparked a power war that still rages today. Built around a Cummins turbo-diesel, which was common in commercial haulers, the pickup had 160 horsepower and 400 foot-pounds of torque—enough muscle to easily yank heavy loads uphill or from a dead stop.

2015-FUTURE

Not-So-Heavy Metals

Steel has always been the backbone of the pickup, but efficiency standards have forced automakers to experiment with other alloys to help reduce heft—without crippling strength. Ford ditched the steel body on the **2015 F-150** and replaced it with heat-treated aluminum. And in 2019, the Chevy Silverado's cab will be made from a new, lightweight composite.

CLOCKWISE FROM TOP LEFT: CAR CULTURE/GETTY IMAGES; COURTESY CONCEPTCARZ; COURTESY HEMMINGS.COM; CAR CULTURE/GETTY IMAGES; COURTESY CHEVYTRUCKS.COM; COURTESY USEDFROMUSA; COURTESY DODGE; COURTESY FORD

by Chuck Tannert

MEAT UP

THE BACKYARD BOSS

THANKS TO CELEBRITY CHEFS, BARBECUE COMPETITIONS, and nonstop food TV, everyone is a meat "expert": Cook it low, and cook it slow. But wavering temperatures can ruin the finale of a daylong smoke. Spike, and dry out your brisket; dip, and serve pink pork. The $13,500 **Kalamazoo Outdoor Gourmet Smoker Cabinet** holds the low-and-slow sweet spot for 16 hours (or two rounds of ribs). A sensor on the cooking grate reports the temp three times per second, signaling tweaks to the coal-stoking fan's speed to maintain a meat-perfect 225 degrees. Its 7-pound coal stack burns from the bottom up, helping the fire smolder longer, while embers drop on hardwood in the ash catcher below, boosting flavor. Finally, 2-inch insulation wraps the 3.9-cubic-foot oven, as nine slabs of ribs, two turkeys, or three briskets try your patience from within.

PROP STYLING BY SARAH GUIDO-LAAKSO FOR HALLEY RESOURCES

by Harlan Murphy / photograph by Levi Brown

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MAY/JUNE
—
2017

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photograph by The Voorhes

GET READY TO

RUMBLE

BY JOSH DEAN
PHOTOGRAPHS BY
GIACOMO FORTUNATO

In big-kid amusement parks, you get to drive the heavy equipment you spent your childhood dreaming of.

PG . 43

W

Working the controls of an excavator is a little like flying a helicopter in that it requires the use of both hands independently, as well as your feet. I say that having never flown a helicopter, and having been in an excavator for all of five minutes, but it is definitely more like flying a helicopter than driving a car. When do I get to crush something?

These are the thoughts I'm having in the climate-controlled cab of a 26-ton Komatsu PC210LC-10 idling in a north Texas pasture while Jason Nibbe speaks calmly into my headset via two-way radio. Prior to handing me the keys to this bright yellow beast, Nibbe asked me and another client to watch a brief instructional video demonstrating the basics of operating this excavator, as well as the bulldozer and wheel loader that we would be driving later. Nibbe says I am to ignore the two pedals—each of which is paired to one of the machine's independent steel treads—and focus on my hands.

The joystick on the left controls the "stick" and "swing," while the one on the right controls the "boom" and "bucket." None of these are useful terms, of course; I've never heard them used in the context of a mechanical arm so powerful that it could, says General Manager David Beardsley, "rip out

a road before the cops even knew what you were doing."

That arm is hydraulically powered and has three parts that you can easily equate to a human limb. The boom is the part from shoulder to elbow, the stick is the forearm, and the bucket is your hand. (Swing refers to how you pivot the cab atop its tanklike treads so you can work in a 360-degree circle around the vehicle without moving the tracks.)

Before this excavator, the largest machine I'd operated was a U-Haul box truck. I've never driven a Bobcat, nor dug a hole with anything but a shovel. Yet shortly after firing up the PC210, I am confidently maneuvering its 28-foot-long arm, ripping up chunks of thick brown clay and, of course, spinning the machine's cab around and around at high speed until I'm so dizzy that the world goes white.

"Are you done yet?" Nibbe asks, as I move the left lever back to neutral, which stops the swinging of the cab. I pause to regain my senses, and then push the stick all the way to the right, causing the cab to spin just as fast the other way.

1 2 3 4 5 6

[1] I'm driving a wheel loader! **[2]** Playing ball with an excavator **[3]** Joy Frick, another sandboxer, runs the bulldozer **[4]** General Manager David Beardsley instructs **[5]** Wheel loader tire *smash* **[6]** The glorious sight of a Texas dirt shower

This is acceptable behavior at Extreme Sandbox, a company founded five years ago precisely so regular people like me can pay to screw around on machines that we've fantasized about since childhood. It's not a free-for-all. Instructors emphasize safety, and mostly the idea is to perform a series of increasingly difficult jobs, but excavator cabs will do infinite 360s—so fast!—and instructors understand that it's something we students just have to get out of our systems. They all make the same Dad joke about "optional vomit insurance" in the classroom sessions.

The 26-ton PC210 is your middle-of-the-road excavator. It's neither some wimpy starter machine nor a full-on metal

dinosaur; mostly you see this digger on a normal building site. "It's not so intimidating for a new operator," Rich Smith, VP of Products and Services for Komatsu, would tell me later. "It's large enough to be impressive, but you don't have to climb an 18-foot ladder to get into the cab."

Still, it's big; and it's surprising how effortless manipulating the massive arm and claw feels. There is virtually no feedback; moving the stick is no more physical than playing an arcade game, thanks to a combination of electronic and hydraulic controls. I expected to somehow experience the weight of lifting a bucket filled with 500 pounds of earth—to sense the strain—but I feel nothing; ditto when I push the claw into clay that's nearly as firm as concrete.

The controls are so responsive that you have to make small, smooth inputs that aren't immediately logical to greenhorns (especially male ones), who tend to apply too much force, which makes the entire machine shudder and jerk. Instructors call this "stabbing" the controls. Proper stick work, Nibbe says, should be delicate, "like surgery."

"OK, Josh," he says, after I've dug two holes, made a pile, and lifted the boom as high as possible to rain a "Texas dirt shower" upon the land. "You've been in this machine 10 minutes, and you know as much about excavation as I do."

Nibbe is exaggerating. What he means is that anyone who pays attention to the classroom instructions and then practices a little can perform basic operations. I can move around, position the arm, dig and dump dirt—but I do so slowly and awkwardly. Experienced operators can do multiple things at once—like dig while swinging the cab. They're also much faster and smoother.

1 2
3 4

[1] An excavator's tread **[2]** The wheel loader should get a "born to pile" bumper sticker **[3]** Picking up a car with the excavator takes as much effort as eating a ghost in *Pac-Man* **[4]** Tony Roberts, another patron of the Sandbox

Slow or not, I'm having fun. And, apparently, I'm being safe. If I had done something stupid or dangerous, Nibbe would have hit the kill switch that every instructor carries.

"OK," he says. "You wanna go pick up a car?"

THE HISTORY OF EXTREME SANDBOX IS SHORT and sensible. Back in 2009, when he was still a manager for Target Corporation, company founder Randy Stenger drove by a construction site with his 9-year-old son. The boy stared at the heavy equipment rolling around in the dirt and asked, "Wouldn't it be fun to go drive those things?"

"Yes, it would," Stenger answered, and the thought stuck. Later, over beers, he mentioned it to his brother. They spent the next year turning the idea into a business, and nearly another year looking for space. They finally opened the first Extreme Sandbox, three rented machines on a leased 10-acre lot outside Minneapolis, in April 2012.

At first, Stenger taught the sessions himself, after getting a crash course from his equipment dealer and practicing for hours. Clients assumed he had a background in construction. "Absolutely not," he'd tell them, with a smirk that he often deploys. "Does that give you a feeling of confidence?"

The business took off. Stenger hired help—including Nibbe, a former heavy-equipment operator—leased more machines, and built a 6,400-square-foot facility to serve as offices, a classroom, and storage for the equipment. Every month was busier than the one before.

This doesn't surprise me. Who hasn't felt the urge to hop the fence of a construction site and hijack a crane? My 6-year-old son, Charlie, loved excavators even before he could talk, and throughout his toddler years, he would search for them obsessively out of car windows, screaming "DIGGER!" every time he saw one. His 2-year-old brother, Nicky, is partial to dump trucks and bulldozers.

I've read them *Goodnight, Goodnight, Construction Site* probably 800 times, and I know I have company. The author, Sherri Duskey Rinker, used to watch her own son get too worked up reading about trucks at bedtime. She made up a calmer story about how diggers and dump trucks and cranes slow down and sleep after dark. Her book earned the No. 1 slot on *The New York Times* Children's Picture Books Best Seller list, bought by millions of parents like me.

If it seems like we're hardwired to love machines, it's because we actually might be. "There is a deeply ingrained attraction to tools that initially evolved long ago with anthropoid primates for object manipulation, and which evolved more dramatically in our hominin line," says Thomas Wynn, professor of anthropology at the University of Colorado, and one of the world's foremost experts on early tool use. "Humans like to fiddle with tools," he says.

Rob Shumaker, director of the Indianapolis Zoo and a specialist in animal tool use, agrees. Using implements to dig, pound, and hammer, he says, "is universal in great apes, which includes humans. Tool use is fundamental. It's at our core." Obviously, there's a big difference between a rock and an excavator, Shumaker says. "But I think our attraction to this stuff is almost primal."

That's the sense I got from Tony Roberts, a retired Navy chief who now teaches aircraft maintenance in Fort Worth and whose wife bought him an Extreme Sandbox experience for Christmas. Roberts spends his days tearing apart airplanes. He flies them, from Cessna single-props to DC9s, for fun. But he was so excited about the prospect of driving bulldozers around an old horse pasture that he'd barely slept the night before and arrived an hour early. "I really joined the Navy just to run equipment," he admits.

IN 2015, STENGER COLD-CALLED A PRODUCER from *Shark Tank* and got on the show. Both Mark Cuban and Kevin O'Leary immediately embraced the concept. They decided to go halfsies on a $150,000 investment in exchange for 15 percent of the company.

Stenger isn't even alone in this space. His primary U.S. competitor, in fact, beat him to market by five years. That would be Las Vegas-based Dig This, founded by Ed Mumm, a fence contractor who drove an excavator for the first time while building his own home, and went nuts for it. "I realized that if I enjoyed it this much, what about all the other people who never get the chance?" he told me. Mumm looked around to see who else had the idea and saw only some failed one-offs and the U.K.-based Diggerland.

Diggerland had four locations around the U.K., but it was too family-focused, in Mumm's estimation. It featured mostly mini machines and gimmicks—like excavators

If it sometimes seems like human beings are biologically hardwired to love this stuff, it's because we actually might be.

Two cars flattened by a corporate group a few days ago taunt me from the cockpit of the bulldozer, which rumbles like a war machine.

converted to rides for kids. He wanted bigger equipment. Mumm opened first in Colorado, then moved to Las Vegas with a marketing slogan he's still very proud of: "There's a new way to get dirty in Las Vegas... even your wife will like it." One pleasant surprise: Almost half of his clients have been female. "I also didn't expect so many engineers," Mumm says. "They're just fascinated with this kind of stuff.... A lot of us never really grow up, I guess."

So far, Stenger and Mumm are friendly rivals, but that might change when the second Dig This location opens in May—in the Dallas-Fort Worth metropolitan area. Los Angeles will follow that. (Diggerland now has a U.S. location too, in Philadelphia's New Jersey suburbs.)

Being in Vegas, Mumm attracts lots of bachelor parties, as well as corporate groups in town for conventions. Groups are huge for Stenger as well, making up about half of his business. They follow a different program than individual clients, typically doing some kind of team-building exercise or competition after the standard instruction. In Texas, there's an entire back pasture with boulders and dirt piles where instructors set up courses. A team might have to build a "garage" out of dirt and rock, and move a wrecked car across the field and into it, using "roads" that the instructors have destroyed. So before a team can start building anything, it might have to move boulders or fill holes. The point is to use all of the equipment.

"When we first started, HR people got nervous," Stenger says. They pictured desk jockeys drunk on diesel, unleashed upon expensive machines—all on the company's dime. "I told them that this is safer than bowling. We use very large equipment on a very solid base. It is virtually impossible to flip one over. You couldn't do it if you wanted to."

THE NEWEST MACHINE IN TEXAS IS A WHEEL loader—a vehicle with a huge bucket on the front to move dirt and other material around a job site. It works almost like a car, with a steering wheel, an accelerator, and a brake—plus a joystick on the right that controls the bucket. It replaced a much smaller machine, a skid steer loader that weighed only around 3 tons. Stenger made the swap after recognizing something counterintuitive: People are much more dangerous in a small, nimble machine. "We had more close calls on the skid steers than any other vehicle."

While the original concept of Extreme Sandbox was that it would be a "bucket-list" thing, some customers want to come back. One way to encourage that is to introduce new toys such as the loader. Stenger's got a firetruck in Minnesota now, and has at times offered a road grader and a combine harvester, thanks to a local farmer. Texas had a giant, articulated, off-road dump truck for a while. How about a crane? That's the machine my 2-year-old son screams at the most. "I would love it," Stenger says. It's one of the few pieces of heavy equipment that requires a license, but he swears he's "working on it." Lately, Stenger says, he's been lusting after those house-size dump trucks.

The thing that really hooked O'Leary on *Shark Tank* was the prospect of crushing a car, which any customer can do for an additional $500. Extreme Sandbox gets (mostly) intact cars from junkyards and lets you go at them with an excavator. Sadly, that wasn't in my budget, but I do get to pick up a junker with the excavator and move it to a new "parking" spot, as well as push around an old minivan and an F150 with the wheel loader and bulldozer, respectively.

Two cars flattened by a corporate group a few days earlier taunt me from the cockpit of the bulldozer, which rumbles like a war machine. I suppress the urge to make a slow turn toward them. What I really want, though, is to drive across the lot and straight through the side of the trailer that's serving as office and classroom until Stenger can build a permanent structure. That would be satisfying.

Stenger laughs when I mention this later, and says I'm not the first to suggest it. He's thought about getting some old RVs for people to crush, but they're filled with plastic and foam, and are, he says, "a nightmare to clean up."

He's got all sorts of ideas for the future. He's even fantasized about how cool it would be to partner with demolition contractors—guys who get paid to tear down houses—and arrange for his customers to do their work. "I have people who will pay to do it," Stenger says.

I'd be down. I bet Matthew Frick—who came out to the Sandbox with his wife when I was there—would be too. Toward the end of the day, I run into the two of them in the office, already plotting their return. They both loved the excavator, but it was the bulldozer that stuck with Matthew. "Until you get in it and feel the torque and power at your fingertips, you don't know," he says. "I'm still coming off the power trip from that bulldozer."

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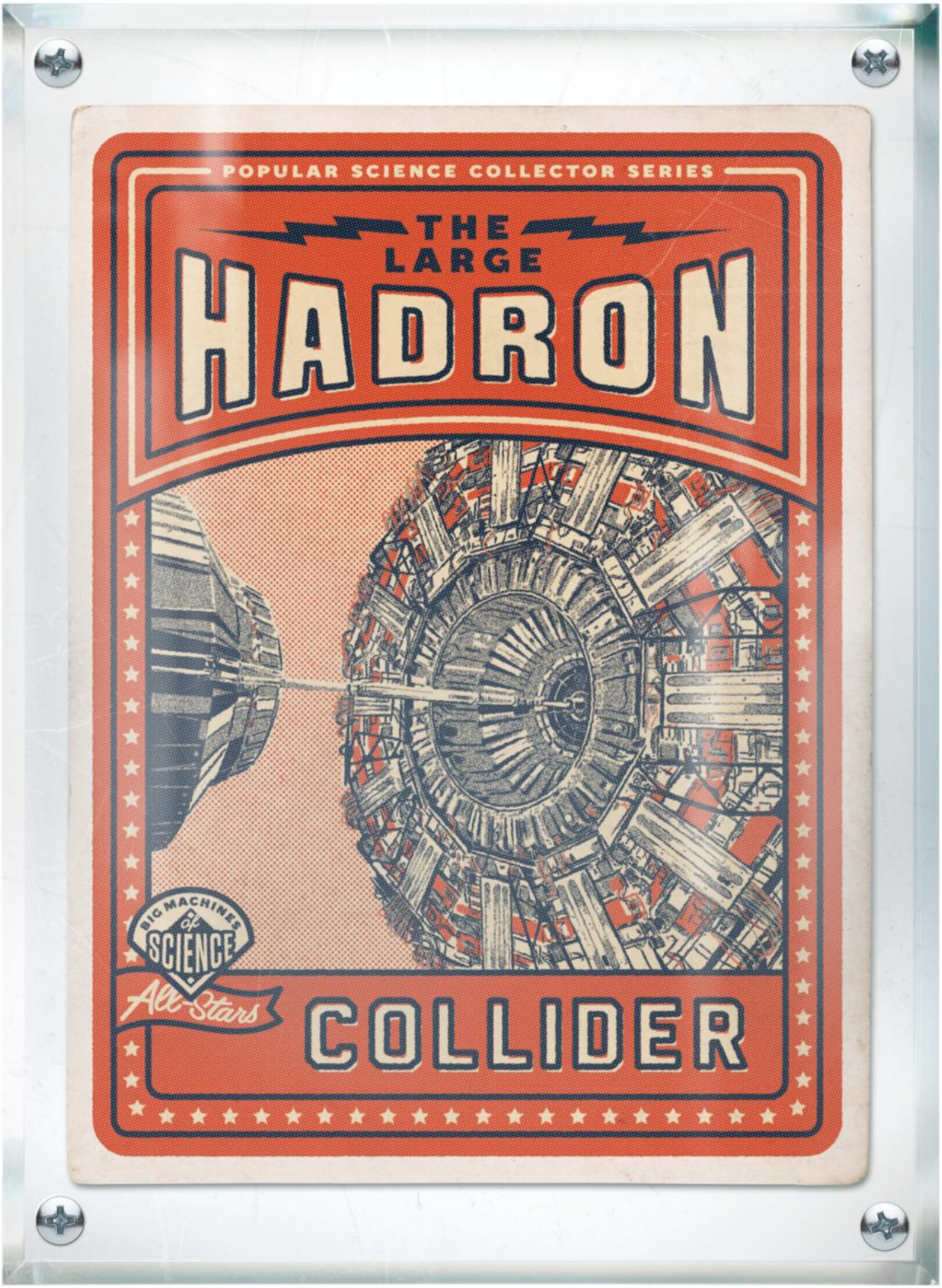
by Erin Blakemore / illustrations by Timba Smits and Eric Heintz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All-Stars
COLLIDER

THE LARGE HADRON COLLIDER

MACHINE STATISTICS

TEAM: Ace Accelerators

PRICE: $3.7 billion

ROOKIE YEAR: 2008

PLAYING FIELD: French/Swiss border

BATTING AVERAGE: Around 600 million particle collisions per second

WITH THIS RING, I THEE SMASH

This ring-shaped proton roller coaster is one of the single largest machines on the planet. Protons shoot through its nearly 17-mile-long underground tunnel at close to the speed of light; the universe can't help but spill its secrets. Protons crash together at high speeds, revealing particles previously unknown. You've probably heard all about its 2012 grand slam, detecting the Higgs boson "God particle." But this heavy hitter is pretty chill: At 456 degrees below zero, the electromagnets that make it all happen are colder than outer space. Could one day upend the standard model of physics—or maybe open up a hole to a new dimension. For now, the Hadron's hard at work re-creating the Big Bang.

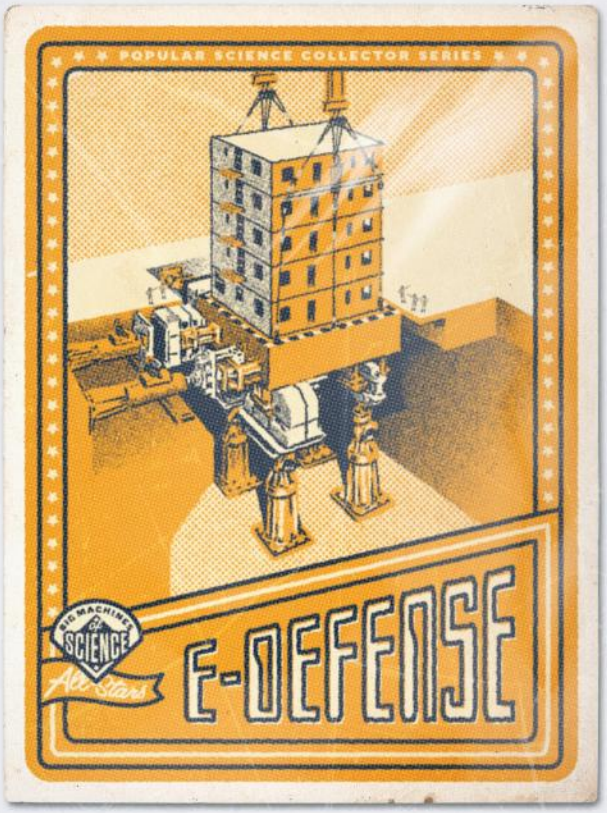
THE INTERNATIONAL SPACE STATION

MACHINE STATISTICS

TEAM: Lofty Labs
PRICE: $107 billion and counting
ROOKIE YEAR: 1998
PLAYING FIELD: 200 miles above Earth
GEAR: Packs in more than 8 miles of wire

FLOATING IN A TIN CAN

The best co-working space in space. Solar panels power 52 computers, 100-plus research bays, and nearly 1 million pounds of laboratory, built to accommodate constant renovations. It's an adventurous earthling's home away from home, with more room than a five-bedroom house, and plenty of international hospitality to go with all the groundbreaking science. These days, the ISS hosts experiments meant to bust us out of orbit: Astronauts munch on lab-grown lettuce to prep for Martian farms, while scientists monitor the subtle ways bodies change during long stretches spent off-world. Bonus: spacewalk selfies.



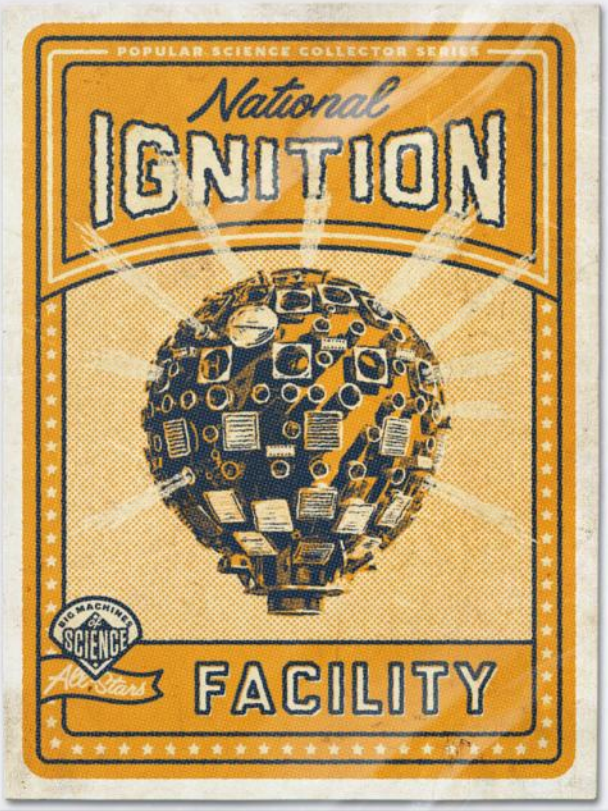
E-DEFENSE

MACHINE STATISTICS

TEAM: Movers and Shakers
PRICE: $400 million
ROOKIE YEAR: 2005
PLAYING FIELD: Hyogo, Japan
FIGHTING WEIGHT: Can support up to 2.5 million pounds

PUT IT ALL ON THE TABLE

Earthquake-resilience testing is on shaky ground—and boy are we glad. Pistons and hydraulics make our killer science kaiju rock and roll. This monster has the mechanical muscles to shake up full-size replicas of six-story apartment buildings. Inspired by the aftermath of a 1995 quake in Japan, this baby gives model cities a seismic ride from hell—so city planners can learn to deal with real-life tremors. And it's got sweet moves: Its shake patterns can produce all kinds of pseudo-seismic activity. If an E-Defense's 7.5 magnitude test doesn't blow your house down, nature doesn't stand a chance. (Knock on wood.)



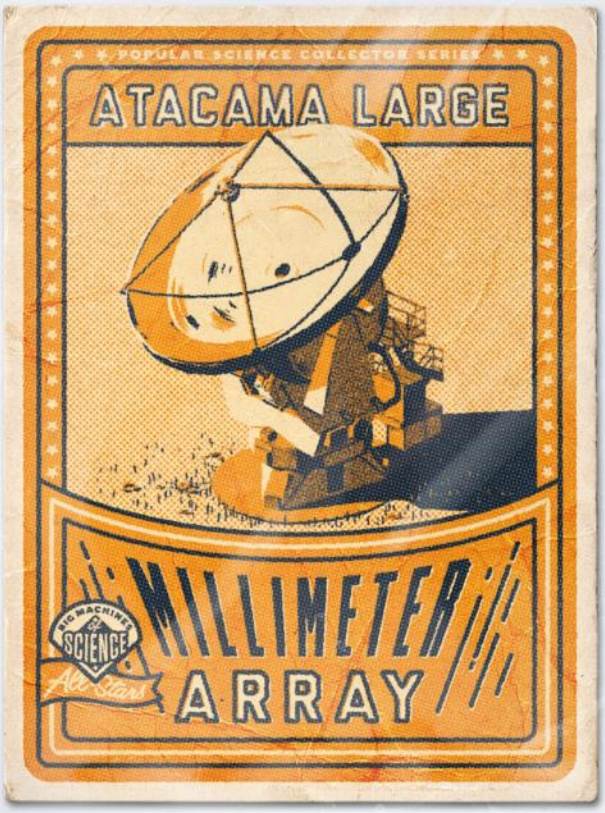
NATIONAL IGNITION FACILITY

MACHINE STATISTICS

TEAM: Major Lasers
PRICE: $3.5 billion
ROOKIE YEAR: 2009
PLAYING FIELD: Livermore, California
POWER: 2 million joules

MY GOD, IT'S FULL OF LASERS

Why build a laser when you could build 192? All those beams focus on one BB-size target, and it feels the pressure—more than 100 billion times the force of Earth's atmosphere. The real aim? Turn a single, tiny hydrogen seed into a starlike explosion. Cue fantasies of full-on fusion that could power futuristic homes around the globe. This extreme experiment is inspired by the reactions that power the sun, so it's no sweat for temps to reach 180 million°F. More than 40,000 mirrors and optical components make for one super superlaser. Could one day help to generate clean, sustainable energy...or blow us to smithereens. *Ka-boom*.



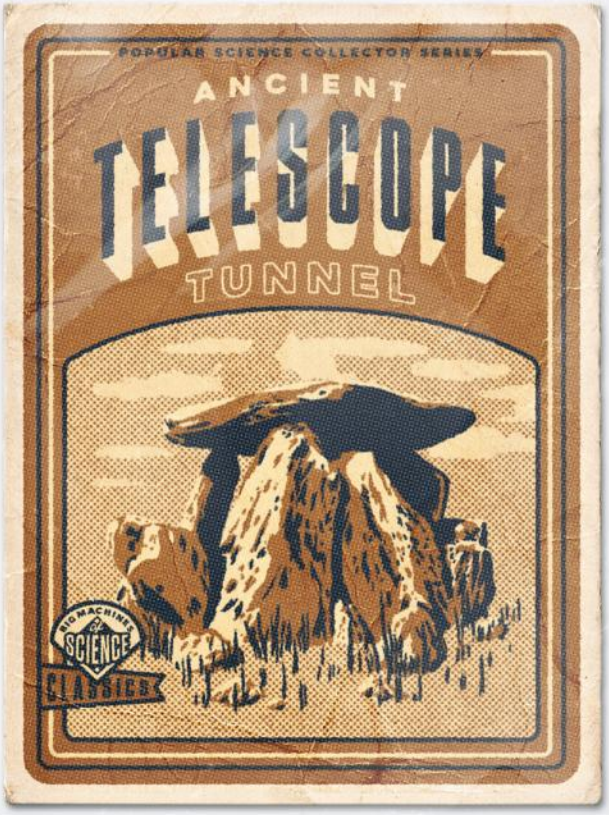
ATACAMA LARGE MILLIMETER ARRAY

MACHINE STATISTICS

TEAM: Telescope Troopers
PRICE: $1.4 billion
ROOKIE YEAR: 2011
PLAYING FIELD: Atacama Desert, Chile
PINCH HITS FOR: A 14,000-foot-wide single scope

STRENGTH IN NUMBERS

The gang hangs out high and dry at 16,000 feet above sea level in the world's most arid desert—the perfect place for pristine stargazing. Not that this team needs darkness to dish on the sky's secrets. Optical telescopes pick up visible light; these tune in to the radio waves distant stars emit instead. We're talking about 66 individual dishes (most a bit over 39 feet across) homed in on distant galaxies. Special 28-wheelers drag players to and fro, hauling them across the desert to form different (trans)formations to zoom in on extraterrestrial targets. The result? Some of the sharpest images of their kind.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CLASSICS

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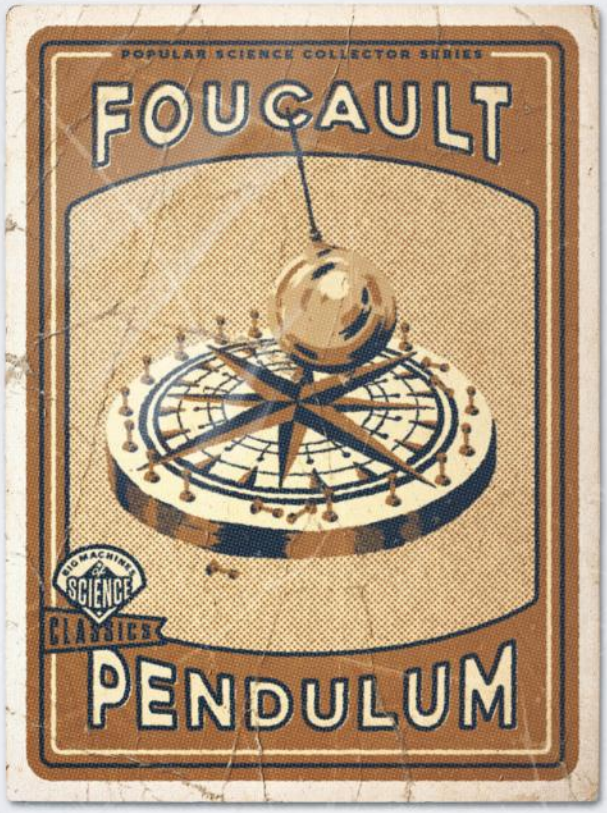
ANCIENT TELESCOPE TUNNEL
MACHINE STATISTICS
TEAM: Stone Stargazers
PRICE: Blood, sweat, rocks
ROOKIE YEAR: Around 4,000 B.C.
PLAYING FIELD: 186 locations in Portugal and Spain
LENSES: Zero
DYING TO SEE THE STARS
These seven-stoned structures—probably tombs—likely did double-duty by helping Mesolithic humans get a glimpse of key constellations. An optical illusion made for stellar sights: By framing the night sky just so, dark tunnels with narrow doors made stars look bigger to whoever gazed up from inside. That primitive play on modern telescope tech might just prove prehistoric humans' astronomy savvy. Seven huge slabs of granite. Stonehenge-like design. Aligned with the rising sun. Probably home to some pretty trippy burial ceremonies. That's some gravely good science for 6,000 years ago.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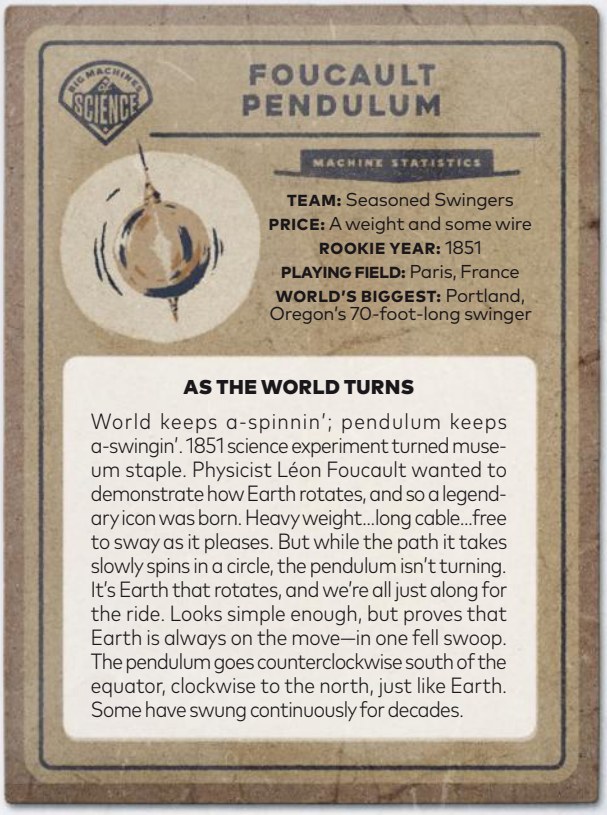
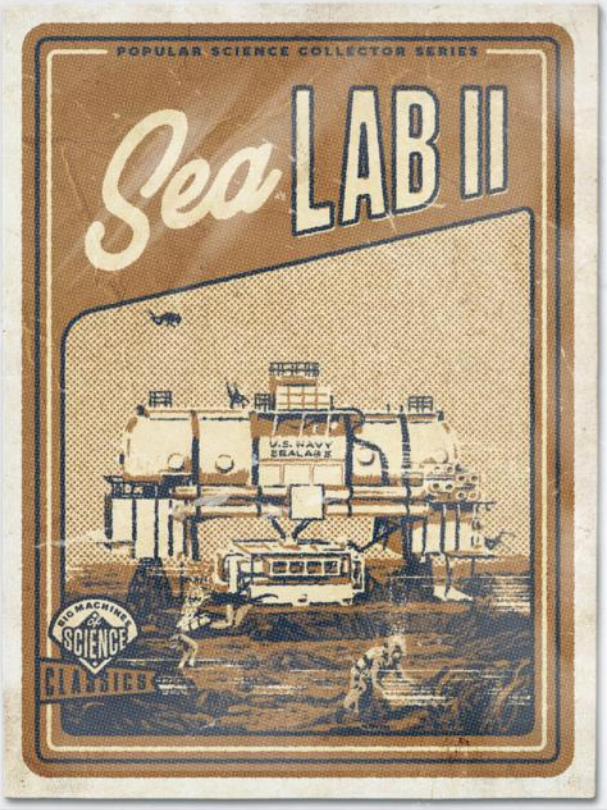

BIG MACHINES & SCIENCE
FOUCAULT PENDULUM
MACHINE STATISTICS
TEAM: Seasoned Swingers
PRICE: A weight and some wire
ROOKIE YEAR: 1851
PLAYING FIELD: Paris, France
WORLD'S BIGGEST: Portland, Oregon's 70-foot-long swinger
AS THE WORLD TURNS
World keeps a-spinnin'; pendulum keeps a-swingin'. 1851 science experiment turned museum staple. Physicist Léon Foucault wanted to demonstrate how Earth rotates, and so a legendary icon was born. Heavy weight...long cable...free to sway as it pleases. But while the path it takes slowly spins in a circle, the pendulum isn't turning. It's Earth that rotates, and we're all just along for the ride. Looks simple enough, but proves that Earth is always on the move—in one fell swoop. The pendulum goes counterclockwise south of the equator, clockwise to the north, just like Earth. Some have swung continuously for decades.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BIG MACHINE & SCIENCE
SEALAB II
MACHINE STATISTICS
TEAM: Nautical Nerds
PRICE: $2 million
ROOKIE YEAR: 1965
PLAYING FIELD: La Jolla Canyon, California
TRAINED DOLPHINS: 1
SO LONG, AND THANKS FOR ALL THE FISH
Astronauts became aquanauts to prove that people could live underwater for a spell. Visitors tested underwater tools, grew plants, mined ore, and studied the ocean floor. But helium-infused air and precarious canyon-edge real estate made the "Tilton Hilton" one lousy vacation spot. Scientists jammed with squeaky voices and ukuleles inside their damp digs—but tests showed they didn't lose strength or smarts below the surface. Astronaut Scott Carpenter lasted a whole 30 days—long enough for a high-pitched call with President Lyndon B. Johnson. MVP: Tuffy the trained dolphin, the crew's cetacean mail courier.

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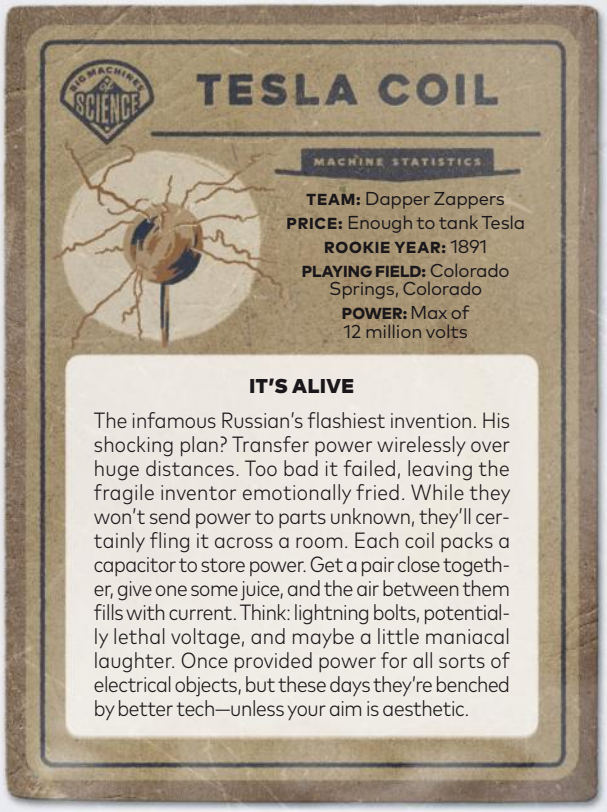

BIG MACHINE & SCIENCE
TESLA COIL
MACHINE STATISTICS
TEAM: Dapper Zappers
PRICE: Enough to tank Tesla
ROOKIE YEAR: 1891
PLAYING FIELD: Colorado Springs, Colorado
POWER: Max of 12 million volts
IT'S ALIVE
The infamous Russian's flashiest invention. His shocking plan? Transfer power wirelessly over huge distances. Too bad it failed, leaving the fragile inventor emotionally fried. While they won't send power to parts unknown, they'll certainly fling it across a room. Each coil packs a capacitor to store power. Get a pair close together, give one some juice, and the air between them fills with current. Think: lightning bolts, potentially lethal voltage, and maybe a little maniacal laughter. Once provided power for all sorts of electrical objects, but these days they're benched by better tech—unless your aim is aesthetic.

POPULAR SCIENCE COLLECTOR SERIES
Skylab
BIG MACHINES of SCIENCE
CLASSICS

SKYLAB

MACHINE STATISTICS

TEAM: Lofty Labs

PRICE: $2.5 billion

ROOKIE YEAR: 1973

PLAYING FIELD: 270 miles above Earth

FINAL INNING: July 11, 1979

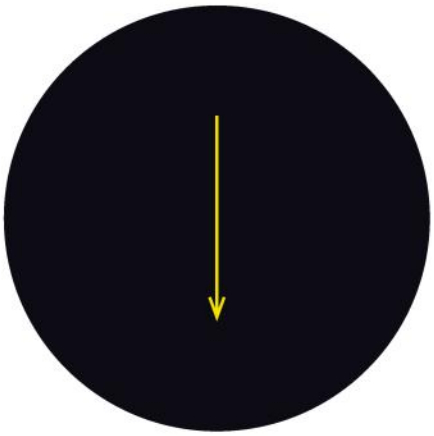
WHAT GOES UP...

First U.S. space station to rise. Only one to fall. Multistory construction. Space shower. Big enough to test spacewalking equipment indoors. In short? Astronaut paradise. Almost. Endless engineering issues plagued the epic enterprise. There were so many onboard problems to fix that one exhausted crew actually went on strike. Budget cuts and good old gravity took care of the rest. But it was a great run: Nearly 300 science experiments helped prove that people could live in space long-term. Then 200,000 pounds of tech rendezvoused with Earth after 34,000 orbits. The atmosphere smashed Skylab to bits, scattering sciency shards across Western Australia. Orbital decay: 1, Skylab: 0.

Oil won't last forever, and Dubai's government knows it. To stay prosperous, the city-state bets big on science and technology.

by
ANDREW
BLUM

THE FUTURE-PROOFING ENGINE



I.
After Oil

Dubai drops away behind us, its comic-book skyline replaced by khaki sand dunes and the occasional wild camel. The first sign of the technological ambition we are about to see is a billboard: a 20-foot-tall portrait of Dubai's ruler, His Highness Sheikh Mohammed bin Rashid Al Maktoum, rendered in a mosaic of solar panels.

At a cluster of buildings about a half-hour south of the city, a guard slides open a high steel gate for our white SUV, with Alhaz Rashid Khokhar at the wheel. A project manager for the Dubai Electricity and Water Authority, Khokhar has, for the past several months, been working toward the opening here of a 200-megawatt expansion of the Mohammed bin Rashid Al Maktoum Solar Park. The dark panels stretch across the desert for more than 2 miles, a distance so far beyond the vanishing point that standing at one corner is like looking through a double mirror. The largest operating solar plant in the United States is just over 550 megawatts, but Dubai grows by exponents. This 200-megawatt section will soon be a smudge on the map beside an additional 5,000 megawatts planned to come online over the next 13 years—a $14 billion investment targeted to meet 25 percent of Dubai's electricity needs. It is only one piece of a technological jigsaw puzzle that, once assembled, is intended to reinvent Dubai's role in the world.

For more than a decade, this city-state's story has been all about superlatives: the world's tallest building, the biggest fireworks display, the busiest international airport. But a new ethos has taken hold, a broad and purposeful strategy to swap profligacy for ingenuity. Unlike some countries, Dubai believes the planet is warming—and is determined to use science and technology not only to adapt to a new era of extremes, but also to make that adaptation the basis of its economy. Dubai wants to be known more as a laboratory for world-saving technology than for the man-made beaches, indoor ski slopes, and vast air-conditioned malls that defined its recent past. Its plan would seem hard to believe if the contemporary reality of Dubai itself weren't already so improbable. Dubai's transformation from a blip on the map to a global hub was a neat trick. But can it pull it off again?

Khokhar moved here with his family nearly five years ago, after turning down a job at home in India working for an international consulting company. In doing so, he became a leading indicator of Dubai's aspirations. Khokhar's not a laborer from the subcontinent, living in an un-air-conditioned work camp and toiling manually in the heat—the notorious scenario that blemished Dubai's recent rise. He ranks among the region's best minds, and was attracted by the pay and lifestyle, as if Dubai were New York or London. "Here we have plans," Khokhar says about the solar park, but he just as easily could be talking about his family and Dubai itself.

He and his peers believe they are building a better future, the outlines of which are all around us. Inside the park's R&D facility—a small concrete slab building with big solar wings on the roof—researchers are working to improve the performance of photovoltaic modules in the parched, dusty environment. "You can easily lose 30 to 70 percent of the power from dust," explains Jim Joseph John, an Indian engineer who recently relocated here from Phoenix, Arizona, where he'd finished up some research for his Ph.D. On an adjacent patch of sand, three visiting technicians fiddle with a sophisticated weather station, their tools spilling out of their rental car's trunk. Behind another fence is a photovoltaic reverse-osmosis system, which transforms brackish groundwater into drinking water. Across a construction laneway, two steel towers a couple of stories tall poke at the sky like half-erected cranes. Technicians are preparing to install 3-D printers on them, which will extrude—in a matter of weeks—a whole building intended to house (naturally) a drone lab. The laneway itself will then be ripped up, its brick pavers replaced with solar panels and a system to wirelessly recharge electric cars as they drive along. For the moment, a run-of-the-mill plug energizes a white subcompact with a Dubai Electricity decal.

"You're going to be surprised," John says. "The whole place is going to change."

II.
Minister of the Future

"We decided that we will go to the future—we will embrace the future without worry," says Mohammad Al Gergawi, the architect of Dubai's vision for the next half-century. He sits in the center seat of a vast table in the lush boardroom of one of the city's newest hotels. A waiter comes with a three-tiered curate stand piled with dates and nuts, his hand trembling with anxiety

OPENING SPREAD LEFT TO RIGHT: PHOTOGRAPH BY ANDREW BLUM; CHRIS RATCLIFFE/BLOOMBERG VIA GETTY IMAGES

PHOTOGRAPH BY SIDDHARTH SIVA

▲ **Mohammad Al Gergawi**
The minister charged with Dubai's vision stands outside the Future Foundation; the building is 3-D-printed.

as he places it in front of Al Gergawi—one of the most powerful men in Dubai and close adviser to Sheikh Mohammed, the city-state's hereditary monarch and prime minister of the United Arab Emirates, the federation of which Dubai is a part.

"We believe that we in the UAE and in Dubai have a mission," Al Gergawi continues. "This region needs a puller from its misery. There is tremendous conflict. There is a lot of hatred, sectarian war, religious war, ethnic cleanses, refugees. We see the story. Then you come to Dubai."

The city appears a postcard for prosperity, youthful diversity, and cosmopolitanism. Taxi drivers skydive on their days off, and the fanciest hotels fill up with civil servants and white-collar professionals on special-occasion dates—alongside Russian oligarchs and Indian industrialists who arrive in 20-foot-long Rolls-Royces. The malls and streets are busy with people of all skin colors and ethnicities, in all kinds of national dress. The sense of mutual tolerance is palpable, sometimes joyful.

Sitting beside Al Gergawi are two 20-something advisers. The three of them are dressed in the kandura, the Emirati version of the flowing gown that's an icon of the Arab world. In golden cream, gray,

▲ **The Financial Centre Metro Station**
Dubai's line of driverless trains helps the city toward its goal of 25 percent of all local trips made via autonomous vehicles by 2030.

or blue, perfectly pressed and fitted, with a sleek collar and a tassel at the neck like a bolo tie, they wear them like power suits, the costume of Emirati privilege. Al Gergawi accessorizes his with black titanium-rimmed eyeglasses and blue mesh Skechers, like an Arab Steve Jobs. This might not be an accident.

Early last year, in a move that didn't go as viral as footage of Dubai firefighters on jetpacks or a tennis match on a helipad, Sheikh Mohammed reshuffled his cabinet. He created new positions for a Minister of Climate Change and Environment, a Minister of State for Happiness, and a Minister of State for Youth Affairs (a 22-year-old). Al Gergawi—already Minister of Cabinet Affairs, got a new appendage to his title: *and the Future*. This was a declaration of purpose. For the past 13 years, among other roles, he served as chairman of Dubai Holding, a state-owned investment vehicle, where he assembled a diverse empire of hotel, real estate, and telecommunications businesses. Now he would shift full time to planning the future of Dubai. "Today I'm excited, actually," he says, in a guru-like cadence. "I'm very excited. I'm excited because I know we'll have a beautiful journey to the future. I can see it. I can feel it."

Cities are machines, the largest things we build. Their airports and seaports digest and expel people and goods, while their roads and rails siphon both through the urban landscape. Their tunnels carry data, power, water, and sewage. Their governing authorities work (one hopes) with deliberateness, imposing coherence on what otherwise could be chaos. It can all hum efficiently—or fail spectacularly. Typically, all of this is constructed over centuries. The Parisian sewer system dates to the 1850s; New York's first subway line opened in 1904; London got its first central power station in 1891. Avenues follow cow paths; creeks become water tunnels; fiber-optic lines slowly take their place beside electric cables. The lesson of city building is that infrastructure takes forever—the tortoise to technology's hare. But Dubai has done it differently. Dubai has built in 50 years what has taken most cities 100. That isn't hyperbole or a PR stunt—though Dubai is famously expert at both—but a reality plainly visible in this metropolis of nearly 3 million people. For centuries Dubai was a sleepy port, serving the pearl trade in the Straight of Hormuz. In 1966, when Al Gergawi was 3 years old, the newly formed Dubai Petroleum Company found oil off the coast. While engineers worked to pump it up from the seabed, his boyhood school still lacked electricity. He drank rust-colored water, filtered with a piece of cloth. "Nothing was here, actually," he recalls. The site of the beachfront hotel we're sitting in had been a smallpox sanitarium. "While you were coming from the airport, probably you drove down Sheikh Zayed, which is an eight-lane highway? My first trip on this road was when it was a dirt road. It was sand dune."

Growth came with infrastructure. Flush with petrodollars, Dubai began to build: roads, a massive seaport, an airport, an airline, and power plants. But they knew their resource wealth was only temporary, while the scarcity of the desert environment

PHOTOGRAPH BY SIDDHARTH SIVA

was forever. Sheikh Rashid bin Saeed Al Maktoum, Dubai's ruler at the time, put it in a maxim: "My grandfather rode a camel, my father rode a camel, I drive a Mercedes, my son drives a Land Rover, his son will drive a Land Rover, but his son will ride a camel." The prophesied second generation of Land Rover drivers are the 20-somethings sitting beside Al Gergawi. (One drives not a Land Rover but a Mercedes G-Wagen.) Al Gergawi's challenge is to bend fate, to keep the camels in the desert, and to put his grandchildren back into Mercedes—or perhaps flying cars.

Over the past generation, Dubai's advantage has been the new geography of air travel. The city is perfectly situated to link Europe and the Americas with Africa, Asia, and Australia. An estimated 95 percent of the world's population is within flying range of the Airbus A380, the giant double-decker flagship of Emirates, Dubai's airline.

For the next generation, Dubai's advantages are more fraught, tied as they are to impending climate catastrophe. Many cities are about to face new extremes of temperature and drought. Dubai already does. Many cities will struggle to find fresh water and clean power. Dubai already does. Viewed in this light, Dubai is a place where the future has arrived early.

Rather than be intimidated by its potentially catastrophic challenges, withdrawing from the world and doubling down on outdated technologies, Dubai is accelerating toward it. The plan is simple: Turn the traditional mechanisms of urban life into a platform for confronting the hazards of contemporary society. Then export those innovations. If a city is a machine, Dubai wants to be the most advanced city-machine the world has ever seen—and it wants to sell its blueprints to everyone. "Dubai is recognizing that climate change is an existential threat to its ability to be a prosperous part of the world," says David Pomerantz, executive director of the Energy and Policy Institute, a watchdog group.

To publicly speculate about the jigsaw puzzle of technological possibilities, Dubai opened a Museum of the Future, housed temporarily in a white-wrapped pavilion until permanent space can be constructed. An opening video, projected in a 360-degree cyclorama, pretends to look back in time from the Dubai of 2050. "Not too long ago, climate change brought us to the edge of extinction," a narrator warns in Arabic and then English as a montage of destruction flashes on the screen: skyscrapers subsumed by sand, riots in the streets, forests disintegrating into dust. "But the UAE saw an opportunity: to move fast and create breakthroughs that the world had never seen."

In this imagined Dubai of the future, the electricity and water authority has blown past today's supersize desalination plant and opened a bio-desalination plant, grown from the genes of a jellyfish (the "most absorptive natural material") and a mangrove tree ("one of nature's best desalinators"). And it sold them too: "We also export jellyfish bio-desalination plants to cities across the world," the stentorian voice continues. Robots construct buildings from sand. An artificial intelligence selects and grows food in indoor farms. And flying cars pulse through traffic-free streets. It's all presented with enough science-fiction flair to maintain a sense of humor. But the punchline is serious: "We solved our own problems, and now climate solutions are our greatest export." At a historical moment when—in the United States, at least—global-warming predictions remain politically controversial, it is startling to see Dubai planning its economic future around these challenges.

"Because we don't have, we need to think harder," Al Gergawi says, tacitly acknowledging that the pieces of the puzzle don't yet fit together. "We need to think faster, and we need to reinvent every single product. You look at history. You look at the future. You look at research and say: 'You know what? How can I create this journey?'" Then he pops a cashew into his mouth.

III.
The Laboratory City

One evening, walking along the beach, I come upon a team of workmen busily disassembling a small wooden platform with a bold "E" stamped into the middle of a blue circle. I was mystified when I first saw it that morning, appearing as if out of nowhere. Was it a dance floor for some extravagant party on the beach? A helipad? These didn't seem unusual questions in Dubai. Why did it appear, only to be removed 12 hours later under cover of night? But if the purpose was a secret, the workmen were never told to keep it. "It's for a drone," says the man who seems to be in charge, momentarily pulling his phone away from his ear. Why were they dismantling it? "Technical challenges."

The next day, Ahmed Hashem Bahrozyan, a senior executive at Dubai's Roads & Transport Authority, clarifies things. "Anything that moves people, we're looking into," he says. We're standing beside what looks like a carnival ride, caged behind velvet ropes: the Ehang 184, a Chinese-designed drone big enough to transport one passenger and one small bag 30 minutes across the city. The official plan is for trial service to begin in July. But later, when pressed on the feasibility of that immediate goal, the chairman of the RTA only laughed. Dubai knows flair. The announcement had the desired effect of generating headlines worldwide. The same went for the fanfare around Dubai's plan to build a Hyperloop passenger-transport system connecting with its neighbor, Abu Dhabi—an announcement that was later downgraded to a "pre-feasibility study."

Dubai's other transportation plans are more proven. In 2009, when it was reeling from the global economic collapse, the city

opened a metro line, the first in the region, with driverless trains. Its nearly 200 million annual rides (compared with 1.763 billion on the New York City subway system) form the basis for Dubai's goal that 25 percent of all local trips be made via autonomous vehicles by 2030. The RTA is looking at driverless buses and aerial gondolas, and is pushing to compete with cities around the world to attract the companies that are developing self-driving technology.

This is a case where being a monarchy has its advantages. Dubai can change regulations quickly to better attract companies like Uber and Daimler to use the city as a lab. "The ability to meet their needs faster than other possible cities around the world—where there's much more bureaucracy, and it takes time to change regulations and policies—that's attractive to them," Bahrozyan says, "because even they don't know exactly what they need unless they come and try." The RTA is working toward providing the sophisticated mapping necessary for autonomous transport, as well as a citywide cloud that would share data among thousands of vehicles from many different manufacturers.

Dubai is banking on the idea that diversity and tolerance can lead to innovation and prosperity.

This is the kind of backbone building that has proved worthwhile for Dubai in the past—not only to improve efficiency at home, but also to export for profit abroad. It's the same strategy that has driven the growth of DP World, operator of Dubai's enormous Jebel Ali seaport, which sells its automation technology globally.

Supercharging the plans is infrastructure spending—$3 billion of it on transportation—in advance of the World Expo, which Dubai will host in 2020, the first ever in the Arab world. The RTA will extend the metro line 9 miles to the site, adjacent to Dubai's sprawling new airport, and starchitects like Norman Foster and Santiago Calatrava are designing pavilions.

Technically speaking, the sustainability goals are bold. Fifty percent of the energy used during the event will be generated from renewable sources, and 50 percent of that is expected to be generated on-site. The Emirates pavilion, designed by Calatrava, will have deployable wings with integrated solar panels.

Whereas past expos—like those in Shanghai and Milan—have been primarily focused on a domestic audience, Dubai expects 70 percent of the fair's 25 million visitors to come from outside the UAE (most likely on an A380). They'll be unwittingly celebrating something else as well: the 50th anniversary of the founding of the United Arab Emirates. It's all a chance for Dubai to punctuate that international outlook—what Reem Al-Hashimy, director general of the Expo, describes as an interconnectivity. "That's how Dubai has survived," she says. "It's been this place where people come from all over and find a better way of life."

Dubai's middle class appears to be far broader and more diverse than it was a decade ago, when the dominant media narrative was about a fantasy city built on the backs of slave labor. The extent to which working conditions have improved is hard to judge, but the reality of the city as a business and commercial hub is plainly apparent. If Dubai's future is as a

PHOTOGRAPH BY SIDDHARTH SIVA

knowledge hub, it will have to fulfill the dreams of more than just the Emiratis. With rare exceptions, only they are allowed to be citizens, and since visas are based on employment, deportation isn't so much an extreme consequence as an everyday worry. That may have mattered less to the Emiratis when labor was expendable. But to compete for global talent, Dubai needs to transform from a transitory polyglot society to a permanently cosmopolitan one—an ambition that has become a talking point of Sheikh Mohammed. "The uniqueness of Dubai is the fact that it is a melting pot of the world's cultures, ethnicities, and minds in one city," he said in a statement.

Al Gergawi acknowledges the challenge of that transition in his own vague way. "I'm saying we're not perfect," he says. "We are young kids on the block, if you look at the block as the world. Every day we say: 'How can we improve? How can we move to the next step in every single aspect?'"

Maybe it is necessary to grade Dubai on a curve. By the standards of a liberal democracy, Dubai remains retrograde. There is no democratic representation, poor freedom of the press, and homosexuality remains illegal. But compared with the rest of the Arab world, Dubai is a beacon of openness and modernity. Thirty percent of the cabinet members are female (compared with 0 percent in Saudi Arabia and 6 percent in Jordan), as is 66 percent of the government workforce.

◀ **Sarah Amiri**
She is the science lead and deputy project manager of the Mars mission.

▲ **Space Centre**
The growing complex includes mission control, research labs, and a clean room to build satellites.

Dubai's long game is to create an atmosphere for future growth. It has taken its initial good luck—its limited oil reserves, along with the unlimited ones of its generous neighbor, Abu Dhabi—and made even more out of it, leveraging finite oil wealth into a viable position as a global hub. As part of the plan for the Expo, the government has established a $100 million fund to finance tech startups from around the world and bring them to Dubai. It is banking on the idea that diversity and tolerance can lead to innovation, and innovation can lead to both economic prosperity and—in the current language of the government—a happy city.

Can that happiness be attained without extending citizenship beyond Emiratis? It is a controversial question. Al Gergawi demurs. "We are a young country," he says.

IV.
Mars and Beyond

Sarah Amiri is a young scientist. At 30 years old, she is the science lead and deputy project manager of what is perhaps Dubai's most audacious project: the Emirates Mars Mission. Before she even completed her master's in computer engineering from the American University of Sharjah, next to Dubai, she landed here, at the Mohammed bin Rashid Space Centre, a small compound of low buildings with facades of silver square panels, not far past the airport. A circular radio dish points to the sky. A colorful parrot chatters inside the cafeteria, darkened on this weekend morning. The building is otherwise quiet, except for a security guard and a single engineer, monitoring *DubaiSat*-2, the polar orbiting imaging (CONTINUED ON P.100)

PHOTOGRAPH BY SIDDHARTH SIVA

Sheila Dwyer, Hanford Observatory
Ripples in spacetime make LIGO's 2.5-mile-long arms quiver so its lasers hit detector mirrors inside. Dwyer kept the mirrors aligned.

Madeline Wade, Kenyon College
Wade writes code to calculate LIGO's moves—within one-ten-thousandth the diameter of a proton—based on laser behavior.

Michael Coughlin, Harvard University
Cosmic collisions—like black-hole mergers—make LIGO dance. Coughlin uses optical telescopes to track down those black holes.

R.C. Essick • T.G.F. Li • A. Pal-Singh • L. Barsotti • C. Palomba • L. Gergely • E. Goetz • S. Biscans • N.D. Smith • H. Wang • M. Cho • A.W. Muir • B. Mours • M. Fays • D. Simakov • J.H. Poeld • T. Prestegard • I.W. Harry • D.J. McManus • R. Poggiani • A.M. Cruise • K. Danzmann • G. Cerretani • X. Wang • G. Heinzel • S.P. Stevenson • J.J. Oh • C.M. Mow-Lowry • K.C. Cannon • M.C. Edwards • L. Zangrando • M.H. Wimmer • A. Heidmann • C.L. Mueller • J.D. Romano • E.C. Ferreira • D. Bersanetti • S.E. Barclay • M. Bazzan • H.S. Cho • V. Dolique • F. Kawazoe • Z. Zhou • C. Bogan • M. Bitossi • P.R. Brady • C. Mishra • M. Branchesi • E.J. Daw • M. Steinke • L. Prokhorov • S. Mirshekari • R. Weiss • C.H. Lee • S.E. Whitcomb • A.F. Brooks • A.G. Wiseman • N. Van Bakel • R. Birney • E.A. Huerta • A. Pele • D.S. Rabeling • E. Coccia • M.R. Smith • M. Korobko • J.R. Sanders • T. Souradeep • C. Affeldt • J.E. Brau • I. Dave • J.A. Clark • A.M. Sintes • Y. Zhang • M. Lorenzini • C.V. Torres • M. Davier • M. Zevin • T. Briant • Z. Khan • Y. Wang • S. Sachdev • M.S. Kehl • R. Everett • M. Montani • S.T. Countryman • B.C. Stephens • M. Wade • B. Patricelli • M. Vardaro • M. Pitkin • B.C. Moore • S.L. Danilishin • S. Grunewald • I. Kowalska • G. Mazzolo • P.M. Meyers • M.A. Bizouard • M. Ast • F. Baldaccini • J. Schmidt • S. Raja • J. Zweizig • A. Singer • M. Hendry • S.D. Reyes • C. Belczynski • O. Lousto • D.M. Coward • M. Pürrer • L.S. Finn • F. Clara • A. Gatto • A.S. Bell • C.F. Da Silva Costa • A. Pai • A. Melatos • B.F. Schutz • B.C. Barish • F. Cleva • D.J. Vine • G. González • R.D. Williams • R.T. DeRosa • J. Bartlett • G. Serna • L. Kuo • M. Mantovani • C.C. Buchanan • A.W. Heptonstall • N. Indik • B.C. Pant • S. Koley • G. Islas • N. Christensen • F. Matichard • Archisman Ghosh • D.R. Ingram • T. Regimbau • M. Cabero • I. Di Palma • R.P. Fisher • M. R. Abernathy • A.D. Silva • A. Buonanno • S.D. Antonio • S.E. Dwyer • C. Zhao • J. Meidam • A. Gopakumar • R. Schnabel • I. Maksimovic • B. Machenschalk • B.L. Swinkels • Y. Pan • R. Mittleman • L. Rei • J.M. Isac • K. Mason • N. Heurs • S. Chao • V. Pierro • D. Cook • J.T. Whelan • H.A.G. Gabbard • G. Newton • A. Pasqualetti • I. Khan • D. Huet • C. Casentini • A.J. Weinstein • A. Kontos • H. Pan • M.C. Heintze • V. Germain • J.P. Zendri • T. D. Abbott • V. Malvezzi • E.A. Khazanov • P.J. King • C. Baune • T. Callister • P. Schale • G. Cella • C. Wilkinson • S. Ghosh • S. Huang • D.E. McClelland • M.C. Díaz • D.J. Murphy • C. Graef • B.D. Lackey • N.M. Brown • B.K. Berger • E. Katsavounidis • T. Adams • H. Vahlbruch • S.M. Koehlenbeck • R. Bonnand • D. DeBra • A. Post • I. Mandel • T. Vo • D. Talukder • X. Fan • S.E. Hollitt • P. Shawhan • N. Kijbunchoo • M. Walker • C.V. Kalaghatgi • L.W. Wei • M. Saleem • L. Rolland • D. Schuette • M. Phelps • F. Barone • H. Yu • A.L. Lombardi • J. Read • L. Sadeghian • G. Lovelace • H. Ward • A. Schönbeck • P. Astone • A. Brillet • C.P.L. Berry • S. Husa • M.E. Zucker • D.A. Brown • A. Glaefke • W.D. Vousden • J.R. Leong • P.F. Cohadon • M. Favata • L. Gondan • R. Bork • P. Brockill • N. Arnaud • J. Birch • D.V. Martynov • L. Sun • D.I. Jones • E. Merilh • R. Singh • J. Oberling • E.E. Cowan • B.J. Owen • K.L. Dooley • L. Cunningham • D. Trifirò • R. Vaulin • G.H. Sanders • H. Vocca • W. Parker • S.A. Usman • P. Groot • T.B. Littenberg • J.C. Barayoga • N.A. Gordon • D. Moraru • T.P. Downes • M.W. Coughlin • M. Neri • J. Powell • F. Nocera • P.J. Veitch • D. Ugolini • J.R. Smith • S. Bloemen • B. Day • F.J. Raab • A. Corsi • W. Del Pozzo • M. Pichot • T. Huynh-Dinh • V. Tiwari • K. Kim • J.P. Coulon • L. Kleybolte • L. Matone • S. Hild • K.A. Hodge • J. Harms • S. Frasca • B. Sassolas • L. Trozzo • R. Cavalieri • M.A. Arain • M. Di Giovanni • G. Kang • R. Kennedy • A. Sheperd • L. Naticchioni • M.J. Hart • S.H. Oh • J. O'Dell • S. Tiwari • K. Jani • P. Oppermann • M. Haney • P. Couvares • S.G. Gaonkar • M. MacInnis • C. Pankow • K. Siellez • F. Frasconi • K.A. Thorne • J.D.E Creighton • J.J. Hacker • G.H. Ogin • F. Sorrentino • P. Kumar • M. Rakhmanov • M. Punturo • M. Zanolin • M. Zhou • G. Hammond • R. Schilling • P. Raffai • F. Ricci • F. Cavalier • A. Paoli • V.B. Adya • S. Ascenzi • E.G. Thomas • M. Lormand • G. Vajente • L. Milano • W. Kells • J. Luo • G. Stratta • E. Capocasa • R.S. Ottens • P. Ehrens • D.J. Hosken • L.T. London • R. McCarthy • Y. Chen • S. Kandhasamy • L.R. Price • F. Garufi • R. Gustafson • H. Fong • J. Cao • E. Calloni • S. Gras • G. Traylor • A. Conte • A. Gupta • C. Hanna • G.A. Prodi • M. Bejger • A.R. Wade • H. Fehrmann • M. DeLaurentis • B. Weaver • S. Vitale • J.H. Chow • I. Yakushin • G. Woan • R. Jones • A.L. Stuver • V. Predoi • J.S. Key • J. Casanueva Diaz • D.L. Kinzel • P. Weßels • K. Kokeyama • J. Ming • M. Prijatelj • T.Z. Summerscales • S.J. Waldman • A. Lenon • T.D. Creighton • C. Biwer • D. Passuello • E.J. Howell • G. Wu • P.J. Sutton • P. Popolizio • O. Puncken • D. Tuyenbayev • L. Cerboni Baiardi • C.S. Unnikrishnan • K.A. Strain • S. Koranda • H. Miao • L. Wallace • G. Wang • A. Chincarini • B.S. Sathyaprakash • B. Sandeen • A. Nitz • G. Ballardin • H. Dereli • F. Robinet • F. Donovan • D.G. Blair • A. Rüdiger • G. Gemme • V.J. Roma • X. Siemens • M. van Beuzekom • Y.M. Hu • S. Privitera • K.V. Tokmakov • J.K. Blackburn • C.D. Capano • E. Cesarini • M. Leonardi • N. Aggarwal • R. Bassiri • D. Steinmeyer • P.R. Saulson • P. Puppo • A. Effler • D. Mukherjee • E.A. Quintero • R. Pedurand • B.L. Pearlstone • C. Lazzaro • R.M.S. Schofield • E. Chassande-Mottin • G. Romanov • S.S. Eikenberry • A. Colla • C.G. Collette • J. Hanks • G. Cagnoli • B. Lantz • M. Evans • D.M. Macleod • C. Messick • J. Eichholz • S.C. McGuire • P. Fritschel • Richard J. Oram • M. Tonelli • O. Bock • Y. Setyawati • E. Oelker • K. Ryan • P. Ajith • C.D. Ott • F. Martelli • S. Steinlechner • P. Hopkins • S. Rowan • D. Barta • T. MacDonald • D.H. Shoemaker • E. Maros • G. Ciani • J. Veitch • W. Engels • N.S. Darman • J. Scott • O. Sauter • S.H. Huttner • J.L. Willis • J.D. Lough • V.P. Mitrofanov • H. Lück • G. Valdes • H. Wittel • A. Freise • D.B. Kelley • D.G. Keppel • S. Jawahar • K. Kawabe • G. Bergmann • R.M. Blair • M. Factourovich • A. Staley • B. Barr • F. Paoletti • M. Turconi • S.J. Chamberlin • J.L. Wright • J.V. Van Heijningen • Z. Du • M.S. Shahriar • S. Strigin • S. Caride • M.M. Hanke • D. Pascucci • M.J. Szczepańczyk • D.M. Shoemaker • F. Piergiovanni • B. Krishnan • M. Granata • R. Bhandare • P.T. Baker • M. Boer • H.P. Daveloza • H. Fair • M.M. Fejer • A.B. Nielsen • E.J. King • P. Schmidt • M. Masso-Reid • S. Babak • S.M. Aston • R.J.E. Smith • M. Kasprzack • Q. Fang • J. Qin • J.

ONE EXPERIMENT

1,011 PEOPLE

Robert Schofield, University of Oregon
A lightning strike 6,000 miles away in West Africa could have caused LIGO's quiver. Schofield proved that it didn't.

Anamaria Effler, Livingston Observatory
Effler tweaked hardware to better catch false alarms. She and her team finished tinkering for the night just before the real signal hit.

Joey Key, University of Washington
By October, the wave was confirmed. Key heads the team that announced the discovery, translating it into 17 languages.

Jessica McIver, Caltech
Any movement can set off LIGO. One pesky rumble occurred every hour for months. McIver's team found the culprit: a refrigerator.

Kiwamu Izumi, Caltech
Izumi found ways to make LIGO less vulnerable to false signals. "It's like detective work, trying to arrest the criminal noise source."

Jenne Driggers, Hanford Observatory
On September 14, it looked like LIGO caught a wave. Driggers was one of many tasked with showing the signal wasn't random noise.

Kim • J.B. Camp • J.M. Gonzalez Castro • O. Piccinni • L. Williams • S. Mukherjee • P. Charlton • D.C. Coyne • O. Palashov • R.M. Martin • V. Loriette • J. Munch • A. Grant • P. Ruggi • D. Buskulic • M. Cavaglià • F. Carbognani • G. Ashton • S. Cortese • N. Cornish • C.-J. Haster • M. Manske • I. Bartos • T.J. Massinger • N.A. Strauss • A.S. Markosyan • F. Ferrini • E.K. Gustafson • H.R. Paris • C. Vorvick • N.A. Robertson • T.P. Bodiya • N. Mavalvala • V. Fafone • S.A. Pai • M.L. Gorodetsky • V.V. Frolov • T. Etzel • T. Dent • M.J. Cowart • A. Viceré • Y. Ma • J. Degallaix • V. Mandic • J.B. Kanner • P.B. Graff • J. McIver • H.P. Pfeiffer • V. Sandberg • P. Bacon • H.K. Lee • R. Kumar • N. Man • V.B. Braginsky • B.P. Abbott • M. Mageswaran • R. Stone • E. Genin • R. Robie • B.R. Hall • K. Mossavi • E. Cuoco • P. Thomas • R. Frey • B.J.J. Slagmolen • D.B. Kozak • K. Haris • A. Cumming • J.R. Palamos • F. Pannarale • T. Dal Canton • M. Constancio • M. Agathos • H. Qi • C.I. Torrie • Y.M. Kim • W.Z. Korth • D. Voss • A.C. Green • F. Kéfélian • A. Ain • X.J. Zhu • C. Cheng • H.Y. Chen • J.R. Gair • K. Gill • Abhirup Ghosh • N. Leroy • S. Karki • A. Masserot • S. Caudill • E. Ochsner • J.R. Gleason • I.S. Heng • C.M. Reed • B.A. Boom • S. Márka • S.E. Gossan • L. Cadonati • P. Leaci • D. Barker • G.M. Harry • V. Bavigadda • S. Mitra • L. Winkelmann • A.S. Sengupta • S.M. Scott • G. Dojcinoski • R. Taylor • V. Frey • J. Calderón Bustillo • M. Was • M. Fyffe • M.C. Araya • P. Jaranowski • R. De Rosa • L. Cominsky • B. O'Reilly • T.B. Edo • J.A. Giaime • R. Douglas • B. Gendre • J. Heefner • K. Arai • M. Barsuglia • G. Mueller • L.K. Nuttall • B. Sorazu • M.A. Barton • G. Losurdo • T. Theeg • R. Passaquieti • D. Sellers • V. Kringel • K. Lee • E.A. Houston • S.R. Morriss • F.Y. Khalili • M. Weinert • C.J. Moore • K. Izumi • A. Moggi • A. Samajdar • T.M. Evans • A. Neunzert • G. Greco • A. Taracchini • F. Marion • G. Kuehn • L. Pekowsky • G. Hemming • J.H. Romie • I. Ferrante • P.D. Lasky • D.D. Brown • K. Venkateswara • F. Mezzani • S. Deléglise • K. Craig • M. Yvert • E. Schreiber • J. Logue • R.W.P. Drever • M. Drago • S. Dhurandhar • A. Buikema • S.S. Premachandra • J. Cripe • T. Westphal • D. Keitel • A. Mullavey • P. Kwee • M.K. Gupta • L.M. Sampson • P. Aufmuth • S. Penn • A. Idrisy • J. Prasad • S. Di Pace • A. Zadrożny • G. Debreczeni • Z. Márka • G. Billingsley • F. Jiménez-Forteza • R. Gouaty • K. Wiesner • S.R.P. Mohapatra • L. Wen • V. Necula • T. Bulik • S. Fairhurst • A.P. Lundgren • K.E. Gushwa • W. Katzman • I. Nardecchia • S. Doravari • F. Acernese • S. Chung • C. Aulbert • R. Romano • S. Reid • A. Sawadsky • R.J.G. Jonker • Arunava Mukherjee • H. Yamamoto • C. Bond • J. Hanson • A. Di Lieto • D. Feldbaum • H. Radkins • C.R. Ramet • L. Ju • R. Abbott • R.J.S. Greenhalgh • N.K. Johnson-McDaniel • H. Middleton • M. Landry • T.T. Fricke • T.T. Nguyen • G.S. Davies • M.E.N. Normandin • A. Kutynia • R. Goetz • K.G. Arun • J.F.J. van den Brand • Nam-Gyu Kim • M. Mohan • M. Thomas • R. Flaminio • S. McCormick • G. Gaur • M.C. Tringali • R. Chakraborty • J. Worden • M. Pickenpack • J.C. Driggers • R.L. Byer • R. X. Adhikari • I.A. Bilenko • H.J. Bulten • F. Bondu • G. Vedovato • C.C. Arceneaux • H. Grote • R. DeSalvo • O. Birnholtz • J. Bergman • M. Tacca • S. Vinciguerra • J. Healy • S. Shah • A.K. Srivastava • A. Sevigny • V. Mangano • D. Meacher • V. Boschi • D.C. Vander-Hyde • K. Wette • M. Razzano • B. Farr • S. Leavey • D.E. Holz • D.J. White • M.P. Thirugnanasambandam • S.G. Crowder • T. Kaur • L. Sammut • R. Prix • W. Winkler • A. Giazotto • S. Bhagwat • H.B. Eggenstein • S.T. McWilliams • S. Meshkov • T. Sadecki • F. Travasso • B.M. Levine • V. Kalogera • J. Miller • J.S. Kissel • S. Farinon • A. Sergeev • A. Perreca • B. Allen • M. Fletcher • L. Di Fiore • A. Basti • L.E. Wade • C.C. Wipf • N. Mazumder • D. Mendoza-Gandara • E.E. Mikhailov • M. Frede • A. Bozzi • W.W. Johnson • F. 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Shaddock • D.H. Reitze • S.E. Zuraw • W. Yam • L. Aiello • D. Nolting • P. Addesso • N. Gehrels • P. Hello • W.M. Farr • S. De • C. Kim • F. Ohme • D.J. Ottaway • M.B. Jacobson • G. Mendell • J.G. Rollins • L. Gammaitoni • B.F. Whiting • S. Khan • J. Hough • V. Re • H.M. Lee • V. Raymond • S.P. Vyatchanin • A.A. Van Veggel • F. Salemi • G. Mitselmakher • A.L. Urban • K. Ackley • E. Thrane • X. Guo • C. Gray • J. Steinlechner • L. Conti • T. Denker • F. Marchesoni • P. Rapagnani • Q. Chu • M.J. Yap • J. George • M. Brinkmann • A. Gennai • J.D. Fournier • M. Merzougui • T. Isogai • S. Nissanke • G.D. Meadors • S. Chua • R. Lynch • A. Bertolini • V. Kondrashov • R.K. Nayak • Z. Frei • Y. Minenkov • R. Sturani • A. Rocchi • K.D. Giardina • G. Pillant • A. Królak

In 2015, the LIGO Scientific Collaboration's twin observatories detected gravitational waves—one of Einstein's major predictions. The feat, expected to win a Nobel, made a few famous. But it depended on this legion of the unsung.

Maria Alessandra Papa, Max Planck Institute
Papa was among six editors of the 1,011-author announcement. Deciding what to cut was a five-month-long labor of love.

Chris Messenger, University of Glasgow
He turned LIGO's landmark detection into audio: a chirp going up in pitch and speed to represent black holes spiraling into collision.

Maggie Tse, MIT
This is just the beginning: Tse is building a noise-reduction device to improve LIGO's range, or "the volume of the universe you can see," by 70 percent.

by Mark Kaufman and Cici Zhang

1/8

WHERE *STEEL* BECOMES *ARSENAL*

by:
KELSEY ATHERTON

photographs by:
SPENCER LOWELL

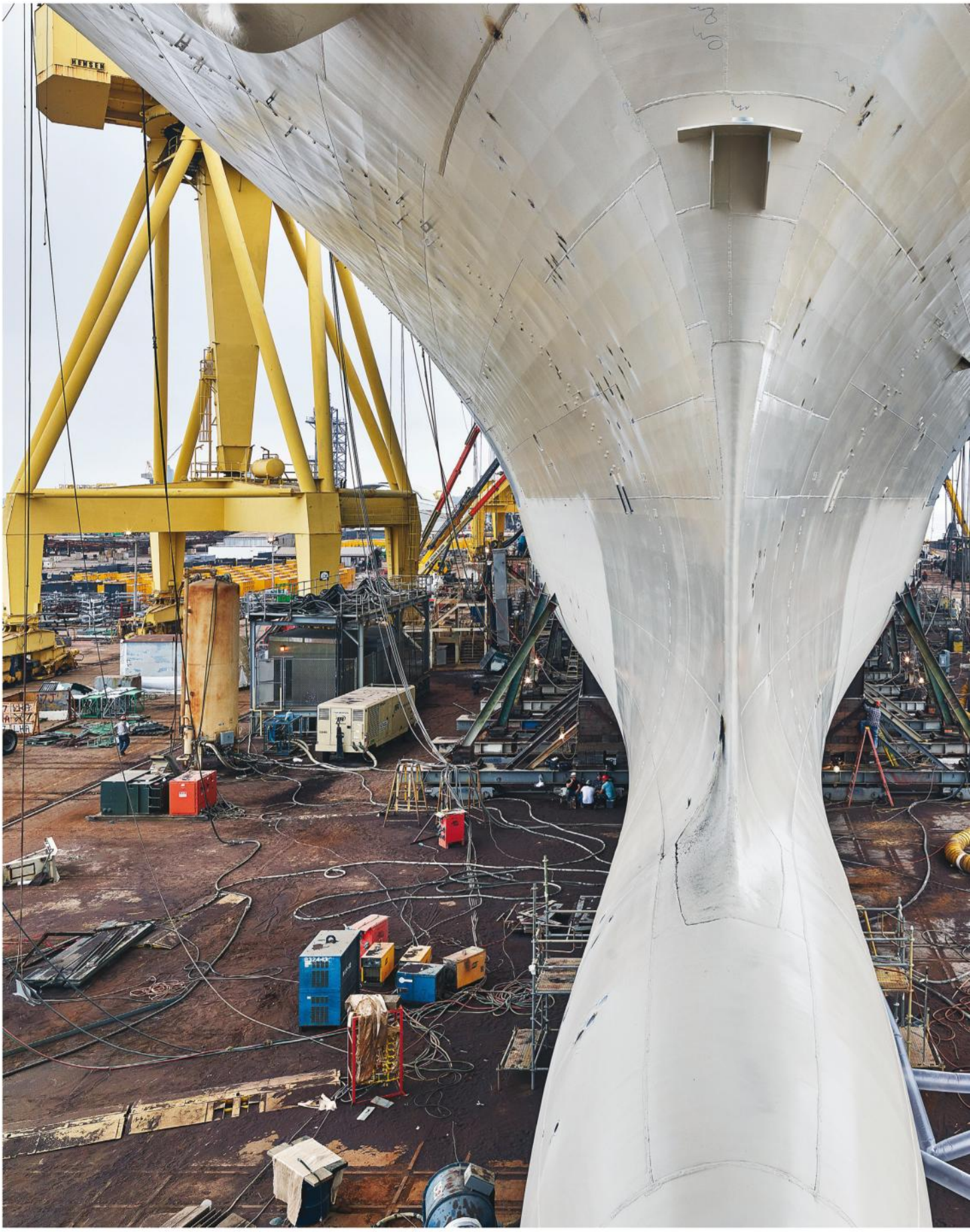
• You need deep water to float a big boat. That's why Robert Ingalls plunked his 800-acre Ingalls Shipbuilding yard on the banks of the yawning Pascagoula River, where it drains into the Gulf of Mexico, in 1938. The Mississippi facility has since birthed nearly 70 percent of the U.S. Navy's warships. Today, its 11,000 workers cut, weld, and otherwise bang together several Navy craft at a time. Shown here is the future USS *Tripoli*, an amphibious assault transport whose 855-foot deck is longer than some nations' aircraft carriers. It will be armed with attack helicopters and 1,600 Marines ready for inland strikes—all thanks to Ingalls' orchestrated feats of manufacturing. *To meet the woman who runs the show, see page 86.*

• The operator of a magnet crane—capable of hoisting 20 tons as high as 18 feet—lifts metal plates and then lowers them onto a cutting bed. There, a plasma beam will shear panels that will become the USS *Fort Lauderdale.* A transport dock, the craft will be able to carry 14 amphibious vehicles, packed with Marines, letting the Navy operate with deadly force in shallow water, close to shore.

A SEPARATE PIECE

• Just like Legos, ships are assembled in sections known as units. This one, seen upside down in a fabrication shed, will block off space for machinery or cargo in *Fort Lauderdale's* hull. The two oval openings at the top will accommodate drive shafts that extend from the engine to the propellers. Once the unit is finished, welders such as the one working here, will fasten it into the completed hull.

3/8


HEREEN

COMING THROUGH

• Even out of the water, it's obvious that *Tripoli*'s curvaceous keel—which reduces drag and increases stability—will cleave whatever is in its path. Though officially an amphibious assault ship, *Tripoli* doesn't actually make its way ashore, or even carry vessels that do: It sends in Marines via chopper and V-22 Ospreys in rapid swarms for what the military calls high-tempo assault operations. For added muscle, it carries the short-takeoff, vertical-landing F35-B fighter jet—the most sophisticated ever built.

4/8

• To keep *Tripoli*'s massive 98 million pounds—including crew, Marines, jets, helicopters, supplies, and the ship itself—in one place atop the waves, it needs anchors. Really big anchors. These two 40,000-pound mud hooks do some of the work. But it's the matching 106,219-pound chains on which they hang (each link is the size of a human torso) that really keep the big boat from drifting. The black and white colors let sailors know how much they've let out. Red means you're at the end of your chain.

ALIMAK

• The forward house on a Navy destroyer supports the bridge, where the command crew literally calls the shots. This one, in the final stages of welding, prior to being painted, will sit atop *Frank E. Petersen Jr.* In an aircraft-carrier group, the destroyer's job is to guard the larger and slower-to-maneuver ship—which is basically a floating airfield for fighter jets—from deadly, small-boat attacks.

• The finished forward house of the destroyer *Paul Ignatius* supports the mast and communications antennas (inside the bulbous fixtures at bottom). The octagonal cover shields the SPY-1 radar, which is part of the Aegis Weapon System. The Aegis can detect and track more than 100 targets, including incoming fire. It also guides the ship's mid-air interceptor missiles and can locate enemy batteries miles away.

• To get *Paul Ignatius* in the Pascagoula River, workers flood the dry dock, and then tugboats nudge the vessel into berth. There, plumbers and electricians will continue to outfit it. Near the end of its stay, a Navy crew will board the boat to learn how to operate it. About four to eight months later, they will sail it to its commissioning and into its (expected) 40 years of Naval service.

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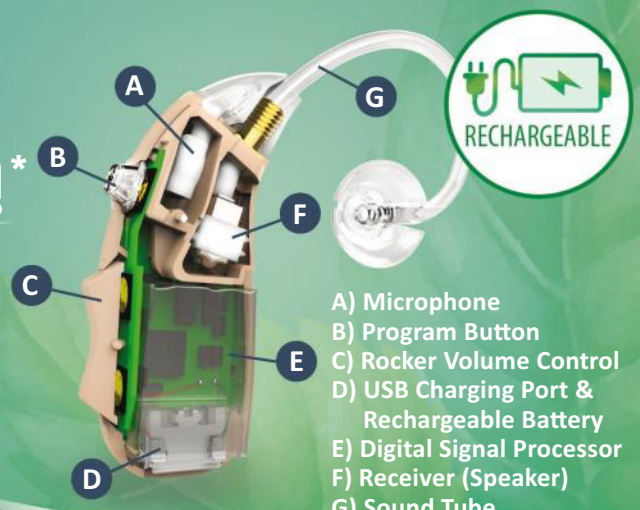

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No More Dead Batteries! "This HearClear HCRC rechargeable hearing aid works all the time! Unlike hearing aids powered by throwaway batteries that go dead at the worst time, I plug these in at night and the hearing aid charge lasts all day, every day." *- Xavier J.*

Great Hearing Aid! "I'm really glad I tried the HearClear HCRC! It works as good as or better than the more expensive ones I've purchased in the past. It's great that the price is reasonable. Thank you for the great product." *- Tim M.*

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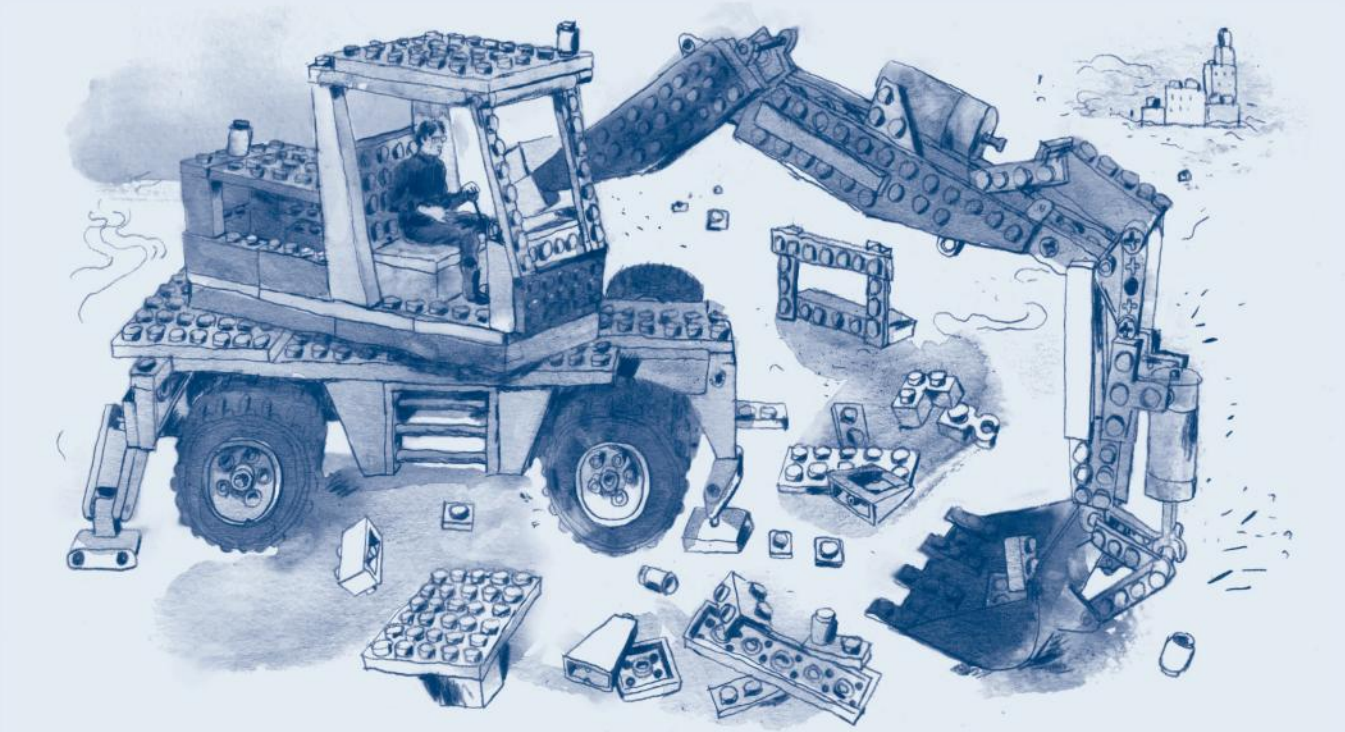
TALES FROM THE FIELD



OH, SNAP

the guy Lego pays to play

ERIK VARSZEGI,
LEGO MASTER BUILDER

When we spoke to Erik Varszegi in January, he'd just finished building a Batmobile. A 17-foot-long, 7-foot-tall Batmobile. "It was so big, we almost couldn't get it out the door," says the Lego master builder. That's child's play compared with the life-size *Star Wars* X-wing fighter he and colleagues crafted in 2013. With 5.3 million plastic bricks, weighing nearly 46,000 pounds and spreading into a 43-foot wingspan, it's the world's second largest Lego sculpture. Varszegi, who jokes that his job is to "play with toys all day," is one of just seven artists that Lego pays to design its head-snapping creations for splashy public events and flagship retail displays. Here's how to construct your own career in Lego mastery:

Step 1: Hit the Bricks
Before you can break rules, you have to learn the rules: Buy a Lego kit and follow the instructions. "The designers are always coming up with new ways to put the bricks together," Varszegi says. "You can learn a lot from that." Then knock it down and create something totally radical.

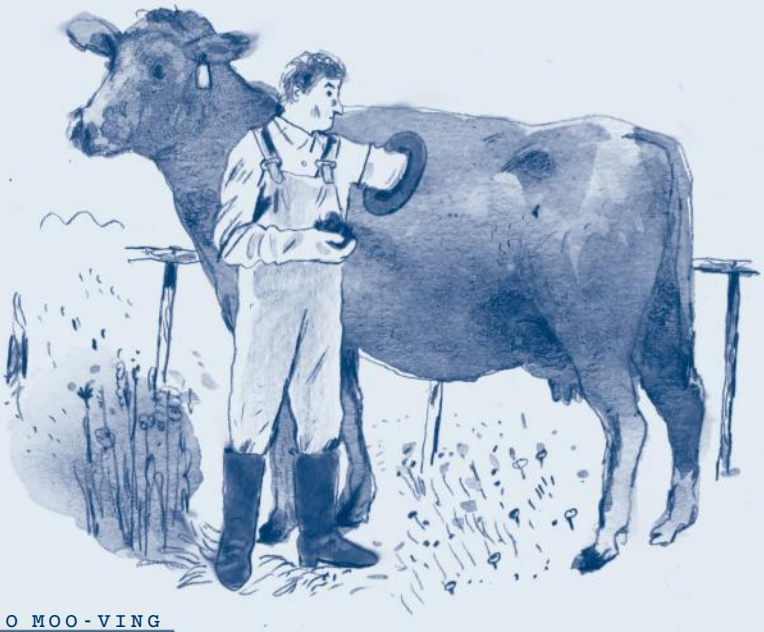
Step 2: Start at the Bottom
Lego hired Varszegi 22 years ago to glue store display models together. He sometimes assembled the same set hundreds of times. Even toys can get tedious.

Step 3: Become a Model Builder
This is apprentice stuff. While the boss free-builds imaginative creations, you're still following his prototype blueprints—at least on company time. Varszegi used his breaks to sculpt models that made him stand out.

Step 4: Achieve Lego Mastery
You did it: Lego's so impressed that they'll let you design your own giant builds. Just don't get lazy. "I'm still learning," says Varszegi. "There'll always be a new piece, new colors—and endless ways to put them together."

"For me, a rough day at the office is one where I run out of the yellow bricks."

by Sarah Fecht / illustrations by Peter Oumanski



SO MOO-VING

i got my hand stuck in a cow for science

MATTHIAS HESS, ASSISTANT PROFESSOR AT THE UNIVERSITY OF CALIFORNIA AT DAVIS

I'm fascinated by cow guts. The microbes in the rumen—the largest of four sections in a cow's stomach—break down plant materials extremely well. Studying that process can help us design better cow feed, which could minimize the greenhouse gases cattle emit. It could even help us find ways to optimize our own guts.

To study these questions in the lab, I designed an artificial cow-gut system. It looks a lot like a beer fermenter. But for the system to work, I need live rumen samples, and for that I have to literally reach into a cow's stomach. You do this using a fistulated cow. That's one where a veterinarian cuts a hole in its side, and inserts a tube between the rumen and the skin that can be sealed with a plastic stopper. The cow isn't really bothered by this process at all. It's remarkable. Sometimes the patient keeps eating during the surgery.

Once a cow is fistulated, you can stick your hand in and pull stuff out of the rumen whenever you need to. Liquids are easy to get: You place a tube in the opening and suck it out. Solids can get tricky, though. It starts out simple enough—you just put your hand deep into the opening. But it's pretty packed in there. And the gut muscles are constantly moving. You can get your arm stuck. That sounds bad, I know. But you just have to stay calm and wait for the muscles to relax. Or you do what I do, and let your students handle the dirty work while you watch them get stuck. Don't worry, they think it's pretty funny.

That's why my favorite cow is the artificial one in my lab. I can switch it on and off, and I can control all the variables, so every result is predictable. And your hand doesn't get stuck in a gut.

as told to Claire Maldarelli

UPS AND DOWNS

six flags is my science lab

LARRY CHICKOLA, CHIEF CORPORATE ENGINEER, SIX FLAGS

I'm responsible for all of Six Flags' amusements, from the kiddie rides to the roller coasters, in all 18 parks in North America. Right now we're considering making a new roof for Zumanjaro, the world's tallest drop tower.

The seats have mesh roofs to protect riders as they shoot 415 feet into the air and plunge into free-fall. We want to make the whole roof bigger because that would make certain design changes easier in the future. But we don't want to increase the air resistance on a ride that relies on speed. That means finding a light mesh that will cut through the air with less resistance.

So I hooked my laptop to sensors that measure air pressure 1,000 times per second, and brought it over to Zumanjaro with some mesh samples.

I needed my laptop to stay open while it rode up and down, so I figured I'd just strap in and hold it myself.

We found a material that lowers the roof's wind resistance by 30 percent, and weighs half of what we use now. Luckily it took me only 25 runs. And I got an amazing view.

as told to Mary Beth Griggs / illustrations by Peter Oumanski

"To you, it's the perfect lift chair. To me, it's the best sleep chair I've ever had."

— J. Fitzgerald, VA

Sit up, lie down — and anywhere in between!

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We've all had nights when we just can't lie down in bed and sleep, whether it's from heartburn, cardiac problems, hip or back aches – it could be a variety of reasons. Those are the nights we'd give anything for a comfortable chair to sleep in, one that reclines to exactly the right degree, raises feet and legs to precisely the desired level, supports the head and shoulders properly, operates easily even in the dead of night, and sends a hopeful sleeper right off to dreamland.

Our Perfect Sleep Chair® is just the chair to do it all. It's a chair, true – the finest of lift chairs – but this chair is so much more! It's designed to provide total comfort and relaxation not found in other chairs. It can't be beat for comfortable, long-term sitting, TV viewing, relaxed reclining and – yes! – peaceful sleep. Our chair's recline technology allows you to pause the chair in an infinite number of positions, including the Trendelenburg position and the zero gravity position where your body experiences a minimum of internal and external stresses. You'll love the other benefits, too: It helps with correct spinal alignment, promotes back pressure relief, and encourages better posture to prevent back and muscle pain.

This lift chair puts you safely on your feet!

And there's more! The overstuffed, oversized biscuit style back and unique seat design will cradle you in comfort. Generously filled, wide armrests provide enhanced arm support when sitting or reclining. The high and low heat settings can provide a soothing relaxation you might get at a spa – just imagine getting all that in a lift chair! It even has a battery backup in case of a power outage. Shipping charge includes white glove delivery. Professionals will deliver the chair to the exact spot in your home where you want it, unpack it, inspect it, test it, position it, and even carry the packaging away! Includes one year service warranty and your choice of fabrics and colors – Call now!

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UNDER SIEGE

game of throwns

TOMMY DUNNE, ARMORER AND WEAPONS MASTER FOR *GAME OF THRONES*

When I build a catapult, a trebuchet, a giant crossbow, it looks and feels authentic. I look at all the historical references I can dig up. I've had 25 years to amass a library on weaponry of all ages and cultures—but at the end of the day, my weapons are original.

Keep in mind, these old weapons were deadly. They were meant to kill. They carried a ton of force. Unfortunately, in my world, it's not all about that—you err on the side of safety. So as engineers, we'll look at Roman and Medieval siege weapons, make sure we get the right look for the show, and then make them just powerful enough to throw a projectile off-camera.

We do this by fooling your eye. So on a siege weapon, the large center rolling winch that you see is made to look period. But really the thing that creates torsion is a much smaller winch, made of metal, that sits inside it. This lets us drop power. We'll throw objects—light objects—30 feet in the air, and 50 feet away. In a real siege, a catapult would need to throw farther than the enemy archers' range, so real weaponized projectiles would fly 10 times farther than ours.

Another concern is getting your money's worth out of these devices. They aren't cheap and can take up to eight weeks to build. So we make sure they're not one-hit wonders. One catapult we built for *Game of Thrones* stood 12 feet high by 8 feet wide, weighed one and half tons, and fired barrels with a sling mechanism. But we also designed it so we could swap in a spoon to hurl flaming balls. That is not inherent in the historical design. Still, in 25 years of building these things, nobody's called me out on these differences. So if I'm not actually building authentic weapons, I'm certainly getting away with it.

as told to Rachel Feltman / illustration by Peter Oumanski

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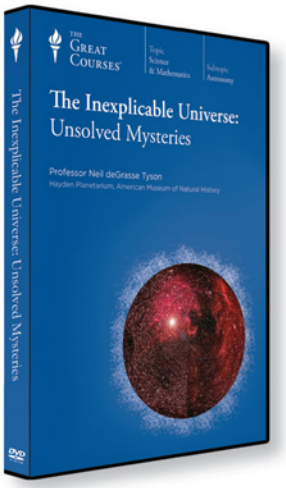

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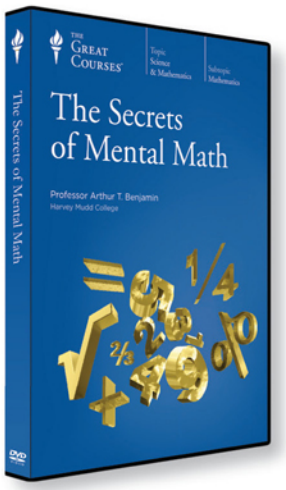

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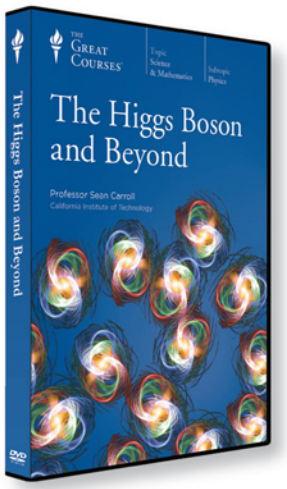

In **The Higgs Boson and Beyond**, award-winning theoretical physicist Sean Carroll guides you through the details of the search for, and ultimate discovery of, the Higgs boson. This course is an intellectual feast as you learn how the Higgs boson discovery validates and deepens our understanding of the universe.

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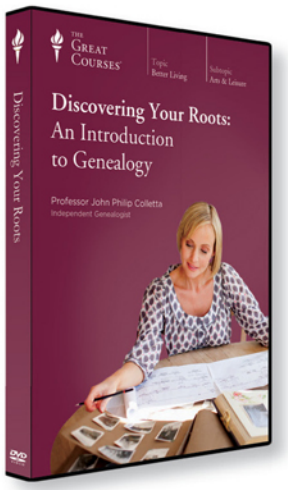

In **Discovering Your Roots: An Introduction to Genealogy**, you'll learn the same skills and methodologies that experts use to solve genealogical mysteries. Genealogist, writer, and lecturer John Philip Colletta shows you how to uncover information from the long-forgotten past in the most effective ways possible.

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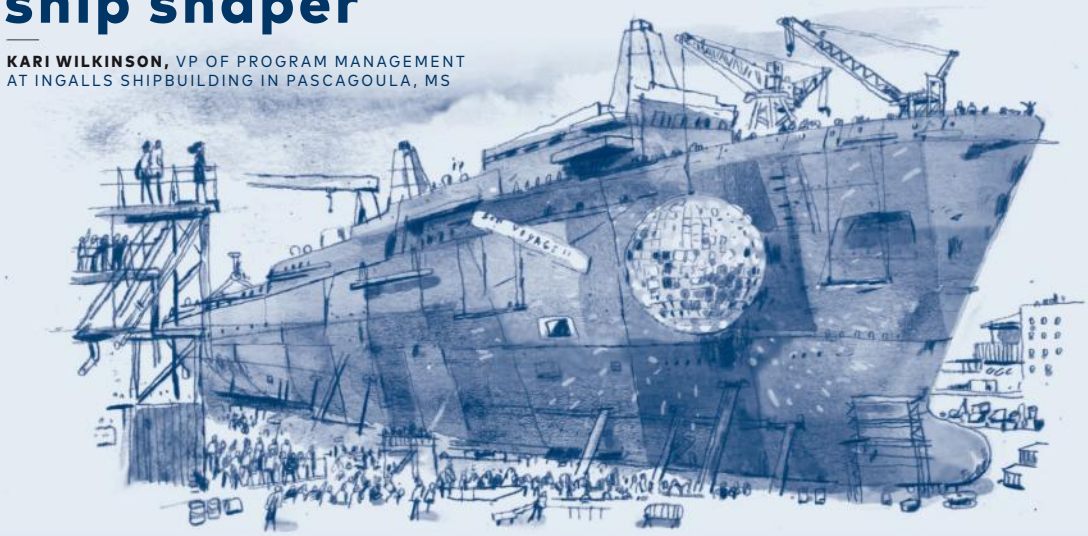
KARI WILKINSON, VP OF PROGRAM MANAGEMENT AT INGALLS SHIPBUILDING IN PASCAGOULA, MS



This is an 800-acre shipyard. When I first came here after college, I saw the massive equipment and huge ships, and realized how little I actually knew about naval engineering. Ingalls has built nearly 70 percent of the U.S. Navy fleet. We have 11 military vessels under construction, and nearly 12,000 employees. The biggest challenge is seeing how the millions of pieces fit together—that's my job. To build one of these boats, which can reach more than 800 feet long, we create units. These are the building blocks, like Legos, that we connect and stack together to make bigger sections of the craft. Some units are four decks high, and some are a single level. We lay down the lowest units along the keel in a cradle while we're putting together sections of piping and electrical components for the water, cooling, and propulsion systems. Later, we launch the ship but continue to finish it in the water. You start seeing the paint and the deck covering and the furniture. At the very end, we're testing everything, from the toilets to the water that cools the engines. It takes three to six years to build one of these ships, and by then, it's almost like it's part of your family. I've never been on a cruise liner, but I've been on sea trials plenty, and I wouldn't trade that for anything. When you feel the engines start and it takes off under its own power, there is no better place to be.
For photos from the shipyard, see page 68.

as told to Sophie Bushwick

An elevator to space is the biggest machine I can think of. It would totally change the calculus of getting things into orbit. And there's nothing impossible about it.

JASON WRIGHT, ASTROPHYSICIST AT PENNSYLVANIA STATE UNIVERSITY

FLIGHT RISK

bruising altitude

MARK FEUERSTEIN, BOEING TEST PILOT

As a youngster, I liked airplanes, and I knew I wanted to be a test pilot. Today, I fly Boeing's 747s, including the 747-8, the world's longest passenger jet. We push planes to their limits, sometimes doing hazardous maneuvers so engineers can enhance the safety of the airliner. For instance, we'll purposely stall an engine and let the craft pitch nose-down to make sure it behaves well without pilot intervention. Jets today generally recover quickly. One of the most fun things we've done is a million-pound takeoff. One million is a big round number! We were testing how the 747-8 flies at its maximum certified takeoff weight of 990,000 pounds. Normally, as you burn fuel, that weight drops before you can get in the air. The extra 10,000 pounds of gas got us off the ground so we could see how the plane handles airborne at 990,000 pounds. When it's that heavy, it's harder for the structure to absorb a firm landing, so you have to be a little careful. If there's damage, your boss will want to know what happened.

as told to Kelsey Atherton / illustrations by Peter Oumanski

Bigger Buttons

"My friends all hate their cell phones… I love mine!" Here's why.

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Say good-bye to everything you hate about cell phones. Say hello to the Jitterbug Flip.

"Cell phones have gotten so small, I can barely dial mine." Not the Jitterbug® Flip. It features a large keypad for easier dialing. It even has a larger display and a powerful, hearing aid-compatible speaker, so it's easy to see and conversations are clear.

"I had to get my son to program it." Your Jitterbug Flip set-up process is simple. We'll even program it with your favorite numbers.

"What if I don't remember a number?" Friendly, helpful Personal Operators are available 24 hours a day and will even greet you by name when you call.

"I'd like a cell phone to use in an emergency." Now you can turn your phone into a personal safety device when you select a Health & Safety Package. With 5Star® Service, in any uncertain or unsafe situation, simply press the 5Star button to speak immediately with a highly-trained Urgent Response Agent who will confirm your location, evaluate your situation and get you the help you need, 24/7.

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Monthly Plan	$14.99/mo*	$19.99/mo*
Monthly Minutes	200	600
Operator Assistance	24/7	24/7
Long Distance Calls	No add'l charge	No add'l charge
Voice Dial	FREE	FREE
Nationwide Coverage	YES	YES
Friendly Return Policy[1]	30 days	30 days

Health & Safety Packages available as low as $19.99/month*.
More minute plans available. Ask your Jitterbug expert for details.

"My cell phone company wants to lock me in a two-year contract!" Not with the Jitterbug Flip. There are no contracts to sign and no cancellation fees.

"Many phones have features that are rarely needed and hard to use!" The Jitterbug Flip contains easy-to-use features that are meaningful to you. A built-in camera makes it easy and fun for you to capture and share your favorite memories. And a flashlight with a built-in magnifier helps you see in dimly lit areas, the Jitterbug Flip has all the features you need.

Enough talk. Isn't it time you found out more about the cell phone that's changing all the rules? Call now, Jitterbug product experts are standing by.

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STAR-STRUCK

on tears and rocket fuel

VICTOR SINGER, FORMER STRUCTURAL ENGINEER FOR ORBITAL ATK

My first interplanetary rocket motor was a solid-fuel Star-24. I can still picture it: 24 inches in diameter, almost spherical, with a nozzle sticking out. That nozzle was mine. I designed it. NASA employed the Star-24 on its 1978 *Pioneer Venus* multiprobe, which studied the planet's atmosphere. Once the probe reached orbit, the rocket's job was to slow the *Pioneer* enough so it would fall toward Venus, gathering data until it burned up. During the week prior to launch, the company left our newly minted design in the final assembly building so we could say goodbye. I remember it was there in the shipping box. I stepped in, put my arms around the motor, and I cried. It's a privilege to put your hands on a rocket destined for another planet. I still choke up over that motor. It's a piece of me.

as told to Sara Chodosh / illustrations by Peter Oumanski

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A Dedication to Health & Human Rights

American Red Cross Founder CLARA BARTON said to her male counterparts: "We nursed you back to health and now we need your help!" But unfortunately some of her counterparts made sure help never came . . . even after thousands of women like my grandmother (Google: Nursing Sisters Port Dover) and Clara Barton went to Rochester, N.Y. and descended on the home of woman suffragist SUSAN B. ANTHONY (Clara Barton's 6th cousin) to offer their support for a woman's right to vote! What follows is a brief history of my family's efforts to make lives better for men and women across the globe . . .

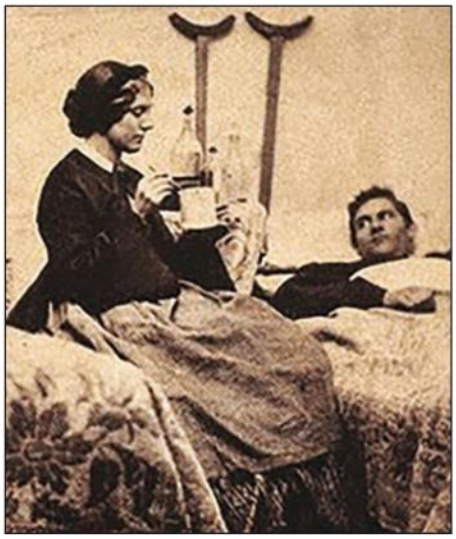
Two nursing sisters with wounded soldiers in a ward room at the Queen's Canadian Military Hospital in Shorncliffe, Kent, England, circa 1916.

By John Ellis

If you Google: Nursing Sisters Port Dover, you'll see a book by Harry B. Barrett. In that book are pictures of my grandmother and her heroic nursing sisters during WWI, including one sister who was mentioned in wartime dispatches for her heroism along with a certificate presented to her by King George V. (In spite of her "valor in the face of the enemy," a woman was ineligible to receive the Victoria Cross!)

There are hundreds of letters and pictures, including one of the ambulances my grandmother donated (before we entered WWII) encouraged by her friend, suffragist CARRIE CHAPMAN CATT, who moved around the corner from my grandmother in New Rochelle, N.Y. As a youngster, I remember all the sewing machines and their many friends at my grandmother's house sewing thousands of pre-die cut clothes together to keep children warm during the brutally cold English winters. Carrie Chapman Catt also founded the League of Woman Voters and is most famous for her Congressional speech resulting in the 19th Constitutional Amendment that gave woman the right to vote in 1920!

Every year thousands visit the grave of suffragette Susan B. Anthony, a fighter for women's rights.



Famed American nurse and Red Cross founder Clara Barton is shown tending to a wounded soldier.

All this took place after Susan B. Anthony died in 1906 in Rochester, N.Y. where my grandfather baked his first loaf of BOND BREAD in 1915, resulting in 50 factories producing over1.5 million loaves of bread a day . . . a Horatio Alger success story which enabled my grandmother to help further woman's rights. She was inculcated with a sense of moral responsibility by her family who emigrated here in 1720 and then moved to Canada because they were Loyalists to the King and the Church of England.

BESET WITH MODERN AILMENTS

Now, history repeats itself, except this time their counterparts have problems with clogged arteries, heart attacks, prostate problems and cancer **by stonewalling a Man's right and a Woman's right to flush DEUTERIUM** (a major cause of Aging and Cancer) **and Pathogens out of their bloodstreams** . . . so these diseases aren't handed down to generations of our unborn children and grandchildren!!

NEW VIDEO SHOWS E5 MACHINE AT WORK

Go to **www.JohnEllis.com/NIH** and you can watch an informative video which explains just how our E5 Water Machine works. And, just below the video, there is a green link to multiple **NIH.Gov** studies demonstrating the adverse health effects of deuterium in your water.

The video shows that by changing water properties, small amounts of this water can treat vast quantities of ordinary water (even an aquifer or lake) so Municipalities can supply this healing water right at the tap!! Go to our website **JohnEllis.com/NIH** with a link to the National Institutes of Health. (Deuterium is found in every bottle or glass of water you drink!)

However, DDW (Deuterium Depleted Water) is only part of the battle for better health as noted by Nobel Prize Winner Albert Szentgyorgy: **"Hydrogen is the Fuel of Life"** because, unlike ordinary DDW, by also changing Water Properties and increasing the Hydrogen Bond Angle between atoms (so it has more room to hold viruses and environmental contaminants in suspension) they can be **eliminated from the bloodstream** with almost **immediate results** (note typical cancer charts)!

Small amounts of this water can treat millions of gallons of ordinary water (as the Municipal Video shows) including markers for disease, so they can be flushed from a human waste lagoon or the blood stream along with heavy metals (Flint, MI: thousands of children have irreversible brain damage)!!

VIOLATING FARADAY'S LAW?

Here's what a man in Zurich said: "I have had your E5 Water Machine for only 24 hours. I had gross swelling in my legs and hadn't worn ordinary shoes in years. Your water immediately destroyed the markers for

Gilbert Daunant (Prince Rainier's cousin): "I just walked 40 blocks and I am 95! Send another E5 to Monaco!"

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elephantiasis in my blood stream!! I lost all the water weight in my legs and I bought a pair of shoes size 10 ½. Also unlike ordinary DDW, using electrolysis (a battery and two thin pieces of stainless steel, anode and cathode, not a stack that negates power) your water produces so much Hydrogen it violates Faraday's Law… producing the energy needed to stop disease!!"

AMAZING POWER PROPERTIES

A company that produces hydrogen generators for trucks found the required power slowly went down over 24 hours (a cascading effect that is immediate once it has been treated) from 31 amps to **less than 1 amp** making the same amount of hydrogen by adding only **20 drops** of this water to ordinary water in their hydrogen generator (another website video)! Using this technology, you can power your car, heat your home and produce electricity for pennies. Watch the Video that shows examples **PROVING** you are drinking the wrong water . . . just as food supplies energy, this water provides the "**BODY ELECTRIC**" energy that powers your heart (defibrillator to stop a heart attack, pacemaker)!

COOK WITH THIS WATER!

Since it's made by boiling and cooling, **this energy is imparted to your food, unlike ordinary water that absorbs energy** (from your food and body) **to reach equilibrium**)! Also, since **DEUTERIUM** studies (150 ppm) show it kills fruit flies and disease carrying mosquitoes, you don't want to remove all the Deuterium!! Instead, **INCREASE** the Hydrogen Bond Angle (so it holds more contaminants in suspension along with Deuterium) and **flush Deuterium along with viral diseases from the bloodstream** with almost **IMMEDIATE** results!! Note the typical cancer charts: The "purest water" is USELESS because it doesn't do the above. They still have cancer!

MAKING DDW YOURSELF

Using our E5 Water Machine, you can make **two types of DDW for PENNIES per GALLON** . . . not $300 for a small bottle! This is done by heating and cooling water hundreds of times per gallon (not just once!) to change the properties of that water. We have 13 International Patents and 332 FDA Tests. You can judge the blatant dishonesty in the water industry using simple electrolysis. A child in science class could do that!

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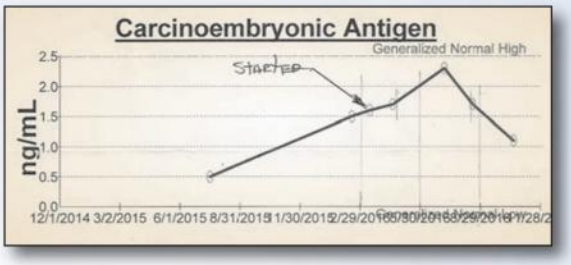
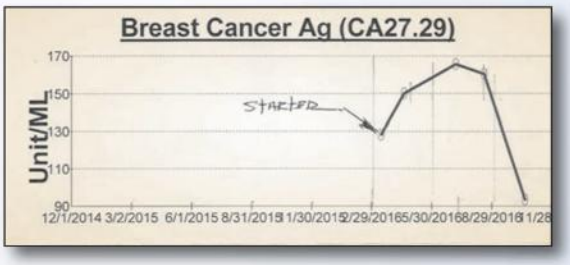
With our 501(c)(3) non-profit Foundation, you can buy a machine and take a Tax Deduction! There are thousands of families around the U.S. and the world who need our water machines—kids in Flint, families in poverty. When you buy a machine, a portion of the proceeds go to this important human aid project. **Contact us at PO Box 553, Westbrookville, NY 12785 or 845-754-8696.**

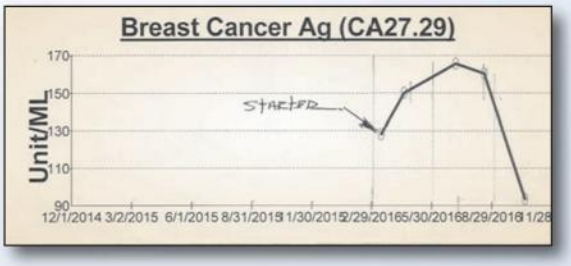
Check Out These Shocking Cancer Results!

The following is a letter we received here at Crystal Clear Water and at right are the charts this customer forwarded to us:

"Please send us a 6-pack of your water. The enclosed charts show my wife's cancer antigen numbers. Of course the doctors think they are responsible for the dramatic downturns [in the cancer markers], but I think differently. Doctors are not aware of my wife using you water." —John W.







Typical results since the Jan. 27, 1992 **Washington Post** investigation: "10,000 people a day said this water will cure anything!" including **The Washington Times**.

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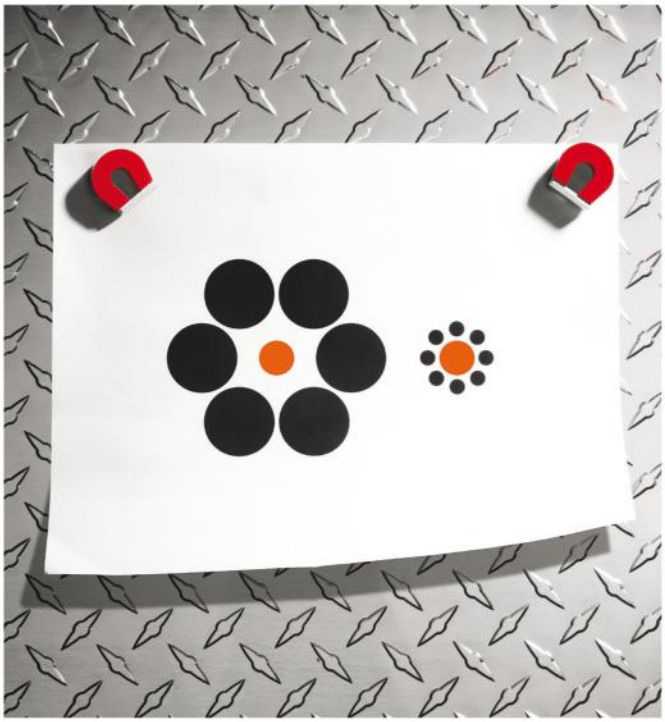

SHAPE SHIFTERS

circulary illogical

trip meter — real world / westworld

WHICH OF THE TWO ORANGE circles is bigger? The one on the right, right? In reality, the pair are identical.

Brain researchers hypothesize that this effect, known as the Ebbinghaus illusion, plays its trick based on how our brains interpret depth. From a lifetime of looking at things, we remember that smaller items tend to be farther away, while larger ones are closer. In this image, the brain reads the left ring of large, black circles as nearby and the right, smaller set as distant. Simultaneously, the brain also groups the orange circles with their black surroundings. So the left one is also seen as nearby, and the right one farther away. When the brain compares the orange circles, the only way for the right one to be more distant is if it's larger than the left circle.

But not everyone is so easily fooled by this illusion. Neuroscientists and psychologists have two theories about why. First, they've found that individuals whose primary visual cortex covers a larger surface area—which varies among individuals as much as threefold—are less likely to fall for the illusion. The researchers surmise that's because the neuron connections that compare the inner orange circle to the outer black ones get weaker as the primary visual cortex gets larger.

A person's daily surroundings also affect their perception. Studies have found that people from rural regions, who aren't constantly bombarded by visual distractions such as moving vehicles, traffic lights, and flashing street signs, are less susceptible to the illusion than city dwellers are. Having a broader view does have an upside, however: It means people can spot speeding buses before they hit them. The downside is that they're less attuned to finer details, and more primed for Ebbinghaus.

by Claire Maldarelli / photographs by Brian Klutch

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— Don, January 2016

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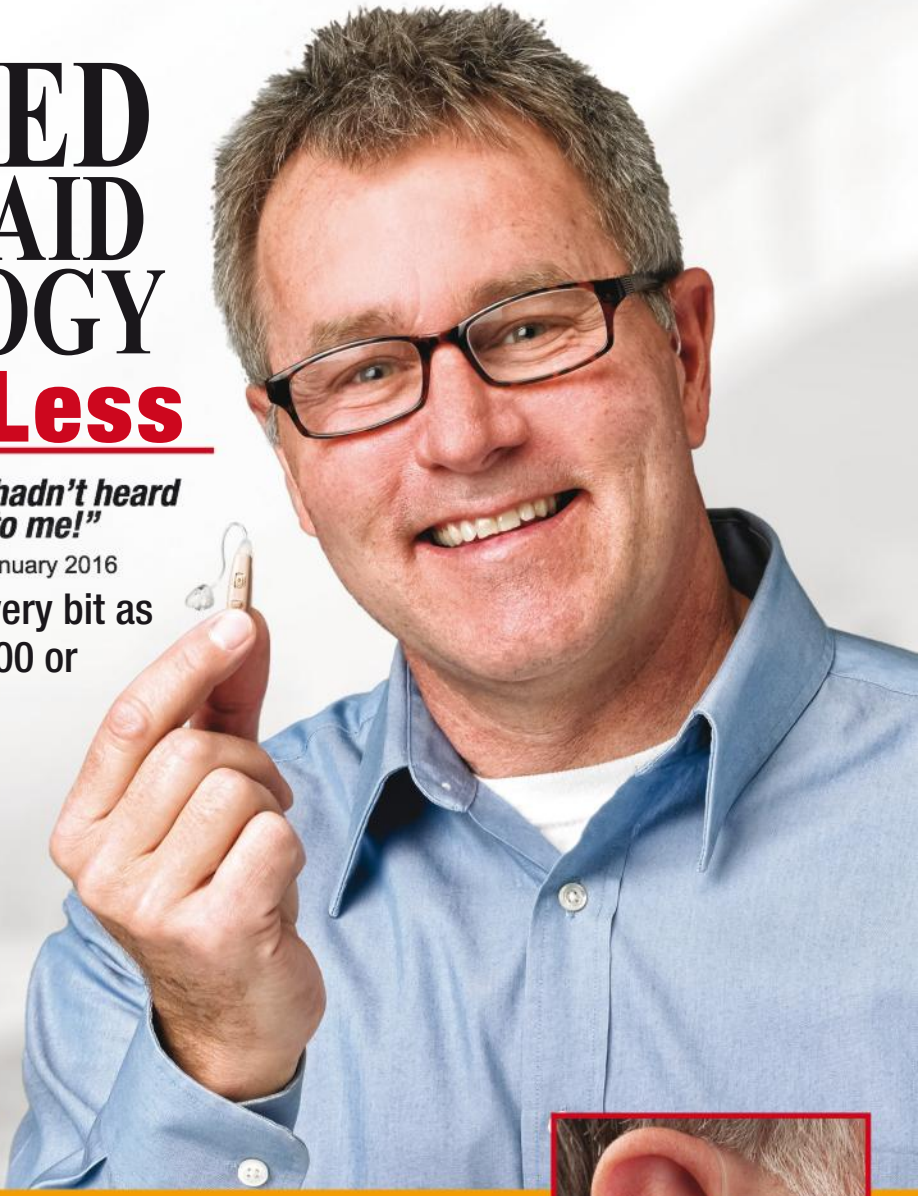

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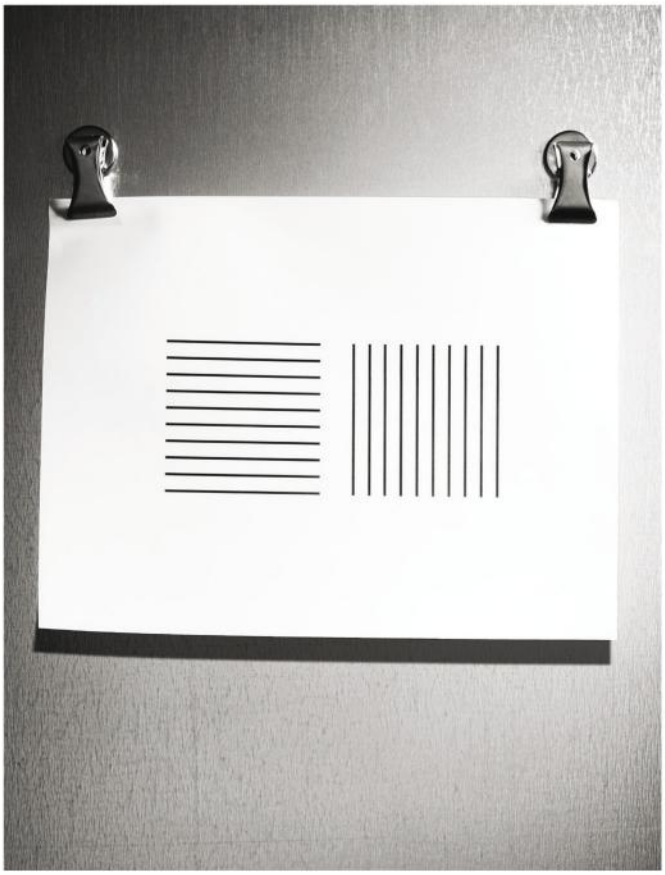

LINE GAMES

a neuroscientist's guide to fashion

THE TRUISMS OF FASHIONISTAS ARE INGRAINED in all of us: Clothing adorned with vertical stripes makes you appear slimmer and taller, while garb with horizontal bands makes you look wider—and perhaps a bit chubby.

Except, maybe not. Compare these squares of black and white stripes. The horizontally striped one looks taller and the vertically striped square seems wider, right?

Hermann von Helmholtz was first to note this illusion (now called the Helmholtz squares) in 1867. But he gave little insight into its cause. Even today, neuroscientists have no compelling theories to offer. In his note, Helmholtz did make a brief but compelling ode to fashion: "Ladies' frocks with cross stripes make the figure look taller."

His style guide is, in reality, more valid than ours. In 2011, psychologists at the University of York in England tested whether the illusion seen in the 2-D version was also true in 3-D. Two identical female mannequins wore either horizontal- or vertical-striped outfits. The team found that the figure sporting vertical stripes appeared wider; in fact, the one donning horizontal stripes would need to be 10.7 percent broader for the two to visually match up. A reminder that fashion is as much a science as it is an art.

trip meter

real world — westworld

✓Yes

✓Yes

xNo

✓Yes

✓Yes

✓Yes

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Grass seed can NEVER grow a lawn like this!

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8 Ways Our Amazoy Zoysia Lawn Saves You Time, Work and Money!

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Would you believe a lawn could look perfect when watered just once? In Iowa, the state's biggest Men's Garden club picked a Zoysia lawn as "top lawn – nearly perfect." Yet, this lawn had been watered only once all summer to August!

In PA, Mrs. M.R. Mitter wrote, "I've never watered it, only when I put the plugs in...Last summer we had it mowed 2 times...When everybody's lawns here are brown from drought, ours stays as green as ever." *That's how Amazoy Zoysia lawns cut water bills and mowing! Now read on!*

2 ENDS COSTLY RE-SEEDING AND NEVER NEEDS REPLACEMENT

Plug in our Zoysia grass and you'll never have to spend money on grass seed again! Since you won't be buying seeds, you won't need to dig and rake – then hope the seeds take root before birds eat them or the next hard rain washes them away.

3 NO NEED TO DIG UP OLD GRASS

Plant Amazoy *your way* in an old lawn or new ground. Or set 1" square plugs into holes in the soil 1 foot apart, checkerboard style. Plugs spread to create a lush, thick lawn, driving out weeds and unwanted growth. Easy instructions included.

4 FOR SLOPES, PLAY AREAS, BARE SPOTS AND PARTIAL SHADE

You can't beat Amazoy Zoysia as the low-cost answer for hard-to-cover spots, play-worn areas, places that have partial shade and erosion on slopes.

Meyer Zoysia Grass was perfected by the U.S. Gov't, released in cooperation with the U.S. Golf Association as a superior grass.

5 IT STAYS GREEN IN SPITE OF HEAT AND DROUGHT

"The hotter it gets, the better it grows!" Plug-in Zoysia thrives in blistering heat, yet it won't winter-kill to 30° below zero. It just goes off its green color after killing frosts, and begins regaining its green color as temperatures in the spring are consistently warm.

Thrives from partial shade to full sun.

Plant it from plugs not seed.

Your Assurance of Lawn SUCCESS
Each Order for Amazoy Zoysia is GUARANTEED

Guaranteed to grow new green shoots within 45-60 days or we'll replace it FREE – for up to 1 year – just call us. We ONLY ship you living genuine Amazoy Zoysia grass harvested direct from our farms. Easy planting and watering instructions are included with each order. Reordering assumes success of previous orders, initiating a **new** one-year guarantee but only for the most recent order.

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6 CHOKES OUT CRABGRASS AND WEEDS ALL SUMMER

Your established Amazoy Zoysia lawn grows so thick, it simply stops crabgrass and summer weeds from germinating!

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No weeding means no costly chemicals. Since Amazoy Zoysia lawns naturally resist insects, you'll save money, while helping to protect the environment. You'll never have to expose your family and pets to the risk of weed killers and pesticide poisons.

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	500	100	4	$45.60	$14.00	35%
	750	150	6	$63.50	$18.00	41%
	1100	400	10	$87.50	$24.00	51%
	1500	900	16	$125.00	$30.00	58%

❑ 30" Step-on Plugger **$8.95 + $5 shipping** ❑ 4" Amazoy Power Auger for 3/8" drill **$14.95 + $5 shipping**

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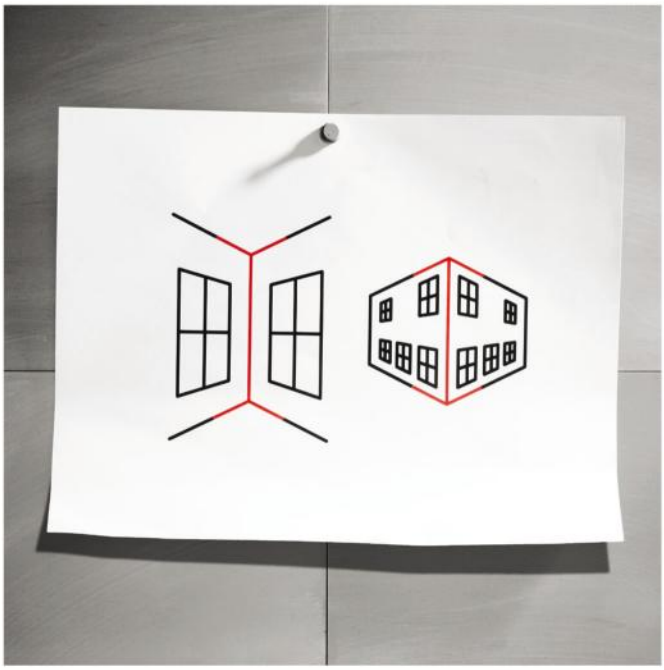

MISMATCHED

welcome to the fun house

OUR MINDS ARE SO USED TO THE WORLD WE LIVE in that we often judge it based on past experience—not on our current view. The Müller–Lyer illusion, at left, is a near perfect case of this visual and mental muscle memory.

We see these two shapes—an erect line with angled tails that point either up or down—every day. The vertical lines that form the interior and exterior corners of the room and building are exactly the same length. But somehow the interior view looks much longer. Why?

According to some neuroscientists, when the red lines form an arrowhead, as seen on the right, they draw focus away from the vertical line, making it look shrunken.

But others think the circumstances in which we encounter these shapes impact how we perceive them. One analysis of a group of images containing the illusion found that configurations that form arrow tails are typically farther away. Couple that with the fact that in general—and for reasons that neuroscience has yet to fully understand—distant vertical lines appear taller than closer ones do. These ideas get imprinted into our brains' neural networks. So, when we see the shapes on paper, we get tricked. At least it's not while we're wandering around.

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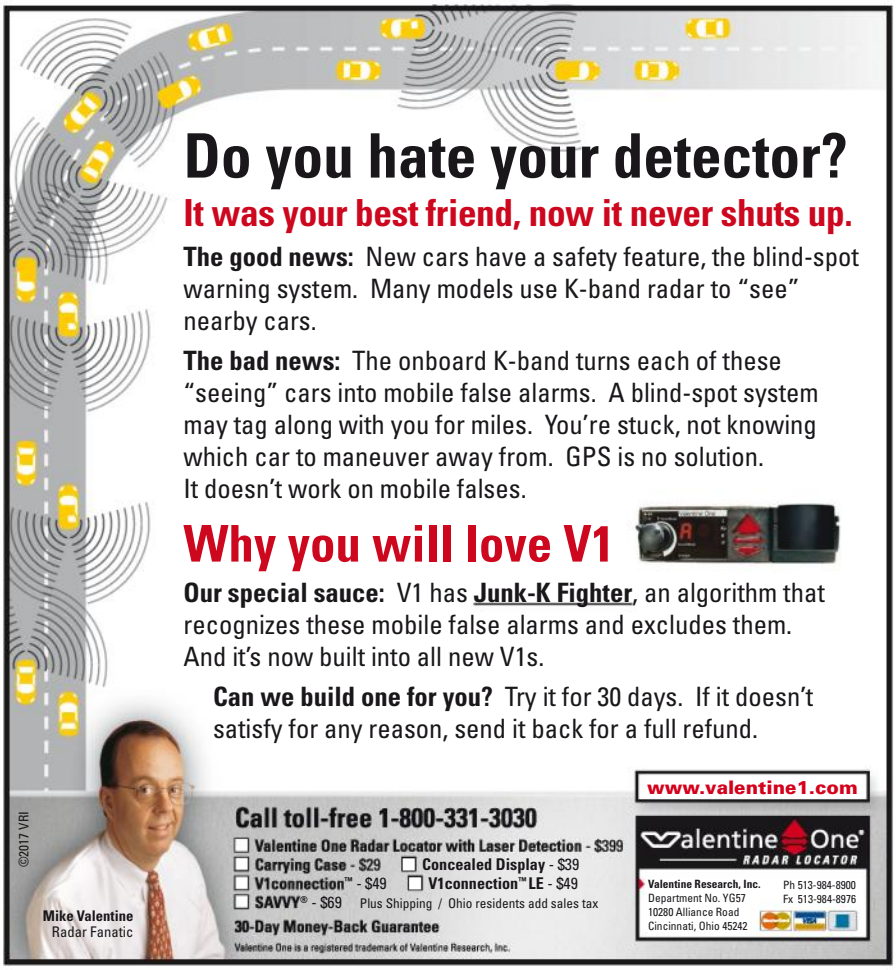

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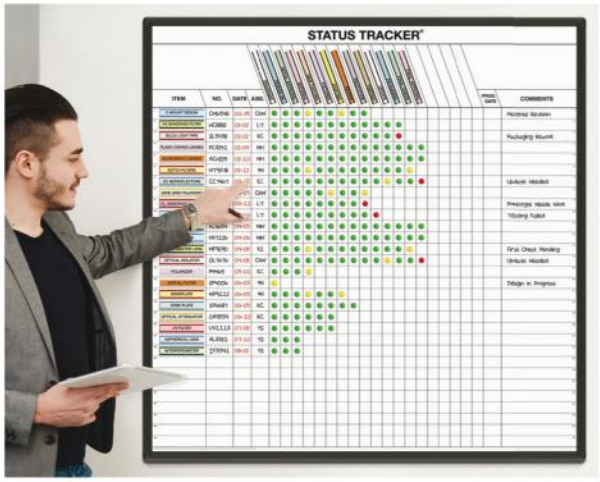

ONE OF THE BIGGEST RESPONSIBILITIES Matthew White, Director of Programs at the Zygo Corporation, faces on a daily basis is the overseeing of projects from the early stages of development to the moment they are purchased by a customer.

As Project Managers, we all know that business proposals often undergo numerous iterations before reaching the final product. All the while, it's the responsibility of people like Mr. White, to ensure important steps of the development process do not fall behind.

Ensuring that every member of the team is on task and in the know with the latest developments has been a priority for Mr. White since he took on the position in early 2016. "Before I took on the role, our projects were primarily tracked using some form of an online spreadsheet. It was a little bit difficult to understand how far along we were in the development process because people would rarely post updates, leading to communication errors. Whether it was forgetting to update something, or the software not syncing properly, it wasn't something that worked for me."

Looking for an alternative solution for tracking project management milestones, Mr. White contacted the team at Magnatag® Visible Systems to help find the best-suited tool for the Project Management team. Tasked with finding something that was not only visually engaging, but also built to manage a number of developing projects, the Magnatag® Sales team recommended the StepTracker® magnetic dry erase system.

The Project StepTracker® system provides your team with a large-scale overview of the entire project development process, using color-coded magnets to indicate whether or not a milestone has been met.

In Mr. White's case, projects are listed down the left side of the board with individual milestones running across the top.

"I actually have my Project StepTracker® hanging above my desk. It's a permanent reminder of how we're progressing on a project. I'll have team members come in and out during meetings and take a look at how we're progressing. Right now, we have a whole lot of green and yellow magnets running from left to right so I know what our current status is."

With the Project StepTracker® outlining the development cycle from start to finish, Mr. White believes that project management and communication will be streamlined as his team heads into the new year.

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(CONTINUED FROM P.65) satellite the Emirates launched in 2013 and uses to take daily photographs of the constantly changing region. He sits sleepy-eyed in front of a shiny bank of screens, in a glistening white-walled control room—somewhere between a stage set and a working model of Dubai's aspirations.

The Space Centre has been methodically building its capabilities, launching a succession of more-sophisticated—and home-grown—satellites. *DubaiSat-1*, launched in 2009, partly replicated an existing design; *DubaiSat-2* was developed in partnership with South Korean engineers. KhalifaSat, launching next year, will be designed, developed, and constructed entirely at the Space Centre. I could see its skeletal frame behind a thick glass window. Down the hall, workers painted a large clean room—the only one of its kind in the Middle East—where the spacecraft would be assembled. The Mars probe, known as *Hope*, would launch in 2020 and arrive in Mars' orbit in time for the Emirates' jubilee in 2021.

But the plan isn't a "firework," as Amiri puts it. "Don't just go and send space junk there," she says. "Don't clutter another planet just to say that you're going to Mars." The scientific goal of the mission is to measure and map the Martian atmosphere, and its political goal is to create a community of Emirati scientists and engineers—to cultivate the talent that will make Dubai a knowledge hub. "We get told by His Highness Sheikh Mohammed that the most important part is the scientists and engineers who are going to come out of this," she explains. Accordingly, the mission staff skews young. Everyone is under 35, the average age is 27, and 30 percent are female. Amiri speaks passionately about inspiring the youth of the Arab world. "We need to give them monumental challenges to solve."

In other parts of the world, not even the most talented 30-year-olds are running Mars missions. But Amiri was born into the extreme privilege of her generation of Emiratis, and has a zeal for Dubai's technological ambitions—and the more-diverse city that they require. "If you block out people from different backgrounds, then you block out innovation," she says. "Innovation comes from differences in thinking and picking up in different ways."

Later she tells me, "We're living in a place that dreams a goal before *you* can even dream it, and provides you with the right tools to work toward it."

I'm reminded of something Al Gergawi told me while recounting Dubai's rapid growth. "We went from no road to Mars," he said. "This is a human story, and this is what humanity can achieve in one generation."

If Sheikh Rashid's great-grandchildren achieve their dreams, the story won't be about driving cars or riding camels, but about designing rocket ships and flying them to other worlds.

advertisement

New electronic lure may catch too many fish; one state bans it.

A bass every seven minutes.

by Mike Butler

NEWARK, DE– A new fishing technology that set a record for catching bass in Mexico is now showing its stuff in the U.S. It has out-fished shrimp bait in Washington State and beat top-selling U.S. lures three to one in Florida. The new technology is so effective one state, Wyoming, has banned its use.

The breakthrough is a tiny, battery-powered electrical system that flashes a blood-red light down a lure's tail when its moved in water. Fish think it's an injured prey and strike. Some fishing authorities, like those in Wyoming, think that gives fishermen too much of an advantage.

They may be right. Three fishermen using a flashing lure in Mexico caught 650 large-mouth bass in just 25 hours. That's a bass every seven minutes for each person, and a record for the lake they were fishing. They said the bass struck with such ferocity they hardly lost a strike.

In Florida two professionals fished for four hours from the same boat. One used a flashing-red lure; the other used some top-selling U. S. lures. The new, "bleeding" lure caught three times as many fish.

Before reporting this, I asked a veteran fisherman in my office for his opinion. Monday morning he charged into my office yelling "I caught six monster fish in an hour with this thing! Where did you get it?"

Then I phoned an ichthyologist (fish expert).

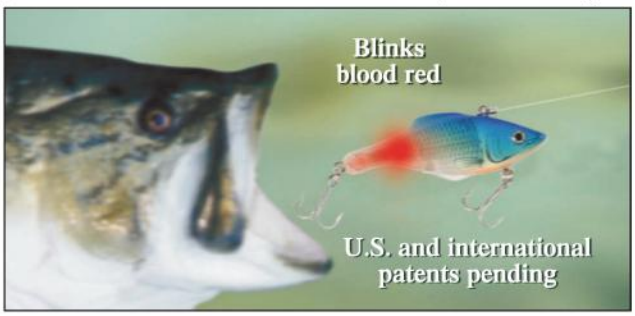
"Predators - lions, sharks," he said, "will always go for the most vulnerable prey. Fish are predators, so if a fish sees a smaller fish bleeding, it knows it's weakened and will strike.

"If a lure could appear to be a live, bleeding fish, a few fishermen could probably empty a lake with it."

I told him three almost did.

Fishes top, middle and deep

There is a U.S. company that offers a kit of three blinking lures (one each for shallow, middle and deep water) called the Bite Light® Each lure is a different color. They work in fresh or salt water, contain rattle attractants inside and last 300 hours in the water.



New Bite Light® lure uses a blinking red light to create appearance of a live, bleeding prey. Triggers strikes.

This year, they're introducing a new series of the Bite Light, the Bite Light MM15, for even better action. One kit of three Bite Lights costs $29.95, two more cost just $25.00 each. S/h is only $7.00 no matter how many kits you buy.

To order, go to **www.FishingTechToday.com** or call 1-800-873-4415 anytime or day and ask for the Bite Light® lure (Item #kbl). Or send your name, address and a check to Scientific Edge LLC (Dept. LL-803), 40 E. Main Street, Suite 1416, Newark, DE 19711.

The company gives your money back, if you don't catch more fish and return your purchase within 30-days.

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THE **MOST COMMON QUESTION** POSED TO ME **BY MEN:**

Male Enhancement Pills... Do They Really Work?

Dr. Steffanie Seaver PSY.D
Researcher, Author, Accomplished Public Speaker

Well, unfortunately, there are not many Natural Male Enhancement products that live up to their hype, but one of my readers recently emailed me about a new **RED** pill that blew his (and his partner's) mind. After a little research on my end, I feel compelled to share this with the rest of my subscribers. Please read on ...

To: Seaver, Steffanie — Today at 7:54 AM

! **Red Hot Pill Partner Reaction Challenge**

Dear Steffanie,

I recently received a sample for a new male enhancement product, **RED FORTERA**, in the mail. I've tried a few of these natural alternatives (not that I have a real problem) and I'm a relatively healthy male – but what guy WOULDN'T want an extra boost every now and then with that special someone? Well, most of the time, results from these products are somewhat underwhelming, but the moment I received this sample, I knew something was definitely different! First, this pill is **RED**, actually a sort of luscious red that you don't ordinarily see. Second, and more importantly, the sample came with an interesting letter from the manufacturer. The letter didn't make any ridiculous claims of how many inches I was going to gain, but *it did* make a rather bold statement that I could not get out of my head, one that intrigued me to the point I had no choice but to try this new red pill. Here's what the letter said, verbatim:

> " ... take our "**Partner Reaction**" Challenge, simply use this **FREE** sample 30 minutes prior to engaging in sexual activity and **TAKE NOTE OF YOUR PARTNER'S REACTION!** That's correct, don't believe our rhetoric, let your partner's reaction tell the real story - we **CHALLENGE** your partner **NOT** to show a reaction to the drastic difference in your performance. We're so sure that you're going to agree, we're **GIVING AWAY A FREE 3 MONTH SUPPLY** to the best testimonials we receive. Simply send us a paragraph or two describing your partner's reaction to your newfound prowess. We'll post the best descriptions we receive to our website (so keep them "clean"), and if yours is one of them, we'll send you a full **3 MONTH SUPPLY** absolutely **FREE!** *(All personal info will be kept confidential.)*

I couldn't believe it - these guys were so confident in their product, they were literally saying **MY PARTNER WOULD NOT BE ABLE TO CONTAIN HER REACTION** to the distinct difference in my performance. THAT'S BOLD! I mean, jeez, it's one thing to say take a pill every day for the next 60 days and feel a difference, but to literally say - take this pill today, ONE TIME, on your very FIRST TIME trying it, and watch how your partner reacts? I was compelled to try just for the pure principle of it.

Steffanie, all I can say is, they weren't kidding. I didn't tell my wife I was trying it. Literally, in the middle of our "experience," she stopped me and said, "Ok what's going on, what did you take..." - I couldn't believe it! They were right! She couldn't help but to react! Steffanie, you have to find out more about **this New Red Hot Pill!** Now, every time my wife and I are intimate, she asks me, "Did you take the pill?" - it's crazy but I had to order a 3 month supply! She won't let me go without it!

In fact, here's the phone number for your readers: **1-800-735-7110**, or they can go to **RedFortera**.com to check it out. If they call today, they may still be able to get the **FREE SUPPLY** with their order like I did.

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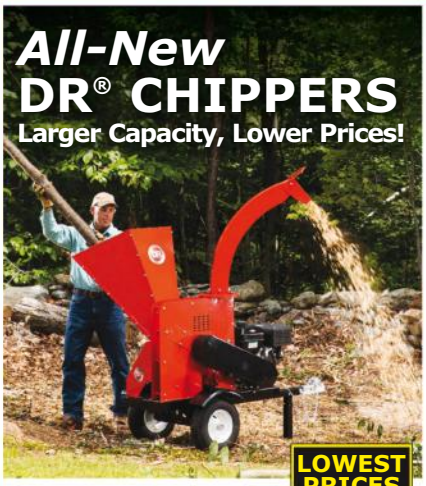

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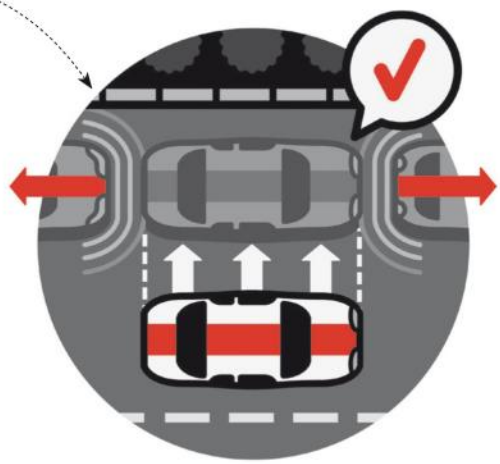

A Device that Moves Poorly Parked Cars

@ANNIENM8 VIA TWITTER

We're so bad at parallel parking that we squander coveted, public asphalt. A massive forklift could create space by shifting offenders, but would block traffic. And it's doubtful that car owners would let you move their property. You could, however, curb congestion. "We all want to park on the street. It's so cheap," says Michael Manville, an urban planner at the University of California at Los Angeles. His solution? Surge pricing. Charge more at busy times, and those spaces will open.

A Smog-Busting Blimp

CLIFF RUSSELL VIA FACEBOOK

Totally doable. Engineers could easily rig blimps with massive catalytic converters—like those found in cars—and send them skyward to transform smog into clean air. However, says Peter Eisenberger, an environmental scientist at Columbia University, that would lead to another sort of air pollution. We would need so many of these low-flying cleaners to make a difference that they would overcrowd the sky.

3-D Printer that Builds Human Organs

CHRISTIANO ADAMS VIA FACEBOOK

This could happen. Printing bone, muscle, and cartilage—even an ear—is easy. Anthony Atala, who heads the Wake Forest Institute for Regenerative Medicine, has done that. Organs are harder. They need to grow slowly, generating massive networks of nerves and blood vessels. Atala's plan is to print organ molds instead. The molds have tiny holes for nutrients and oxygen to flow through as injected cells blossom into organs.

▶ WANT TO KNOW IF YOUR IDEA COULD BECOME REALITY? TWEET @POPSCI, EMAIL LETTERS@POPSCI.COM, OR TELL US ON FACEBOOK.

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